ESAP Proceedings

INTERNATIONAL CONFERENCE ON DAIRY SECTOR TRANSFORMATION IN ETHIOPIA

Proceedings of the 29th Annual Conference of the Ethiopian Society of Animal Production (ESAP)
Held at the Ethiopian Skylight Hotel , Addis Ababa
October 28-30, 2021

Ethiopian Society of Animal Production (ESAP)
P.O.Box 62863, Addis Ababa, Ethiopia

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Opening Speech

Dear your Excellences, ESAP members, national and international distinguished guests, participants, ladies and Gentlemen,

It is my greatest pleasure to be with you this morning to officiate the opening of the 29th Ethiopian Society of Animal Production (ESAP) Annual Conference. I wish to thank the ESAP organizing committee for inviting me to this occasion. I would also like to commend ESAP, SNV Bridge and ILRI for sponsoring and facilitating the Conference.

Your Excellences, ladies and Gentlemen, this Conference I believe has been organized at the right time when Ethiopia is undergoing the popular reforms in Agriculture in general and the Livestock sector in particular that contributes towards the transformation of the - Dairy sector.

Recent data from the Ministry of Agriculture indicate that the livestock sector contributes 45 percent of the agricultural Gross Domestic Product which translates into 16-19 percent of national Gross Domestic Product. In addition, livestock provides protein-rich foods that complement the diet of the population both in urban and rural areas. Thus, this is critical for achieving food and nutrition security at the household level. The sector is also a source of employment and income for millions of people in the country, and thus serving as a safety net for poor households not to fall into poverty.

Ethiopia holds large potential for dairy development particularly with its favorable climatic conditions for dairying, its population growth, rapid urbanization, and emerging middle class consumer segments. However, currently, the dairy sector in Ethiopia is predominantly consisting of the traditional herd which is not productive but very important to the livelihood of farmers and pastoralists.

Over a number of years, there have been a lot of efforts put into this sector to modernize it and improve its productivity. Despite these efforts, the sector is still suffering from low level of productivity and production mainly due to limited access and high cost of dairy genetic materials, feed shortage, poor nutrition, disease and low level of dairy cattle management. However, with all the above mentioned limitations, the total volume of milk produced has increased gradually, from less than 4 billion litres to approximately 7 billion litres per annum (CSA, 2021). Besides, there is an overall improvement in modern input adoption, and number of dairy processing firms seemingly linked to incentives from increasing urban demand.

Dairy producers and marketing cooperatives are playing an important role. But there are still many challenges, as milk yields overall remain low and consumer prices are high. The demand for dairy products has increased in the last decades and it is projected to increase significantly through 2028 and beyond.

Ladies and gentlemen, Government Policy put a lot of emphasis on Dairy Development through Cattle Genetic Improvement and creating enable environment for investment. The Holetta nucleus herd breeding center with a well-equipped and mechanized facility to alleviate the quantity and quality of genetic material availability is good example.

The primary features of Integrated Agro-Industrial Parks are the clustering of essential infrastructure, utilities and services required for business operations and growth. In addition, the parks enable links with value chains. Moreover, increased integration with commercial value chains encourages the inclusion of informal economic actors into the formal system.

It is my hope that this conference will deal with dairy transformation bottlenecks and issues critically and come up with doable interventions which will help us solve some of the chronic problems.

To end I wish you all the best in your deliberations. The exchanges of experiences are the healthiest treasures. I want to thank you all again for your invitation and your attention.

May I now, with pleasure and honor, declare that the ESAP annual conference is officially opened.

Thank you for your attention.

Fikru Regassa (PhD)
State Minister, Ministry of Agriculture, Livestock sector development

Plenary Session

Digitalization of Livestock Extension: Experiences and Lessons of Mobile Phone Advisory Services

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Abstract

Ethiopia has huge and diversified livestock resources, which has significant contributions to the livelihoods of farmers and pastoralists, employment generation, impact nationwide nutrition, and increase forex exchange. However, the sector is suffering from inefficient production system, poor access to inputs and services, underdeveloped livestock marketing etc. Inefficient livestock extension system, and lack of access to extension advisory service are among the major challenges with significant contributions. Digitalization of livestock extension system is an indispensable approach to enhance the extension system and improve access to advisory service. Digital innovations have created new opportunities to provide and deliver tailored, timely and actionable information to farmers. 8028 Farmers' Hotline Interactive Voice Response (IVR) system is one example of such digital innovations where the Ethiopian Agricultural Transformation Agency (ATA) uses to enhance extension services. The objective of this study was to share lessons and experiences of ATAs 8028 hotline from the technology, content, and user experience perspectives. The study employed desk review of global experience, data from the call logs, phone back-checks and focus group discussions and employed qualitative and quantitative analytical tools. The 8028 system has 4 major components (automated call service, broadcast IVR and SMS alerts, IVR help desk and interactive survey tools) and contents in 4 pillars (rainfed crops, irrigated crops, livestock, covid-19) and in 5 languages. The system is able to serve 5.7 million users, and they have made about 50 million calls throughout. 8028 is the largest service of its kind in Sub-Saharan Africa. Radio campaigns were used as a major tool to promote the service, and it is successful in attracting new users and bringing back existing users. With a lesson from the crop menu, the livestock menu is arranged a little differently. A recent experiment with four major menu items in the livestock option showed evenly distributed choices were seen for dairy (31%), fattening (30.3%) and poultry (30.3%) and apiculture (8.3%). The introduction of the livestock content brought significant changes. In addition to the fact that the country's livestock producers have got access to digital livestock extension, the new addition helped to the redistribution of menu choices by farmers. Before the introduction of the livestock menu, about 52% of the users choose rainfed, 28% of the users choose irrigation and 19% choose reset menus. With the introduction of the livestock menu, the proportion of calls that went into rainfed, irrigation, livestock and reset respectively are 39%, 25%, 24% and 12%. The results indicate the great potential of mobile phone based advisory services to reach farmers at scale, and continuous iterations are quite critical to fit into farmers and pastoralists needs.

Key words: Digitalization; livestock extension; 8028 IVR

Introduction

Ethiopia has huge and diversified livestock resources that are adapted to the diverse agro-climate that exists in the country. With 70 million heads of cattle, Ethiopia stands first in Africa and 5th in the world. The country has also about 43 9 million heads of sheep, 52.4 million goats, 57 million poultry and 8.1 million camels (CSA, 2021). With this potential, the livestock resources of the country impacts farmers/pastoralist/ agro-pastoralists livelihoods, improve nationwide nutrition, and increase foreign currency. The volume of milk and eggs produced from these livestock resources has been estimated to be 7.1. billion litters and 368 million eggs, respectively (CSA, 2021). When the contribution of livestock to traction and other agricultural activities is considered, the livestock resources of the country contribute to about 45% of agricultural GDP (IGAD, 2013). The sector is responsible for about 20% of the GDP , 16-19% of foreign exchange earnings, and 37-87% of the Ethiopian farmers and pastoralists livelihood (MoA 2012).

Despite the potential, the production and productivity and income generated from the sector is disproportionately low. For example, the average daily milk yield per cow was 1.4 litre, which is 3.3 times lower than global average of 4.6 litres and 3.8 times lower than 5.3 litres reported for Kenya (FAOSTAT, 2018). Consistent with this, the average beef carcass weight per head was 110 kg which is lower by 1.5 times compared to the global average of 159 kg/head (FAOSTAT, 2017). Poor and inefficient livestock extension system, and lack of access to extension advisory service are among the major challenges with significant contributions to the current underdeveloped livestock sector.

Digitalization of livestock extension system is an indispensable approach to enhance the extension system and improve access to advisory service. It is believed that digital technologies for extension services are expected to play an increasingly important role in transforming the agriculture sector in general (USAID, 2018; Rajkhowa & Qaim, 2021). Digitalization of agricultural extension system increases productivity by delivering timely and precise information on improved production practices, new technologies or inputs through ICT based extension services, etc. (Mahantesha et al, 2021). Digitalization of livestock extension system is timely since dissemination and demonstration of extension materials through development agents and experts has been limited due to the current COVID-19 pandemic.

The objective of this paper was, therefore, to highlight the relevance of digital agriculture for agricultural transformation and share ATIs experience in digitalizing livestock extension through mobile phone based advisory service.

Global Experience

The world must be prepared to increase food, fibre, and energy supplies to meet the needs of our planet’s rising population, which according to Food and Agriculture Organization (FAO) estimates, is expected to reach 9.7 billion people in 2050 (FAO, 2019). To this end, the use of technology, the internet, and cell phones have the potential to positively contribute to agricultural productivity which includes but is not limited to promoting better farm management by optimizing the efficient use of various inputs; increasing farm productivity by delivering timely and precise information on agricultural practices and new tools; narrowing information gap by promoting the inclusion of rural and often marginalized producers in regional, national, or even global market with providing the ability to access market information; and promoting strong market linkage.

Generating new agricultural knowledge and information flow and making it available for use by smallholder farmers is important in promoting sustainable livelihoods and reducing rural poverty in the world. In this regard, the use of ICT technology is very important for timely dissemination of information, best practices, and lessons. Knowledge and information sharing platforms are advancing from time to time and made the physical presence of the trainer and trainee irrelevant. Besides, digital agriculture and its tools are providing better alternatives of managing the farm with better and more reliable means of accessing the inputs and improved farm management practices. Based on the

Groupe Speciale Mobile Association (GSMA), there is a visible growth in all the digital agriculture tools but most of them focus on the provision of specific knowledge resources such as extension advisory, weather information, market prices, and government-related announcements (Figure 1).

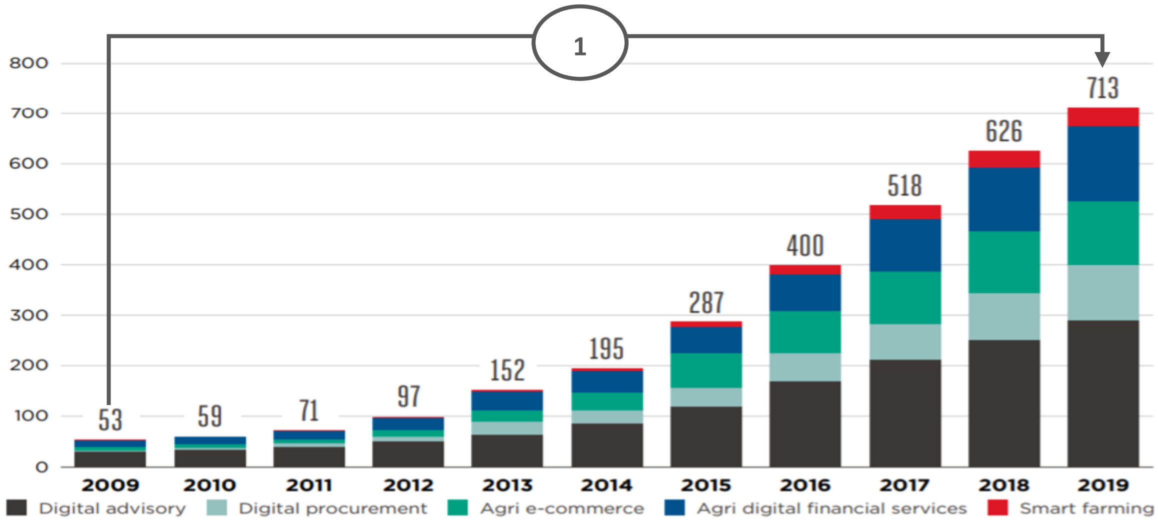

Figure 1: - Active digital agriculture services worldwide from 2009 -2019 (GSMA, 2020)

There are several digital agricultural services in Sub-Saharan African countries with the aim to connect farmers to timely and relevant knowledge, where most of them focused on the provision of specific knowledge resources. According to the CTA (2018/19), most of the ICT based agricultural extension advisory services in Africa are dominated by public sector which are supported by non-governmental organizations and external funding, and they are actively engaged in service delivery to small-scale rural farmers. Among the different information provision platforms that existed in Africa, Viamo is the rapidly growing Digital firm extending its services throughout the entire continent. Viamo, originally known as VOTO Mobile, was started in 2012 by a handful of Ghanaian and Canadian engineers in Kumasi on the campus of KNUST (Kwame Nkrumah University of Science and Technology). The founders noticed that there had been a huge increase in mobile phone usage, but that very few organizations were using this communication channel to reach their end-users. So, they decided to first create an SMS channel to spread information to end-users but soon found that did not effectively reach or engage rural populations, especially rural women. They decided to add a voice (IVR, Interactive Voice Response) channel, which proved much more effective. Viamo now has representation in more than 20 major markets in Africa and Asia reaching more than 100,000 people per day — more than 10 million people from 2012 to 2017.

8028 Farmers' Hotline

Overview of 8028 farmers hotline - Despite the strength and volume of agriculture-related information and available training through Ethiopia's vast public extension system, ensuring that farmers receive up-to-date data and knowledge in a timely manner remains a great challenge. This is particularly the case for the rural smallholder farmers who make up most of the sector in Ethiopia. At times, new extension advice emerging from Ethiopia's research centres can take multiple years to cascade down to smallholder farmers around the vast country. Access to agricultural information is critical for smallholder farmers to optimize farm activities. Timely, local, and context-specific information can help smallholder farmers yield the greatest returns from their investments. Additionally, to minimize production damage, farmers need to be able to report on and be warned about outbreaks of diseases.

The Ethiopian Agricultural Transformation Agency (ATA) in collaboration with the Ministry of Agriculture (MoA), Regional Bureau of Agriculture, Federal and Regional research institutions, and Ethio Telecom developed Farmer's hotline which works with Interactive Voice Response and Short Message Service (IVR/SMS) to deliver information directly to farmers through any type of mobile phones. The 8028 Farmers Hotline is a toll-free service that distributes best practices of crops and livestock production and collects field information via an automated hotline. It supports sustainable agriculture by empowering smallholders with access to improved production practices. The system's main objective is to ensure that smallholders have real-time access to pertinent agricultural information, which will help them make more informed decisions about their farming practices. The Interactive Voice Response (IVR) component is especially critical given the low literacy rates and smart phone penetration in many rural parts of Ethiopia. From this basic premise, a range of functionalities could be specified and developed.

Components of 8028 Farmers Hotline

The 8028 farmers hotline has 4 components as described below.

1. **Automated Call Service**: This is the service where smallholder farmers and other users access agriculture related information. The service can be accessed through calling a toll-free number 8028, which provides menu of options for specific information. Through this service users have access to information on a wide range of livestock and crop best practices, covid-19 responses, and digital finance literacy information. The contents of major livestock commodities included under livestock menu are Dairy (cattle), small and large ruminants fattening, poultry (family and small scale commercial), apiculture and camel (focus on dairy) (Figure 2). The library of contents for agricultural commodities were developed through the involvement of relevant experts from the ATI, MoA, Federal and Regional Research Organizations and validated in a national workshop.
2. **Broadcast Interactive Voice Record (IVR) and SMS Alerts**: The 8028 Farmers Hotline system provides functionality for administrators to broadcast selected advisory services to registered system users at a time using voice message and SMS technologies. The hotline administrators also "push" or broadcast customized content in cases of drought, pests, and disease with tailored information to callers based on commodity, geography, or demographic data captured during the registration. This feature has been used successfully in Ethiopia to combat crop disease and other issues such as wheat rust and desert locust. The same feature is also being used for pushing nutrition messages to create awareness on the improved feeding system among the rural communities.

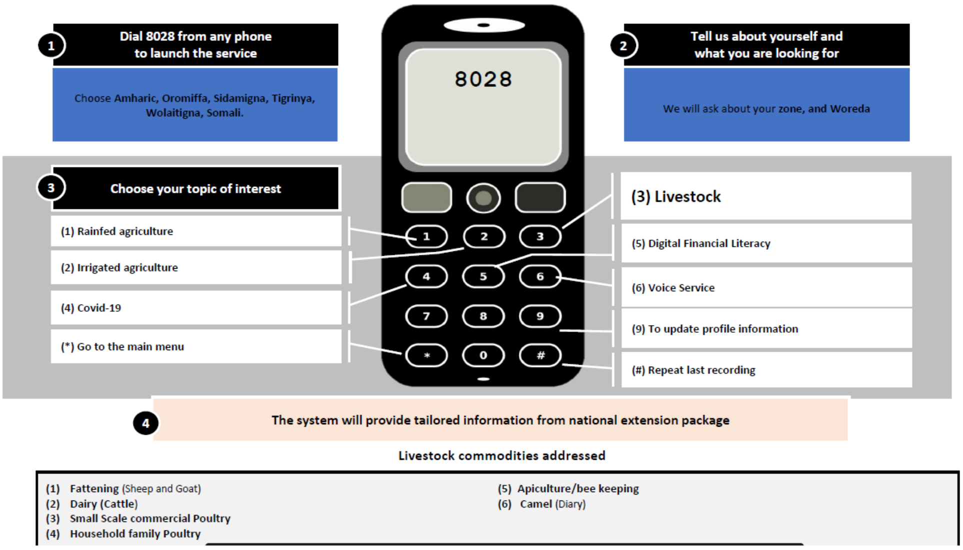

Figure 2. 8028 Call-in automated Extension information dissemination

3. **Help Desk Service**: the 8028 also allows smallholder farmers to ask questions and experts to respond to their inquiries that occur in real-time via a Help Desk service. If there are queries that farmers might not find on the pre-set automated menu, they can call and leave a question for specific advice. The message is then passed on to the relevant crop expert of the woreda office, who is tasked with providing a voice message response within three days. The system has worked well, and on average good experts typically provide an answer within 12 hours.
4. **Interactive Survey**: Using the list of caller's data, the interactive survey feature allows system administrators and users of the 8028 Farmers Hotline to collect information via IVR or SMS surveys directly from smallholder farmers and extension agents. This feature can assist the agriculture sector and extension network to collect real-time information, course-correct based on the information on the ground and develop and distribute accurate advisory services. The system is currently available in six languages: *Amharic*, *Afan Oromo*, *Tigrigna*, *Sidamigna*, *Wolaitigna* and *Somaligna*. Activities can be monitored in real-time via the 8028 Farmers Hotline dashboard, which is available to any approved administrator across government agencies (Figure 3).

Figure 3: - 8028 FHL general dashboard

Achievements

The ATA started piloting 8028 farmers hotline in February 2014 with seven crop contents availing to farmers in 21 woredas. Since then, the ATA has increased number of commodities, and expanded the services to wider geography where the Ethio-telecom network is available (Figure 4).

- Commodities increased to 21 crops, 4 livestock, 1 COVID-19, and 1 Digital Financial Literacy
- 5.8 + million registered callers
- 51 + million calls with advisory service provided nationally
- 6.4 million interactive voice response alerts broadcasted
- Over one million short message services to registered users
- More than 20 thousand questions answered by experts
- 682 thousand surveys broadcasted via interactive voice responses and 49 thousand via short message services.
- 11 Integrated Services Digital Network (E1 lines) which can accommodate 330 concurrent calls to access contents from both the farmers' hotline and National market Information system.

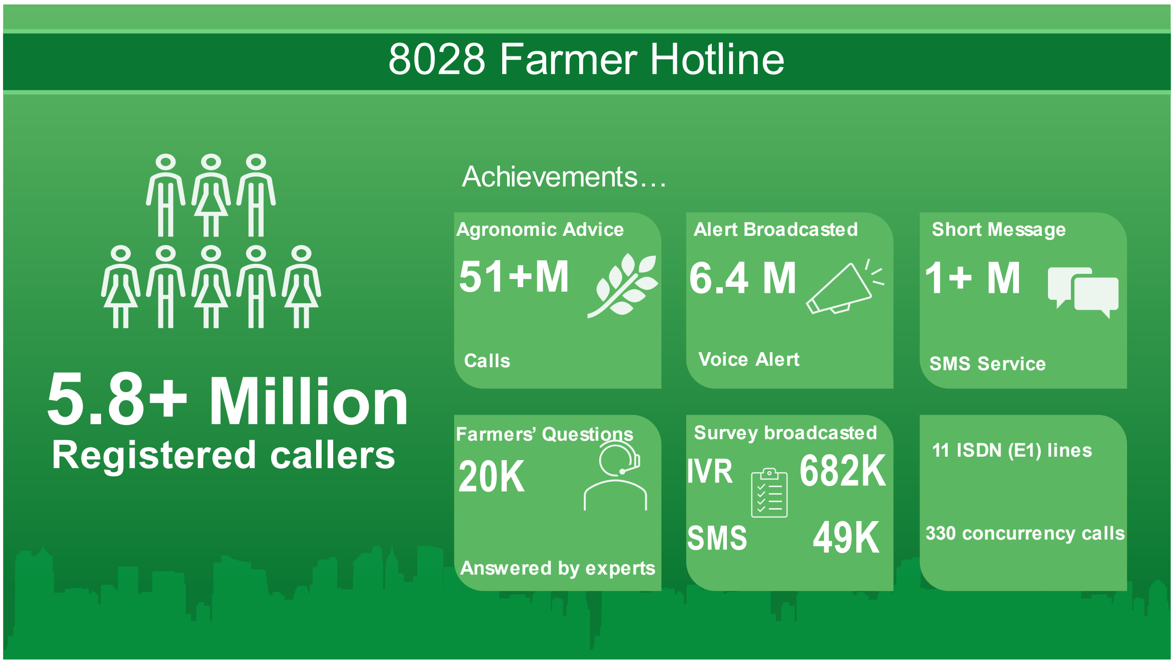

Figure 4: Achievements of ATAs 8028 farmers hotline

Analytics on the experiences of 8028 farmers' hotline

The Ethiopian ATI has used radio campaigns as a major tool to promote the service in different periods. Based on the analysis that Precision for Agriculture Development (PAD) has done on the number of new and additional users on periods with and without a radio campaign, the effort is successful. Radio campaigns have meaningful contributions in attracting new users and bringing back existing users. For instance, in 2017 & 2018, radio campaigns were followed up with 120,000 new and the same magnitude of existing users (compared with between 20,000 and 50,000 new and existing months without radio campaigns). This also matches with the field assessment work that the team has done through farmers interviews. More than half of the respondents have indicated that they learn about 8028 from radios (Figure 5).

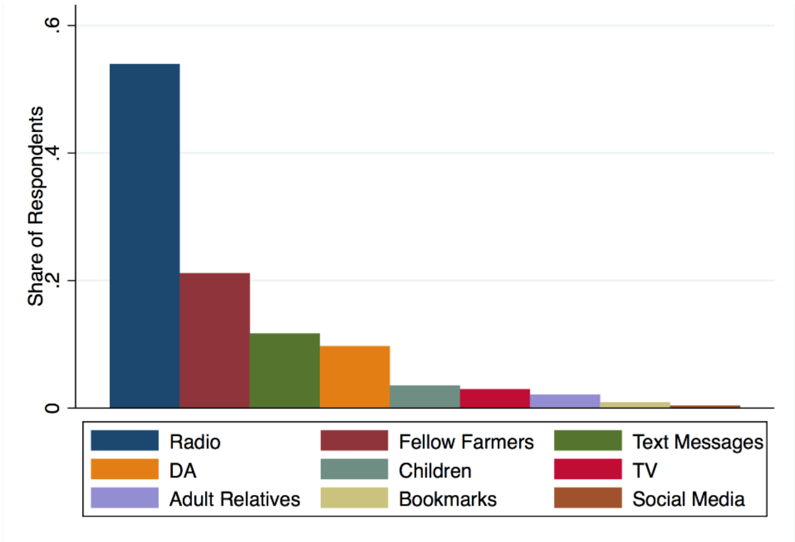

Figure 5. Source of information

Sending push calls for alerts (weather alerts, pest and disease infestation etc.) is one of the key features of 8028 farmers' hotline. We have also used push calls as reminders of the service to bring back passive users of the system. The attempt is successful in bringing back some of these passive users, and the result showed that among proportion of the users who picked up the phone when the push call rang, about 10% of the users call back and access contents (Figure 6).

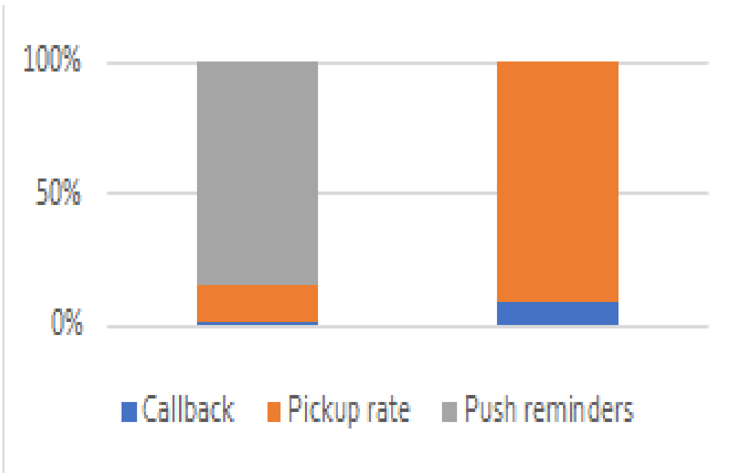

Figure 6. Use of push reminders to bring back users

The introduction of the livestock content (May 2020) through 8028 farmers' hotline also brought significant changes. In addition to the fact that the country's livestock producers have got access to digital livestock extension, the new addition helped to the redistribution of menu choices by farmers (Figure 7).

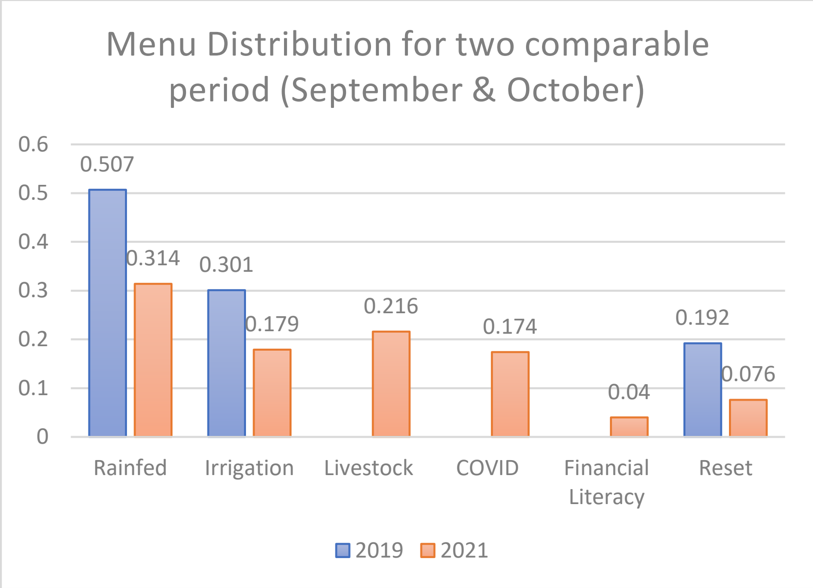

Figure 7. Menu distribution for two comparable seasons

Before the introduction of the livestock menu, about 52% of the users choose rainfed, 28% of the users choose irrigation and 19% choose reset menus. With the introduction of the livestock menu, the proportion of calls that went into rainfed, irrigation, livestock and reset, respectively, are 39%, 25%, 24% and 12%. The next graph shows the distribution of callers that goes to the main menu in 2019 and 2021 to showcase the before and after the livestock content distribution.

There are key features that make the livestock menu unique. Unlike the crop menu where farmers first choose production stage (e.g. pre-planting) and then crops, farmers in the livestock menu have to choose commodities (e.g. dairy) first and then specific issues (e.g. livestock disease). It also has a late comer advantage that farmers have some knowledge of how to explore the system. That may have helped the menu to get substantial proportion of the users despite little or no promotion. Figure 8 shows the distribution of users (new and return users) that have reached the livestock sub-menus (the one in blue) and accessed the contents (the one in brown).

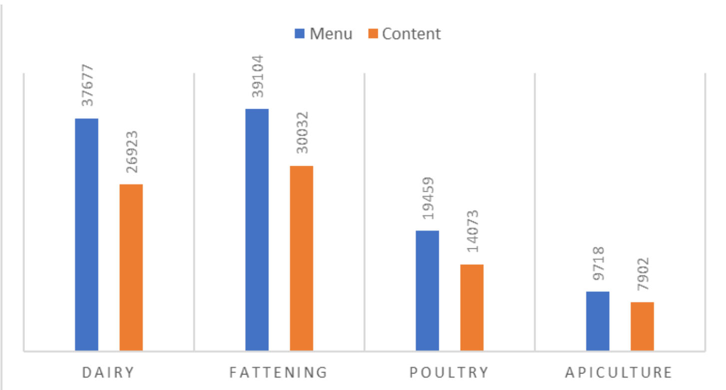

Figure 8. Livestock content (Oct 2021 to Dec 2021)

With a lesson from the crop menu, the livestock menu is arranged a little differently and the distribution of farmers' choices are also comparatively evenly distributed. A recent experiment with four major menu items in the livestock option showed evenly distributed choices were seen for dairy

(31%), fattening (30.3%) and poultry (30.3%) and apiculture (8.3%). This presents a big shift from what we saw in the main menu of the crop stream where most users tend to choose the first in the menu order. In the rainfed crop menu, about 60% of the users choose pre-planting and 20% of the uses choose planting. The rest 20% is divided between crop protection, fertilizer side dressing and post-harvest handling.

There were two poultry options in livestock menu. This has a few potential problems. First, the architecture is only different for this menu. From the livestock top menu, they are supposed to choose commodities, and not the specialized production activities for the rest of the menu. This would also influence users' learning of the menu structure. In addition, the number of options in the livestock menu is unnecessarily long. Instead of choosing between the four livestock commodities in the menu, users are supposed to choose between five items/commodities/activities. Though both are poultry production types with different orientations, the way it is presented could create a confusion to 8028 users. Thus, an experiment was carried out and tested the implication of merging the poultry menu at commodity level and splitting it on submenu level (Figure 9).

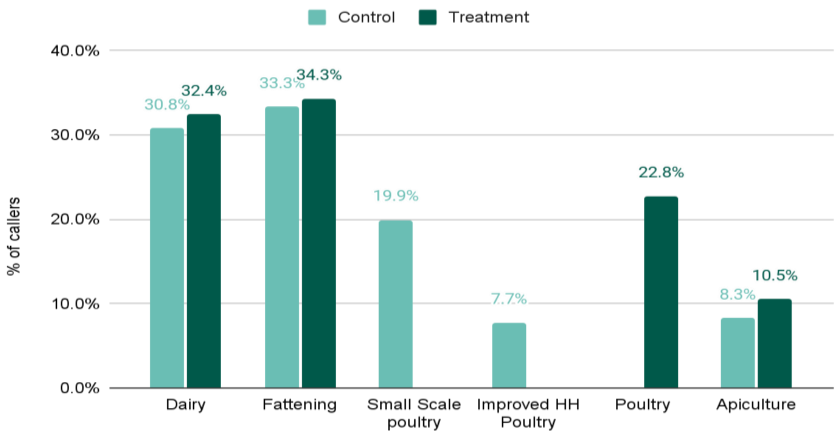

Figure 9. Percentage of callers before and after merging poultry content

As can be seen in the graph above, the result matches with our hypothesis in changing the distribution of choices from the livestock menu. The chi-squared test of homogeneity confirmed that the distribution of callers between the control and treatment are statistically different for dairy, fattening and apiculture. The distribution of users for the treatment group (i.e. dairy - 32.4%, fattening - 34.3%, poultry - 22.8% and apiculture - 10.5%) is significantly different from the distribution of users in the control group (i.e. dairy - 30.8%, fattening - 33.3%, small-scale commercial poultry – 19.9%, improved household poultry - 7.7% and apiculture - 8.3%).

Challenges

The experience with the ATA shows that the efforts made to design and make 8028 farmers hotline service available for smallholder farmers and pastoralists are encouraging but not without any challenge. Below are the list.

- **Telecom Issue:** Shortage of the lines, poor network quality at the remote rural areas, discontinuity of VOIP (technologies which accommodate more than 1000 concurrent calls at a time), and other issues the project faced during its implementation.

- **Low Digital Literacy:** Because of their low-level digital literacy, it was noticed that using the voice-based system is still becoming problematic let alone other advanced technologies. Even these days, many users of the 8028 Farmers Hotline require assistance from their children and/or support from their fellow farmers or friends.
- **Inadequate Awareness creation campaigns:** Although it was recorded a significant result in promoting the platform using the radio advertisement, live activation campaign, in disseminating promotional printing materials (such as posters, calendars, fact sheets, and others), it was not enough to attract more users to the hotline as there is a huge gap in awareness and unfamiliarity to the technologies like the hotline.
- **Slow in Institutionalization of the hotline in the government structure:** Even though the hotline has huge support to the existing public extension service, there is a big delay in understanding its importance and exploiting its potential from the Ministry of Agriculture side.

Future directions

- **Artificial Intelligence (AI)/Machine Learning (ML) Engine**: 8028 IVR System has a huge call log data. AI/ML engine to be developed shall be responsible for analysing call footprint of each caller and identify caller behaviour and preference. The engine shall constantly update caller profile as new data comes in. The design work includes identifying, listing, and categorizing caller attributes.

- **Smart IVR:** This is about implementation of smart IVR for 8028 system based on the recommendations provided by AI/ML engine. The existing static IVR system is built as a one-size-fits-all solution which does not provide the most relevant content to each caller. Through the integration of AI/ML recommender system the Smart IVR shall build live profiles for callers and optimize the current structure and content delivery beyond traditional information delivery. The existing static information service shall be revamped providing targeted content and better user experience. The ultimate outcome shall be optimizing the current traditional structure and content delivery mechanism enhancing caller's experience.

- **Develop and integrate meteorology components into the existing IVR/SMS system:** This increase farmer's resilience and adaptation to climate change and its consequences. This component will inform farmers on what to dos in severe and erratic weather patterns. It will also provide information on how to contribute to the fight against climate change. Modules will be integrated and promoted to farmers that will teach farmers on soil conservation, soil treatment and on natural resource and vegetation conservation.

- **Develop 8028 Mobile Application for Development agents (DAs) and agricultural experts -** This application can organize farmer clusters in three hundred wreathes application will provide farmers with farm management tools and tips. It will be capable of receiving and disseminating Farmer and DA specific information using multiple channels and languages.

- **Develop Web Portal to avail advisory content:** This is for availing the detailed and contextualized extension package content in different local languages and English via web for advanced users such as development agents, experts, and others. The web portal shall provide agricultural advisory in text format which can be categorized by topics and menus and be associated with pictures and videos. The portal shall also have API to fetch and display dynamic contents like crop diseases and pest infestations from other partner sources**.** It shall also display latest news and publications.

- Enhance effective partnership and collaboration with Ethio-telecom, MoA, and other partners

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Application of ICT Tools and Genomics Technology for the Transformation of Dairy Cattle Genetic Improvement in Ethiopia: ADGG Approaches, Experience and Prospects

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Abstract

Dairy farming in Ethiopia is constrained by lack of a sustainable breeding program to generate and deliver tropically adapted high producing breeds of dairy cattle. Artificial insemination (AI) has been extensively used over many years. However, lack of a performance recording scheme has limited follow up and monitoring of calves born. The AI system is unidirectional mainly focused on the supply of semen and service of animals. A sustainable breeding program requires continuous field data recording, analysis and selection of top-ranking bulls and cows for breeding. The African dairy genetic gain (ADGG) program was initiated in Ethiopia and Tanzania in 2016 to introduce and advocate the use of information and communication technology (ICT) and tools for capturing performance data of animals, providing feedback and extension messages to support better farm management, and integrating genomic technologies in the selection of animals with the best genetic merit for desired productivity traits within the targeted environments. In Ethiopia ADGG is implemented in 6 regional states and 98 districts. The ADGG program established a national dairy cattle data base and requisite tools to enable real time on and offline data capture. Besides, selected dairy bulls and cows are sampled to determine their true genotypes. Since the start of the program 72,000 farmers and 116,000 animals are registered in the data base and 279,000 test-day records captured have been collected, and 6,800 animals have been genotyped using the 50K bovine SNP chip. More than 9 million education extension messages have been sent by ADGG to farmers via SMS in the last four years. The genomic and phenotypic data collected was used to evaluate and rank dairy animals from the different farming systems based on genomic estimated breeding values obtained through a so called single-step genomic evaluation model. Top ranking animals identified were published in a catalogue and paraded in the first national dairy animal parade held virtually in March 2021 and the best bulls were purchased by NAGII for semen production. National capacity to sustain the breeding program has been enhanced, with requisite infrastructure for continuity. It is evident that with the correct policy framework, government supported interventions implemented in collaboration with private sector actors, a sustainable dairy breeding program in Ethiopia can be catalyzed. Interventions initiated need to be scaled up through institutionalization of the breeding activities initiated, and continuous capacity building, engaging a wider category of private sector actors and supporting the building of partnerships among these actors in the dairy value chain. Animal identification and registration systems in the country need to be harmonized and farmers encouraged to continuously record performance data on their animals with relevant feedback provided for improved productivity and informed decision making.

Keywords: Dairy, ADGG platform, Genomics, ICT tools, Data capture, Feedback

Introduction

Milk production in developing countries, including Ethiopia, is dominated by smallholder dairy farmers, each keeping 1-3 dairy cows. Majority of these farmers are not currently extracting optimum benefits, because herd and cow production and productivity levels are low (Shapiro *et al*, 2017). About 95% of milk produced in Ethiopia is from local breeds (CSA, 2019) which are kept by smallholder farmers under an extensive management. However, demands for milk and milk products is increasing and meeting the increasing demand for milk and dairy products cannot be realized without rapidly increasing the following: the number of high producing tropically adapted dairy cows, the number of commercial dairy herds, the number of cows per herd and productivity per cow (Shapiro *et al*., 2017). To narrow the gap between the projected demand and supply of milk and milk products, milk production per cow needs to significantly increase. To achieve this, the challenges facing smallholder dairy systems which include little or no systematic and sustainable breeding programs, limited access to the dairy genetics or breed types/choices that best suit the different production systems, inadequate access to various services and inputs, and access to information or farmer education and training services, must be addressed. In Ethiopia, genetic improvement of indigenous breeds through crossbreeding via artificial insemination (AI) started more than 40 years ago. However, the number of improved breeds in the country is currently only 2.34% of the total cattle population (CSA, 2019). This number is too small to support or help realize commercialization of smallholder dairy production. The high variability in milk production within the local breed cows (Yohannes *et al*., 2002) and among crossbred cows could be effectively exploited through selection.

Past genetic improvement for milk production by research institutes and universities has so far, mainly focused on evaluation of crosses of exotic dairy breeds with indigenous ones (Demeke *et al*., 2004) and most of these studies were based on multi-year data collected in research centers under herd managements that were different from the smallholder farmers' management systems or environments. Due to the free grazing management, smallholder farmers breed their cows with uncertified local bulls which are in most cases inferior in performance because of castrating vigorous bulls for draft power. The ministry of agriculture has been using and promoting Holstein-Friesian and Jersey semen for crossbreeding with local breeds. However, data on the artificial insemination service has not been routinely captured and analyzed, hence the performance of the resulting crossbred cows under smallholder farmers' management and conditions have not been comprehensively assessed. Lack of record keeping made monitoring and subsequent inseminations difficult and resulted in crosses with very high (average 78%) exotic dairy breed blood level (Strucken *et al*., 2017) which do not match the farmers' management conditions, resulting in underperformance of the dairy animals, high cost of production (feeding and health care) and high risk of animal loss.

In Ethiopia, genetic evaluation studies in which lactation milk data (Demeke *et al*., 2004) or test-day milk records (Gebreyohannes *et al*., 2016; Meseret *et al*., 2015), collected from progenies across years, have been undertaken. To achieve estimated breeding values of adequate accuracy and reliability (Wiggans *et al*., 2011) and to have sustained genetic gains, these genetic evaluations and methodologies require continuous recording of pedigree and phenotypic data which is costly, and time consuming. African Dairy Genetic Gains (ADGG) (https://africadgg.wordpress.com), working in collaboration with national animal genetic improvement institute (NAGII) and the Natural Resources Institute of Finland (Luke) have developed and are implementing a performance recording systems that employs ICT tools and genomic technology to capture phenotypic and genomic records from herds kept by smallholder farmers, and medium scale dairy farms. The data generated is used to define more robust breeding objectives, develop realistic selection indices and the latter eventually used select top ranking bulls and cows for breeding under local production conditions. Working with a partner program, the Public-Private Partnership for Artificial Insemination Delivery (PAID), led by Land O' Lakes Venture 37, appropriate dairy genetics is being promoted. This paper shares and presents lessons drawn from the experience of ADGG in Ethiopia, its prospects, and challenges for sustainability and scaling up.

African dairy genetic gain project

Project vision goals and objectives

The African Dairy Genetic Gains (ADGG) https://africadgg.wordpress.com/category/adgg/ program is a farmer and country-focused International Livestock Research Institute (ILRI) led project, funded by the Bill and Melinda Gates Foundation (BMGF), which has been piloted in Ethiopia and Tanzania since 2016 and is recently being scaled in Kenya with plans for implementation in Uganda and Rwanda underway. ADGG was initiated with a **vision** to see that African smallholder dairy farmers are continuously accessing more productive dairy genetics, breeding and farmer education services and other related input services enabling their farming enterprises to be profitable and competitive businesses. The **goal** is to establish working systems based on public-private partnerships with a clear route to long-term sustainability within the life of the program. The **objectives** of the program are to (A) establish performance recording and sampling systems in Tanzania and Ethiopia; B) Use the information and samples collected to develop systems to select crossbred bulls and cows of superior genetic merit for artificial insemination (AI) and natural mating; C) Pilot farmer-feedback systems that assist farmers to improve their productivity and D) Establish public-private, non-government organizations, and producer partnerships necessary for funding and scaling the ADGG data capture system into a regional platform. The project covers the Oromia, Southern Nations and Nationalities and People (SNNP), Sidama, Amhara, and Tigray regional states and Addis Ababa city administration. In Ethiopia, ADGG is jointly working with the National Animal Genetics Improvement Institute (NAGII), the Ministry of Agriculture (MoA), regional bureaus of agriculture and livestock and several other domestic and international partners. ADGG responds to the above listed challenges that the Ethiopian dairy sector currently faces via innovative application of ICT tools and genomic technology through a harmonized national dairy cattle database and animal identification and registration system.

Experience: Approaches and achievements

Establishment of national database and data capture system

Genetic evaluation requires herds and animal data, captured accurately and consistently, and an organized national database with high-capacity servers and high security to maintain data. For timely and accurate data capture at reduced cost, the manual paper-based data capture system must be replaced with ICT tools that are more efficient but less expensive and ensures access to data online and offline.

Ethiopia dairy cattle database was officially established in 2012 under a joint project entitled "Capacity building in herd performance recording and genetic improvement to strengthen the Ethiopian dairy development" between the Finnish and Ethiopian Government. The project was financed by the Institutional Cooperation Instrument of the Ministry of Foreign Affairs of Finland and a substantial financial and in-kind contribution from the Ethiopian government. The implementation of the project was coordinated by Natural Resources Institute of Finland (Luke) in close cooperation with MoA and NAGII. The project built a computerized national dairy cattle database center and provided capacity building trainings for several experts and farmers. Towards the end of the Luke led pilot project the ADGG project was starting to implement its program on a wider scale and higher capacity.

The ADGG program supports Ethiopia's national dairy recording center [https://portal.adgg.ilri.org/] to routinely capture data digitally. It has established and continuously refines a digitalized online and offline data capture system to collect performance records of animals from the field. The offline data capture system is enabled using customized open data kit (ODK) collect forms. Moreover, systems for direct data collection from farmers via mobile apps and short messaging service (SMS) has been developed and is being fine-tuned and adapted for Ethiopia. These different avenues of data capture enumerated are supported by a robust and agile digital data platform, as illustrated in Figure 1.

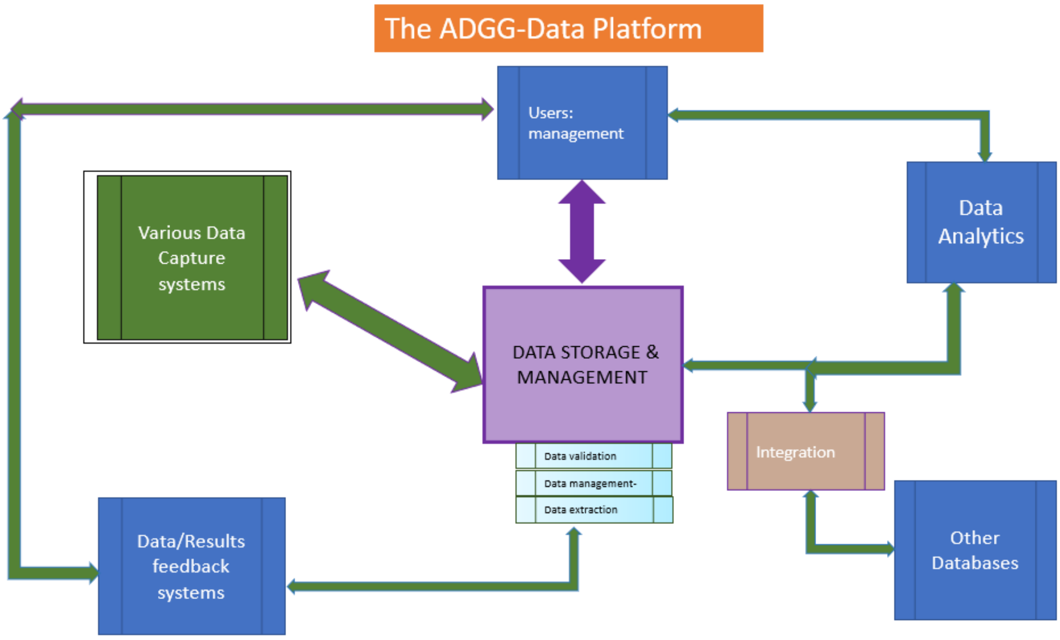

Figure 1: The schematic structure of ADGG data platform

National dairy animal identification

A national animal identification should be adopted as a system to support genetic improvement, control animal diseases and track animal movement, thus enable traceability of live animal and products. Currently, dairy cattle kept under research and private farms in Ethiopia are identified using ear tags which lacks uniformity and full of repeated numbers which makes it difficult to bring these data into one database. The ADGG platform has adopted a system of national animal identification and registration that was developed by NAGII and Luke, and if properly adopted, solves the problems associated with uniformity and repetition to register and monitor the performances of individual animals within a herd. In the naming nomenclature, the plastic ear tag consists of the national country code "ET" and nine-digit numbers with the last four digits printed in bold and bigger font just below the full identification code (see Figure 2). The numbering is designed to identify at least one billion animals if the system is promoted nationally, adopted and awareness created at different levels. To ensure sustainability of the system, The PAID project donated five ear tag printing machines, placed at NAGII, and at Bahir Dar, Nekemet, Hawassa and Mekelle AI centers. NAGII in collaboration with the regional livestock offices is authorized to control the printing, purchasing and distribution of the plastic ear tag and applicators across the country.

Figure 2: Plastic ear tag and identification number in Ethiopia

ICT for dairy data capture from farms

The rapid expansion of ICT alongside mobile based solutions for "paperless" exchange of information has catalyzed a transformation for information sharing in the smallholder farming systems of Africa (World Bank, 2011). The challenge within countries, Ethiopia included, is to adapt and expand critical infrastructure to support ICT adoption which includes mobile telecommunications networks and cloud computing facilities. ICT-enabled services can use multiple platforms (eg radio, e-tools, short message services) to provide information for various actors in the dairy value chain. Through the ADGG Program, mobile phone-based solutions have been adapted to capture and transmit data on performance of dairy cattle to the centralized national databases hosted on a cloud-based data platform (ADGG Data Platform). The ADGG data platform collates and synthesizes farm information and subjects it to various analyses using advanced analytical tools. Results from analyses are used to develop targeted feedback information that are then shared with farmers and extension service providers, to respectively inform their management and service delivery planning or decisions. Initial feedback information includes herd assessment, and individual animal and herd performance benchmarking. The platform has also developed electronic training resources that provide valuable information on breeding management practices in dairy herds (ADGG Dairy Tool).

Dairy herds and animals registered by ADGG, PAID and Luke projects have been harmonized into one national dairy cattle database. Total number of dairy herds, dairy cattle with pedigree and test-day milk records and test-day milk data registered in the digital ADGG platform are more than 72,000, 116,000 and 279,000, respectively. The data can be accessed via the Ethiopia country landing page (see Figure 3). This program is piloted in 98 districts in Amhara, Oromia, SNNP, Sidama and Tigray regions and Addis Ababa city administration.

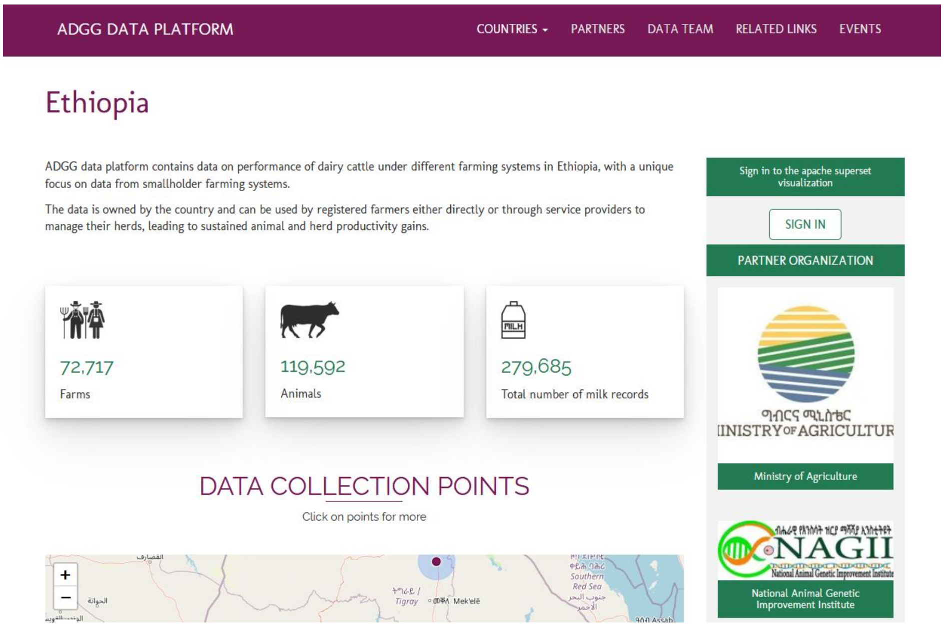

Figure 3: ADGG data platform landing page

ICT based extension and feedback

ICT based farmer-feedback systems have been developed and deployed to assist farmers improve their cows' productivity based on performance data collected from their herds. SMS based feedback system following the "cow's gestation calendar and dairy production management" support messages were reaching smallholder dairy farmers through digital extension. Farm data on milking and calving, AI service, feeding and other records, received from the farm through the ADGG platform is then synthesized and feedback shared with producers in the form of short text messages through their mobile phones. More than 8,890,258 education SMS messages and 162,456 instant feedback SMS messages based on cow gestation dates have been provided to farmers by ADGG in the last four years. The SMSs' have been translated into and delivered in three local languages (Amharic, Tigrigna and Afan Oromo). Information received by farmers guides their adoption of improved cow management practices which will ultimately lead to sustained productivity gains, income, nutrition, and poverty reduction.

Investors and service providers including cooperatives can also leverage on the platform's agility and robustness to better aggregate information on product quantities and demands for inputs in different areas. The public sector needs to have requisite policies in place that encourage innovation around ICT to enable the use of ICT services to promote improvements while at the same time protect the smallholder producers from complex challenges when exposed to large global actors, and secure smallholders' ownership of data and appropriate data access rights. Appropriate, locally accessible, affordable, and smart tools and applications are required to inform timely decision making and to improve herd and system's productivity and profitability. Viability and sustainability of the dairy industry in sub-Saharan Africa, hinges on the integration of ICT tools that help increase accessibility of extension services by farmers. This is because of the highly fragmented nature of smallholder dairy herds, they can't all be reached by the public extension service and such limited access to extension services and support significantly hamper the sector's overall performance. Inadequate access to technical advice and services reduces the ability of farmers to address everyday challenges resulting in poor performance of the herd. Development and deployment of ICT based services would facilitate improvements in farm production and profitability, animal health, animal welfare, and the environment and at the same time create access to technical and market information that leads to improvement in efficiency and productivity gains along the dairy value chains (Mwantimwa, 2019). Moreover, the use of ICT holds considerable potential to make agriculture more attractive to the youth because of their receptiveness to ICT tools, making it easier for them to access dairy information and services (Nuer, 2018). Obstacles that hinder dairy farmers from accessing agricultural information using ICT tools include availability of electricity, internet connectivity and its ability to deliver timely agricultural information and feedback. Thus, advancement of policies and legislations by the government to enhance the adoption and use of ICT technologies in dairy farming are necessary to transform the dairy sector in the country.

Use of genomics technology for dairy genetic evaluation

Genomic selection has become the method of choice for identifying genetically superior sires and dams in developed countries due to the accelerated rate of genetic progress mostly because of the reduction in generation interval and increased prediction accuracy. In genomic selection animals can be selected accurately early in life, based on their genomic predictions. Furthermore, it is much more suited for selection of traits that are difficult or expensive to measure: such as fertility, disease resistance, methane emissions, and feed conversion traits (Hayes *et al*., 2013). Garcia-Ruiz *et al*. (2016) reported that genetic gains for milk, fat, and protein yields for registered cows in the USA were 50, 2.2, and 1.6 kg per year before genomic selection was adopted but increased by over twofold to 109, 6.0, and 4.1 kg per year after genomic selection was introduced. The enabling factors for the huge success in genomic selection in developed countries include the availability of well-established infrastructure for routine data capture systems and conventional genetic evaluation. In addition, the existence of well-developed dairy breeding companies has significantly contributed to this success. These companies routinely undertake and/or contribute to the design of the genotyping strategy for widely used dairy bulls and the associated cost (Mrode *et al*., 2019). However, in developing countries, most of the dairy production occurs in small holder systems, where herd sizes are small and with little or no routine systems for capturing performance and pedigree data (Kosgey and Okeyo, 2007). The use of genomic information for genetic evaluation and determination of the breed composition of crossbred animal using admixture analysis (Strucken *et al*., 2017; Marshall *et al*., 2019), parentage identification and prediction of the genetic merit of animals using the genomic relationship matrix for genotyped animals present unique opportunities for mitigating the limiting data infrastructure in developing countries. In situations where only a proportion of the dairy cows are genotyped, the genotypic information can be combined with pedigree information using the Single

Step GBLUP (ssGBLUP) approach (Misztal, *et al*., 2009) to undertake prediction of the genetic merit for all animals.

In Ethiopia, ADGG has applied genomic technology to genetically evaluate and determine breed composition of crossbred animals kept under small and medium dairy production system. Hair samples were collected from crossbred cows and bulls for genotyping. The samples were genotyped, and genotype information was combined with phenotypic data collected through the ADGG platform to estimate genomic estimated breeding value (gEBV) and thus select bulls and cows with higher genetic merit for breeding. The estimation of gEBV was based on a pilot data from 3,802 cows with 53,955 test day records and a pedigree consisting of 113,447 records. Genotypic data were available on 5,146 animals which were genotyped with the GeneSeek Genomic Profiler (GGP) Bovine 50K chip. About 47,843 single nucleotide polymorphisms (SNPs) were returned from the laboratory and after the usual edits, 40,581 SNPs were available for analysis. These were imputed to the Illumina HD chip (686,052 SNPs) using a reference population consisting of crossbred cattle from a previous East Africa Dairy Genetics Gain project and several European Holstein-Friesian, Jersey, Guernsey, and Ayrshire purebred animals (Aliloo *et al*., 2018).

Initially, genetic parameters for milk yield were estimated from the same pilot data consisting of 3226 cows and 53147 test day records using ASReml (Gilmour *et al*, 2009) with ssGBLUP. For the parameter estimation, cows were required to have at least three test day records in a lactation, a minimum age at first calving of 18 months and days in milk was restricted to between 4 and 500 days. Data from all lactations were used but lactation greater than 1, were set to 2. The model fitted was:

Milk = HY + PYm + age.lac + fixed-lactation-curves(calving-season) + breed + htd + pe + animal

Where **HY-** herd-year of calving, **PYm** = production year-month, **htd** = herd-test-date, **age.lac** = age effects as interaction with lactation and fixed lactation curves consisted of Legendre polynomials and Wilmink function, **pe** and **animal** represents the permanent environment and additive animal genetic effect. The **H** matrix used in the ssGBLUP procedure consisted of 5169 animals with 4719 having only pedigree information and 450 of these with genotypes. The variances obtained from the model for the animal genetic, **pe**, **htd** and residual effects were 2.631, 4.264, 1.339 and 6.805 respectively and the heritability estimate was 0.17±0.03.

Similar edits applied for the estimation of genetic parameter were used for the genomic prediction except that cows with one test day records were included in the analysis. Thus 3802 cows with 53955 test day records were used for the genomic prediction. The genotypes on 5146 animals were included in the analysis, although only 609 of these cows also had test day records. All genotyped animals with no records were included in the genomic prediction analysis, so these animals can obtain predicted gEBV. The ssGBLUP procedure implemented therefore involved an H matrix consisting of 21724 animals with a weight of 5% on the A matrix in forming G_{22} matrix. The MiX99 software (Lidauer, *et al*. 2016) was used in the analysis to predict the gEBVs of animals and their reliabilities.

The animals were selected following the guideline developed by the ADGG project (https://portal.adgg.ilri.org/sites/default/files/ADGG_ETH_BULLCOW_sel_GUIDE_2020.pdf). The gEBVs of bulls ranged from -3.88 to 4.35Kg with a standard deviation of 0.84, implying that some of the top bulls available for selection are 4 to 5 standard deviations above the average bull, indicating that genetic progress can be made through using these the top bulls. Similarly, corresponding values for cows were -3.86 and 4.22 and 0.80 respectively. Top bulls and cows ranked on the estimates of gEBVs were made available for farmers.

Capacity building and awareness training

Building research and development infrastructure enables NAGII and regional livestock offices to effectively implement their genetic improvement plan. To this effect, the ADGG program equipped NAGII with high-capacity server (8 TB storage and 256 GB memory) to collect and store data. Besides, four Combo Lacto-Scan machines are procured to capture milk compositional traits and somatic cell count and each piloted district was provided with 100 motorbikes, 92 tablets, 15 laptops, printed plastic ear tags and heart girth measurement flexible tapes to enable smooth data collection and reporting and ensure uninterrupted monitoring of farms.

Work has also been done to strengthen the human and infrastructural capacity of the national system to collect field data, manage, analyze, and provide feedback to smallholder farmers. A total of 120 performance recoding agents (PRAs) are recruited and trained from 98 districts and large-scale farms from project regions on national dairy animal identification, importance of performance recording and data capturing using the ODK tool. PRAs visit dairy farms at least once a month, during which they advise the dairy farmer to whom they are assigned and capture new performance records. A critical component of the program, included, awareness creation, through trainings, which were organized and delivered to farmers, regional, zonal and district livestock office experts focused on merits of animals' identifications and keeping the history of individual animals to improve genetics, increase productivity and profit.

The capacity of 15 Ethiopian experts in quantitative genetics was enhanced through tailored training courses on data management, related statistical analyses, and hands-on genomic breeding value predictions exercises. The data generated from the national herd performance recording system is being used for related research by five MSc and two PhD students' in writing their theses. Forty-five days full-fledged AI training was delivered to 15 PRAs in collaboration with the PAID project. AI kit and motorcycles were procured and distributed to all trained PRAs to ensure sustainability of data capturing and AI service provision to smallholder farmers.

First dairy cattle virtual parade

The first dairy cattle animal parade was held virtually on March 30, 2021, in the presence of dignitaries from the MoA, ILRI and BMGF and with the participation of senior government officials, farmers' representatives, researchers, development workers from domestic and international organization, private firms, research institute, and universities. The top ranked animals were exhibited and, six farmers (two out of the six are women), who owned three best bulls and cows were recognized and awarded. The purpose of the award is to motivate dairy farmers to participate in national animal identification, record keeping and genetic improvement activities actively and continuously. Further information on the first dairy animal parade event can be accessed from published articles in both hard copy and online using the following links:
https://www.ilri.org/news/building-sustainable-livestock-genetics-improvement-system-food-secure-ethiopia
and https://www.capitalethiopia.com/featured/ministry-of-agriculture-eyes-to-triple-dairy-production/

Dairy Animal Directory

The first dairy cattle directory in Ethiopia was also inaugurated by the Ministry of Agriculture on March 30th, 2021 and published online. The directory can be freely downloaded from the link below: https://hdl.handle.net/10568/113558.

Mobile application

Mobile based application has been developed and officially launched, the application has two modules, and presents top ranked animals, and artificial insemination center bulls with detailed information about the animals alongside pictures (see Figure 4). The list of top ranked animals will be continuously updated after all new national genetic evaluation results are released. The application is freely available to beneficiaries and service providers such as artificial insemination technicians. It helps in connecting seller and buyers of the top ranked animals, whilst the list of bulls at AI centers will support farmers to select the bull breed type and exotic dairy breed composition best suited to their cows. The application can be downloaded using APK from " http://45.79.249.127/adggapi" link.

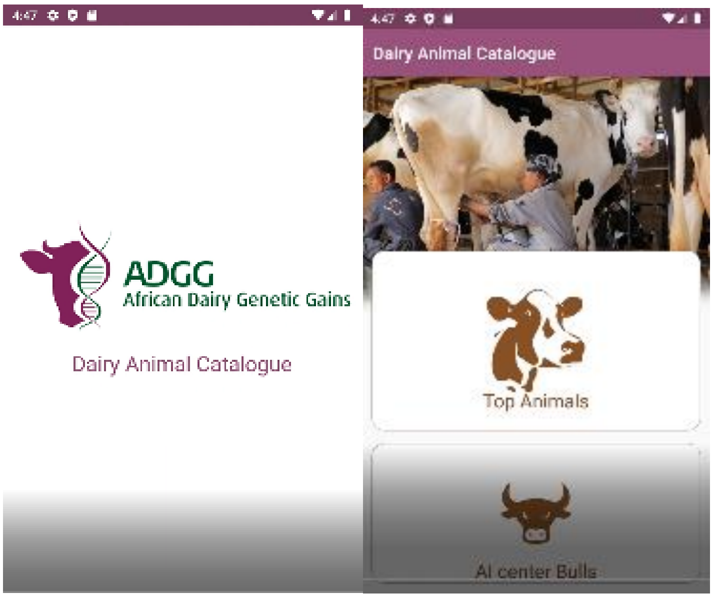

Figure 4: Mobile application for dairy animal mobile based catalogue, front pages

Animal certification

The first dairy animal certification system was based on the results from genomic based evaluation of the animals (see Figure 5). Farmers who own certified top ranked dairy animals are getting better price for their animals. Besides, cows and heifers with record builds confidence for both sellers and buyers of replacement animals. Provision of certificates to farmers increase trust and motivates them to continuously provide and send accurate data to the national dairy cattle platform. Soon dairy farmers will use their elite animals as collateral for loan arrangement from different financial institutions. Bulls certified through the genetic evaluation scheme could also be used for natural mating, replacing the unknown sires in communal grazing system.

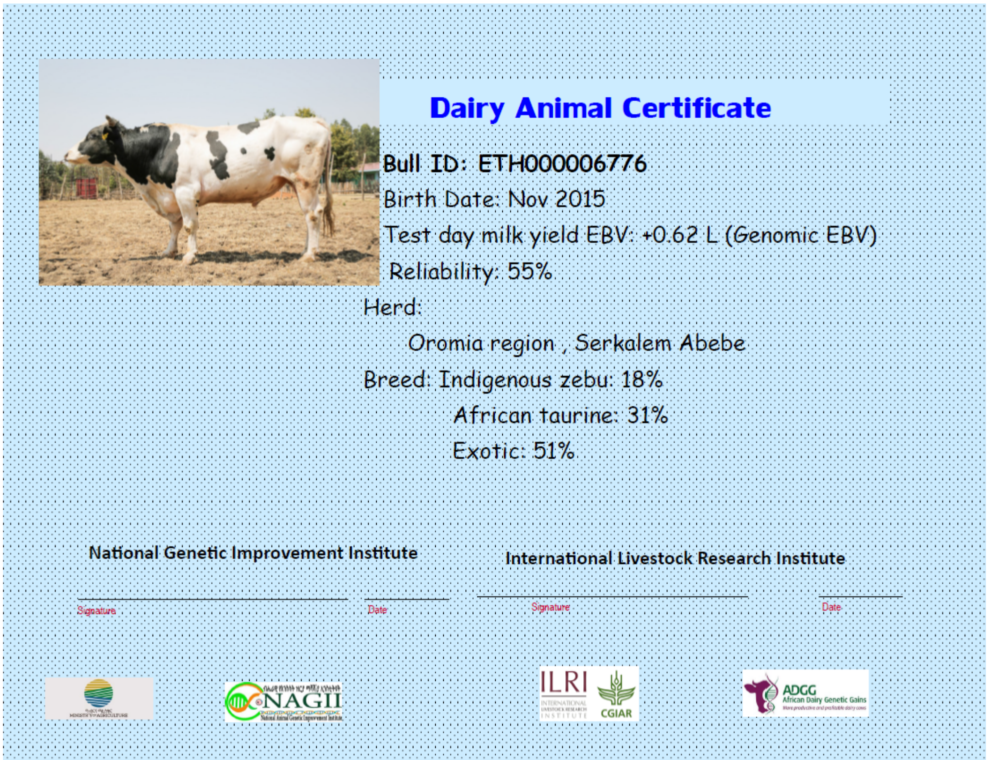

Figure 5. Dairy animal certificate developed after the first-round of genetic evaluation

Partnerships

In Ethiopia, ADGG is working in collaboration with NAGII which represents the Ministry of Agriculture and many other domestic and international partners. Sustainable genetic improvement can be ensured through the participation of all stakeholders at various levels. To avoid duplication of efforts and ensure that partners complement each other for greater impact, institutions, the private sectors, non-Governmental organizations who are actively involved in Ethiopia dairy cattle research and development activities, have formed a partnership platform. The platform is working to harmonize animal identification, data collection and sharing or building sustainable genetic improvement program. Members of the platform are: NAGII, Agricultural transformation agency (ATA); Public artificial insemination delivery (PAID), Precision agriculture for development (PAD), Building rural income through inclusive dairy business growth in Ethiopia (BRIDGE), Project Mercy (PM), International Livestock Research Institute (ILRI), Green Dreams Technology (GDT) and Natural Resources Institute of Finland (Luke). Other potential institutions will be approached/invited to join the Ethiopia dairy cattle partnership platform for the betterment of dairy farmers in Ethiopia.

Prospects and challenges for scaling up and sustainability

Despite the huge livestock resources in the country, the benefits that the smallholder farmers get from their efforts, are currently relatively low. One challenge that contributes to the observed low productivity and profitability levels is limited access to productive but locally adaptable dairy genetics. The inputs and services required for genetic improvement and improved genetics delivery are inefficient with limited private sector participation. The ADGG project has laid a firm foundation for long term breeding program. Some of the cornerstones for the breeding program are the establishment of a harmonized national database, field data capture tools, pipeline for the analysis and selection of top-ranking sires and dams, genotyping strategy, and a digital system for sharing feedback and delivery of educational messages using ICT tools. Thus, it must be scaled up and sustained by engaging more farmers, the private sector, associations, and societies. The following are some of the suggested interventions for scaling up and sustainability.

Institutionalizing the breeding program: Sustainability of a breeding program requires ownership, commitment, and support by the government. The breeding program must be institutionalized within NAGII and supported with resources to ensure the continuity of data capture, feedback, extension educational message, genetic analysis, selection of top ranked animals, promotion and use of top ranked bulls for semen production.

Engaging private sector: Private sector could play a pivotal role in designing and implementing a successful breed improvement programs and delivery of improved genetics. Government must support and encourage private sector to engage in long term business investment. Loan, land, property right and protection, etc. creates confidence to invest in breeding business in sustainable manner.

Continuous capacity building: Establishing a sustainable long-term breeding program requires continuous human and infrastructural capacity building. Domestic universities should play this role by designing or adjusting existing curriculum to produce skilled, well versed, and capable professiona1 in the field of animal breeding. Besides, linking graduate thesis and dissertations with ongoing activities will boost the data collection and facilitate execution of different trials or research within a specified period.

Farmers' continuous education: Creation of awareness to, and participation of farmers in good animal husbandry practices that relates to the ongoing breeding programs should be improved through continuous education. The system of educating farmers follow different modalities based on ease and access to infrastructure such as ICT, practical and theoretical trainings. Without feedbacks and continuous farmers education and using appropriate contents, long-term sustainable breeding programs might not be attractive for farmers to engage and participate in since the fruits of the whole process of data collection, genotyping and genetic evaluation are harvested after many years. Farmers' education methods currently being used including cellphone-based text messages, voice education messages, use of tablets for data capture, and videos should be scaled up for wider reach. Current data collection system uses PRA to collect data, upload and send to the central database. Such approach may not be a long-term solution to data collection. Farmer's education should also include aspects of data collection and sending using their mobile phone. This requires, continuous education on the importance of data capture and engaging farmers in participatory genetic evaluation.

Harmonized animal identification and registration system*:* Animal identification and registration are key to implementing sustainable genetic improvement, traceability of animals and animal products, disease control, management of animal movement and use of animals as collateral for loan acquisition. Identification and registration must therefore be scaled up and institutionalized within government structure. Short- and long-term government plans must include national animal identification and registration as one of the activities supported with budgets.

Building partnership among actors in the dairy value chain: Sustainable breeding program should be matched with improved feeding, health care, and access to quality inputs and services and market linkages to fully extract improved genetics and genetic gains. This way, national consumers, would be assured access to safer and more nutritious milk and milk products. Different initiatives targeting a specific node of the value chain should build partnership to complement their efforts and sustainably support the breed improvement programs.

Supportive government policies: Supportive government policies, regulations and guidelines needs to be formulated, enacted, and respectively availed to encourages the generation and wider application/uptake of new technologies and innovations related to improved breeds. This way, ownership, and property right and privileges to use the improved genetics at a wider scale would be ensured. To this end, policies that support establishment of breed societies aiming to improve specific breeds, benefit sharing, etc are needed.

Challenges for scaling up and sustainability

Project syndrome: Projects by nature are time-bound, with some being short lived and targeted to only demonstrate, generate, or design innovations. On the contrary, breeding program are long term, thus, scaling up, sustained implementation and demonstrated innovations needs long-term buy in from the government or private sector.

Lack of ownership and long-term government commitment: Long-term investments and lack of demonstrable immediate benefits or profit from breed improvement has not and may not attract policy makers attention and incentivize them to allocate adequate resources and make related investments. Thus, continuous dialogue with, and creation of awareness to the government is required.

Delay or limited private sector participation: Private sector engagement in long term genetic improvement, improved genetics multiplication and delivery, and the provision of supportive services depends on the profitability of the business as well as government incentives and support. Thus, unless these are in place private sector participation could be limited at least in the short-term.

Business competition for improved genetics delivery: Globally, the business of improved genetics is dominated by international companies, with many years of experience and reputation. Joining the improved genetics market for tropically adapted dairy breeds faces unique challenges, hence evidence needs to generate and packaged in ways that clearly demonstrate the relative competitiveness of such businesses before selling them the experienced companies. The ADGG program is trying to do that.

Conclusions

From the above review, the following conclusions can be made:

- Successful and sustainable breeding program depends on a functional national animal identification and registration system, phenotypic data recording, robust genotyping strategy, appropriate data analysis and estimation of genomic breeding values, proper selection indices, the basis on which ranking of bull and bull-dams and are done and finally the top genetics aggressively promoted and widely used through AI and natural mating to breed future cows.
- Farmer's participation will depend on the feedback and benefit they get by participating in the breeding program, thus periodic feedbacks and extension educational messages need to be shared with them for improved productivity and production. The accuracy of estimated genomic breeding values depends on the amount and quality of data and the size of the reference population with both phenotypic and genotype information, thus, enhancing phenotypic data collection and increasing the number of animals genotyped improves the accuracy of the estimate.
- The success of a sustainable breeding program depends on the improved genetics delivery system and promoting the use of animals selected. Public and private service providers must use semen produced from elite bulls selected as top ranked animals. Elite bulls which are not used for semen production could be used for natural mating to replace indiscriminate uncontrolled natural mating.
- Sustainability of breeding programs depends on the degree participation of the private sector in the genetic improvement companies, breeder's society, professional societies or associations and in the delivery of improved genetics. Enabling environment must be designed by government to attract more private sector participation in such new business.

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Trend of Investment Climates in Ethiopian Dairy Sector: Current Status, Major Challenges and Potential Interventions for Improvement

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Abstract

The study aimed to review trend of investment climates in Ethiopian dairy sector using primary and secondary data. The primary data was collected from EMDIDI routine all round supports (training, research and creating enabling investment climate) of the sector and investors' feedback on stakeholder's meeting. Secondary data from Ministry of Agriculture, Ministry of Trade and Industry, National bank of Ethiopia, Ethiopian Customs Authority, Food and Agricultural Organization and World bank reports was also revewed to determine the status of the sectoral investment climate. The study used a value chain approach and identified actors and their roles, the horizontal and vertical integration. The main challenges in the dairy sector are lack of market, and inefficient input and service delivery, limited private sector investment, weak regulatory institutions, limited technical, technological and financial capacity, lack of market infrastructure and weak market linkages were among actors in the value chain. Reorganizing and strengthening institutions supporting the dairy sector, creating an enabling environment for private sector participation, improving inputs supply, service provision, value addition and market linkages and strengthening research to develop high yielding dairy breeds recommended to drive the commercialization of the dairy sector. Actors in the dairy value chain and their engagement modalities are also suggested to bring a sustainable integrated dairy development. Public sector interventions in selected and targeted investments and revising existing and designing new policies, strategies, regulations and standards supportive to the dairy sector transformation could lay a foundation for private sector investment. At the same time, development partners engaged in dairy development must be aligned with government initiatives for a better and wider impact and to move the sector from being a net importer of dairy products to a net exporter.

Key-words: Dairy, Ethiopia, husbandry practices, investment climate

Introduction

Ethiopia has the largest livestock population of any African Country. According to central statics agency (CSA 2021) there are 70 million heads of cattle, 42.9 million sheep, 52 million goats,2.15 million horses,10.8 million donkeys,0.38 million mules, 8.1 million camels,6.99 million hives and about 57 million chickens. Livestock is an integral part of agriculture contributing to the household livelihood and economies of developing countries (Herrero *et al*. 2013). Livestock production and marketing of its products are essential to the livelihoods of more than one billion people in Africa and Asia (McDermott *et al*. 2010). Livestock contributes to poverty reduction, nutrition, food security, improved income and job creation which are the United Nations' Sustainable Development Goals (Jimmy 2015). Increasing urban population and rising real income, changes in lifestyles and food preferences are expanding the demand for milk and milk products in Ethiopia. Consequently, production of dairy products falls below demand and the country is dependent on imports of milk and milk products (FAO, 2012). Moreover, factors like urbanization, shrinkage of grazing land and skilled labour shortage are shifting the dairy production system. Culturally and economically, the society invest on dairy that demand minimum investment for minimum output instead of holding highly productive pure or cross breed dairy cows to the growing practice of stall-feeding (Tekleab, 2009; Funte *et al.*, 2010; EIAR, 2016).

Dairy sector characterized by low production and productivity, dependent on local breeds, and managed under extensive grazing and uncontrolled breeding. Milk produced in these systems is dominantly from local breeds, and in Ethiopia, about 95% of milk produced is from local breeds (CSA 2021). The demand for milk and milk products is increasing in developing countries and the drivers of change to the dairy sector are demography, growing economies, underserved markets, conducive policy and enabling environment, globalization, and market opportunities (Shapiro et al. 2017). To support the dairy sector, different interventions have been made by the government, development partners, national and international research institutions, and non-governmental organizations. However, in Ethiopia, the sector is yet to fully realize its potential to produce enough milk and dairy products to meet the domestic demand. As a result, the country is forced to import powdered milk and other milk products.

Ethiopia has a large livestock population, a relatively favourable climate for improved, high yielding dairy cattle breeds and regions with less animal disease-stress that make the country to have a substantial potential for dairy development. Considering the huge potential of the country, investing in development interventions to the dairy sector will contribute to poverty alleviation by increasing the income of smallholder dairy producers and creating employment and transforming the existing largely subsistent type of milk production to commercial level (World Bank, 2009; Hunde *et al.*, 2015; Tadesse *et al.*, 2017; Shapiro *et al.*, 2017).

Review of the dairy sector in Ethiopia indicates that there is a need to focus interventions more coherently. Development interventions should be aimed at addressing technological gaps and marketing problems. The government needs to take actions and should make developmental interventions in the various components such as breeding, animal health, feeding, milk collection, storage, processing and distribution (Hunde *et al*., 2015; Tadesse *et al*., 2017).
There are potential dairy producing farms but there is no linkage with potential dairy products processing industries, due to infrastructural gaps that should be intervened by Public-Private partnership, NGOs and other value chain actors (EMDIDI, 2021).

Livestock contribute to food supply by converting low-value materials, inedible or unpalatable for people into milk, meat, eggs and have the potential of enhancing food and nutrition security, providing income to pay for education and other needs, can enable poor children to develop into healthy, well-educated, productive adults. The challenge is how to manage complex trade-offs to enable livestock's positive impacts realized while minimizing and mitigating negative ones, including threats for health of people and the environment (Herrero et al., 2013). The type of dairy products needs to be considered is whole, liquid milk and other dairy products from fermented processing butter, ghee, ergo, ayib, buttermilk (Wytze et al., 2012). Ethiopia’s dairy value chains have been assessed in the past by Yilma et al. (2011). However, there is need to have periodic assessments of these value chains to provide up-to-date information for informed evidence based interventions by policymakers. The objective of this paper is to review the status of the dairy investment in Ethiopia, identify the key challenges and potential interventions, and describe how the latter can be effectively implemented.

Ethiopian meat and dairy industry development institute (EMDIDI) contributions in the Dairy value chain investment

Ethiopian Meat and Dairy Industry Development Institute established to enable the country to be benefited from its high livestock population bases in the agro-industry sector. It is aimed to develop products with value-adding in meat, honey, wax, feed and milk products to earn foreign exchange. Based on the country's strategic direction, the institute had established four times by the council of the Ministers. Accordingly, the institute was established by regulation No. 143/1998 in the year 1998. it was reestablished again for the second time by regulation No. 176/2008 with modification of its name "Ethiopian Meat Dairy Technology Institute (EMDIT)" being accountable to the Ministry of Agriculture. For the third time, it is reestablished again with the regulation No. 295/2009 with modification of its name "Ethiopian Meat Dairy Industry Development Institute (EMDIDI)" being accountable to Ministry of Industry with some slight modification of its name and some more added powers and duties as well. EMDIDI now is restructured with NAGII with the name of "Livestock Development Institute" under the umbrella of Ministry of Agriculture With special emphasis of the entire livestock value chain.

Ethiopian meat and dairy industry development institute Services, Duties and Responsibilities

Ethiopian meat and dairy industry development institute (EMDIDI) Provide all round support of investment facilitation and market linkages to the industry accelerates technology transfer, achieve transformation and enable the industry to be competitive at international level. The Institute formulates policies, strategies, directives and action; Conduct Training, research and development; Collect, analyze and organize technological, market & other data Provide consultancy services, Prepare and disseminate project profiles and provide practical training; Conduct Lab Testing service (Chemistry Laboratory and Microbiology Laboratory).

Ethiopian dairy sector investment climate trends

This will provide a brief description of the current status of the dairy investment sector in Ethiopia and shows the main stakeholders that are active in the dairy Investment. The direct actors at the core supply chain are the collectors, cooperatives, unions and private investors who form the link between farmers and processors most of the time that usually collecting the milk via central Milk Collection Centers (MCCs). Currently the numbers of processors are increasing each year that increased competition and expansion of processing facilities forced to source milk at distances of up to 400 km from their facilities. Finance providers and the Government of Ethiopia are important enablers of the value chain. The government, specifically EMDIDI and Ministry of Agriculture are responsible for supporting an enabling environment for all value chain actors in the dairy sector. To encourage investment in the dairy sector, especially regarding the establishment infrastructure, it is important to ensure that banks and impact investors can bridge this financial gap for processor.

Livestock population trends

In Ethiopia, dairy Sector is generally a subsistence smallholder-based industry with relatively few medium commercial dairy farms. The dairy sector has the potential for creating jobs in developing countries, such as Ethiopia where job creation for the youth is a priority government agenda. The dairy value chain has the potential to generate gainful job opportunities. As indicated by Filippo et al. (2017), dairy-related activities at farm level are estimated to generate 77 direct full-time jobs per 1,000 liters of milk produced. This means that, the top potential for job creation, the government must put in place enabling policy and infrastructural environments for all actors in the dairy value chain to invest in expansion of existing dairy investments. The Ethiopian government has more recently invested in: capacity development through introduction of exotic breeds to enhance production capacity and establishment of supporting institutions; establishment of new and strengthening existing AI centers, training of AI technicians and; Development and promotion of policies that support private sector participation and investment in this sector. On the other hand, private sector players have invested and continue to invest in commercial dairy farms, milk processing plants, feed processing, and supply of dairy inputs and services. Developing a country-specific dairy strategy that transforms the sector requires critical assessment of the opportunities and challenges and possible interventions (EMDIDI, 2021)

Table 1. Cattle population, milking cows, and annual milk production in Ethiopia

Year	Cattle Population (million)			Female out of total cattle population (%)	Number of Dairy cows (Million)	Dairy cows out of female population	Annual Milk Yield (Billion litres)
	Total	Male	Female				
2014/15	56.71	25.26	31.44	55.45	6.50	20.66	3.07
2015/16	57.83	25.81	32.02	55.38	6.74	21.05	3.06
2016/17	59.49	26.48	33.01	55.49	7.16	21.68	3.10
2017/18	60.39	27.37	33.02	54.68	6.66	20.17	3.10
2018/19	61.51	27.27	34.24	55.67	7.09	20.71	3.30
Average	59.19	26.44	32.75	55.33	6.83	20.85	3.13

Source: CSA (2015, 2016, 2017, 2018 and 2019).

Production, consumption and market trends

In Ethiopia total milk production has increased gradually over the last 15 years from less than 1 billion liters to 3 billion liters in 2021. Although this rising trend is positive, there is still a lot of potential to increase milk production substantially in a short timescale, given the fact that the total herd of more than 70 million cattle includes 12 million dairy cows. Current production rates per cow are extremely low, ranging between 1 and 2 liters per cow per day for the majority of dairy cows. With respect to domestic and household consumption of raw milk, 32% is consumed by calves or goes to waste while 68% is used for human consumption. Looking at human consumption, half of it is consumed at home and the other half processed into local dairy products such as butter and *ayib*. At the same time, market reports indicate increasing consumer demand in formal markets for quality milk and dairy products in the urban areas. This is especially the case for Addis Ababa, where consumption rates per capita are increasing annually, and reaching 55 liters per capita per year. Annual imports of dairy products, especially milk powders used in infant formula milk, fluctuate between 10 and 20 million dollars. The situation offers an opportunity for dairy farmers to meet the growing internal market demand by increasing quality milk production (EMDIDI, 2021)

Private sector involvement

Dairy farms

In Ethiopia almost 95% of dairy cows are kept and maintained by smallholder farmers with fewer than five head of cattle per household. The other 5% are held by bigger commercial farms with 10 or more dairy cows. This is also reflected in milk consumption around 5% of the raw milk reaches the formal market while 95% is consumed at home or sold through informal market systems. On average

95% of smallholders produce between one and two liters of milk per cow per day, compared to 10–15 liters per day for cross-breeds kept by larger farms and more than 20 liters per day for commercial dairy farms(EMDIDI, 2021).

Dairy processing

Dairy processors in Ethiopia are the main drivers of milk uptake from dairy farms and play an important role in the development of the sector. They collect the raw milk from different sourcing destinations through collection centre's, ensure the refrigerated transport of raw milk to the milk factory, process the milk into cheese, yoghurt and other dairy products. The main distribution destinations in Addis Ababa and other larger cities are supermarkets, shops, hospitals, schools, and the hotel and restaurant sector. The number of dairy processors is growing each year in response to increasing market demand. In 2021 around 40 dairy processors are active in processing and selling dairy products, but new processors are planning to establish dairy factories in the various areas. The capacity of milk processors varies greatly, from small and Medium Industries that process 1,000 liters per day up to large processors like Family, Lame Dairy, and Mama Milk that can process up to 90,000 liters of milk per day. Some processors have plans to produce Ultra High Temperature (UHT) processed milk. One of the main challenges for dairy processors is the insufficient supply of quality raw milk, resulting in limited capacity utilization by processing facilities. The poor quality of raw milk is another challenge for processors. This explains the current trend of processors investing in milk collection points and cooling facilities to better control supply and quality. Some processors have introduced quality-based payment systems to provide incentives to dairy farms to provide better quality milk. However, rejection rates by processors remains high and dairy farmers can always sell their milk through informal market systems in their own villages. As a result trust among value chain players is low (EMDIDI, 2021).

Milk collection

In Ethiopia milk is usually collected private milk collectors or by processors directly from milk collection centers (MCCs) sometimes using aluminum cans. However, processors increasingly invest in MCCs, financed by private grants or own capital. Processors gain control over milk quantity and quality, and build more direct relationships with dairy producers. By introducing quality-based payment systems, processors provide financial incentives for dairy farmers to ensure a more consistent supply of milk (EMDIDI, 2021).

Inputs and services

Feed supply is a weak point for the dairy sector. Fodder and silage are scarce, leading to very high prices for hay and fodder that's an important challenge to the Ethiopian dairy sector. The Government of Ethiopia has several plans to establish a new institute responsible for these issues in order to boost production. Animal health is also an area of concern.

Financial Sector Involvement

Ethiopia is one of the largest sub-Saharan economies, with a GDP of more than 72 billion dollars, and has a high annual GDP growth rate of between 8% and 13.6%. The growing economy is attracting foreign direct investment slightly faster than other East African nations, at 11.4% of gross fixed capital formation compared to the East African average of 10.1%. Ethiopia is strongly dependent on the agricultural sector, which has a 37% share of GDP and is one of the sectors with the highest domestic investment. Nevertheless, the total amount of foreign investment is low compared to the regional average, as FDI for Ethiopia are 18.9 % versus a 25.3 % regional average. The private banking sector has developed slowly since the liberalization of the economy in 1991. A large part of the banking sector is still under government control. The Ethiopian banking sector is sound in its capital and ratios, it remains small and offers only limited services. Obtaining credit from banks is difficult, because of a practice of not serving early-stage firms and the high levels of collateral value to loan value required. As a result, there is little or no financial support available for activities high-potential Dairy Investments. In recent years, there have been some feed processors, milk collectors and milk processors being financed by the Ethiopian Development Bank, Commercial Bank of Ethiopia and private Banks. Despite this, it creates lack of access to finance in the supply chain. This is recognized that milk processing companies need to invest in backward integration within the supply chain as a loan condition (EMDIDI, 2021).

Public Sector Involvement

The government is aiming to reduce dairy imports and work on policies to stimulate the export of dairy products. The government has set an overall milk production target of 9.4 billion liters for cow, goat and camel milk. One of the recommendations made to the government by input and service providers, international donors and dairy processors is to support the privatization and input provision for dairy investments to ensure that more investments can access the services easily. EMDIDI is a government institution that facilitates and attracts foreign investors in dairy and other livestock investments. It encourages more vertically integrated businesses that include land for Dairy Investments. Last but not least, the Government of Ethiopia is encouraging dairy investors, especially in high-density areas (EMDIDI, 2021).

Ethiopian Dairy Value Chain

Milk processing value chain

Sustainable food value chain is the full range of farms, firms and their successive coordinated value-adding activities that produce raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use (FAO 2014). The dairy value chain includes supply of inputs and services, milk production, processing, marketing, and consumption (Gebremedhin *et al*. 2012). The success of dairy Investment depends on how well the value chain is supported and how well the challenges at each value chain are sustainably resolved. It is important to critically assess the whole dairy value chain, identify the challenges, and exploit the opportunities by adopting viable solutions, focusing on responsibilities of different actors in the value chain and modalities of engagement of actors based on their comparative advantages. Depending on the distance to market, milk produced is either consumed locally or sold as butter. This is mainly due to the low daily milk production, lack of access to market, and an underdeveloped milk market infrastructure (EMDIDI, 2021).

Dairy Value Chain Strengths, Weaknesses, Opportunities, and Threats

Table 2: Strength, weakness, opportunities, and threats analysis of the dairy value chain

Strengths	Weakness
▪ Widely acknowledged economic and social benefits of dairy ▪ Presence of ongoing projects and good experiences and lessons for scaling up ▪ Presence of private sector investment in dairy processing, feed processing and input supply ▪ Growing investors engaged in milk collection and processing, and input supply	▪ Interventions lack continuity ▪ High cost of production ▪ Low milk quality and high milk losses ▪ Weak regulatory capacity ▪ weak to invest in milk collection centre, equip ment, transport ▪ Lack of quality-based milk pricing ▪ Extended value chain actors

Opportunities	Threats
▪ Supportive policy (nutrition, job creation, food security, import substitution, establishment of industry parks) ▪ Increased demand for milk and milk products ▪ Continued government investment support ▪ Growing private sector interest investing in dairy, value addition and feed processing ▪ Presence of different stakeholders and projects supporting the dairy sector ▪ Presence of international and national research in stitutions, nongovernmental organization	▪ Poor quality control ▪ Poor infrastructure for marketing milk ▪ Lack of regulation ▪ Seasonality in market ▪ Animal diseases ▪ Low number of improved breeds ▪ Low investment by private sector ▪ Low quality feed and risk of Afla toxin ▪ Milk importation and lack of protection of local producers from ▪ market competitiveness

Ethiopian Dairy Investment Bottlenecks

This section summarizes the main bottlenecks in the dairy supply chain.

Table 3 Challenges and bottlenecks within the Ethiopian dairy sector

No	Value Chain Se	Main Challenges/ Bottlenecks
1	Dairy Farming	▪ Low milk production ▪ Shortage of land and fodder production resulting in limited availability of feed for dairy producers as a result of scarcity high fodder prices. ▪ Poor quality of raw milk as a result of limited infrastructure to ensure a cooled chain of milk products towards the formal market. ▪ Weak veterinary, AI, and extension support services ▪ Lack of private sector engagement results limited quality service incentives
2	Dairy Collection and Processing	▪ Lack of proper quality controls in the value chain by processors, combined with limited quality price incentives for suppliers, leading to high rejection rates by milk processors. ▪ Limited professional and business-driven Collectors leading to poor collection and marketing of reliable milk supplies. This is also the result of weak governance and management structures. ▪ Lack of minimum quality standards should be in place (enforced) to secure the supply of high quality milk to processing companies and to motivate processors to invest in cooled storage and transport. ▪ Limited infrastructure (roads, collection, cooling) for producers to deliver their milk to collection points and markets. ▪ Limited capacity utilization of processors resulting from unstable and limited supplies of poor quality raw milk, leading to overcapacity of processing facilities and unprofitable facilities. ▪ Limited dairy technology expertise at processor level results in poorly managed processing facilities and product and market development.
3	Enabling Environment	▪ Limited access to finance for dairy processors (working capital, supply chain investments) resulting in insufficient investment to encourage economic growth and sales of milk and financial sustainability in the value chain. Underdeveloped local banking sector resulting in a lack of specific and tailored loans for agribusinesses. ▪ Limited supporting policies by the government of Ethiopia to encourage private sector engagement in AI services, veterinary services, fodder production and extension support services to improve the availability and quality of these services for producers. ▪ Weak linkages and coordination between chain actors resulting in insufficient use of resources, duplication of efforts and uncoordinated initiatives, with few tangible results showing how they contribute to government aims.

Supportive role of Ethiopia Government on Dairy investment

The Government of Ethiopia has focused strongly on attracting foreign and local investors for dairy development. They provide incentives in the form of establishing industrial parks and dedicated support from various government agencies. The Government has therefore allowed several public-private partnerships (PPPs) in this domain to prove their added value, and breeding policies. More commercial fodder and feed production is being encouraged through the provision of dedicated, currently unused, land for this purpose (EMDIDI 2021).

Intervention packages

The intervention highlights support the development of an inclusive dairy value chain through innovation, data technology, learning and the development of business and investment plans. Furthermore, it supports the process of public–private partnerships (PPPs) by bringing different stakeholders together, including financial institutions, private companies and governments. For more details about the intervention packages refers: Farmers support that develop production and entrepreneurial skills in of dairy Industries for scaling up; Commercial dairy farms that Introduce well-established commercial farms (>15 cows) with modern production and management techniques; Dairy Investment that Introduce new professional milking and collection systems at community level with strong marketing and long-term relationships with market players; Commercial fodder production and service centers that Promote and support professionally managed that combine production, distribution, training and service provision in companies to assure optimal yields, product quality and quality assurance and; Finance and investment that develop an investment model to finance professionalized dairy investments with all relevant stakeholders. This can only become effective when the business case can be translated into an investment case. All the intervention packages link to businesses and support investments in developing a healthy business.

Dairy processing Industries in Ethiopia

Commercial processors are those adopting modern technology with the majority of their output being pasteurized milk , Yogurt, cheese, Butter cream, Mozzarella and other Processed Dairy Products. Currently, there are over 31 medium- and large-scale dairy processing companies in Ethiopia with nine of them operating in Addis Ababa and the rest in other major regional cities (Appemdix table Table 1).

Policy Interventions to Improve the Dairy Value Chain in Ethiopia

The 1991 to present policy made several macroeconomic policy changes. Some of the major policy changes had the fixed exchange rate system to a more market and series of devaluations of the local currency since 1992 is believed to have discouraged imports of dairy products. Following the changes in policy to allow the private sector investment in dairy production, processing and marketing, several dairy processing industries were established around Addis Ababa and other urban areas. The entrance of the private dairy processing firms, in the late 1990s offered producers a better milk price as compared to that paid by the previous ones, thereby stimulating competition and helping the expansion of the formal market (Table 4). Taking advantage of the newly created market opportunities through economic reforms, dairy producers within 100 km radius of Addis Ababa formed the Addis Ababa Dairy Producers Association (AADPA) with the main objective of providing feed (Haile, 2009; World Bank, 2009; Yilma *et al*., 2011; Shapiro *et al*., 2017; EMDIDI, 2021). EMDIDI (2021) has also recommended breeding policy intervention.

Conclusions and Recommendations

Ethiopian dairy sector has increased over the last decades, but is not reaching the quality standards necessary to meet the demands of formal markets. Over the next five years, the government is aiming to reduce dairy imports and work on policies to stimulate the export of dairy products. There is a lack of trust among value chain players. Processors do not provide guarantees for a stable and predictable off take of milk. The private sector participation in the market for input and service provision is still limited. As a result, risks within the value chain are high while performance is low; this is not an attractive investment case. New ideas and transformations in the dairy sector will require external financing from international banks, impact investors or strategic investments from existing companies that have access to capital. The following recommendations can help transform dairy sector from subsistence to commercial market-oriented investments in Ethiopia:

- Established PPP for Sustainable inputs, production and marketing system
- Promote a market-driven and integrated value chain approach milk processing
- Establishing integrated commercial dairy farms and processing in potential areas
- Increased production will create opportunities for export of surplus produce.
- Strengthening the dairy value chain actors to play role in developing infrastructure
- A breeding policy that targets indigenous breed improvement is needed in the country.
- Promote milk consumption and integration of dairy development with ongoing government programs (e.g. nutrition, school milk feeding).
- Market linkage of smallholder dairy farmers with processors should be strengthened by organizing producers in marketing associations and cooperatives.
- Develop local capacity to manufacture dairy equipment and to produce qualified technicians and extension to support extension services for dairy producers.

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Appemdix Table 1: Major private dairy enterprises operating in different parts of Ethiopia

No.	Investments	Location	Investor type	Daily processing capacity (liters)	Average capacity (liters)
1	Sebeta (Mama) Dairy	Sebeta	Domestic	60,000	50,000
2	Shola (Lame) Dairy	Addis Ababa	Domestic	700,000	90,000
3	MB PLC (Family Milk)	Addis Ababa	JointVenture	90,000	30,000
4	Ada'a Dairy Cooperative	Bishoftu	Domestic	16,000	1,200
5	Adama Dairy	Adama	Domestic	8,000	1,500
6	Almi Fresh Milk	Hawassa	Domestic	20,000	2,000
7	Ruth and Hirut Dairy Farm	Chacha	Domestic	7,000	1,000
8	Chuye Milk Processing	Addis Ababa	Domestic	8,000	500
9	Life Milk Processing	Sululta	Domestic	15,000	1,500
10	Elemtu	Sululta	Domestic	60,000	25,000
11	Fana Milk	Awash Melkasa	Domestic	8,000	5,200
12	Happy Milk Processing	Debre berhan	Domestic	16,000	4,000
13	Zagol Milk Factory	Sululta	Domestic	16,000	6,000
14	Misale Dairy	Sululta	Domestic	16,000	7,500
15	Loni Dairy	Sululta	Domestic	20,000	5,000
16	Good Friday Dairy	Sululta	Domestic	16,000	2,500
17	Evergreen Milk processing	Bahir Dar	Domestic	30,000	5,000
18	Jantekel Dairy Union	Gondar	Domestic	1,200	300
19	Emebet and Daughters	Bahir Dar	Domestic	5,000	1,000
20	Prime Milk	Bishoftu	Domestic	3,200	300
21	Adis Kidan Camel Milk Export	Awash 7	Domestic	12,000	2,000
22	Boru Waqo Camel Milk Export	Jigjiga	Domestic	15000	1,500
23	Z Tambs(Lala Milk)	Teji	Domestic	30,000	5,000
24	Salvation(Melkam Milk)	Teji	Domestic	24,000	3,000
25	Mulu milk processing	Mekele	Domestic	10,000	3,000
26	Holland Dairy plc	Bishoftu	FDI	35,000	14,000
27	IDC	Muke Turi	FDI		
28	Etete	Muke Turi	FDI	16,000	2,200
29	Jojo Milk	Yirgalem I/A/ Park	FDI	30,000	10,000
30	Pinguin (cheese world)	Addis Ababa	FDI	20,000	1,800
31	AJGG Milk processing	Mekele,Adigudem	Joint Venture	30,000	5,000
32	7-D Milk processing	Addis Ababa	Domestic	20,000	5,000
33	Lasal Milk processing	Meki	Domestic	15,000	3,000
34	Berta	Addis Ababa	Domestic	15,000	3,000
35	Selale	Muke Turi	Domestic	20,000	5,000
36	Gimel Camel Milk Export	Dire Dawa	Domestic	15,000	2,000
37	Gape Milk processing	Debre Markos	Domestic	30,000	2,000

Source: EMDIDI (2021)

Dairy Production Potential and Investment Opportunities in Amhara Region: a Brief Overview

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Abstract

The aim of this paper is to present an overview of the dairy production potential and investment opportunities in Amhara region. The region is currently producing 1.196 million tone of milk per year; the local lactating cow production is 2 liter while the crossbreds are giving 11.8 per day. In 2020, the region annual production projection shows 2.6 million tons per year and the annual personal consumption will reach 26 liter per year. The major challenges of the dairy farming in the region are shortage of feed / poor ration formulation, low milk production per cow, lack of chilling facilities on farm and the majority of dairy farmers are smallholders. Since the dairy industry is at a turning point in its history, with a shift from public sector involvement towards private sector participation, new investors have abundant opportunities to develop the industry and tap into the rapidly growing demand in the market. Despite these assets, the productivity of the dairy sector is disproportionally low due to some dynamic economic, technical, and institutional challenges. Thus, enabling the private farms in the region to develop medium and large dairy farms, increase local milk cows' productivity, solve existing dairy farms roadblocks, promote private investors to engage in the processing business and enable the area to access better feed and support feed producers to target the dairy products market are very crucial. The private sector must become a key player by providing simple, sustainable technologies that will enable communities to create jobs, raise incomes and reduce poverty through the dairy production. There are considerable investments opportunities and untapped resource for the dairy sector in Amhara Region. For this, the region identified new potential areas (Gondar, Bahir Dar, Debre Markos, Dessie and Debre Birhan) for dairy sector investment to achieve the plan of increasing the number of commercial dairy farms from the currently existing 3 middle specialized dairy farms to 41 and the milk production from 1,197 to 13,259 tons per year. Moreover, the region is promoting the cluster basis dairy farming in the selected milk shed areas to be encouraged around agroindustry (e.g Bure Agro industry), sugar plantation (e.g Tana Belese), near the established (five) rural transforming center for milk collection and livestock feed processing factories.

***Key words**: Amhara Region; Dairy industry; Investment opportunities; Milk production and Private sector.*

Introduction

The agricultural sector is the backbone of the Ethiopian economy despite the fact that the sector has been characterized by low productivity and operating with antique equipment for centuries. In the Amhara region, the agriculture sector is the leading contributor of the regional economy constituting 55% of the regional GDP; and serve as a source of employment for about 81.9% of the regional population. About one-third (33 percent) of the agricultural production in Ethiopia is produced in

Amhara region. The regional total agricultural products are composed of crop products with 62.5%, livestock with 29.4%, and forestry and fishery with 7.7%. Crop and livestock production are the two dominant sub-sectors with the highest production potential and are sources of regional comparative advantages. In terms of dairy and livestock, the region owns more than 15 million cattle population, and accounts 29% the total livestock population of Ethiopia as well as 1.5% of the world. Particularly, the two major sub-sectors, dairy and livestock, and oil-seed and edible oil, are identified to be the main sources of comparative advantages; and hence considered to be the key growth areas in the region. Based on own observations and expert opinions on farms with crossbreds, crossbred cattle reach an average milk production between 10 to 15 litres per day, with a lactation period of about 10 months. The indigenous breeds have an average milk production between 1 and 2 liters per day (average in 2015 is 1.35 liters per cow per day) for a lactation period of six months (Zijlstra, J. et al., 2015).

It is estimated that more than 2 million youth in Ethiopia are entering the labor market every year. Being the second most populous with 25.5 percent of the country's total population, Amhara region is assumed to follow similar growth pattern of Ethiopia. Over 2.1 million individuals were believed to enter the workforce in Amhara between 2016 and 2021 and over 3.39 million are expected to enter the labor market between 2020 and 2025. However, experiences in the previous years have not been seen to absorb this influx and no warranty was set out if this scenario continues. To tackle this trend of growth-employment correlation, the regional government of Amhara has bid to increase private sector led investment and job creation along with diversification of the economy and revenue bases of the region. In collaboration with the development partners, the region conducted a youth employment diagnostic survey and labs in Agriculture, Manufacturing, Mining, and Tourism. The lab then identified important projects in these sectors and showcased the potential to create up to 2.94 million jobs. The main ingredient to far-fetch this ambition is monitoring of project implementation progresses against the identified commitments and promoting accountability among stakeholders. Framing a roadmap, which shows how Amhara can unlock its potential for private investment and job creation and then brings about a multifaceted multiplier effect on the economy by providing a unifying practical guide for stakeholders, is an integral part of this growth initiative. Thus, the regional investment roadmap is, therefore, developed to provide a clear and systematic direction for developing and transforming the key potential growth sectors, which are selected based on the region's comparative advantages.

While efforts have been on-going to improve the investment climate, challenges are there constraining full utilization of the potential and reap the expected benefit of economic growth that can provide job opportunity for the ever-increasing labor force. The region has been grappling with a multitude of challenges of which unemployment is one of the key problems. It has an estimated population of 30.78 million people in 2020, and about 39.9 percent is reported to be under 15 years of age 4 (APDU, 2021). Cognizant of this problem, the Amhara national regional state, in collaboration with **Big Win Philanthropy**, launched an initiative to encourage private investment, transform the economic sectors and create employment opportunity for about 2.1 million people by 2021. A key driver to this is identification of Entry Point Projects (EPPs) which are selected based on a rigorous diagnostic process. Accordingly, five strategic sectors and 142 Entry Point Projects (EPPs) as well as 97 Business Opportunity Projects (BOs) are identified. This will lead to the creation of over 209,996 immediate and 559,456 gradual jobs with 1.98 billion USD and, eventually, galvanizes the economy to create up to 2.1 million additional jobs by 2024. Doing this, the private investment is expected to increase in volume, the effects leak into other sectors, job opportunities grow, and thereby the regional and national economy transforms.

This paper therefore provides an overview on 1) the dairy production potential in Amhara region, 2) investigations on the opportunities for dairy investment 3) the major challenges of diary investment, 4) the synthesis of the way forward for the dairy investment in the Amhara region

Description of the Amhara region

The Amhara region occupies an area of 170,000 square kilometer (Figure 1 and Table 1). Over 22 million people live in the region. Nearly 87% of the population in the region depends on agriculture. The major crops grown in the region are cereals, oilseeds, pulses, vegetables and fruits, and owns about 27.9% of the nation's livestock population,

The region has a wide agro-ecology suitable for agriculture. The region has huge potential for livestock production. The mean annual rainfall of the region varies from 300 mm to 2,000 mm while annual mean temperatures mostly lie between 15 and 21°C. Ethiopia's largest inland body of water, Lake Tana, as well as the highest peak of the country Mount Ras Dashan are located in Amhara region. Abay (the Blue Nile), Beles, Tekezie, Angereb, Athbara, Mili, Kessem, and Jama are major rivers within the region. The Amhara Region hosts three of the nine UNESCO registered heritages in Ethiopia. Bahir Dar, Gonder, Debre Tabor, Dessie, Kombolcha, Debre Birhan and Debre Markos are the most prominent cities and towns with population sizes of over 50,000 people. The capital city is Bahir Dar, located on the shores of Lake Tana out of which the Blue Nile flows. Amhara has five different agro-ecological zones, with each providing a different potential in agricultural opportunities (Figure 2).

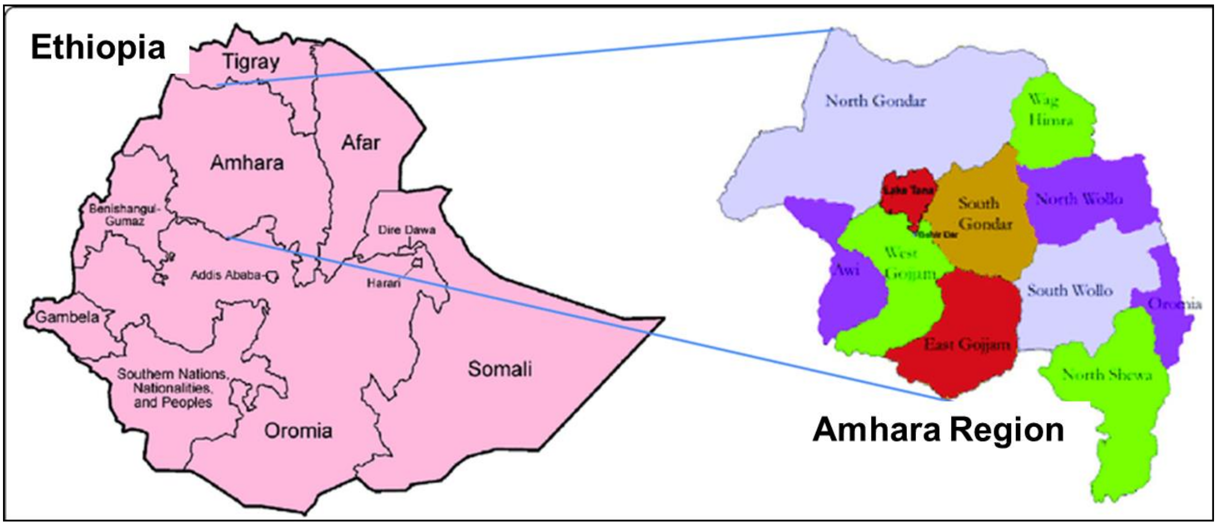


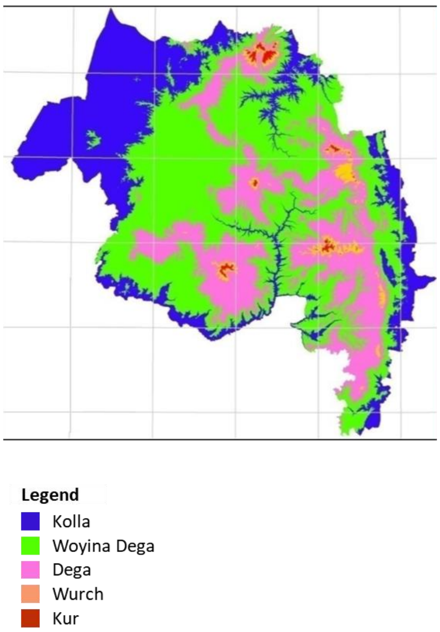
Figure 1. Map of Amhara region.

Table 1. Description characteristics of the Amhara region

Geographic coverage	Land area= 170,152 Km square; Number of Zones: 12 Zones; Number of rural woredas: 158; Number of Kebeles: 3,483; Number of urban woredas: 42
Population	Total: 22,189,999; Female: 11,121,173 (50.1%); Male: 11,068,822 (49.9%); Economically active population (15-64 years of age): 55.7%
Agro-Ecology	*Climate Zones: Woina* Dega (~ Temperate):44.3%; *Kola* (~ Tropical): 28.11%; *Dega* (~ Cold):: 20.52% *Berehama* (~ Desert): 3.14%; *Wurch*: 3.93%; Temperature (Max: 26 degree C., Min: below 11degree C.); Annual Rainfall: (Max: >1400 mm, Min: 500-700 mm.)
GDP Growth Rate	5.5 %
Growth by Sector	Agriculture: 2.9%; Industry: 9.2 %; Service: 8.9 %
Sectoral Composition	Agriculture: 54.1 %; Industry: 16 %; Service: 31.1 %
GDP	404.8 Billion ETB (USD 13.76 Billion)
Per Capita Income	18,241 ETB (USD 620)
Population below poverty line	26.1 % *
Employment rate	71.2 %

Source: ANRS, Plan Commission (2018/19), *CSA (2016/17)

Amhara Zones' Climate and Agricultural Suitability



No	Climate	Zones*	Agricultural Suitability
1	Kolla	• Present in all zones (except North Gondar) but mostly at the fringe • ~70% of North Gondar is of this type of agro-climate	• Suitable for the production of various crops including sorghum, finger millet, sesame, cowpeas, groundnuts, etc
2	Woina Dega	• Present in all zones • Covers from 20-40% of all zones (except North Gondar)	• Suitable for the production of various crops including wheat, teff, barley, maize, sorghum, chickpeas, haricot beans, etc
3	Dega	• Present in all zones but North Gondar • Covers approximately 20-40% of the zones	• Suitable for the production of high land Suitable for the production of various crops including wheat, highland oilseeds, highland pulses, etc
4	Wurch	• Present in mainly Wag Hemra, South Gaondar, North Wello, South Wello and East Gojam • Covers approximately 5-10% of the zones	• Suitable for the production of high land barley
5	Kur	• Present in mainly Wag Hemra, South Gaondar, North Wello, South Wello and East Gojam • Covers approximately 2-5% of the zones	• Not suitable for crop production • Suitable for grazing pasture

Note:*Percentage of coverage is based on approximate estimation only. Source: Ethiopian Institute of Agricultural Research.

Figure 2. The different agro-ecological zones of the Amhara region with

***Cattle population in the region*:** the Amhara region has the 2nd largest cattle population among the regions in Ethiopia & is growing rapidly. The cattle population of the region increased from 11.76 million in 2007/08 to 15.98 million in 2016/17 by 4.22 million (CSA, 2016/17). Within Amhara, North Gondar has the largest cattle population, constituting 23% of the cattle population followed by W. Gojam, E. Gojam, S. Gonar and S. Wolo zones of the region.

Dairy production potential in Amhara region

The Amhara region produces over 740 million liters of milk per annum accounting for 22% of the national milk production. Nearly all the milk production comes from smallholder farmers. Prominent milk producing areas within the region are South Gondar, Awi, North Shewa and East and West Gojam. The most promising business opportunity for international investors targeting dairy lies in the processing aspect. Two interesting sites for milk processing in Amhara region are Bahir Dar city and Debre Birhan town. In Bahir Dar there is a place reserved for urban agriculture and hence interested investors can set-up their own dairy farm within the suburb to secure part of the milk for processing but the biggest supply can be sourced from small holders in Fogera and Tis Abay areas in a radius of 50 km land for processing plant is available at Bahir Dar industrial zone for marginal lease payment. Similarly, Debre Birhan or North Shewa offers tangible business opportunity in milk processing as well as large-scale commercial dairy farming. It is close to Addis Ababa, which is both the input and output market for dairy. The North Shewa corridor hosts few commercial processors as Timret Agro Industry, Ruth and Family Dairy Farm and many small and micro enterprises; all delivering to Addis Ababa market. Lame Dairy has also a bulking and chilling center in Debre Birhan, where it bulks milk from Basona Worana and neighboring districts, until transported to the dairy's processing plant in Addis Ababa. The Dessie/ Kombolcha corridor offers another option for milk processing. Dessie and Kombolcha towns have combined a population of over 250.000 people and hence a significant market. This belt is situated at strategic location with easy access to market cities like Mekelle in Tigray region and is very close to Djibouti (480 km) for potential export to neighboring countries as well as serving the eastern part of Ethiopia. The supply of pasteurized milk in Bahir Dar and other cities within Amhara region solely come from Addis Ababa areas.

In Amhara region, about 1.196 million tone of milk is produced per year. While the local lactating cow production is 1.45 liter per day, better breeds are giving 11.8 liters per day. In 2020 the region annual production projection shows 2.6 million tons per year, the annual personal consumption is also expected to reach 26 liter per year (Table 2).

As indicated in Table, 2 most of the dairy producers use their produces for household consumption. 92.62 percent of the milk production in ANRS and 35.03 percent of the milk production at national was consumed at household level in 2019/20. Only 3.31 percent of the milk production in ANRS and 9.97 percent nation-wide was supplied to the market in the same year. This shows how the market supply for dairy products are limited and the potential for commercializing is constrained at national level, and more so in the Amhara region. The ANRS producers sell substantial amount of butter (38.38 percent) compared to fresh milk (3.31) and Cottage cheese /ayib (0.714 percent). Generally, the above data clearly shows the huge untapped potential for the Amhara region to develop the dairy industry. If the outstanding problems in the livestock sector are resolved, Amhara region will be the leading producer of milk, meat, livestock, and their derivatives for local and export markets. The vision is to make the Amhara region a '***Dairy and livestock capital of Ethiopia and become the leading livestock exporter for the region'*** by producing milk and milk products of the whole country.

The Amhara region has still a demand of 1.1 million fresh milk based on the FAO 62.5 lit/year standard. This offers a huge opportunity for potential investors to engage in milk production in ANRS. In 2020 the region annual production projection shows 2.6 million tons per year, the annual personal consumption is also expected to reach 26 liter per year. With the involvement of various value-chain actors including commercial dairy farmers, milk collectors, dairy processors, feed producers, veterinary and artificial insemination service providers. It is estimated that the diary sub-sector has the potential to create about 225,146 direct and indirect jobs.

Table 2: Utilization of Dairy Products in Amhara National Regional State (CSA, 2019/20).

Type of milk	Household Consumption (%)	Sale (%)	Wage in Kind (%)	Other (%)	Total (%)
Fresh Milk Utilization					
Ethiopia	50.11	9.97	0.56	39.36	100
ANRS	35.03	3.31	0.72	60.94	100
Butter					
Ethiopia	54.89	38.60	0.48	6.02	100
ANRS	54.96	38.38	0.38	6.28	100
Cheese					
Ethiopia	77.21	17.17	0.48	5.14	100
ANRS	94.29	0.71	0.47	4.53	100

Dairy investment and its opportunities in the region

Until recently (3–4 years) Amhara region has been static in attracting foreign direct investment. The major investments within the region are construction, agriculture and manufacturing. In the past the attention given to attract investment to the region has been weak, but this trend seems to be reversed lately. Several factors account for the increased investment interest in Amhara, but the most notable ones are the relatively strong desire and commitment of the regional leadership to attract investment; range of untapped opportunities and availability of key investment resources such as labor, water and land; the relative position of the region from the national centers notably areas around Debre Birhan. Over the last 3–4 years the regional government has been actively promoting available opportunities and exerting efforts to facilitate for an easy entry for investors coming to the region. Account of investors who started business in the region shows that the process of investment evaluation and land acquisition is much faster than their experience in other regions. However, they noted that there are serious problems in terms of electricity and quality of investment service. The most notable investment opportunities within the region are listed in the table below.

Industrial and Agro Parks: the Government of Ethiopia is building industrial and agro parks at different places within the country. Bure integrated agro-ecological park is one of the ready places for investors (Figure 3). Three strong points raised about the investment service in Amhara were:

1. Desire to attract new investments to the region.
2. Relatively active engagement of the top leadership to listen and follow-up on investors.
3. availability of skilled labor.

On the other hand, problems related to (1) electricity (2) honoring words and promises (3) skills and competencies of people working at the regional investment office (4) reliable telecommunication service like Internet (5) centralized decision-making.

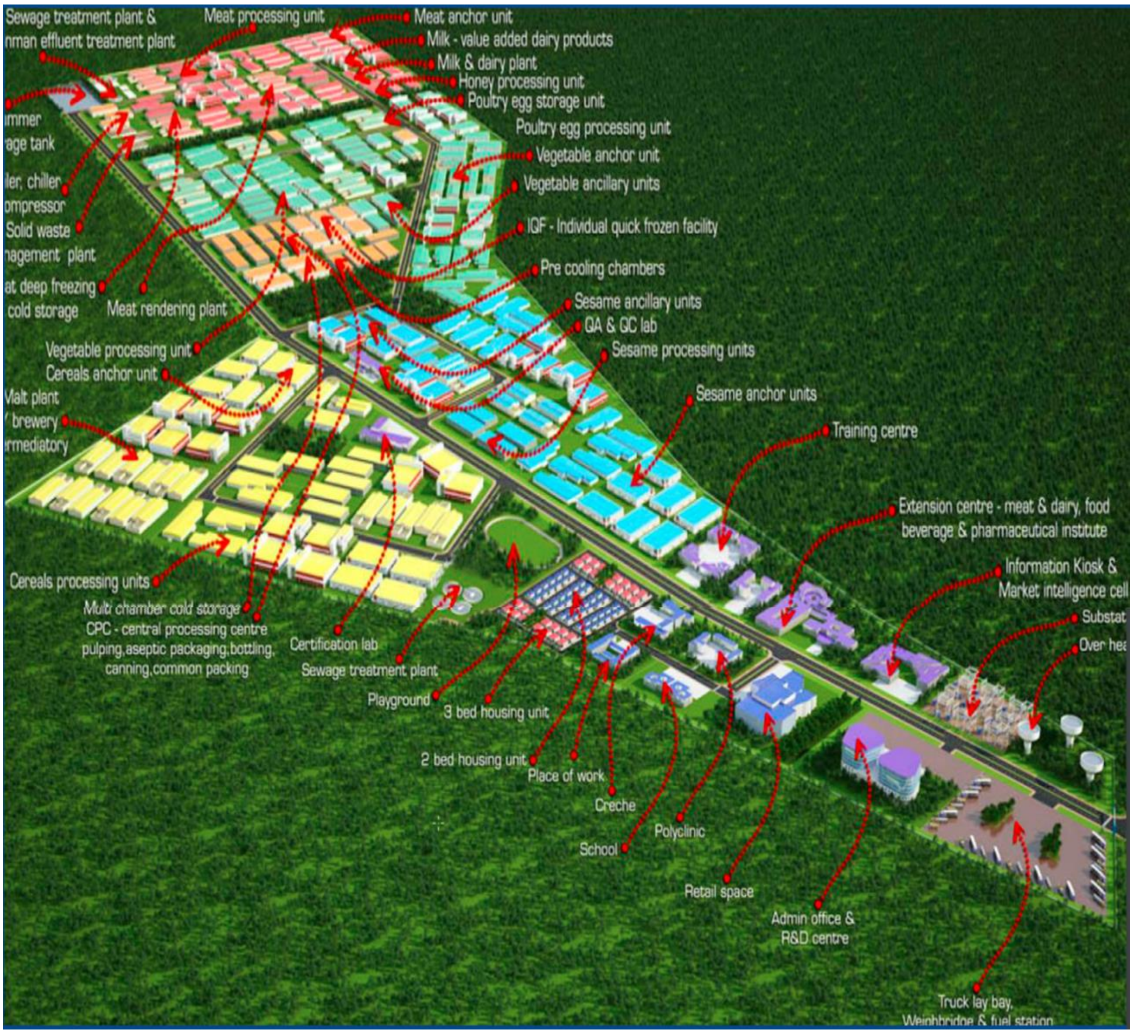


Figure 3: Bure integrated agro-ecological park

Investment Corridors: ***Tana Corridor*** **-** refers to areas surrounding the regional capital Bahir Dar and can extend up to Gondar and areas surrounding Lake Tana. This area offers strong opportunities for horticulture, floriculture and dairy investment. It also provides tangible opportunities for manufacturing and agro processing. The area has abundant water resources from Lake Tana and Abay River and fertile land. It is close to Bahir Dar and hence following issues is easier. Currently an industrial park is under construction by the Ethiopian Industrial Park Development Corporation on 750 ha plot. It is also a very interesting area for further development of aquaculture, as there is already one commercial aquaculture investor in the Koga Lake. Outside of Agriculture this corridor has one of the highest potential for tourism – the monasteries on Lake Tana, the Blue Nile falls, Gondar castles and Semien Mountain Park all locate within this corridor. ***Debre Birhan–Minjar Corridor*****:** the Debre Birhan–Minjar Investment corridor is one of the most active investment sites in Ethiopia over the last 5 years. Debre Birhan–Minjar corridor can be divided in two sites: Hageramariam–D/B and Minjar Site. The Hagermariam–D/B site is the area 60–130 km from Addis Ababa to Debre Birhan fully served by the main road going to the Wello and Tigray. This area is very close to Addis Ababa (60–130 kms). The Minjar site currently hardly has any investment, but investors aiming poultry, dairy and horticulture (using ground water) as well as manufacturing companies can take this site as a serious option. ***Kombolcha–Shewa Robit Corridor:*** the Kombolcha–Shewa Robit corridor is an area from 200 to 380 kms on the main highway to Northern Ethiopia. Kombolcha city within this corridor hosts big textile, steel, plastic and some export processing companies, including in oilseeds and pulses processing. This area is served by railroad connecting it to Djibouti and Addis Ababa via Awash. There is a daily flight from Kombolcha to Addis Ababa. The Kombolcha Industrial Park was inaugurated a year ago and international companies such as the Texas based Trybus group have taken shade. An industrial base in Kombolcha is suitable for export-oriented manufacturing because of the proximity to Djibouti (480 kms). ***Kobo Corridor:*** the Kobo corridor is a potential for horticultural investments in fruits and vegetables in particular. There is a big ground water reserve that spans from Kobo in the north to Girana in the south with estimated irrigable potential of 96,000 ha as per estimation by the Regional Bureau of Agriculture. An area of 5.000 ha is now covered by irrigation but the plan is to expand this to 29.000 in the next ten years. The Kobo corridor is suitable for different vegetables such as onion, garlic, tomato, cabbage, lettuce, green mung beans as well as perennial fruits like mango, avocado and orange.

The Amhara Regional State Investment Commission is established by the Regional House of Councils under Article 233/2015 to promote and attract investment to the region. According to Article 6 of the establishment, the commission shall have the investment board, commissioner, deputy commissioner and staffs within it. The Regional President is the chairperson of the investment board. The commission has its head office in Bahir Dar. At zonal and wereda level the Investment Commission is merged with the Bureau of Trade and Industry whereby one officer sitting at those offices. However, article 4 of the establishment states that the commission shall have branch or coordination offices at selected areas of the region as well as outside the region if necessary. As of now the regional office in Bahir Dar handles all issues in relation to investment applications, licensing, monitoring and reporting progress.

Opportunities in the Livestock -Dairy Sub-sector to promote in the region

The gains from opportunities along the diary value chain needs to be optimized using all the tools assisting the sector to excel out. Here are the opportunities:

- ✓ ***Increasing attention to develop the sector*****:** the regional livestock bureau has prepared a package to organize the youth who are interested to operate in the dairy farming at small scale level. In this line, for instance, the regional government develops a barn for each organized team, give training and assist in accessing loan. Breeding policies also encourage growth of the sector.

- ✓ ***Strengthened dairy cooperatives and unions*****:** increasing number of primary cooperatives, which directly work with the smallholder farmers in feed distribution, AI and VET service, financial support and milk collection for the processors. There are cooperative unions procured and ready to process the milk, which are collected by the primary COOPs.

- ✓ ***High market demand for milk and milk products (especially during non-fasting period)*****:** individuals and institutions such as hotels, universities, prisons, hospitals, thousands of cafe and restaurants, and more governmental and nongovernmental institutions use dairy products for their own direct and indirect activities in the institutions. They purchase from collectors and commercial farms directly. Communities' awareness in milk marketing is also getting better.

- ✓ ***Improved availability of technologies to collect, preserve and process milk and derivatives*:** growing number of supportive institutions along technical and technological lines by governmental and non-governmental organizations. In this regard, research institutes, universities, TEVTs, and other technology providers can also count as opportunities in the area.

- ✓ **Increasing access to infrastructures that enable the diary businesses perform well:** Although not adequate, road, electricity and connectivity networks are expanding, which are pivotal to unlock the potentials along the diary value chain.

- ✓ ***Increasing interest of investors to work in the diary business:*** the wide range of agro-ecology**:** supported by improved breeds, the varied agro-ecology adds favorability of the region to reap benefits in the livestock sector. To increase the regional dairy sector productivity the region targeted to take a measure on the following identified problems in the sector:
  - *Promote better barn and animal handling in the farm*: most of the dairy smallholder farmers are using a traditional way of doing their farm, which is not enabling the milking cows to produce with their breed capacity. Their harvesting process and product storage also has lack of handling and that is making the farmer to lose its produce.
  - *Better supply of dairy cattle breed*: artificial insemination (AI) service promotion by increasing its reach and access in kebele level.
  - *Increase the number of commercial dairy farms in the targeted potential districts**:*** currently there are 3 middle specialized farms, the government planned to increase to 41 until 2030. It increases the production from 1,197 to 13,259 tons per year.
  - *Support feed processers to access land and manufacturing place* in the regional identified milk shades.

- ✓ ***Identifying new potential areas for investment in the sector***: The following targeted woredas are identified as a new potential for dairy Gondar, Bahir Dar, Debre Markos, Dessie and Debre Birhan (Those area which is found in 100 km radius). Promote cluster basis dairy farming in selected milkshed area, around agroindustry, sugar factories and livestock feed processing is also essential.

- ✓ ***Enabling the private firms in the district to develop a small and medium dairy farms:*** increase local milk cows productivity, solve existing dairy farms roadblocks, promote private investors to engage in the processing business, enable the area to access better feed and support feed producers to target the market.

- ✓ ***Entry Point Projects in the Agriculture and Agro-Processing Sectors:*** the agriculture sector in Amhara region grew by 2.9 Percent and contributes over a third of the national agricultural products in 2019/20. Agriculture is not just the main GDP contributor in the region with 55 Percent, but also driven by the crop sub-sector (65.2 Percent), followed by livestock (29.4 Percent), forestry and fishery (7.7 Percent) in 2017/18. The agricultural EPP projects are encased mainly under the four sub-sectors of crop, vegetable, livestock, and agro processing. Agro-processing: Increase manufactured agricultural products and boost up foreign exchange through export promotion and import substitution.

- ✓ ***Animal Feed Processing:*** Bahir Dar has a natural competitive edge for animal feed processing. There is big volume of maize produced in the area. Oil cake can easily be sourced from local millers and importantly the largest soybean production zone in Ethiopia-Metekel is located only 235 km. currently, the main sources of feed are hay/straw, grass and oilcakes but a small amount is imported from Debre Zeit. A feed processing in Bahir Dar can easily reach wider markets in the North Western and Western parts of the country including export options to Sudan.

- ✓ ***Transport and logistics***: flight connection to Bahir Dar is via Addis Ababa: flight is available many times a day. A dry-port, cold room facility and direct cargo flights are available. There are also other cases, such as a direct cargo flight from Bahir Dar to Europe. Investors targeting Debre Birhan corridor can base in Addis Ababa and hire car to drive one and half hour to meet the zonal investment bureau to get information. Ethiopian Investment Commission (EIC) for licensing and registration.

- ✓ ***Human power:*** The majority of the regional population is within economically active age range. The region hosts seven universities including Bahir Dar and Gondar Universities that are among the biggest universities in Ethiopia.

- ✓ ***Duty Free Import of Capital Goods:*** to encourage private investment and promote the inflow of foreign capital and technology into Ethiopia, the following customs duty exemptions are provided for investors (both domestic and foreign) engaged in eligible new enterprises or expansion projects such as manufacturing, agriculture, agro-industries, generation, electrical energy, information and communication technology: The people are hospitable and welcoming to foreigners. Plenty of hotels are available and can be booked online. The ideal base for the scoping mission to Amhara is the regional capital Bahir Dar city located at 560 km from Addis Ababa. It is one of the most beautiful cities in Ethiopia lying along Lake Tana.

- ✓ ***Joint Investment between domestic and foreign investors:*** an application form duly filled and signed by the agent of the business organization; where the application is made by an agent, a photocopy of his power of attorney.

- ✓ ***Livestock: Enhance the livestock products and improve the revenue and food nutritional value of the region***. Livestock population in Amhara accounts for 29 percent of Ethiopia and 1.5 Percent of the world. With more than 15 million cattle population, Amhara is on average producing only 740 million liters per annum. Projects in this sector eyes on creating over 1,228 jobs, of which 47.7 Percent permanent, with investment capital of 1.219 billion ETB.

- ✓ **Identified Key Stakeholders:** aligning stakeholders and enhancing accountability is highly essential for the investment implementation. This requires identification of key partners and stakeholders that will support the investment implementation directly or indirectly. The main key stakeholders:
  - Amhara Livestock Resources Development and Promotion Agency
  - Amhara Industry and Investment Bureau
  - Rural Land Administration and Use Bureau
  - Bureau of Agriculture
  - Financial Institutions: development Bank of Ethiopia, private banks
  - Universities, technical, vocational & Enterprise Development Bureau
  - Amhara Authority of Electricity/ Amhara Region Electric Power Authority
  - Bureau of Water, Irrigation and Energy

✓ **Business Opportunities in the Agricultural Sector**

With the crop, livestock, diary, and agro-processing sub-sectors on target, 54 projects come under business opportunities. These projects will unlock over 5.3 billion ETB investment and release 179,229 jobs by 2024/25 (Table 3).

Table 3: Number of Business Opportunities in the Agriculture and Agro-processing Sector

Sub-sectors	Crop	Livestock	Diary	Agro processing	Total
number of Projects	39	7	4	4	54
Total Jobs	165, 967	1228	533	8,765	176,493
Permanent	2736	586	281	4007	7610
Total Investment (million ETB)	**1415.7**	**613.6**	**155.2**	**3,139**	**5323.5**

Major challenges in Dairy investment in the region

In 2017/18, only 8 percent of investment licensed in Amhara came into operation; with foreign direct investment accounting only for 13 percent. The growth of Foreign Direct Investment (FDI) is not just slow, but also struggles to grow from a very narrow base. Since 2009, although 410 FDI projects were expected to be realized, only 18 percent of the projects are in operation while 82 percent have still been in pre-implementation and implementation phases, respectively. In the same period, only 6 percent of expected jobs were created and 37 percent of them were permanent jobs. These all indicate that the region has fallen short of gaining the best out of private investment in general, and FDI. It is well pronounced that Amhara region has high livestock potential although many challenges hold the sector back from realizing its potential. If the undermentioned challenges under each value actor in the livestock sector are resolved, Amhara region will be the leading producer of milk, meat, livestock, and their derivatives for local and export markets.

Lack of Commercial Dairy Farmers: lack of skilled manpower: including the expertise to coach members to have sustainable and productive dairy farms VET and AI service: Limited access to drug, machinery, equipment, breeding tools and AI professionals for the target dairy woredas or milk shades in ANRS. This increases susceptibility to diseases and parasites. Market related issues: Shortage of reliable market access for milk and milk products (partly due to poor consumption habit), poor packaging, narrow diversification of milk products, cool transportation, distance of potential markets from diary shades, small shelf life compared to UHT milks. Limited availability of animal feed: Shortage of quality animal feed and high preparation cost Restricted access to finance: Shortage of credit such as for working capital and import of spare Spare parts problem: Frequent break down of milk processing equipment (cream separator, butter churner, etc.). Lack of infrastructure: Poor infrastructure facilities such as road and transportation access, water supply and electric power. Shortage of sustainable milk supply to dairy processors: Adultration, quality compromised, low and inconsistent supply of milk from farmers. Shortage of improved breeds: local breeds are less productive than improved ones. Restricted supply of land for dairy farming and processing: The land lease policy restrict the dairy farms in the rural areas with 5-15 years of land contract, which caused the farms to have a confined vision and invest on their farm for a long period. It also caused limited access to credit backing with their farm (Table 4)

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Table 4: Bottlenecks and Proposed Strategies in the Livestock Sector

Bottleneck	Explanation	Proposed Strategies
Land access	Difficulty in accessing land for forage production, livestock and dairy production especially in peri-urban and urban areas close to markets	• Land access models piloted for out grower diary, livestock and forage production • Land prioritized for forage/ feed, dairy and livestock
Low productivity of indigenous breed for milk and meat	The dominance of indigenous breeds with low milk and meat production	• Deployment of clear genetic enhancement strategy for Amhara, which include: provision of AI, and AI with synchronization services. • Training of AI technicians
High animal feed costs	Animal feed is estimated to account for 70% of total livestock rearing costs.	• Develop animal feed strategy, including: • The establishment forage nursery sites • Forage seed production and certification • Apply crop residue treatment to improve digestibility • Policy reform to reduce tax burden on compound feeds
Poor access to credit or financing for dairy, livestock and forage related initiatives		Suite of solutions to enable livestock, dairy and feed related industries access to credit and lease financing service o Communications campaign to encourage adoption of new credit mechanisms and facilitate investment into related industries
Poor market linkages	Poor market linkage and transparency for dairy farmers to access consistent accurate market prices	✓ Operationalize Evergreen Integrated milk processing project to showcase model for expanding distribution centres, efficient milk collection and contracts with smallholder farmers ✓ Policy reform to incentivise all large-scale dairy processors to have supply contracts with necessary extension services, between and milk cooperatives/ smallholder/ outgrower schemes ✓ Public-private mechanism to increase creation and maintenance of milk collection centres
Low consumption / demand of milk products	High domestic demand for milk	• Behavior change campaign to increase household consumption of milk • Identification of projects/ investors related to UHT powdered and processed milk
Lack of investment into processing or value addition	Lack of milk processing operations, Poor understanding of the export market, Limited capacity, for packaging and processing meat to produce high value meat products	• Investment prospectus for milk processing opportunities • Investment incentives for milk processing projects • Marketing campaign to increase domestic consumption of milk products Marketing initiatives to develop export market for offal intestines, meal and other animal parts

Conclusions and the way forward

The Amhara Regional State is well situated to have a comparative advantage on several investment areas in agriculture specifically in livestock sectors. There are considerable investments opportunities and untapped resource for the dairy sector in Amhara Region. For this, the region identified new potential areas (Gondar, Bahir Dar, Debre Markos, Dessie and Debre Birhan). The private sector will be encourage to develop medium and large dairy farms. The region has plan to increase specialized dairy farms to 41 to boost the milk production. The region is promoting the cluster basis dairy farming in the selected milk shed areas to be encouraged around agroindustry.

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Parallel Session I

Dairy Production

Opportunities for Scaling up Climate - Smart Dairy Production in Ziway-Hawassa Milk Shed, Ethiopia

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Abstract

The study was conducted to identify the best climate-smart dairy farming practices and to design a smallholder dairy farmers' business model for scaling up climate-smart dairy in the Ziway-Hawassa milk shed. Eighty sample dairy farmers from five districts (which were then categorized as urban and peri-urban dairy farmers) were selected purposively based on their strong dairy farming practice. The data was then collected through a structured questionnaire and focus group discussion. The collected data were subjected to SPSS analysis. The result showed that urban dairy farmers possessed cross breed cattle and very few local cattle. A high percentage of cattle in peri-urban areas were indigenous unproductive local breeds. The dominant manure management was solid storage and dung for fuel. Management of manure as composting and biogas was limited in both systems. The study identified Fifteen types of feed resources in the milk shed. A higher percentage of the urban respondents were using purchased concentrates, crop residue and a small amount of green forage. High energy diets were given in urban farming than peri-urban farming. Improved forage production was very low in both production systems. The existing business environment of the study area lacks some aspects of linkage and resource efficiency. Thus, the study concluded that, the use of improved crossbreed cows, provision of high energy feeds, as a recognized climate-smart dairy farming practices of the milk shed. However, limitations and gaps were also observed in manure handling herd size management and feed resource selection. Therefore, the new recommended business model be suggested for linking farmers to different partners to increase milk productivity, reduce greenhouse gas emissions from feed and manure, and enhance the economic efficiency of milk production.

Keywords: Smallholder dairy farmers, milk production, climate-smart dairy production, business models

Introduction

The Climate-Resilient Green Economy (CRGE) strategy of Ethiopia was initiated to protect the country from the adverse impacts of climate change by identifying environmentally sustainable economic opportunities that could accelerate the country’s development (FDRE, 2011). The key pillars of this strategy are to improve livestock productivity to ensure food security and farmer livelihood improvement while reducing emission of greenhouse gases. Specifically, the government selects dairy sector as a priority sector, which aims to increase the annual milk production rate.

The Smallholder farmers represent about 85% of the population and are responsible for 98% of the milk production. Most of the milk produced is channelled through the un-organised marketing system (Tadesse *et al.,* 2017). With consideration of dairy sector enterprise to rural livelihoods and its potential role in poverty reduction, implementing a low-emissions development strategy for the dairy sector through the adoption of performance-enhancing technologies is expected to significantly increase milk yields with net benefits in the short and medium term producers. Moreover, with an economy highly dependent on agriculture, Ethiopia is likely to suffer disproportionately from the impacts of climate change. In the other side, livestock systems have been found to be responsible for the most significant global source of methane emissions resulting from ruminant digestion and poor management of manure (FAO,2013).

The Ziway- Hawassa milk-shed has several opportunities to supply milk for the area (Brandsma *et al*.,2013). However, different technical and non-technical factors were suppressed the growth and competitiveness of the sector (Sintayehu *et al.*, 2008). These posses a significant challenge to ensure that livestock products will be produced sustainably without adverse effects on the environment. So, for farmers to invest in climate-smart dairy businesses, there needs to be an attractive and interactive business model which can create revenue or a form of income diversification, spreading investment risks and reducing stress on a family's disposable income. Additionally, interventions must have the potential for improving productivity while at the same time reducing enteric methane emissions per unit of output.

Currently, the smallholder dairy farmer, who produce 93% of the total milk production, lack an appropriate dairy business model which results in less business competitive in the market. Moreover, there is a knowledge gap in climate-smart dairy (CSD) practices, and limited research has been done on scaling up CSD. In line with this, the study was conducted to identify appropriate climate smart dairy practice and to design business models for smallholder dairy farmers to scale up sustainable climate-smart dairy farming in Ethiopia.

Materials and Methods

Area description : - The study was conducted in Ziway-Hawassa milk shed of Mid-Rift Valley of Ethiopia. The altitudes of these areas range from 1500 to 2600 meter above sea level. The Mid- Rift Valley has an erratic, rainfall ranging between 500 and 1300 mm per annum. The rainfall is bimodal with the short rains from February to May and long rains from June to September. The dominant production system in these areas is mixed crop-livestock farming. Cattle are the most important livestock species in the areas (Sintayehu Yigrem, 2015).

Research design: Five districts namely Dugda, Adamitulu, Arsinegele, Shashemene and Kofele were selected purposively based on their potential in milk production. The districts then classified in two clusters (urban and peri-urban farming system) based on their distance from major towns/cities, the purpose of production, and input use like feed. Urban farmers included were from Shashemene, Arsi-negele, Ziway and Meki town and peri-urban farmers where from kofele, Adamitulu and countryside of Meki. Based on this, 16 sample household from each district and a total of 80 respondents were used purposively based on their dairy farming practice and experience.

Data collection : The survey, focus group discussion, and personal observation was used to collect primary information. The information was translated into Afan-Oromo language and discussed with the owners of dairy cattle. The secondary was collected from district livestock and fishery office, annual reports, published articles and journals. Personal observation was also used as a means of triangulation.

Data analysis: - Data were managed in such a way that the qualitative, as well as quantitative variables, were used for analysis. The data generated from the survey (quantitative) part of the study was analysed using the Statistical Package for Social Science (SPSS) version 20. Business canvas model was also used to describe the current and recommended business environment of the milk producer.

Results and Discussion

Characterization of the current farming system

The relative importance of the current farming system shows a different pattern for urban and peri-urban farmers. The result shows that 72.5% of urban farmers and 72.41% of peri-urban farmers followed livestock and mixed crop-livestock production system respectively. A significant number of (80.3%) of urban farmers were producing milk as a major activity (Table1).

Table 1. Farming system in urban and peri-urban areas in Ziway-Hawassa milk shed

	Variable	Urban %	Peri- urban %	P- value
Farming system	Livestock Production	72.5	27.5	0.000
	Crop- livestock Mixed production	27.4	72.4	
Major agricultural activity	Milk production	80.3	51.7	0.011
	Crop production	19.6	48.2	

Climate smart dairy farming practice

Herd Composition and management

About 89% of urban dairy farmers keep cross breed cattle (Figure 1). On the other hand, a high percentage of cattle (43%) in peri-urban areas were local indigenous breed. The independent sample test also showed the significant difference in holding of local and cross breed cattle in the system.

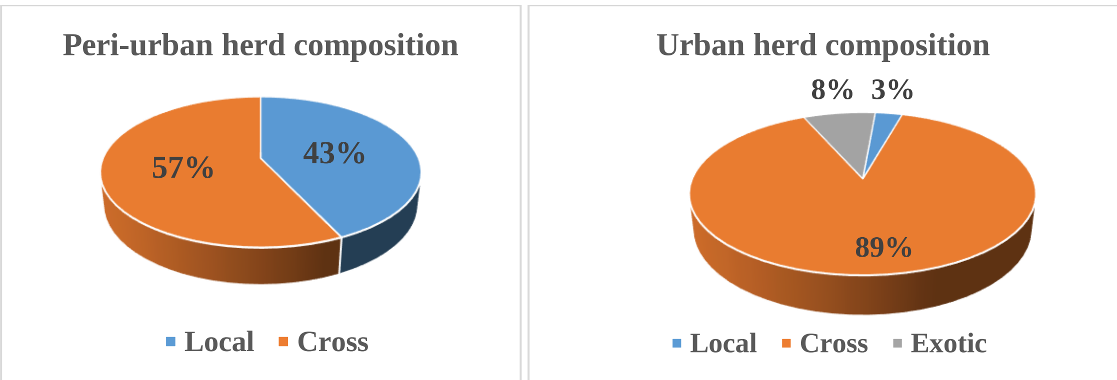

Figure 1. Proportion of herd type in peri-urban and urban dairy production system

On average, peri-urban farmers hold high number of milking cows (8.3) than urban dairy farmers (3.6). Moreover, the average composition of other farm animals also higher in peri-urban dairy farmers (Table 2).

Table 2. Herd structure and average herd size in urban and peri-urban dairy production system

Animal type	Urban			Peri-urban		
	N	%	Averge / HH	N	%	Averge / HH
Milking cows	187	49	3.6	243	47	8.3
Oxen	8	2	0.1	37	7	1.2
Bull	10	3	0.1	33	6	1.1
Heifer	93	24	1.8	101	19	3.4
Calf	87	23	1.7	106	20	3.6

Manure Utilization and management system

It has been found that 86.2% of peri-urban and 58.8% of urban respondent dairy farmers were using or selling cattle manure for different purposes. Farmers especially peri-urban farmers also used the manure as crop fertiliser. However, using manure for biogas was not a common practice although, the urban farmers had better initiations towards biogas utilisation (Table 3).

Table 3. Manure utilization options in urban and peri urban production system

Utilization options	Urban					Peri Urban				
	R1	R2	R3	Index	Rank	R1	R2	R3	Index	Rank
Crop fertilizer	4	2		0.16	2	7	9		0.37	2
Biogas	5			0.15	3				0.00	
Dung cake for fuel	19	4		0.63	1	16	5		0.55	1
Construction			1	0.01	5		1	1	0.03	4
Sell	2			0.06	4	2			0.06	3

*Index= Rn*C1+ Rn-1*C2.... + R1*Cn/∑Rn*C1+ Rn-1*C2....+ R1*Cn*

The study shows that management of manure as solid storage and dung for fuel was a common practice in the milk shed (Table 4). Peri-urban dairy farmers managed manure for burning fuel more commonly. However, urban farmers accumulated manure as solid storage for an extended period. Management of manure as composting and anaerobic digester was limited in both systems.

Table 4. Manure management systems in urban and peri urban production system

Management	Urban		Peri-urban	
	Farmers (%)	Duration of storage	Farmers (%)	Duration of storage
Anaerobic digester	9.8	12	0.0	0
Burned for fuel	43.1	5.9	72.4	5.9
Composting	2.0	12	3.4	12
Daily spread	0.0	0	3.4	12
Solid storage	88.2	8.3	89.7	5.8

Feed resources in the milk shed

Identified feed resource in the milk shed

The primary feed resources of the study area are listed in Table 5. Fifteen types of feed resources were identified in the milk shed. From urban dairy farmers, a higher percentage of the respondents were using purchased concentrates, crop residue and a small amount of green forage. High protein and energy diets were given in urban farming than peri-urban farming.

Table 5. Identified feed resource in urban and peri-urban in Ziway-Hawassa milk shed

Feed Category	Feed Type	% of urban farmers using the feed	% of peri-urban farmers using the feed
Green forage	Green pasture	23.5	31.0
	Maiz green forage	25.5	27.6
	Cabbage	1.9	1.9
	Alfalfa	1.9	0
Crop-residue	Wheat straw	82.3	72.4
	Teff straw	33.3	17.2
	Barley straw	19.6	48.3
	Maize stover	1.9	17.2
Concentrates	Linseed cake	78.4	48.3
	Wheat bran	84.3	69.0
	Formulated feed	50.9	6.8
	Cottonseed cake	1.9	10.3
	Lentil bran	0	3.4
	Noug seed cake	0	6.9
	Atella	35.2	3.4
	Sugar cane molasses	0	10.3
	Brewery spent grain	15.6	6.8

Improved forage production

The result revealed that both urban and peri-urban farmers are not in a strong position to produce cultivated improved forages. From the sampled respondents, only 3.3% of the farmers were initiated to produce improved forage.

Awareness of farmers on animal emission

Figure 2 shows the majority of the urban and peri-urban dairy farmers in the milk shed believed that animals do not have any contributions to climate change. Some of the farmers did not have any idea on the potential contribution of animals to climate change. From the sampled respondents, only a few of them (19.6%) knew about this issue.

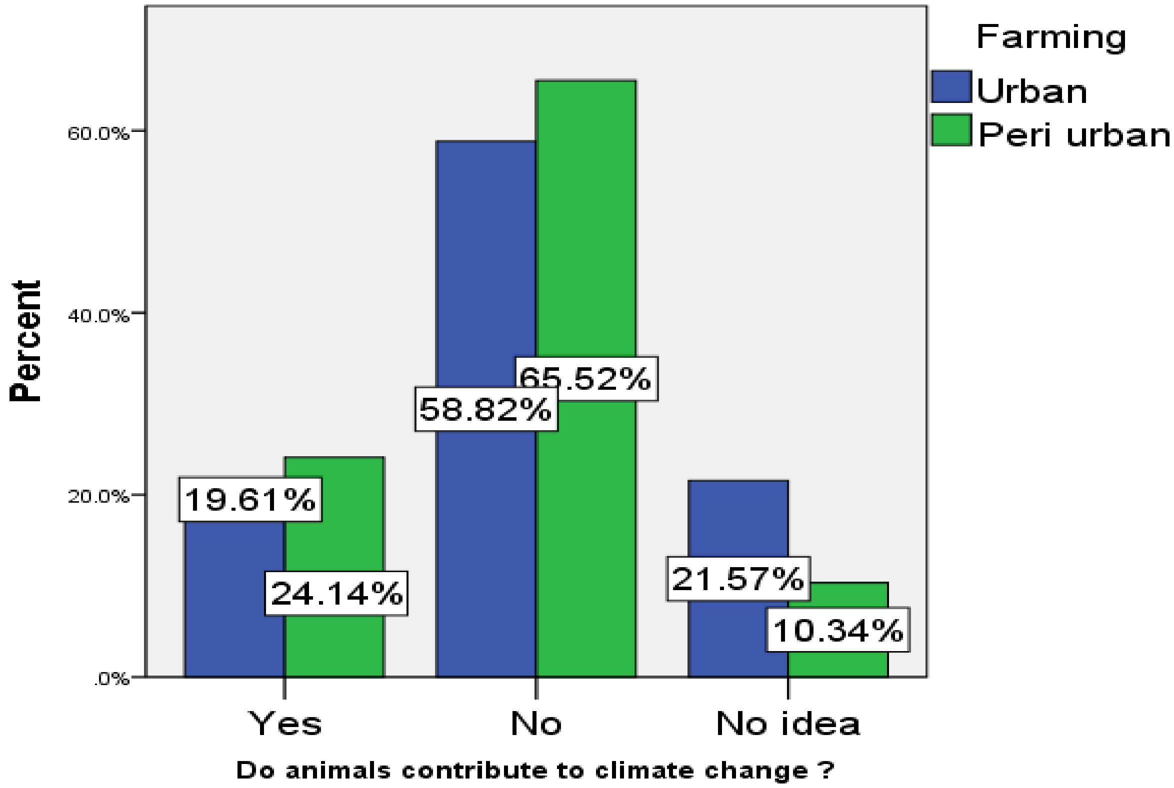

Figure 2. Awareness of farmers on animal emission

Business model canvas of the Ziway- Hawassa milk shed

The business environment of the study area was described in Figures 3 and 4. The existing business environment of the study area was assessed based on its accessibility to inputs, labour, time and resource efficiency. Based on this, the current business model lacks some aspects of linkage and resource efficiency. So, to scale up climate-smart dairy, the scalable business model was suggested which link farmers to different activities and partners.

Business model canvas for urban dairy farmers

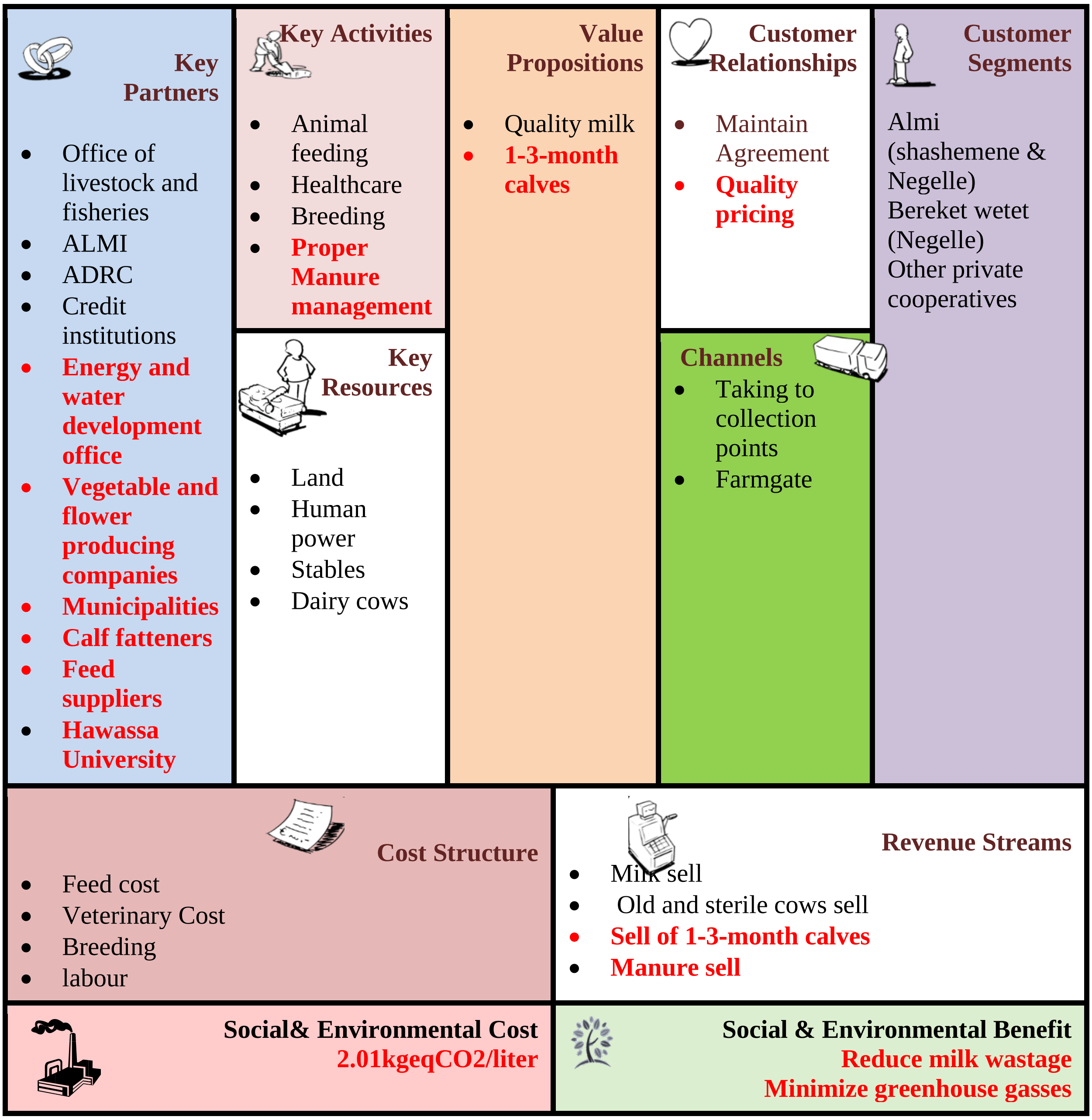

Figure 3. Urban Business Model Canvas

Business canvas for peri-urban dairy farmers

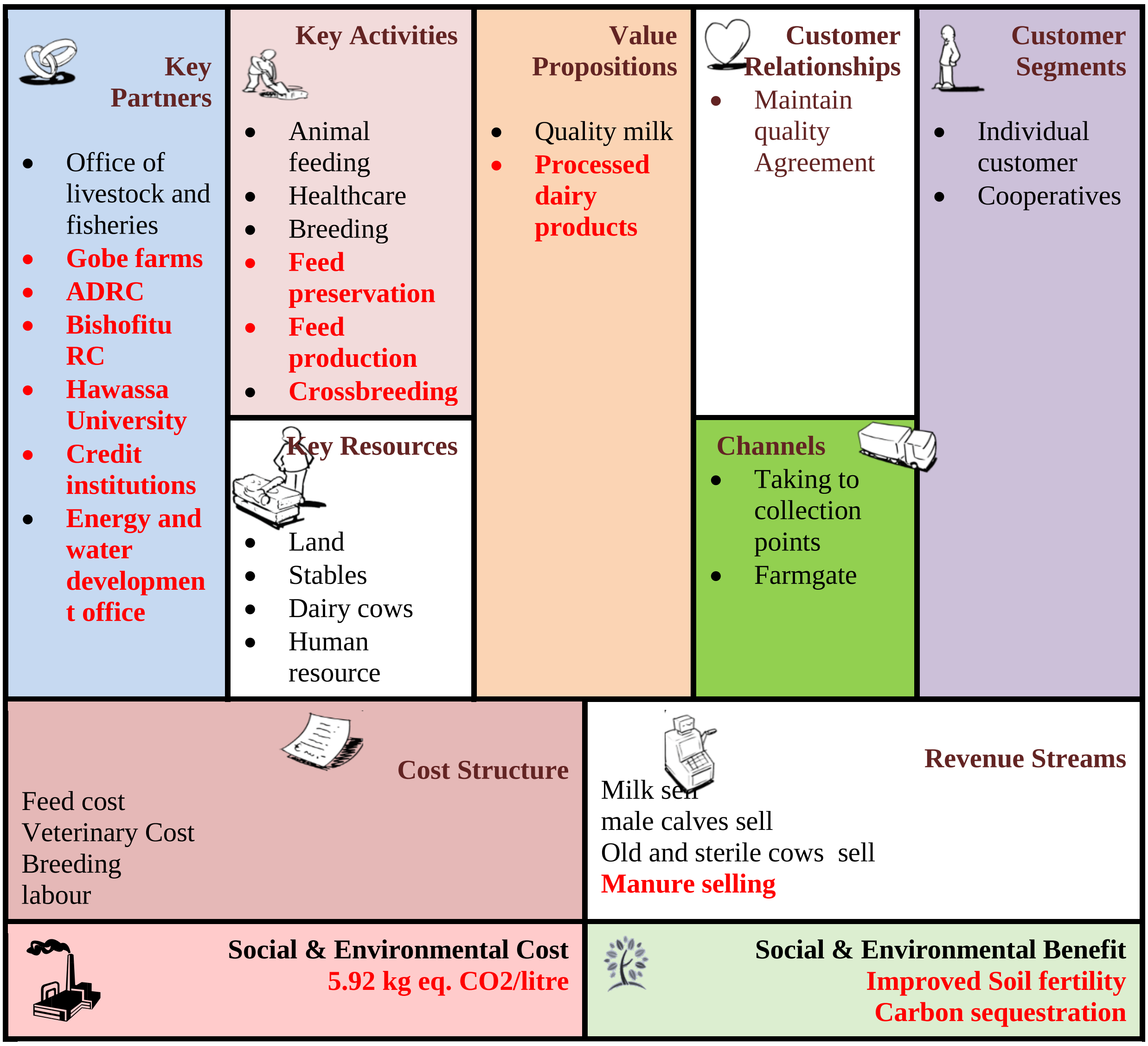

Figure 4. Peri-urban Business Model Canvas

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Carbon Footprint of Smallholder Milk Production in Ziway-Hawassa Milk Shade, Ethiopia

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Abstract

This study was conducted in Ziway - Hawassa milk shade, found in Oromia administrative region, Ethiopia to quantify greenhouse gases (GHG) emissions from smallholder milk producers under multi-function setting. Five districts (Shashemane, Arsi - Negelle, Kofelle, Adami Tulu and Dugda) were selected from West Arsi and East Shewa zones by their milk production and supply in the shed. Field data were collected from eighty urban and peri-urban smallholder dairy farmers from all districts through a structured questionnaire. Focus group discussion with farmers was conducted. Statistical Package for Social Science (SPSS) software was used to analyze data. Descriptive statistics was applied to summarize and present data. Life Cycle Analysis (LCA) approach was used to quantify GHG emissions. Emission factors and GHG emission estimation equations from different sources were applied from Intergovernmental Panel on Climate Change (IPCC). Smallholder dairy farmers in the shed kept dairy cattle for multifunction of which milk production was the primary. Urban dairy farmers produced significantly higher milk per day per cow (12 lit.) as well as per year (9260 lit.) than peri-urban dairy farmers (6.5 L/day and 5500 L/year). Peri-urban dairy farms emitted higher (255 KgCO2eq/year) greenhouse gases than urban dairy farms (179 KgCO2eq/year) from crop residue production. However, urban dairy farms emitted higher (4748 KgCO2eq/year) greenhouse gas than peri-urban (2203 KgCO2eq/year) from off-farm feed production. There was no significant difference in average emission from feed transportation between urban (27 KgCO2eq/year) and peri-urban farm (31 KgCO2eq/year). An average peri-urban dairy farm emitted significantly higher enteric CH4 (23206 KgCO2eq/year) and N2O (64 KgCO2eq/year) from manure management. Overall, the carbon footprint of milk production under the smallholder dairy system in urban and peri-urban was 2.07 kgCO2 eq/ litre and 4.71 kgCO2eq/ litre. This was reduced to 1.76 kgCO2eq/ litre and 3.33 kg CO2eq/ litre for milk production when multifunction of dairy cattle was considered. In general, the study indicated that enteric CH_4 had a considerable contribution (80%) to the carbon footprint of smallholder dairy farms. Improvement in cow genetic makeup and feeding system are recommended to reduce carbon footprint in the current milk shade.

Keywords: Multifunction, urban and peri-urban, Smallholders, carbon footprint.

Introduction

Climate change is taken as the main threat to the survival of different species, ecosystems and the livestock production sustainability in many parts of the world. GHG (Greenhouse gases) are released into the atmosphere both by natural sources and anthropogenic (human-related) activities (Sejian and Naqvi, 2012). Developing countries are more susceptible to the effects of climate change due to their high reliance on natural resources, insufficient capacity to adapt institutionally and financially and high poverty levels (Thornton et al., 2009). Greenhouse gas (GHG) emissions have gained international attention due to their effect on global climate. There are many sources of GHG emissions, with agriculture estimated to contribute about 11% of all global emissions (Smith et al., 2014), of which the livestock sector contributes 14.5% of global greenhouse gas (GHG) emissions, driving further climate change (Rojas-Downing et al., 2017).

Dairy farms are an important source of greenhouse gas emissions. The primary GHG emissions in dairy farm include methane (CH_4) from the animals (enteric) and manure, Methane (CH_4) and Nitrous oxide (N_2O) from manure storage and during field application. Also, Nitrous oxide is released from nitrification and denitrification processes in the soil used to produce feed crops and pasture (Rotz, 2018). In Ethiopia, milk production is mainly from smallholder production from indigenous breeds, which are kept for multipurpose function in different agro-ecological zones (Yigrem, 2015). According to the report of FAO (2017), there are 14 million estimated households of livestock keepers, of which 63% keeps less than three tropical livestock unit. The sector is an enormous contributor for climate change through emission of greenhouse gases, generating 65 million tons CO_2 (40% of emissions in 2010) equivalent GHG, and is predicted to contribute 124 million tons in 2030 (FDRE, 2011). Climate change is a concern to Ethiopia and needs to be tackled in a state of emergency (Zerga and Gebeyehu, 2016).

Zeway-Hawassa milk shed is one of the major milk shed in Ethiopia dominated by smallholder dairy farming. In the smallholder dairy production system, dairy cattle are kept for multipurpose including milk, meat draught (Tegegne et al. 2013 and Beriso et al. 2015). Though, there have been limited efforts to estimate emission from the dairy sector, the multifunction of cattle have not been considered which appear to have overestimated the emission from milk production. Therefore, this research was conducted to quantify greenhouse gases (GHG) emissions from smallholder milk producers under multi-function setting in Zeway-Hawassa milk shed.

Materials and Methods

Study area description - This study was conducted across the Zeway - Hawassa milk shed in Ethiopia. Major towns found in the shed are Shashemane, Hawassa and Zeway (figure 1). The shed located in central Rift Valley mainly in Oromia region, with altitudes ranging from 1500 to 2600 m.a.s.l. The Rift Valley has an erratic, unreliable and low rainfall averaging between 500 and 1300 mm per annum. The temperature in the rift valley varies from 12-270C. Crop-livestock mixed farming is the dominant production system in these areas. Major crops grown around the area are cereals such as barley, teff, maize, wheat, sorghum, and root crops like sweet potato and potato and vegetables such as spinach, cabbage and onion as cash crops. The majority of producers in the rural setting process milk at home, however, the majority of urban producers (79.2%) produce milk for sale (Chalchissa et al., 2014, Negash et al., 2012 and Yigrem et al., 2008). The specific sites were Shashemane, Arsi - Negelle, Kofelle, Adami Tulu, Jido Kombolcha and Dugda. From each district, 16 smallholder dairy producers were selected from urban and peri-urban locations, following purposive random sampling.

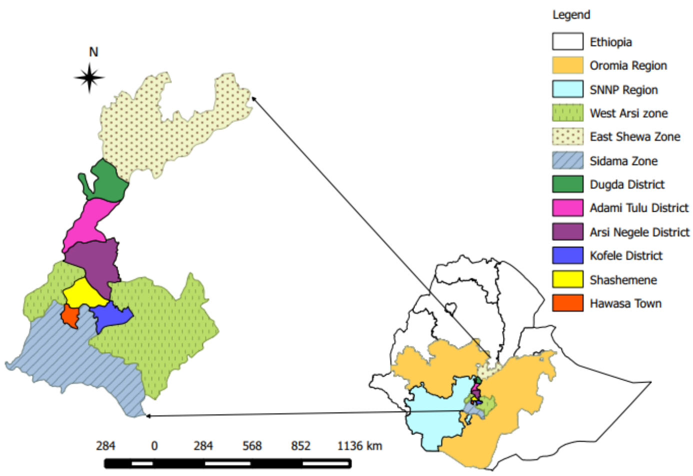

Figure 1. Map of the study area

Research approach

Life cycle analysis (LCA) was used to quantify greenhouse gas emission associated to the production of milk in the current situation. Attributional life cycle assessment method was used since this method uses allocation for different functions, suited to the current milk production scenario where smallholder farmers keep cattle for multifunction.

System boundaries, functional unit and emissions - A carbon footprint (CF) is a single-issue LCA, focussing only on the emission of GHGs. In this study, the GHG emissions were quantified for all processes involved up to the farm-gate, including feed production and transportation, the animals (enteric emission), and manure management (Figure 1). The CF assessment of milk considered emissions under current smallholder production in multi-functional use conditions. The multi-functionality of the dairy production in the current milk shed required economic allocation for each purpose (output) that the animals kept which is essential to determine the share of emissions from each function.

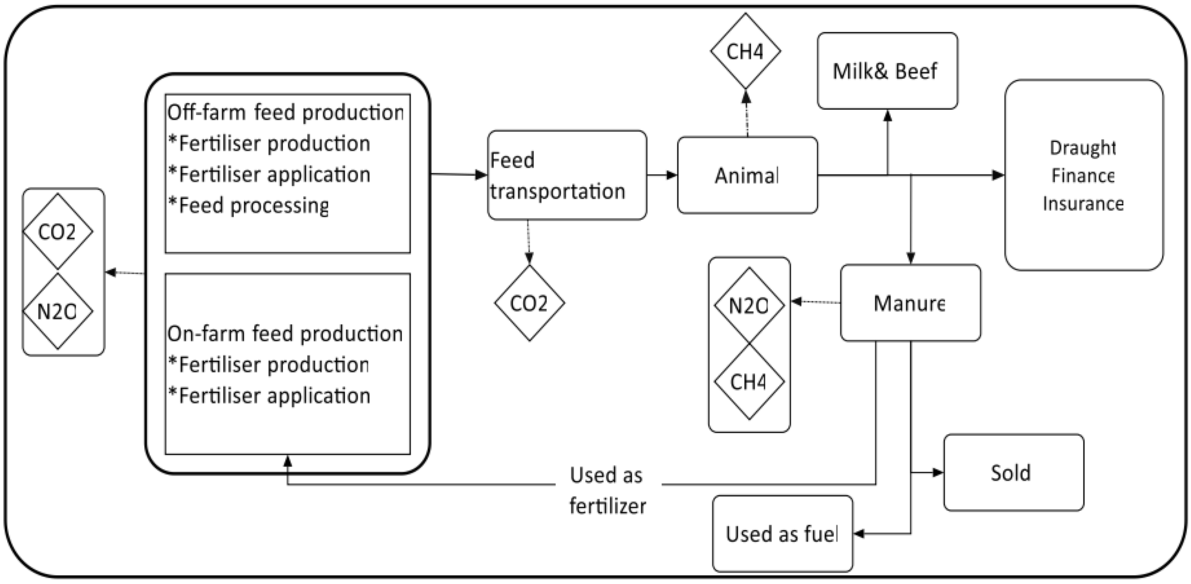

Figure 2. System boundaries for LCA in Ziway-Hawassa milk shed

Quantification of greenhouse gas emissions - This study considered three different emission sources: cattle feed production and transportation, enteric fermentation and manure management (Figure 2) for the estimation of greenhouse gas emissions.

Research Design - Quantitative research design was used. Herd composition, ranking of the functions of dairy cattle, the quantity of milk production, amount and type of feed offered for dairy cattle, are the main inputs for this study. GHG emissions from different sources based on multi-functions of dairy cattle were estimated.

Methods of data collection

Desk review - A desk review was conducted to describe the context, define the research problem and design the methods on quantification of GHGs (allocation procedures, emission factors and formulas) for smallholder dairy systems with multipurpose functions.

Survey - A structured questionnaire was used to gather information from eighty (80) urban (51) and peri-urban (29) smallholder dairy producers in the shed. During the survey data was generated about type and distance for feed transport, the type and amount of feed offered for different classes of dairy cattle and manure management practices.

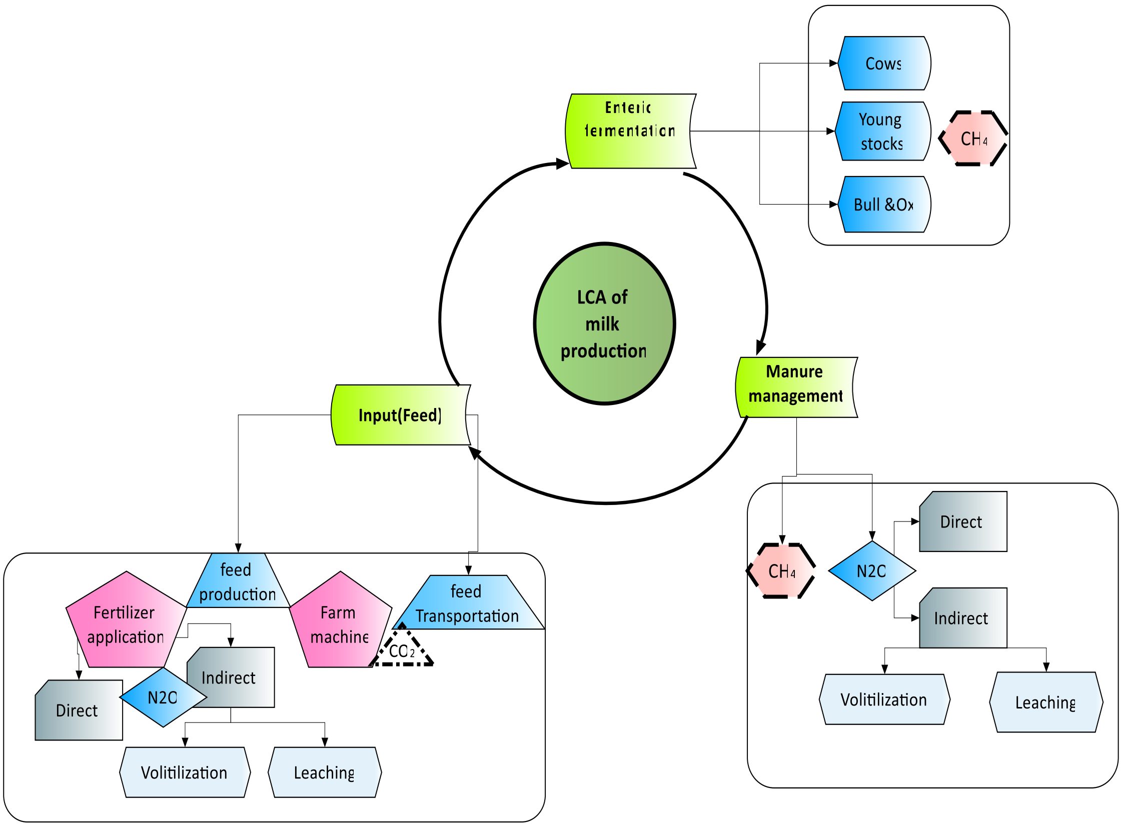

Figure 3. Sources of GHG emissions in LCA of milk production

Data analysis - The collected data was organized, coded and entered in to excel spread sheet. Statistical Package for Social Science (SPSS) software was used for data analysis. Descriptive statistics (mean, minimum, maximum) was applied to summarize and present data in table and chart to compare between different producer groups. Emission factors (EF) and Green House Gas emission estimation equations of different sources were applied from Intergovernmental Panel on Climate Change (IPCC, 2006) document to quantify GHG emission. Statistical test (independent sample t-test and chi-square test) was applied to compare the carbon footprint of milk between both urban and peri-urban milk production.

1. Emission from feed production

In the process of feed production, two main emission sources were considered; one is from the use of fertilizer and the second source is from the use of farm machines.

a) Emissions from Fertilizer application

Direct and indirect methods were used to estimate total anthropogenic emissions of N_2O from managed soils. Tier 1 approach of IPCC was used to compute both direct and indirect emission of N_2O from managed soils.

Direct emission from crop production can be determined by direct emission of N_2O from synthetic and organic fertiliser application. Direct N_2O emissions occur via combined nitrification and denitrification of nitrogen contained in the fertiliser. The following formula was adopted from IPCC guideline to compute direct N_2O emission from feed production from managed soils considering fertiliser application as emission source.

$$N_2O_{\_ND} = N_2O_{inputs}$$
$$N_2O_{inputs} = \left[\left[(F_{SN} + F_{ON}) * EF_1\right]\right]$$

Conversion of N_2O–N emissions to N_2O emissions was performed by using the following equation:

$$\boldsymbol{N_2O} = N_2O_{\_ND} * \frac{44}{28}$$

Where:

- $N_2O_{\_N\,D}$ = annual direct N_2O–N emissions produced from managed soils, kg N_2O–N per year
- N_2O_{inputs} = annual direct N_2O–N emissions from N inputs to managed soils, kg N_2O–N per year
- F_{SN} = annual amount of synthetic fertiliser N applied to soils, kg N per year
- F_{ON} = annual amount of organic fertiliser N applied to soils, kg N per year
- EF1 = emission factor for N_2O emissions from N inputs, kg N_2O–N per (kg N input), default value is 0.01

Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and NO_x. Emissions of N_2O take place through two indirect pathways; i.e. **volatilisation and leaching**.

Volatilisation, N_2O (ATD)

The N_2O emissions from atmospheric deposition of N volatilised from managed soil was estimated using the equation below

$$\boldsymbol{N_2O_{(ADT)-N}} = \left[\left(F_{SN} * Frac_{(GASF)}\right) + \left(F_{ON} * Frac_{(GASM)}\right)\right] * EF_4$$

Where:

- $N_2O_{(ATD)-N}$ = annual amount of N_2O–N produced from atmospheric deposition of N volatilised from managed soils, kg N_2O–N per year,
- F_{SN} = annual amount of synthetic fertiliser N applied to soils, kg N per year
- F_{ON} = annual amount of organic fertiliser N applied to soils, kg N per year
- $Frac_{GASF}$ = fraction of synthetic fertiliser N that volatilises as NH_3 and NO_x, kg N volatilised per (kg of N applied)
- EF_4 = emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces, [kg N–N_2O per (kg NH_3–N + NO_x–N volatilised)]

Conversion of N_2O (ATD)-N emissions to N_2O emissions for reporting purposes was performed by using the following equation:

$$\boldsymbol{N_2O_{(ADT)}} = N_2O_{(ADT)\_N} * \frac{44}{28}$$

Leaching/Runoff, N_2O (L)

The N_2O emissions from leaching and runoff was estimated using the following equation

$$N_2O_{(L)\_N} = (F_{SN} + F_{ON}) * Frac_{LEACH\_(H)} * EF_5$$

Where:

- N2O(L)–N = annual amount of N2O–N produced from leaching and runoff of N additions to managed soils, kg N2O–N per year
- FSN = annual amount of synthetic fertiliser N applied to soils in, kg N per year
- FON = annual amount of organic fertiliser N applied to soils, kg N per year
- FracLEACH-(H) = fraction of all N added to/mineralised in managed that is lost through leaching and runoff, kg N per (kg of N additions)
- EF5 = emission factor for N2O emissions from N leaching and runoff, kg N2O–N (kg N leached and runoff)

Conversion of N_2O (L)–N emissions to N_2O emissions was performed by using the following equation:

$$N_2O_{(L)} = N_2O_{(L)\_N} * \frac{44}{28}$$

b) Emission from farm machinery

The second source of GHG emission in the feed production was from farm machines. Emissions that contributed by farm machine (used to plough land and for harvesting) were accounted for the combustion of fuel by the machine. The primary source of GHG emission from farming machine was CO_2. The following equation was adopted from IPCC guideline to determine GHG emission from fuel combustion.

$$E_{fuel} = Fuel_{cons} * EF_{fuel}$$

Where:

- E_{fuel} = emissions of a given GHG by type of fuel (kg GHG), $Fuel_{cons}$ = amount of fuel combusted (L)
- EF_{fuel} = emission factor of a given GHG by type of fuel (kg gas/L).

Table 1. Emission factors of carbon dioxide per litre of fuel combusted in Ethiopia.

Source of emission	Emission factor
Gasoline	2.42kg CO_2/liter
Diesel	2.67kg CO_2/liter

Source: Gebre, 2016 and FDRE, 2011

c) Feed transportation

The following method was applied to estimate the carbon footprint of feed transportation

- The type of transport used, kilometres travelled, and the quantity of feed transported were determined (Table 2).
- The fuel consumption by the vehicle per kilometre and its full capacity of transportation was considered (Table 2)..
- Allocation of fuel was made to find the quantity of fuel consumed only for a particular kilogram of feed that is transported together with other additional stuff by the same vehicle.
- Then, total estimated CO_2 emissions from feed transport were a product of the distance of feed transported, fuel consumption per kilometre and CO_2 emissions per litre of fuel.

$$Fuel = S \times L$$
$$E = Fuel \times EF$$

Where:

- Fuel is the total litres of fuel consumed by the vehicle to transport the feed to a certain distance (liters).
- S is the distance that the feed is transported (kilometers).
- L is the litres of fuel consumed by the vehicle to transport the feed to one kilometre distance (liters)
- E is the total emission from feed transport
- EF is the emission factor of CO_2 from fuel consumption

Table 2. Fuel types and distance travelled by different type of vehicles

Type of vehicle	Type of fuel consumed	Distance travel by litre of fuel (Km)
Motor bicycle	Gasoline	30
Bajaj (three-wheel vehicle	Gasoline	14
Minibus	Diesel	4
ISUZU	Diesel	4

d) Animal (enteric emission)

Depending on IPCC guideline Tier 2 Approach for methane emissions from enteric fermentation was used for the current study to quantify enteric emission. The Tier 2 approach was selected for the reason that enteric fermentation was a key source category for the animal category that represents a large portion of the total emissions. The amount of methane emission depends on age and the quality and quantity of the feed consumed. To specify the variation in emission rates among animals, the population of animals were divided into subgroups, and an emission rate per animal is estimated for each subgroup. To estimate enteric emission cattle were divided into three subgroups;

1. Cows,
2. Young stock and
3. Bulls and Ox.

For each of the representative animal subcategories defined, the following information was determined:

- Average daily feed intake (mega joules (MJ) per day and/or kg per day of dry matter); and
- Methane conversion factor (percentage of feed energy converted to methane).

The animal daily mount and type of feed intake was estimated by smallholder farmers for different cattle subgroups. According to the IPCC guideline methane conversion factor (Y_m) of cattle that are primarily fed low-quality crop residues and byproducts, or grazing is taken as 6.5%. The equation presented below was used to determine the enteric methane emission factor.

$$EF = \left[\frac{GE * \left(\frac{\text{Ym}}{100}\right) * 365}{55.65}\right]$$

Where:

- EF = emission factor, kg CH_4 per head per year
- GE = gross energy intake, per head per year
- Ym = methane conversion factor, percent of gross energy in feed converted to methane
- The factor 55.65 (MJ/kg CH_4) is the energy content of methane

The total Methane emission can be computed by multiplying the number of animals in each category by the emission factor

$$\boldsymbol{Emissions} = EF * (N_T)$$

$$\boldsymbol{Total\ CH_{4enteric}} = \sum_{i} \boldsymbol{E_i}$$

Where:

- Emissions = Enteric methane emissions, Kg CH_4 per year
- EF = emission factor for the defined livestock population, kg CH_4 per head per year
- N_T = the number of heads of cattle / category
- T = species/category of livestock
- Total CH_4Enteric = total methane emissions from Enteric Fermentation, Kg CH_4 per year
- Ei = is the emissions for the *i*th cattle categories and subcategories

e) Manure management

Methane (CH_4)

Methane emission from manure management can be calculated by using the following equation as indicated by IPCC guideline.

$$\boldsymbol{CH_{4\,Manure}} = \sum \boldsymbol{EF_{(T)}} * \boldsymbol{N_{(T)}}$$

Where:

- CH_4Manure = CH_4 emissions from manure management, for a defined population, Kg CH_4 per year
- EF(T) = emission factor for the defined cattle population, kg CH_4 per head per year
- N(T) = the number of head of cattle /subcategory *T*
- T = subcategory of cattle

The main factors affecting CH_4 emissions are the amount of manure produced and the portion of the manure that decomposes anaerobically. The Tier 2 method relies on two primary types of inputs that affect the calculation of methane emission factors from manure

i) Manure characteristics: Includes the quantity of volatile solids (VS) produced in the manure and the maximum amount of CH_4 able to be generated from that manure (Bo). Production of manure volatile solids can be estimated based on feed intake and digestibility. The VS content of manure equals the fraction of the diet consumed that is not digested and thus excreted as a faecal material which, when combined with urinary excretions, constitutes manure.

$$VS = \left[GE * \left(1 - \frac{DE\%}{100}\right) + (UE * GE)\right] * \left[\left(\frac{1 - Ash}{18.45}\right)\right]$$

Where:

- VS = volatile solid excretion per day on a dry-organic matter basis, kg VS per day
- GE = gross energy intake, MJ per day
- DE% = digestibility of the feed in percent
- (UE • GE) = urinary energy expressed as a fraction of gross energy. 0.04GE can be considered urinary energy excretion by most ruminants (reduce to 0.02 for ruminants fed with 85% or more grain in the diet).
- ASH = the ash content of manure calculated as a fraction of the dry matter feed intake (e.g., 0.08 for cattle).
- 18.45 = conversion factor for dietary GE per kg of dry matter (MJ per kg).

ii) Manure management system characteristics*:* Includes the types of systems used to manage manure and a system-specific methane conversion factor (MCF) that reflects the portion of B_o that is achieved. MCF is affected by the degree of anaerobic conditions present, the system temperature, and organic material retention time in the system. The default MCFs values will be taken by considering the manure management system and the temperature of the area. Default value 0.1 of methane producing capacity from manure (B_o) was taken as indicated in IPCC guideline.

Based on Tier 2 approach of IPCC the following equation will be used for computation of emission factor.

$$\boldsymbol{EF_T} = (VS_T * 365)\left[B_{o(T)} * 0.67\, {}^{kg}/_{m^3} * \sum_{s,k} \frac{MCF_{s,k}}{100} * MS_{(T,S,K)}\right]$$

Where:

- EF(T) = annual CH_4 emission factor for livestock category *T*, kg CH_4 per animal per year
- VS(T) = daily volatile solid excreted for livestock category *T*, kg dry matter per animal per year
- 365 = basis for calculating annual VS production, days per year
- Bo(T) = maximum methane producing capacity for manure produced by livestock category *T*, m3 CH_4 kg-1 of VS excreted
- 0.67 = conversion factor of m3 CH_4 to kilograms CH_4
- MCF(S,k) = methane conversion factors for each manure management system *S* by climate region *k*, %
- MS(T,S,k) = fraction of livestock category *T*'s manure handled using manure management system *S* in climate region *k*, dimensionless

N_2O emission

N_2O emission was estimated directly and indirectly, during the storage and treatment of manure before it is applied. Direct N_2O emissions occur via combined nitrification and denitrification of nitrogen contained in the manure. Nitrification is likely to happen in stored animal manures provided there is a sufficient supply of oxygen. Nitrification does not occur under anaerobic conditions. Nitrites and nitrates are transformed to N_2O and dinitrogen (N_2) during the naturally occurring process of denitrification, an anaerobic process. Indirect emissions result from volatile nitrogen losses that occur mainly in the forms of ammonia and NO_x. The portion of excreted organic nitrogen that is mineralised to ammonia (NH_3) and nitrogen during manure collection and storage depends primarily on time, and to a lesser degree temperature.

Direct N_2O emissions from manure management was based on the following equation:

$$N_2O_{D(mm)} = \left[\sum_{S}\left[\sum_{T}\left(N_{(T)} * Nex_{(T)} * MS_{(T,S)}\right)\right] * EF_{3(S)}\right] * \frac{44}{28}$$

Where:

- N_2OD (mm) = direct N_2O emissions from Manure Management, kg N_2O per year
- N(T) = number of head of cattle/subcategory *T*
- Nex(T) = annual average N excretion per head /subcategory *T* , kg N per animal per year
- MS(T,S) = fraction of total annual nitrogen excretion for each animal/category *T* that is managed in manure management system *S*, dimensionless
- EF3(S) = emission factor for direct N_2O emissions from manure management system *S* in the country, kg N_2O-N/kg N in manure management system *S*
- S = manure management system
- T = subcategory of cattle
- 44/28 = conversion of (N_2O-N)(mm) emissions to N_2O(mm) emissions

Indirect N_2O emissions from Manure Management

Tier 2 approach of IPCC guideline considers Nitrogen volatilisation in forms of NH_3 and NO_x from manure management systems which is based on multiplication of the amount of nitrogen excreted (from all cattle categories) and managed in each manure management system by a fraction of volatilised nitrogen

$$N_2O_{G(mm)} = \left(N_{volatilization-MMs} * EF_4\right) * \frac{44}{28}$$

Where:

- N_2OG(mm) = indirect N_2O emissions due to volatilization of Nitrogen from Manure Management, kg N_2O per year
- EF4 = emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg N_2O-N per (kg NH3-N + NOx-N volatilised)- ; default value is 0.01

$$N_{Volatilization-MMS} = \sum_{S}\left[\sum_{T}\left[\left(N_{(T)} * Nex_{(T)} * MS_{(T,S)} * \left(\frac{Frac_{GasMS}}{100}\right)_{(T,S)}\right)\right]\right]$$

Where:

- N volatilization-MMS = amount of manure nitrogen that is lost due to volatilisation of NH3 and NOx, kg N per year
- N(T) = number of head of cattle /category *T*
- Nex(T) = annual average Nitrogen excretion per head /category *T* , kg Nitrogen per animal per year
- MS(T,S) = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S* in the country, dimensionless
- FracGasMS = percent of managed manure nitrogen for livestock category *T* that volatilises as NH_3 and NO_x in the manure management system *S*, %

The indirect N_2O emissions based on tier two due to leaching from manure management systems (N_2OL (mm)) was estimated using the following Equation

$$N_2O_{L(mm)} = \left(N_{leaching-MMs} * EF_5\right) * \frac{44}{28}$$

Where:

- N_2O_L (mm) = indirect N_2O emissions due to leaching and runoff from Manure Management, kg N_2O per year
- EF_5 = emission factor for N_2O emissions from nitrogen leaching and runoff, kg N_2O-N/kg N leached and runoff (default value 0.0075 kg N_2O-N per (kg N leaching/runoff)

To determine the amount of manure nitrogen that leached from manure management systems

$$N_{leaching-MMS} = \sum_{S}\left[\sum_{T}\left[\left(N_{(T)} * Nex_{(T)} * MS_{(T,S)} * \left(\frac{Frac_{leachMS}}{100}\right)_{(T,S)}\right)\right]\right]$$

Where:

- N leaching-MMS = amount of manure nitrogen that leached from manure management systems, kg N per year
- N(T) = number of head of cattle /category *T*
- Nex(T) = annual average N excretion per head of species/category *T* kg N per animal per year
- MS(T,S) = fraction of total annual nitrogen excretion for each cattle /category *T* that is managed in manure management system *S*, dimensionless
- Fracleach MS = percent of managed manure nitrogen losses for livestock category *T* due to runoff and leaching during solid and liquid storage of manure (typical range 1-20%)

Results and Discussion

Household characteristics

As presented in Table 3, the majority of farmers engaged in dairy production in the shed were males (62.7% in urban and 82.8% in peri-urban). In both production systems, young people were involved in the dairy sector, i.e. 23.5% and 20.7% of dairy farmers found under the age of 35 years in urban and peri-urban respectively. Majority of dairy farmers attended either primary or secondary education in both urban and peri-urban dairy production.

Table 3. Household characteristics

Parameters	Categories	Urban (%)	Peri-urban (%)
Sex	Male	62.7	82.8
	Female	37.3	17.2
Age (years)	24- 35	23.5	20.7
	36-45	37.3	44.8
	46-55	15.7	17.2
	Above 56	23.5	17.2
Education	Illiterate	19.6	6.9
	Primary	31.4	58.6
	Secondary	35.3	17.2
	Higher	13.7	17.2

Since urban dairy farmers were milk production oriented than peri-urban farmers they kept more (49%) milking cows than peri-urban farmers (47%). Urban farmers kept fewer ox and bulls. When looking at the number of cattle herd categories per farm bases, peri-urban farmers kept large number than urban farmers (Table 4).

Table 4. Cattle herd category in urban and peri-urban production

Herd category	Urban			Peri-urban		
	N	%	Mean per farm	N	%	Mean per farm
Milking cow	187	49	3.667	243	47	8.379
Ox	8	2	0.157	37	7	1.276
Bull	10	3	0.196	33	6	1.138
Heifer	93	24	1.824	101	19	3.483
Calf	87	23	1.706	106	20	3.655

N= number of respondents, HH= households,

As shown in Figure 3, the majority (89%) of dairy breeds in urban production were crossbreeds (mostly different levels of Holstein Friesian with local cattle breeds). This is because the urban farmers have relatively better access to services such as artificial insemination provided by the public and private sectors (Tegegne et al., 2013). Pure local and exotic cattle breeds in urban production accounted for 3% and 8% respectively. However, in peri-urban production, the dairy herd was composed of pure local breeds (43%) and cross breeds (57%) of local with exotic. Since urban farmers were milk production oriented, they kept more crossbreeds that give more milk than the local cows and also applied relatively better cow management. Urban dairy farms of the current milk shed had higher crossbreeds (89%) than in Hawassa and Debre Birhan, reported by Mekuria (2016), where 42% of the dairy herd were Holstein Friesian cross.

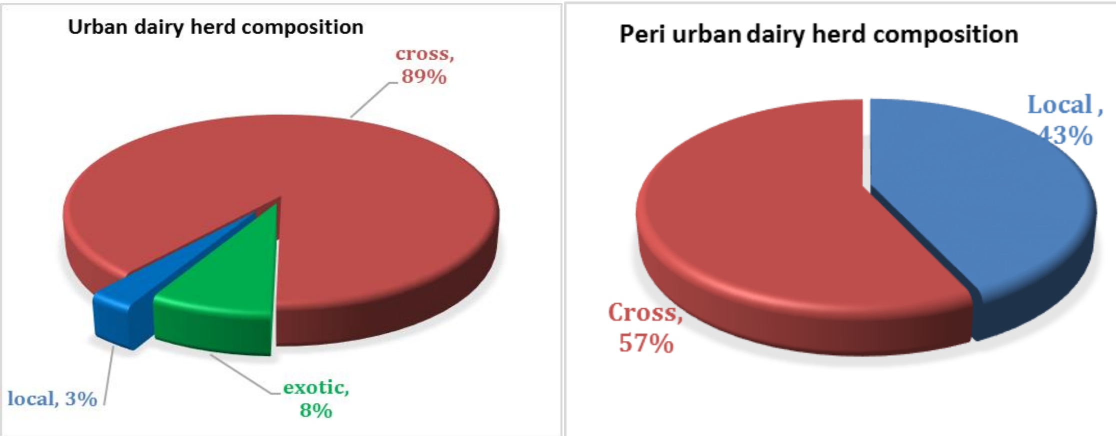

Figure 4. Herd breed composition in the urban and peri-urban production

Farming system

As presented in Table 5, majority (72.5%) of dairy farmers in urban areas practice only livestock production where their major concern (80.4%) was for milk production from dairy cows. However, the reverse is true for peri-urban dairy farmers; they practised mixed type of farming system where both milk and crop production was closely equally important. Tegegne et al. (2013) reported that peri-urban dairy production usually practised mixed crop-livestock farming, which produced part of the feed in the form of crop residues and grazing. This agrees with peri-urban dairy farmers in Ziway-Hawassa milk shed. Furthermore, 63% of the dairy cattle population in Ethiopia was found in the mixed crop-livestock dairy system (FAO & NZAGRC, 2017).

Table 5. Major farming activity

	Urban		Peri-urban	
Farming	**N**	**%**	**N**	**%**
Livestock	37	72.5	8	27.6
Crop livestock mixed	14	27.5	21	72.4
Major farm activity				
Milk production	41	80.4	15	51.7
Crop production	10	19.6	14	48.3

Multifunction of dairy cattle
As presented in Table 6, in both urban and peri-urban areas cattle were kept primarily for their milk production. This result agrees with Beriso et al. (2015) who reported the same for Aleta Chuko district in southern Ethiopia. Urban dairy farmers next look for insurance and thirdly for financing the dairy business. In addition, peri-urban dairy farmers also raise cattle for draft purpose, a higher percentage than the urban farmers. This is resulted from the mixed type of farming by peri-urban farmers. The result of this study also consistent with Tegegne et al. (2013) who reported that in peri-urban production animals are also kept for manure (fuel production and fertilise the soil), and male animals are kept for draught power.

Table 6. Functions of cattle in urban and peri-urban dairy production.

	Urban					Peri-Urban				
Function	**R1**	**R2**	**R3**	**Index**	**%**	**R1**	**R2**	**R3**	**Index**	**%**
Milk	51	0	0	0.57	57	27	2	0	0.53	53
Beef	0	2	5	0.03	3	0	2	3	0.04	4
Finance	0	18	7	0.16	16	2	10	1	0.17	17
Manure	0	1	1	0.01	1	0	0	2	0.01	1
Insurance	0	25	6	0.21	21	1	10	3	0.16	16
Draft	0	1	1	0.01	1	0	2	8	0.08	8

R1= first rank, R2 =second rank, R3=third rank, Index = sum of a given purpose rank (3*R1+2*R2+1*R1) divided by the sum of all purpose rank (3*R1+2*R2+1*R1).

Milk production
Table 7 shows the average milk yield in urban and peri-urban production system. Urban farmers keep more cross breed dairy cows, which yield more than local cows. As a result, urban dairy farmers obtain significantly large volume of milk per cow per day (12 litres) as well as per year (9260 litres) than the peri-urban dairy farmers. Because urban dairy farmers focused on fluid milk production and sale with little land resources, using the available human and capital resources mostly under stall feeding conditions (Land O'Lakes Inc., 2010). Furthermore, the milk produced in peri-urban system was mostly used for home consumption when compared to the urban system. In the current milk shed, total milk production per farm per year in the urban production system (9200Kg) was higher than Mekelle milk shed in Ethiopia; reported as 8900 kg by Woldegebriel (2017).

Feed sources

Majority of dairy farmers in the current milk shed provide crop residues mainly wheat straw in both urban (82.4%) and peri-urban (72.4) production for dairy cattle. However, barley straw and maize stover were more common feed in peri-urban dairy farming (Table 8). This result is in line with Tadesse et al. (2015) and Ali et al. (2015) who reported that crop residues were the major feed resources for urban and peri-urban areas at Hosanna and for eastern Ethiopia respectively. Next to crop residues dairy farmers in the current milk shed also use industrial by-products. Wheat bran and linseed meal were the most common feed used for dairy cattle in both urban and peri-urban dairy production system. This result completely agrees with Yasar et al. (2016) who reported that Wheat bran and linseed meal were main feed supplements in urban and peri-urban areas in Bale zone of Oromia region. This result is also similar to Tadesse et al. (2015). However, it contrasts the report for Mecha woreda by Tasew and Seifu (2009) where communal grazing lands provide the major feed to cattle.

Table 7. Milk production (Mean ± SE) in urban and peri-urban production

Production	Urban	Peri-urban	Significanse
Milk yield/year /farm (000, litres)	9.26±1.26*	5.50±.88	Sig. (2-tailed) (.041)
Milk yield per day per cow(litres)	12.02± .63*	6.59±.79	Sig. (2-tailed (.000)
Milk consumed at home per day(litres)	1.89± .27	5.32±.1.93*	Sig. (2-tailed0 (.012)

The use of improved forages for dairy cattle feed was not common in the current milk shed in both urban and peri-urban production which is consistent with the report of Tasew and Seifu (2009) for Mecha woreda dairy farmers. Urban dairy farmers had a higher tendency to provide dairy ration that was processed and distributed by *Alema Koudijs Feed PLC* for milking cows. The result of this study also showed that local distillery byproduct called Atella was commonly used by urban dairy farmers particularly in Arsi Negelle where distillation of local liquor is widely practised. This agrees with the result of Tasew and Seifu (2009) for Bahrdar Zaria and Mecha woreda dairy farmers. Dairy farmers offered feeds for dairy cattle mixing different feeds together for all kinds of herds nevertheless, dairy ration from *Alema Koudijs was only offered for milking cows.*

Table 8. Different feeds types and composition

Type of feed	Urban (%)	Peri-urban (%)	DM (% fresh weight)	CP (% DM)	GE (MJ/kg DM)
Green pasture	25.5	27.6	31.3	9.8	18
Maize green forage	25.5	27.6	23.3	7.9	18.2
Alfalfa green	3.9	3.4	90.6	18.3	18
Cabbage waste	2.0	3.4	9	23	18
Wheat straw	82.4	72.4	91	4.2	18.5
Teff straw	35.3	17.2	91.7	14.6	18.5
Barley straw	19.6	48.3	90.9	3.8	18.2
Maize stover	2.0	24.1	28.9	6.9	18.1
Lin seed meal	76.5	55.2	90.6	43.1	20.7
Wheat bran	84.3	69.0	87	17.3	18.9
Dairy ration	51.0	6.9	92.3	21	23
Cotton seed hull	2.0	10.3	90.6	5.1	19.6
Lentil bran	0.0	3.4	88.9	19.3	18.6
Nug seed cake	0.0	6.9	92.2	31.3	20.2
Atella	35.3	6.9	15.6	20	19.9
Sugarcane molases	0.0	10.3	73	5.5	14.7
Brewery grains	15.7	10.3	91	25.8	19.7

DM=dry matter, CP = crude protein, GE= Gross energy

Manure management and utilization

The result of this study revealed that majority (63%) of the urban dairy farmers used cattle manure for fuel as dried dung cake (Table 9). Similarly, (but in a lesser extent) peri-urban farmers also used manure for similar purpose and apply on soil when cultivating crops. This result is consistent with research report in Adigrat town, Ethiopia where manure was used as a source of fuel and important input for crop production and for nutrient recycling (Nigus et al., 2017). Lower percentages (37%) of dairy farmers in the current milk shed used manure as fertilizer when compared with Kenya where 90% of the smallholder dairy farmers used manure as a fertilizer on their land (Weiler et al., 2014). In peri-urban production, manure handling as biogas system was not practised, which is similar with dairy farmers in Adigrat

Table 9. Different manure utilization in urban and peri urban areas

	Urban				Peri-Urban			
Application	**R1**	**R2**	**R3**	**Index**	**R1**	**R2**	**R3**	**Index**
Crop fertilizer	4	2		0.16	7	9		0.37
Biogas	5			0.15				0.00
Dug cake for fuel	19	4		0.63	16	5		0.55
Construction			1	0.01		1	1	0.03
Sell	2			0.06	2			0.06

R1= first rank, R2 =second rank, R3=third rank, Index = sum of a given purpose rank (3*R1+2*R2+1*R1) divided by the sum of all purpose rank (3*R1+2*R2+1*R1).

Majority of dairy farmers stored manure as solid storage in both urban and peri-urban production systems with longer duration (8 months) in urban (Table 10). This result is inconsistent with Garg et al., 2016, who found that smallholder farmers in Anand district of western India stored manure for 2–4 months before it was utilized. Peri-urban farmers apply manure directly to crops as dairy spread without storing which is also similar to the report of the same author. Besides, few dairy farmers in Ziway-Hawassa milk shed also sale manure mainly as organic fertilizer (Table 7), the same with the result of Woldegebriel et al. (2017) in Mekelle milk shed area.

Table 10. Manure management systems in Zeway-Shashemane milk shade

Management	Urban		Peri-urban	
	Farmers (%)	Duration (Months)	Farmers (%)	Duration (Months)
Daily spread	0.0	0	3.4	12
Anaerobic digester	9.8	12	0.0	0
Burned for fuel	43.1	5.95	72.4	5.90
Composting	2.0	12	3.4	12
Solid storage	88.2	8.39	89.7	5.8

As indicated in Table 11 total manure produced from all sampled farms in urban and peri-urban was 30,771.6 and 42,393.6 Kg dry matter per year respectively. In other words, the average amount of manure produced per farm in urban and peri-urban was 603.34 and 1461.84 Kg DM per year. This is lower when compared with the result for Anand district in western India, 3067 Kg DM/year was produced per farm (Garg et al., 2016). It is also considerably lower than Kenyan smallholder dairy farms and urban or peri-urban dairy farms in Mekelle (Weiler et al., 2014 and Woldegebriel et al., 2017). Eight percent of the manure produced in peri-urban dairy production was utilized to fertilize cropland while the major portion was managed as solid storage and burned for fuel (Figure 5). This situation is totally different in Anand district of western India where a major portion of manure

produced was used as crop fertilizer (Garg et al., 2016). None of the manure was managed as a daily spread in urban and as anaerobic digester in
peri-urban.

Figure 5. Major manure management system; Burned for fuel (left) and as solid storage (right

Table 11. Amount of manure managed under different management system

Management	Urban		Peri-urban	
	Amount (KgDM/year)	(%)	Amount (KgDM/year)	(%)
Daily spread	0.00	0.00	3326.4	7.85
Anaerobic digester	5328.00	17.31	0.00	0.00
Burned for fuel	5946	19.32	17294.40	40.79
Composting	345.60	1.12	144.00	0.34
Solid storage	19152.00	62.24	21628.80	51.02
Total	30771.6	100.00	42393.6	100.00

Greenhouse gas emission

Emission from on-farm feed production

a) Emission from fertilizer application

The overall GHG emission from fertilizer application for crop production in urban and peri-urban was 14,888 and 12,251 Kg eq CO_2 per year respectively (Table 12). The biggest contribution (75%) for this total emission was by a direct emission that occurs through combined denitrification and nitrification of nitrogen contained in the fertiliser. The indirect emission (volatilization and leaching) took the rest percentage contribution (25%) of the total emission from fertilizer application that resulted from volatile nitrogen losses that occur primarily in the forms of ammonia and other nitrogen compounds.

Table 12. Emission from fertilizer use for crop and residue production

Emission type	**Urban**	**Peri-urban**
	Kg CO_2 eq/year)	**Amount (KgCO_2 eq/year)**
Direct	11225	9186
Volatilization	1132	994
Leaching	2526	2067
Synthetic fertilizer production	6	5
Overall	14888	12251
Average Per farm	292	422
Average per hectare	384	243

b) Emission from farm machine

The overall emission from farm machine use in urban and peri-urban were 607 and 1465 Kg CO_2 eq/year respectively (Table 13). The overall emission from machine use in peri-urban production was more than double of the peri-urban emission. This is magnified when emissions from farm machine converted to farm level. In peri-urban milk production, the emission per farm from farm machine was 51 Kg CO_2 eq/year that is over 4 folds of the urban emission per farm.

Table 13. Emission from farm machine

Type of machine	Urban		Peri-urban	
	Fuel (liters)	(Kg CO_2 eq./year)	Fuel (liter)	Amount (KgCO2 eq./year)
Tractor	100	267	245	654
Combine harvester	128	340	304	811
Overall	228	607	549	1465
Per farm	5	12	19	51

c) Allocation of emission to crop residue production

As shown in Table 14, the amount of GHG emission accounted for the production of crop residues as animal feed was 179 and 255 Kg CO_2 eq/year per farm level in urban and peri-urban respectively. The figures suggested that higher emission per farm per year from crop residue production was detected in peri-urban dairy production.

Emission from Off-farm feed production and processing

Emission of Off-farm feed production was estimated based on the quantity of concentrate feed offered to dairy cattle multiplied by emission per kilogram of concentrate feed production and processing. Emission related to off-farm concentrate feed production and processing of 1.36 KgCO2/Kg (Weiler et al., 2014) was taken for the current estimation. Therefore, emission per farm from off-farm feed production and processing was significantly higher in urban (4748 Kg CO_2 eq/year) dairy production (Table 15)

Table 14. Allocation of emissions for on-farm crop residue production

	Urban	Peri-urban
	(Kg CO_2 eq/year)	(KgCO_2 eq/year)
Fertilizer use	14888	12251
Farm machine	607	1465
Overall	15489.5	13716
Allocation for crop residue	9142	7407
Average per farm	179	255

Table 15. Emission from off-farm feed production and processing

	Urban	Peri-urban
Concentrate feed (Kg/year)	178068	46969
Emission (Kg CO_2 eq/year)	242173	63878
Average per farm	4748*	2203

Emission from feed transport

The amount of CO_2 emitted per farm per year in feed transportation in the current location appears less. The majority of dairy farmers in both locations do not use any vehicle, or they use locally available transport (horse or donkey carts) for feed transportation (Table 16) that resulted in lower emission from feed transportation.

Table 16. Feed transportation and emission per year

Type of vehicle	Urban			Peri-urban		
	Kilometre	Fuel consumed (L)	Emission (Kg CO_2eq.)	Kilometre	Fuel consume d (L)	Emission (Kg CO_2eq.)
Motor bicycle	695	23	56	-	-	-
Bajaj	1262	90	218	-	-	-
Minibus	35	9	23	209	52	140
Isuzu	1582	395	1056	1135	284	757
Overall	3574	517	1353	1344	336	897
Average per farm	70	10	27	46	12	31

The current study focused on emission from feed production (crop residue production) and off-farm feed production and processing. Almost all smallholder dairy farmers in the shed did not produce animal feed on the farm. Very few (3.44%) farmers were identified to produce forage. However, they used neither fertilizer nor farm machines. The total emission per farm per year from feed production and transportation in urban (4954 kgeq.CO_2) was higher than peri-urban (2489 kgeqCO_2) dairy production (Table14, 15 &16). Because urban dairy farmers mostly purchase animal feeds (they used more processed feeds) while peri-urban farmers used crop residues and no on-farm feed processing. Emission from feed production and processing in the current milk shed was higher than Kenyan smallholder dairy farms (1044.16 kgeqCO_2) (Weiler et al. 2014).

Enteric Emission

Type and quantity of animal feeds that offered for cattle were identified at the household level. Farmers estimated the amount of feed offered for cattle for different herd categories per day. The nutrient content of those different feedstuffs was obtained from online websites of Feedpedia (Table 17). The quantity of feed intake from grazing was difficult to estimate, and it was not accounted in the current enteric emission estimation. The total enteric carbon footprint from all sampled dairy farms in urban and peri-urban was 716729 and 672987 Kg CO2eq per year (Table 27). When compared to other dairy herd categories cows contributed largest to the total enteric emission in both urban (74%) and peri-urban (66%) followed by young stocks and ox and bulls. The mean enteric emission from all herd categories per farm per year in peri-urban (23,206 Kg CO2eq) production was significantly higher than the urban enteric emission (14,054Kg CO2eq). Nevertheless, emission from each production systems is much higher than Kaptumo smallholder dairy farms in Kenya and in Anand district of western India where total enteric emissions per farm averaged 4437 kgCO2eq/year (Weiler et al., 2014) and 10610 kgCO2eq/year (Garg et al., 2016). This higher enteric emission resulted from higher number of cattle per farm and low-quality feed. Furthermore, the higher fraction of enteric methane emission was mostly related to the nature of ruminant digestion that was influenced by the quality of feed (Garg et al. 2013). However, the mean enteric emission per cow per year in urban production was 2967 Kg CO2eq which is significantly larger than peri-urban enteric emission from cows per year per farm (2105 Kg CO2eq).

Table 17. Enteric emission (Kg CO_2eq/year) contributed by different herd categories.

Herd categories	Urban			Peri-urban		
	Total	Range	Average/farm	Total	Range	Average /farm
All cows	530161	1796- 42788	10395	442396	588-81922	15255^{NS}
All bulls and Ox	45446	0 -15559	891	71465	0-11229	2464*
All Young stocks	141121	0-16877	2767	159125	0-21684	5487*
Per cow	151329	638- 8660	2967*	61044	175-5461	2105
Per ox or bull	14764	0-5186	289	27168	0-4436	937*
Per youngstock	30618	0-2946	600^{NS}	14297	0-1524	493
All herd	716729	2260- 59665	14054	672987	662-81922	23206*

NS = Non-significant at $P<0.05$, * = significant at $P<0.05$

Emission from manure management

Methane emission from manure

The total annual methane emission from manure management from all sampled dairy farms in urban and peri-urban was 8329.81 and 5055.22 Kg CO_2 eq respectively (Table 18). Methane emission per farm from manure management system did not significantly differ between the two production systems.

Table 18. Methane emission from manure management system (Kg CO_2 eq./year)

Domain	Urban	Peri-urban
Overall	8330	5055
Average per farm	163	174^{NS}

NS = Non-significant at $P<0.05$

Nitrous oxide emission

The total direct and indirect nitrous oxide emission per year from manure management from sampled dairy farms was 1762 and 1850 KgCO_2eq in urban and peri-urban dairy production respectively (Table 17). In urban production a given dairy farm averagely released 35 KgCO_2eq per year while 64 KgCO_2eq per year was released by the peri-urban dairy farm specifically from manure management, significantly higher than the urban dairy farm.

Table 19. Emission from manure management

	Urban	Peri-urban
	Kg CO_2 eq/year)	Amount (KgCO_2 eq/year)
Direct	651	718
Volatilization	687	653
Leaching	424	479
Overall	1762	1850
Average per farm	35	64*

*=significant at $P< 0.05$

Both CH_4 and N_2O emissions were considered from manure management systems. The current study revealed that emission per farm in urban and peri-urban production from manure management system averaged 198 kgCO_2eq/year and 238 kgCO_2eq/year respectively. Of which CH_4 accounted 163 kgCO_2eq/farm.year and 174 kgCO_2eq/farm.year in urban and peri-urban production. The current result is lower when compared with Kaptumo smallholders in Kenya; reported as 1040 KgCO_2 eq/farm.year where emission from manure accumulation on pasture accounted for 95% (Weiler et al., 2014). N_2O emission from manure management in the current milk shed is higher in peri-urban than in urban due to large quantity of manure production resulted from higher number of cattle per household

Total emission from all sources

The overall annual emission from all emission sources from the sampled farms in urban and peri-urban production was 979,488 and 752,074 KgCO_2eq. respectively (Table 20). The average emission per farm in peri-urban was significantly larger than the peri-urban production. In other words, the emission per farm in peri-urban dairy production was twice higher than the urban dairy farm.

Table 20. Emission from all sources (Kg CO_2eq.)

Sources	Urban	Peri-urban
On-farm feed production	179	255
Off-farm feed production	4748	2203
Feed transportation	27	31
Enteric emission	14054	23206
Manure management	198	238
Overall (per year)	979,488	752,074
Average per farm (per year)	19,206	25,934 *
Average Per liter	2.07	4.71 *

*=significant at $P < 0.05$

Emissions by function

As presented earlier dairy farmers in the current milk shed kept cattle for different purposes (milk, beef, draught, manure, insurance and finance). Economic value for each of the functions that cattle served was computed. As presented in the Table 21 milk took the majority of dairy cattle herd value in both urban and peri-urban, i.e. it accounts about 85.06% and & 70.65% of all the functions that cattle serve in urban and peri-urban respectively. The share of GHG emission from different cattle purposes was allocated by the proportions of economic values. In urban dairy production, insurance, beef and finance took the next positions in the share of GHG emission next to milk production. However, insurance, draught and beef were in the order of sharing GHG emissions in peri-urban production after milk production.

Table 21. Allocation of emission for different functions of dairy cattle per year

Functions	Urban			Peri-urban		
	Economic value (ETB)	%	(KgCO_2eq.)	Economic value (ETB)	%	(KgCO_2eq.)
Milk	8,595,132	85.06	833,183	2,825,451	70.65	531,334
Beef	385,300	3.81	37,350	108,500	2.71	20,404
Draught	81,689	0.81	7,919	129,303	3.23	24,316
Manure	7,330	0.07	711	22,542	0.56	4,239
Finance	111,435	1.10	10,802	38,000	0.95	7,146
Insurance	923,535	9.14	89,524	875,477	21.89	164,636
Total	10,104,421	100.00	97,9488	3,999,272	100.00	752,074

Carbon footprint of milk production

Carbon footprint (CF) of milk production without allocation to other dairy cattle functions was 2.07 KgCO_2eq/ litre and 4.71 KgCO_2eq/ litre in urban and peri-urban production respectively. CF of milk in urban smallholder dairy farm is comparable with smallholder farms in Anand district (2.2 kg CO_2eq/kg FPCM) and urban dairy farm in Mekelle shed (2.25 kg CO_2eq/kg milk) (Garg et al., 2016 and Woldegebriel et al., 2017). When allocating to other co-products (functions), the CF of milk production accounted about 85% and 70.06 % of the entire emission in urban and peri-urban production. Thus, an urban smallholder dairy farm averagely released 1.76 Kg CO_2eq/ litre while a peri-urban dairy farm released averagely 3.33 Kg CO_2eq/ litre (Table20). Therefore, the CF of milk reduced by 15% and 29.04% in urban and peri-urban smallholder dairy production. Similar pattern on CF of milk was reported by Garg et al. (2016); milk CF decreased by 22% after applying allocation to all services and products. Furthermore, Weiler *et al*. (2014) reported that CF of milk production in Kaptumo smallholder dairy farm was 2.0 kg CO_2 eq/kg milk when only milk and meat product were considered. The CF of milk was further reduced to 1.6 kg CO_2eq/kg of milk when economic function allocation (including milk, meat, finance, manure and insurance) was applied. The current study also showed that CH_4 took the largest share (80%) of the overall emission per farm. This result is lower when compared with the report of FAO & NZAGRC (2017) reported as 87.3% of the emission in the dairy farming was contributed by enteric.

Table 22. Total emission from milk production (Kg CO_2eq)

	Urban	Peri-urban
Total per year	833,183	531,334
Average per farm per year	16,337	18,322
Per liter	1.76	3.33

Conclusion

The carbon footprint of milk at smallholder production indicated that inclusion of multi-functions of cattle had strong impacts on the overall figure of carbon footprint. Hence, the carbon footprint of milk in urban production was reduced from 2.07 to 1.76 Kg CO_2eq/ litre while from 4.71 to 3.33 Kg CO_2eq/ litre in peri-urban dairy production. Peri-urban dairy farms had higher emission per litre of milk than urban dairy farms that is due to low milk production and large number of cattle per farm. In addition, peri-urban dairy farms emitted higher GHGs in other different multifunction. In smallholder production, enteric emission had a huge contribution to carbon footprint of milk which cows had the largest share. Emission related to feed transportation is less due to the common use of locally available transportation systems which do not consume fuel. Emission from manure management was higher in peri-urban dairy production which is related to large amount of manure production.

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Dairy Production and Marketing Systems in Urban, Peri-Urban and Rural Dairy Production Systems in Bona Zuria District of Sidama Region, Ethiopia

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Abstract

The study was aimed at characterizing dairy production & marketing systems, identifying major constraints hindering dairy development, and improvement options in Bona District of Sidama Region, Ethiopia. The district was stratified into urban/peri-urban and rural production systems based on the distance from the woreda town, market orientation, improved breed availability, and production and consumption systems. Each production system was further stratified into PAs. The number of PAs selected from each production system was 20% (2 from urban/peri-urban and 4 from rural). A total of 150 households (25 from each PA) were selected and individually interviewed. Both structured and semi-structured questionnaires were used to collect data on milk production and marketing systems, and challenges hindering dairy development in the study area. The major farming activity across the sampled households was dairy production, and the major livestock feed resources used were natural pasture and crop residues (including enset and cereals residue). About 72% of sampled households keep their cattle within family house while 58% keep either in corrals or separately built house. Milking and milk processing was mainly (70.9-80.8%) accomplished by women's while decision on breeding was made by males (95%). The average age at first calving, calving interval and lactation length was 53.9±0.19, 25.8±0.13 and 8.9±0.08 months for indigenous cows and 36.9±0.20, 16.04±0.13, and 10.0±0.60 months for crossbred dairy cows, respectively, and this was consistent across the production systems studied. Although both controlled and free mating were practiced, about 25.3%, 32.5% and 42.2% of sampled households use artificial insemination, bull service and combination of both, respectively. Milk and butter were found to be marketed mainly through informal marketing systems. Feed shortage, disease, lack of awareness on improved production and marketing practices, shortage of improved dairy cattle breeds and distance to marketing points were listed as the major constraints hindering dairy development in the study area. It is, therefore, concluded that introduction of market-oriented extension system, creating access for inputs and establishment of market linkage are crucial to develop dairy in the woreda.

Key words: *Bona district; production systems; reproductive performance; milk and butter marketing.*

Introduction

Ethiopia possesses the largest livestock population in Africa. Estimates for rural sedentary and pastoral areas indicate that the country has about 70.3 million heads of cattle, 42.9 sheep, 52.5 million goats, and 8.1 million camels (CSA, 2020/21). The livestock sector contributes to about 15–16% of the GDP, and 35-49% of agricultural GDP excluding the values of draught power, transport and manure, and contributes to the livelihoods of about 37–87% of the Ethiopian population (ILRI, 2010). A study conducted by IGAD study showed that the value of the animal draught power input into arable production is about a quarter (26.4%) of the value of annual crop production, and if the value of draught power services is included, the sector contributes up to 45% of agricultural GDP (Behnke and Metaferia (2011).

In Ethiopia dairy production heavily depends on indigenous unimproved cattle, goats, camels, and sheep where the contribution of cattle is the largest (65%) (CSA 2020/21). Despite the potential for dairy development, productivity of indigenous livestock genetic resources in general is low, and the direct contribution it makes to the national economy is limited. A recent report by CSA (20/21) indicated that the total production of cow milk is about 4.7 billion liters, and this translates to an average daily milk production/cow of only 1.48 liters/day. As a result, the per capita milk consumption of the country is about 20 kg (MoA, 2012), which is much lower than Africa and world per capita average of 27 kg/year and 100 kg/year, respectively (CSA, 2015).

Sidama is one of the 10th national regional states established recently. The major farming system in this region is livestock-crop mixed system where cattle, enset (*Ensete ventricosum*) and coffee are the dominant agricultural commodities. Bona Zuria, one of the woredas in this region, is consistently surplus agricultural products producing district in Sidama region (Kettema, 2013). It is believed to have high potential for dairy, which has been identified by the stakeholders as a priority commodity in the district. There is also an increasing demand for milk as a result of urbanization, increasing population growth and favorable milk consumption culture in the area. Small scale enset based dairy farming is the predominant production system in the mid to highlands of Bona (CSA, 2009). However, consistent to other parts of the country, the production and productivity and income generated from dairy sector is disproportionately low. It is, therefore, imperative to assess the challenges and constraints hindering dairy development and marketing in the area. Identifying the challenges and opportunities for the success of the milk enterprises in the district is crucial. This study was, therefore, undertaken to characterize dairy production and marketing systems, identify major constraints/challenges hindering dairy development in the study area and recommend improvement options.

Material and Methods

Description of the study area

This study was conducted in Bona Zuria district of Sidama National Regional State. Bona zuria is located at 127 km east of Hawassa city, the capital of the region. The woreda lies within the Rift Valley, with altitudes ranging from 1700 to 2400 meters above sea level (masl). It receives an annual rainfall of 700–950 mm, and has an annual temperature range from 11to 22ºC.The study woreda has a total area of 33,720 hectare of land. The total population of the study woreda is 121,236 of which 61,001 are male while 60,235 are female (CSA, 2007). The woreda comprises 28 kebele administrations of which 7 kebeles are urban and peri-urban, while 21 kebeles are rural. More than 90% of the population earns their living from agriculture and livestock raring and the rest (less than 10%) earn a living from petty trade and other livelihood activities. There are two cropping seasons. These are Belg (starting from February to May) and Maher (starting from June to September).The kebeles in the woreda are categorized as Woinadega (89%) and Dega (11%). Enset, maize, teff and haricot bean are the major crops in the Woreda while wheat, barley, sweet potato and sugar cane are grown in small amounts and banana, avocado and potato are grown in a very small amount. Coffee and chat are the major cash crops grown in the woreda (Bona Zuria Woreda agricultural office annual reports 2014).

Sampling method

Multistage stratified sampling technique was used to select target groups. Accordingly, Bona woreda was selected based on its potential for production. The Woreda was stratified into 2 production sub-systems based on its distance from the woreda town, market orientation, improved breed availability, and production and consumption systems. These were urban/peri-urban and rural production systems. The total number of kebeles in urban/peri-urban and rural dairy production system in the Woreda was 7 and 21, respectively. About 20% of these PAs (n=6) (2 from urban/peri-urban and 4 from rural kebeles) were selected from both production systems for this study. For household survey, the number of households selected from each kebele was proportional to size (about 10% of the total households were selected randomly from a list of farmers registered as milk producers of the respective kebeles) of which 40-50% were females (both female headed households and women's within male headed households) (Bona District Office of Livestock & Fisheries Annual Report, 2015). The total number of households interviewed for this study was 150 (25 per kebele).The households were selected using random sampling method. The target sampling population was defined as all households in the study area who have dairy cattle and produce milk for home consumption or for market.

Data collection

Types and source of data

This study used both qualitative and quantitative data collected from primary and secondary sources. Primary data was collected through focus group discussions, household survey and field measurement from sample respondents, (from urban/peri-urban and rural milk producer households) and key informant interviews who had better knowledge and skill on the subject. Secondary data was collected from woreda office of agriculture, office of marketing, rural job opportunity creation office, gender office and other relevant institutions. Pertinent information was also gathered from research reports, books, internet sources, government publications, journals etc. Data on the first part of the study (assessment of milk production and marketing, and identification of challenges and constraints) was collected using focus group discussion, key informants interview and household survey, while data on monitoring part of the study was collected through field measurements.

Focus group discussion

Focus group discussion was undertaken in each of the 6 selected kebeles to discuss on the dairy production practices and marketing systems, and major challenges/constraints and opportunities for dairy development in the area. The discussion was based on the checklist and facilitated by researchers. There were 6 FGDs (one per kebele) and the number of participants per FGD was 12. The outcome of the FGD also enabled to refine the questionnaire to be used for household survey.

Key informant interview

Key informant interview was conducted to gather relevant information from those who were knowledgeable and have better experience in the subject. The interview also extended to value chain actors and service providers such as traders, processors, transporters, input suppliers, service providers and others who contribute to dairy value chain in the area.

Household survey

The questionnaire was used to collect primary data from selected respondents. The questionnaires were pre-tested and essential amendments were made. The questionnaires were edited for its validity, consistency and clarity based on a pre-test result. The following data was collected through the questionnaires:-livestock species, type and number by physiological stage, age and sex; feed resources, feeding calendar, reproduction and management; artificial insemination; health and breed improvement practices and challenges, milk and milking practices; available local milk breed productivity and livestock disease incidences of the study area, handling, processing, consumption and marketing of milk and milk products, dairy cattle housing, manure managements, type of dairy extension service they are getting, and major constraints and opportunities for milk production and marketing systems were addressed in the questionnaire.

Statistical analysis

The data generated from the survey study was summarized and analyzed using Statistical Package for Social Science (SPSS) version 16.0. Descriptive statistics such as percentage, means and standard errors were employed to describe the results.

Results

Socio-economic characteristics of households

Household characteristics - The overall mean family size (mean ± s.e.) and age of respondents (mean ± SE) in the study area was 5.96 ± 0.23 persons and 43.03 ± 0.66 years, respectively (Table 1). The mean family size was higher for rural (7.03) compared to urban/peri-urban (3.82) production systems whereas there was no difference ($p>0.05$) in mean age of the respondents between the two production systems. About 84% of the sampled respondents were males while the rest 16% were females. With respect to education, most of the respondents (95.4%) are literate, of which about 56% completed elementary school.

Land holding per households in the study area - The overall mean land holding in the study area was 1.38 ha. of which about 59% was allocated for crop farming (includes perennial crops such as enset and coffee, and annuals such as cereals) while about 41% was allocated for grazing and forage production (Table 2). However, as expected, the total land size was significantly higher ($p<0.05$) for rural production system compared to urban/peri-urban.

Table 1. Household characteristics in the study area

Variables	Production systems		
	Urban/peri-urban	Rural	Overall mean
	Mean+SE	Mean+SE	Mean+SE
Family size	3.82+0.27	7.03+0.26	5.96+0.23
Age of respondents (year)	43.12+1.11	42.9+0.82	43.03+0.66
Sex of respondents (%)			
• Male	82	85	84
• Female	18	15	16
Education of respondents (%)			
• Illiterate	-	7	4.6
• Read and write	-	19	12.7
• Elementary school	72	44	53.4
• High school	18	20	19.3
• Diploma and above	10	10	10

Table 2. Land holding (ha) per sampled households in the study area

Variables	Production systems		
	Urban/peri-urban(n=50)	Rural(n=100)	Overall(N=150)
	Mean+SE	Mean+SE	Mean+SE
Crop land	0.36+0.05	1.04+0.54	0.81+0.05
Grazing land	0.27+0.31	0.59+0.35	0.48+0.03
Forage land	0.11+0.02	0.09+0.01	0.09+0.01
Wood land	0.05+0.01	0.06+0.01	0.05+0.01
Total land holding	**0.68+0.07^{b}**	**1.73+0.06^{a}**	**1.38+0.06**

N=number of respondents; SE=standard error; $^{a-b}$ means with different superscripts for the same variable across the same row are significantly different (P<0.05).

Livestock holding in the study area - The livestock species kept in the study area include cattle, poultry, small ruminants and equines, and the total livestock holding per households (TLU) was 8.08 (Table 3.) There was no difference in the number of livestock species between the two production systems. Cattle are dominant accounting for about 87% of the total livestock holding, and the contribution of crossbred cattle was about 42% of the total cattle holding per household.

Farming activity of the respondent households in the study area - Majority of the respondents were primarily involved in dairy production (78%) followed by poultry (14.7%) and shoat production (7.3%), and this was consistent among the production systems studied (Table 4). The major source of livelihood of the farmers in the study area was livestock and crop production (57.7%) while the contribution of others was variable.

Table 3. Livestock holding per sampled households (TLU) in the study area

Livestock type	Production systems		
	Urban/peri-urban	Rural (n=100)	Overall (n=150)
Livestock type	Mean±SE	Mean±SE	Mean±SE
Total cattle	7.08±0.75	7.11±0.43	7.10±0.59
• Local cattle	3.88±0.32	4.39±0.26	4.14±0.29
• Crossbred cattle	3.20±0.43	2.72±0.17	2.96±0.30
Sheep	0.14±0.02	0.16±0.01	0.15±0.01
Goats	0.15±0.05	0.12±0.01	0.13±0.03
Equines	0.65±0.05	0.74±0.04	0.70±0.04
Total livestock (TLU)	8.02±0.87	8.13±0.49	8.08±0.67

Table 4. Livestock farming and income sources of sampled households in the study area

Variables	Urban/peri-urban (%)	Rural (%)	Overall (%)
Livestock farming			
• Dairy production	60	87	78
• Poultry production	34	6	14.7
• Small ruminant production	6	7	7.3
Income sources			
• Livestock production only	14	3	6.7
• Crop production only	4	10	7.9
• Livestock and crop production	26	74	57.7
• Livestock and off-farm activity	30	2	11.6
• Crop and off-farm activity	4	4	3.8
• Crop, livestock and off-farm activity	22	7	12.3

Dairy cattle husbandry practices in the study area

Involvement of family members in milk production - Milk production activities in the study area were done by both male and female members of the family and children above six years of age (Table 5). Cattle herding and feeding is mostly undertaken by boys and girls between 6 and 14 years of age. About 15% and 3.7% of the boys in the age range of 5–10 years were involved in cattle herding and feeding, respectively. Milking, milk processing, cleaning and selling of milk and butter is performed by adult male and female. All cows are hand milked, and milking of cows is mostly (70.9%) done by women. However, men milk the cows when the wife is not around. On the other hand, women are solely responsible for milk processing, barn cleaning and sale of milk and milk products. Men have greater contribution in breeding decision. Processing of the sour milk into butter is done by the wife (80.8%) and/ or daughters and in few cases by hired labor (2.7%). As long as there is sufficient family labor, hired labor is kept to the minimal.

Table 5. Involvement of family members in milk production.

Activity	% of responsible family members				
	Men	Women	Boys	Girls	Hired labour
Herding	12	3	47	15	23
Feeding	27.6	8.5	44.5	3.7	15.7
Caring of calves	11.4	32.5	28.7	17.5	9.9
Milking	12.6	70.9	4.2	8.5	3.8
Milk processing	1.5	80.8	2.6	12.4	2.7
Barn cleaning	1.3	63.6	6.5	22.7	5.9
Sale of milk products	5.5	63.9	8.4	18.0	4.2
Breeding decision	95.5	4.5	-	-	-

Feed resources - The major sources of feed for livestock in the study area were grazing on natural pasture (57.5%), crop-residues (26.3%), and crop-aftermaths (16.2%). According to the respondents, livestock production system in Bona district is heavily dependent on grazing from natural pasture and crop stubble. However, these feed resources are generally poor in quality and their productivity and supply is seasonal, particularly a critical problem during the dry season.

Feeding calendar - The feeding calendar of the study area is shown in Table 6. The major feed resources from October to February were cereal residues, Enset leaf and after math grazing, while it was grazing during the other months (February to September). However, about 53.3% of the respondents reported that they face feed shortage mainly during the dry season (October to January) due to poor availability of feed from the grazing land. On the other side, about 34% of the sampled households reported that they face feed shortage from February to September. While about12.7%) reported that they face feed shortage year-round. The farmers strategies used to cope with the feed shortage in the months were supplementing livestock with any available dry crop residues and Enset leaves, sugar cane and banana residues.

Table 6. Relative feed availability of the major feed resources over the months of the year

Feed type	Months of the year											
	J	F	M	A	M	J	J	A	S	O	N	D
Natural pasture (private)	-	x	x	xx	xx	xx	xx	x	x	-	-	-
Maize stover	x	-	-	-	-	-	-	-	x	xx	xx	xx
Teff straw	x	x	-	-	-	-	-	-	-	xx	xx	xx
Enset leave	xx	xx	xx	-	-	-	-	-	-	-	x	x
Aftermath	x	xx	-	-	-	-	-	-	-	xx	xx	xx

– =Less available; x = fairly available; xx = better available;

Major constraints of dairy development in the study area

The major constraints limited dairy production according to the perception of sampled households is presented in Table 7. Thus, shortage of feed followed by low production capacity of indigenous cattle were the major constraints across all the production systems considered in the woreda.

Table 7. Major constraints ranked by sampled households in the study area

Constraints	Urban/peri-urban (n=50)				Rural (n=100)			
	1	2	3	Index	1	2	3	Index
Shortage of feed	34	7	12	0.43	73	12	5	0.41
Low production capacity of indigenous cattle bred	5	27	9	0.26	16	61	7	0.30
Overstocking	8	12	23	0.24	7	18	82	0.23
Disease	3	4	6	0.07	4	9	6	0.06

Index = [(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for each constraints to feed]/[(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for all constraints to feed].

Since feed shortage was reported to be the leading constraint in the area (Table 7), effort was made to further assess the root cause of the problem by feed type; viz, forage, agro-industrial by-products and crop resides (Table 8). Accordingly, shortage of land due to increasing population pressure (43.3%), lack of access for forage seed (26.7%) and lack of awareness on improved forage production (22%) were the major challenges in the order of priority. On the other hand, high price (34.7%), limited access (28.7%) and lack of awareness were the major problems limited agro-industrial by product utilization in the study area. The major challenges limited crop residue availability in the study area were shortage of cereal crop production as the major crops grown in the area perennials such as enset and coffee (78%), and multiple use of the available crop residues (22%).

Table 8. Challenges limited feed availability in the study area

Variables	N	Percent
Forage availability		
• Lack of awareness	33	22
• Lack of seed	40	26.7
• Shortage of land	65	43.3
• Poor adaptability	4	2.7
• Shortage of improved forage in the area	8	5.3
Agro-industrial by-products availability		
• Lack of awareness	23	15.3
• Less accessibility	43	28.7
• High price	52	34.7
• Shortage of supply	32	21.3
Crop residue availability		
• Shortage of production	117	78
• Utilization for other purposes	33	22

Cattle housing systems in the study area - According to the survey result, majority of the sampled households from urban/peri-urban system keep their cattle in separate house (80%) while about 68% of the sampled households in the rural production system share their house with cattle. Besides, unlike urban/peri-urban system, about 32% of the households in the rural production system also house their cattle in corral. with about 52% of the households keep their dairy cattle within family house (Table 9). Cattle houses in rural areas were constructed from locally available materials, mainly grasses and woods. The floor of livestock houses were made of earthen material and house was roofed temporarily using grasses. Sampled households in the study area indicated that cattle dung was disposed from the house using hired labor or family members. On the other side, calves and small ruminants were housed separately.

Table 9. Dairy cattle housing system in the study area

House type	Urban/peri-urban (%)	Rural (%)	Overall mean (%)
Share same house with family	20	68	52.0
Corral	-	32	21.3
Separate house from family	80	-	26.7
Total	100	100	100

Reproductive and productive performances of cows in the study area - The average ages at first service of indigenous dairy cattle breeds in the study area was 44+0.18, and it was consistent across the production systems studied (Table 10). Similarly, the average age at first calving, calving interval, lactation length and number of services per conception of indigenous and crossbred dairy cattle was consistent across the two production systems.

Table 10. Reproductive performances of dairy cattle according to perception of sampled households in the study area.

Breed	Variable	Production systems		
		Urban/peri-urban (n=50)	Rural (n=100)	Overall (n=150)
		Mean±SE	Mean±SE	Mean±SE
Local	AFS (month)	44.2±0.45	43.9±0.20	44+0.18
	AFC (month)	54.2±0.45	53.8±0.20	53.9±0.19
	CI (month)	25.9±0.26	25.8±0.15	25.8±0.13
	LL (month)	8.82±0.16	8.93±0.09	8.90±0.08
	NSC	1.82±0.18	1.86±0.11	1.85±0.09
	Mean daily milk yield (l/head)	1.84±0.12	1.56±0.07	1.65±0.06
Crossbred	AFS(month)	27.1±0.45	26.9±0.21	26.98±0.20
	AFC(month)	37.1±0.45	36.9±0.21	36.98±0.20
	CI(month)	15.8±0.24	16.1±0.15	16.04±0.13
	LL(month)	9.86±0.11	10.1±0.08	10±0.06
	NSC	2.11±0.11	2.02±0.10	2.06±0.07
	Mean daily milk yield (l/head)	4.23±0.17	4.23±0.14	4.23±0.11

N=number of respondents; AFS=age at first service; AFC=age at first calving; CI=calving interval; LL=lactation length; NSC=number of services per conception.

However, the mean daily milk yield of indigenous cows was slightly higher for urban/peri-urban compared to rural system. (Table 10). On the other hand, AFS and AFC of crossbreds was shorter than indigenous cows by about 17 months while it was shorter by 10 months for calving interval. The average daily milk yield and lactation length was slightly longer for crossbreds compared to indigenous cows.

Dairy cattle breeding, and challenges limited AI service delivery in the study area

The dominant exotic cattle breeds used for crossbreeding in the study area are Jersey and Holstein Friesian, and the common breeding methods used in the study were natural mating using bulls and artificial insemination (AI). Both free mating and controlled mating using bulls were also practiced. About 25.3%, 32.5% and 42.2% of respondent in the study area use artificial insemination (AI), bull service, and both AI and bull service for dairy cattle breeding, respectively. Lack of access to AI, shortage of liquid nitrogen and semen, and lack of skilled AI technicians were ranked as first, second and third important constraints limited AI service delivery across both production systems in the study area (Table 11).

Table 11. Major constraints limiting access to artificial insemination service as ranked by households in the study area.

Constraints	Urban/peri-urban (n=50)				Rural (n=100)			
	Rank				Rank			
	1	2	3	Index	1	2	3	Index
Lack of access	29	4	5	0.33	76	8	8	0.42
Shortage of liquid nitrogen and semen	6	28	2	0.25	10	71	5	0.30
Lack of skilled AI technician	8	12	5	0.18	6	12	69	0.18
Non-effective services	5	3	26	0.16	5	3	13	0.06
Distance to AI station	2	3	12	0.08	3	6	5	0.04

Index = [(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for each constraints to artificial insemination]/[(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for all constraints to artificial insemination].

Major cattle diseases, and animal health service-related challenges in the study area

The major cattle diseases prevailing in the study area, according to the respondents, were respiratory diseases, pasteurolosis, skin disease, tuberculosis, blackleg, and foot and mouth disease. Consistent with this, the major challenges limiting access to animal health service delivery in the study area were shortage of veterinary drugs (34.7%) followed by lack of veterinary laboratory services (20.7%) and lack of timely vaccination (13.3%) (Table 12). In the study area, animal health service was provided mainly by government (51.2%) followed by NGOs (13.4%) and private sector (6.1%).

Table 12. The animal health problems reported by households in the study area

Problems	Urban/peri-urban (%)	Rural (%)	Overall (%)
Shortage of veterinary drugs	42	31	34.7
Less frequent animal health service	16	9	11.3
Distance to animal health service center	6	8	7.3
Shortage of skilled animal health technician	10	14	12.7
Lack of veterinary laboratory services	20	21	20.7
Lack of timely vaccination	6	17	13.3
Total	100	100	100

Marketing of dairy products in the study area

Dairy producers in the study area sell dairy products to consumers, retailers, and traders. According to sampled respondents, the major milk (68%) and butter (79.3%) buyers were consumers (Table 13). The reported modes of payment for milk and butter purchase were cash (88.7%). On the other hand, the dominant outlet for milk and butter in the study area was market center (76-77.3%) followed by door-to-door delivery (16.7-22.7%)

Table 13. Dairy products buyers, mode of payment and outlet in the study area

Milk buyer	**n**		**%**	
• Consumers (directly)	102		68	
• Traders	48		32	
Butter buyer				
• Consumers	119		79.3	
• Retailers	31		20.7	
Mode of payment				
• Cash on the spot	133		88.7	
• Cash in advance	6		4	
• Contract	11		7.3	
Dairy product outlets	**Milk**		**Butter**	
	n	**%**	**n**	**%**
Farm gate/homestead	11	7.3	-	-
Market place	114	76	116	77.3
Door to door delivery	25	16.7	34	22.7

Milk and butter marketing constraints

Among all the constraints of milk and butter marketing in the study area lack of awareness related to milk and milk product marketing, distance to marketing points and adulteration of milk and butter were considered as the major problems ranked first, second and third by households in urban/peri-urban and rural production systems with different index values, respectively (Table 14).

Table 14. Milk and butter marketing constraints ranked by sampled households

Parameters	Urban/peri-urban(N=50)				Rural(N=100)			
	Rank				Rank			
	1	2	3	Index	1	2	3	Index
Lack of awareness	31	13	6	0.42	65	21	14	0.42
Distance to marketing points	16	28	6	0.37	30	61	9	0.37
Adulteration of milk and butter	3	9	38	0.22	5	18	77	0.21

Index = [(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for each constraint to milk and butter marketing] / [(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for all constraints to milk and butter marketing].

Discussion

Household Characteristics

The average household size observed in this study was smaller than 7.71 persons per family reported for Mecha and Bahir Dar Zuria districts (Asaminew, 2007) and 8.73 persons per household reported for household in Bale highlands (Solomon, 2004). In contrast, the present finding was nearest to 6.621 reported for Meiso district, Eastern Ethiopia (Kedija, 2008).

Education is an important entry point for empowerment of rural communities and an instrument to sustain development. In this context, educational level of the farming households may have significant importance in identifying and determining the type of development and extension service approaches. The role of education is obvious in affecting household income, adopting technologies, demography, health, and as a whole the socio-economic status of the family as well (Kerealem, 2005). The majority of urban/peri-urban and rural dairy producer household heads were literate with educational level ranging from elementary school up to high school. The results in general indicate that most of dairy cattle owners in the study area were literate; indicating that with good extension and training program they can improve their dairy production and marketing systems which are mainly based on traditional system currently.

Land and livestock holding

The overall mean land holding size per households in the study area was lower than the national average land holding size of 1.77ha (CSA, 2013). It is also less than the land holdings of 2.0 to 5 ha for 32.6% and 16.2% of the smaller farmers in the country and SNNPRS, respectively (CACC, 2003) and greater than 1.1 ha in Shashemene-Dilla area (Yigrem et al., 2008). Low land holding has negative implications on household income and livestock production. It was also revealed that 93%of the total cattle population was local zebu cows which is different from what was reported (99.5%) by Fiseha (2009) in the Bure district. The average number of cattle in the current study is smaller than what Dawit Asseffa (2013) reported for Adami Tulu Jiddo Kombolcha (8.27 TLU cattle).

Dairy cattle husbandry practices in the study area

Involvement of family members in milk production - This study demonstrated that sampled household members participated in various dairy cattle management practices in the studied area. The selling and purchasing of cattle was mostly the responsibility of males commonly older than 15 years of age. This group was also responsible for breeding, healthcare and feeding activities whereas their female counterparts were responsible for milking, making and selling dairy products and feeding cattle. Males and females under 15 years of age were given responsibilities mainly for feeding. Young females were also involved in helping older women in dairying activities. The findings are in agreement with Asfaw (2009) who reported that most of the time females are responsible for dairy farm operations such as milking cows, cleaning of milk containers, milk storing and preserving etc.

Feed resource - Livestock feeds are the major inputs of milk production (Sintayehu *et al*., 2008). This study also indicated that the major sources of feed for livestock in the study area were natural pasture, crop-residues, and crop-aftermaths. Consistent with this finding, Azage et al. (2013) reported that natural pasture (grazing) and crop residues are the major feed resources used as a basal diet for dairy production in rural and peri-urban dairy systems. Tolera et al. (2012) also indicated that natural pasture and crop residue to be the major feed resources for highlands of Ethiopia. Crop residues, natural pasture and aftermath grazing were the major feed resources for dry season, in their descending order. Currently with the rapid increase in human population and increasing demand for food, grazing lands are steadily shrinking due to the conversion of grazing lands to crop lands, and are restricted to the areas that have little value of farming potential. Agro-industrial by-products are rarely used with the exception of those milk producers who keep crossbred cows. This finding is in line with the report of Asaminew (2007) and Seyoum et al. (2007) who indicated that the major basal feed resources for cattle in Bahir Dar and Mecha districts and the highlands of Ethiopia, respectively, are natural pasture, crop residue and stubble grazing. Tethering of cattle in the homestead and nearby farmlands is practiced to take advantage of fertilization of their back yards through rotational manuring in the study area. The dung is used to fertilize the crop land.

Feeding calendar - This study showed that there was extreme feed shortage during the months October to January. Although crop residues are available its utilization is limited due to poor quality, and the experience of feed quality enhancement through value addition with various technologies was poor. Although farmers store crop residues for dry season, the way of storage is not generally appropriate. Silage making is not known in the area and also hay making is not practiced.

Feed related constraint in the study area - The main feed related constraints prevailing in the study area were low productivity of natural pasture, shortage of feed, overstocking and disease. The reported feed related constraints in this study are consistent with the reports of Belete (2006) in Fogera district and Asaminew (2007) in Mecha and Bahir Dar Zuria districts. The dominant crop residues in the study area were enset leaf and the by-products of its processing, maize stovers, teff straw, banana residue and wheat straw. The majority of the respondents practice storing feed for times of feed shortage. There were no respondents who exercise urea treatment. To overcome the seasonal shortage of feed, the respondents practice various coping mechanisms like storage of crop residues and supplementation with enset leaf, sugarcane and enset corm. Furthermore, agro-industrial by-products and improved forage supplementations are practiced by few respondents especially those who own crossbred cows in Bona town.

Cattle housing practice in the study area - Most farmers house their cattle in the dry as well as wet seasons. This practice is in agreement with the results of Belete (2006) in Fogera district. The purposes of housing in the study areas are to protect cattle from theft and from extreme weather conditions. With regard to housing of crossbred cattle most of the milk producers keep their cattle in separate house. This finding is in line with the finding of Asaminew (2007) at Mecha and Bahir Dar zuria district.

Reproductive and productive performance of cows in the study area

The average ages at first service (AFS) reported for local Zebu heifers (44 months) in this study is similar with what Gidey (2001) reported for Fogera heifers (44±8months) at Andassa Livestock Research Centre, while the reported result (26.98 month) for crossbred heifers is found to be less (35.7±0.4).

The AFC obtained in the present study for both local and crossbred cows is shorter than the result reported by Asaminew (2007) that the average AFC for the local cows is 57.12 months whereas the average AFC for crossbred cows was 37.6 months in Bahir Dar milk shed area. Average AFC obtained in the current study is shorter than the finding of Fisseha (2007) with the overall mean of AFC 43.13 ±1.7 months for Holstein Frisian cows in Alage. The AFC of this study for local zebus is almost similar with what was reported by Mukasa-Mugerwa et al (1989) for local zebus (53.0 months) but is less than the AFC reported by Gidey (2001) for Fogera cows (54.6 months). The result depicted for crossbred cows (36.98 months) was higher than what was reported by Albero (1983) for Fresian x Zebu cows (29.1 months). This variation might be due to the difference in the level of management and other inputs as this figure is an on-farm finding in contrast to that of Albero (1983).

The reported average number of services per conception (NSC) of local and crossbred cows was 1.85 and 2 respectively. According to Mukassa - Mugerwa (1989), cows with values of NSC greater than two (2), are regarded as poor. However, the higher NSC in crossbred cows (2) might be attributed to the low efficacy of artificial insemination (AI) services for various reported reasons like lack of skilled AI technician, non-synchronization of heat and insemination and lack of effective frozen semen in the district.

The reported CI in this study are almost similar to the estimates of Mukassa-Mugrewa et al. (1989) (25 months) in zebu cattle. The calving interval of current study was much higher than the value reported by McDowell (1971) for Horro breed (12.2 months); Swensson et al. (1981) for Arsi breed (12.9 months) but; lower than the value reported by Gidey (2001) for Fogera breed (18.6 months) and higher than reported by Goshu (1981) for Barka breed (11.8 months).

The lactation length in the current study was higher than the average lactation length of local cows (7.29 months) at Meiso district (Kedija, 2008). The lactation length of the indigenous cows observed in this study is higher than the national average (7 months) (CSA, 2005), while the lactation length in crossbred cows observed in this study is slightly shorter than the lactation length of 11.7 months reported for crossbred cows in the Central Highlands of Ethiopia (Zelalem and Ledin, 2001). The overall mean milk yields per cow per day of local cows was higher than the average milk yield per cow per day (1.24 litres) of local cows in Meiso district of Oromia Regional State (Kedija, 2008). In general, the higher average daily milk yield per cow and the variation in lactation length in the present study might be attributed to the difference in agro-ecology, nature of research (on-farm and on-station) and breed of animals characterized. However, although the average daily milk yield per cows of crossbreds was higher than indigenous cows in the study area, it was by far lower compared to crossbreds in other studies, which might be attributed to poor management and inbreeding depression.

Breeds and breeding methods in the study area

The current study showed that both natural mating and artificial insemination are practiced in the study area. With respect to natural mating, bulls can be used for either free mating or controlled mating. In controlled mating systems, heat detection and timing of service was carried out by the farmers and each cow was mated once or twice during each heat period. During the breeding season some farmers breed their cows and heifers with superior bulls owned by themselves or their neighbors. Most of the farmers bred their cows with any bull available in the herd when their cows come to heat. The use of unselected bulls could have negative implication on productivity of the herd and disease transmission such as brucellosis. The majority of the respondents prefer natural mating to artificial insemination for their own reasons that artificial insemination has high chance of resulting in the birth of male calves, and the belief that natural (bull) service has high degree of conception.

Major disease of Cattle

The major reported cattle diseases prevailing in the study area was in line with the finding of Asaminew (2007) at Mecha and Bahir Dar zuria district. According to animal health technicians, the occurrence of these diseases was serious in the district. On average farmers travel about 2 km and a maximum of 5 km to get to an animal health centre. A milk producer on average spends about 4.85 ETB per head for control of ecto-parasites such as ticks. The average cost per head for controlling endo-parasites was about 2.68 ETB per head. The major veterinary services delivery reported in this study agreed with the finding of Adebabay (2009) at Bure district.

Milk and butter marketing constraints

There are a number of highlighted constraints that hamper further development of milk sector in Bona district. Given the current production level the milk producers in the study area had market problems. In this case, the less possibilities of improved milk production technology, underdeveloped milk market and absolute absence of milk processing plants in the area might have contributed to problems currently prevailing in the study area. The seasonal fluctuation in demand of milk product was found to be the major bottleneck in both milk production and marketing in the study area. Milk producing households also reported that seasonality of demand and supply of milk was one of their vital problems in milk production and marketing. With regard to marketing of milk products in the studied district, distance to marketing points, lack of training related to milk product marketing and adulteration of milk with water and butter was considered as a problem. This result is similar to the findings of Sintayehu et al. (2008) in Shashemane, Dilla area of Southern Ethiopia. In the same work it has been stated that for the seasonality in demand for milk and milk products, processing technologies which could extend the shelf life of milk products may resolve the problem. For potential milk areas, where there is no market access, a milk collection scheme through establishment of milk marketing groups may alleviate the problem. Moreover, market-oriented milk extension trainings that cover a wide range of marketing and socio-economic issues should be provided to extension officers to enable them link these skills and knowledge to efficient production through improving farmer's access, understanding and utilization of market in formation. This finding is similar with the finding of Adebabay (2009) at Bure district.

Conclusion

This study evaluated dairy production & marketing system in urban/peri-urban and rural production systems in Bona Zuria districts of Sidama region. The study showed that dairy production is the dominant production system compared to other livestock productions in the study area. However, the milk production and reproduction performance of dairy cattle was very low. Shortage of feed resources, poor breeding and reproductive management, diseases, undeveloped marketing systems and lack of awareness on improved production and marketing technologies are the major challenges limited dairy production in the study area. Therefore, coordinated efforts is required to address the constraints through technological innovations across the different stages of the value chain.

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Potential of Probiotic Yoghurt in Ethiopia: Findings from Consumer Insight Study

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Abstract

Building Rural Income through Inclusive Dairy Business (BRIDGE) partners with the Yoba for Life Foundation worked to introduce probiotic yoghurt. To effectively respond to the continued growth of the probiotic yoghurt market, BRIDGE conduct a rapid consumer insight study. The aim of the current study was to gain more insights in the role of probiotic yoghurt in consumers' diet, identify the attributes which give probiotic yoghurt an advantage over conventional yoghurt, and how consumers form their intentions to purchase. Primary consumer research using telephone interview of 98 current consumers and checklist-based observation at the milk shops was conducted. The study revealed diversified group probiotic yoghurt consumers in terms of educational status, occupation, physical activity level and income. The only sources of information about probiotic yoghurt were the milk shops and 95% of respondents believe they don't have enough information. A limited availability has constituted a major barrier that prevents them from consumption of probiotic yoghurt. Among the attributes, perceived product safety, organoleptic property, shopping location and nutritional/health benefit were mentioned as factors that affect their purchasing decision, respectively. The study recommends the need to bridge knowledge gaps of consumers provide and complete information about the products using different channels.

***Keywords**: Probiotic yoghurt, consumer, attributes, purchasing decision*

Background

The term probiotic refers to live microbial cultures, which, when administered to humans or animals (in the form of dehydrated cells or fermented products), positively affect the host's state of health by improving the properties of the original micro-flora (Margoles & Garcia, 2003). The prophylactic and therapeutic effects of these micro-organisms have been reported in various studies in the following terms: (a) balancing the intestinal flora; (b) increasing lactose tolerance and ingestion; (c) reducing cholesterol levels; (d) synthesis of B complex vitamins; (d) absorption of calcium; (e) modulating the immunological system (Wang & Ascheri, 1991; Hyun & Shin, 1998; Gomes & Malcata, 1999; Margoles & Garcia, 2003).

Since February 2020, Building Rural Income through Inclusive Dairy Business (BRIDGE) partners with the Yoba for Life Foundation worked together to introduce probiotic yoghurt made with Ethiopian milk, produced by small- and medium scale entrepreneurs using low-cost technologies to reach the urban poor with dairy products having multiple health benefits.

Within the first six months of this collaboration between SNV Ethiopia and Yoba for Life, the local field team has trained 26 entrepreneurs, with 22 of these now consistently processing some 20,000 liter of pro-biotic yoghurt per week. The Ethiopian market has demonstrated great potential, as the production of 20,000 liter/week after 6 months compares favorably with the 55,000 liter/week that Yoba for Life achieved elsewhere in East Africa after many years (Yoba for life six-month report).

To effectively respond to the continued growth of the probiotic yoghurt market, companies need to identify the attributes which give probiotic yoghurt an advantage over conventional yoghurt and to understand how consumers form their intentions to purchase probiotic yoghurt. To the best of our knowledge there is no such study focused on probiotic yoghurt conducted in Ethiopia. The aim of this was thus to gain more insights in the role of probiotic yoghurt in urban consumers' diet, identify the attributes which give probiotic yoghurt an advantage over conventional yoghurt, and understand how consumers form their intentions to purchase probiotic yoghurt.

Specific Objectives

- Assess socio-demographic profile of probiotic yoghurt to consumers
- Explore how urban consumers perceive probiotic yoghurt compared to conventional yoghurt
- Identify attributes of probiotic yoghurt influence their intentions to buy.

Materials and Methods

The rapid assessment of the probiotic yoghurt consumer and market was conducted using primary consumer research. Accordingly, a mixed qualitative and quantitative tool was developed, and in total 98 selected current probiotic consumers were interviewed by telephone. Besides, checklist-based observation was conducted at milk shops. KoBoToolBox was used for data collection and analysis.

Result and Discussion

Socio demographic profile of Probiotic Consumers

All the 98 interviewed participants (61 males and 37 Females) responded to the questionnaires administered by telephone. Most of the participants (64.3%) were married. Out of the total respondents, 93.6% were regular buyers of probiotic yoghurt for their family (some respondents mentioned specifically children and elders with gastrointestinal problem and diabetics). Educational status of respondents ranging from primary (14.3%) to secondary (56.1%) and tertiary level (29.6%). Occupation wise 50 % of current consumers are office workers/traders/housewives with sedentary to simple physical activity level and the remaining include drivers/machine operators/laborer with moderate to vigorous physical activity level. The majority (76.5%) of consumers have an income between 3000-15000 ETB. The implication to strategy of this diversified probiotic consumer during the pilot phase emphasize the need to segment the market based on these characteristics and adapt product characteristics, prices, and promotional tactics to suit the requirements of each target segment during the scale up phase.

Buying, storing and consumption patterns of Probiotic consumers

All participants (100%) reported that the only source of probiotic yoghurt are small milk shops supported by BRIDGE and Yoba for life. Among the studied participants, 59 % and 39% % consume Yoba probiotic yoghurt occasionally and frequently, respectively. Study participants reported consumption of probiotic yoghurt during regular meal and snack time. When they were asked whether probiotic yoghurt substitute their other dairy product consumption, 64.3% and 28.6 % of respondents reported probiotic yoghurt somewhat and completely substitute their consumption of other dairy products. Although Yoba probiotic yoghurt has a proven quality of long shelf life and compositional integrity, 96% of buyers consume immediately and afraid to store for future use due to lack of promotion of this attribute and the remaining 4% reported they store in the refrigerator for later consumption.

Consumers knowledge and perception on probiotic yoghurt

When participants were asked about their reasons for consuming probiotic yoghurt, 34.7% of the study participants had mentioned health benefit as major reason for consuming Yoba probiotic yoghurt. Similarly, 89.8% of respondents had positive attitudes on the safety of Yoba probiotic yoghurt. Regarding their perception of how probiotic yoghurt differ from conventional yoghurt, 53 % and 22% of respondents mentioned taste & texture and health benefit as the attributes that make the two yoghurts different. However, the study found that, 98% of respondents had neutral position on the nutritional excellence of probiotic against the conventional yoghurt. The survey indicated that 55% of the respondents agree that probiotic yoghurt has an equally pleasant taste and texture as conventional yoghurt and 28.6% of respondents disagree that probiotic yoghurt has an equally pleasant texture as conventional yoghurt due to creamy taste and texture of the probiotic yoghurt which is different from their experience of conventional yoghurt. However, parents reported that their children preferred probiotic yoghurt for its limited sourness and creamy taste. Taste and texture play an important role in the choice of yoghurt. Regarding whether probiotic yoghurt will be their choice in the future, 45 % of reported it will be their choice of buying next time instead of conventional yoghurt.

Information source and barriers Probiotic consumption:

During the pilot phase the only sources of information about probiotic yoghurt was the milk shops and only 5 % of respondents claimed they have information about health benefit of probiotic yoghurt. Whereas 95% of respondents believe they do not have enough information on probiotic yoghurt and would like to receive additional information via traditional and social media. Although participants mentioned a wider range of barriers like distance/location of milk shops, a limited availability has constituted a major barrier that prevents them from consumption of probiotic yoghurt.

When asked about the driving factors for purchasing this product, perceived product safety (98%), organoleptic property (92%), shopping location and nutritional/health benefit (89%) were prioritized as the main driving factors.

Recommendations

The following are key issues that emanate from the rapid assessment of the probiotic yoghurt market:

- The present study identifies significant knowledge gap about the benefits of probiotic yoghurt and emphasizes the need for bridging knowledge gaps of consumers
- Currently, most customers learn about probiotic yoghurt via milk shops. It would be important to provide additional information about the product using different channels.

- To expand the market for probiotic yoghurt there is a need to segment the market based on different socio demographic and economic characteristics, product characteristics, prices, and promotional tactics.

- A consumer product choice as well as factors that affect purchasing decision are dynamic, the study suggest the need of continuous market and consumer analysis to respond to a change in the dairy market.

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Parallel Session II

Value Chain, Dairy Extension and Marketing

Overview of Challenges and Opportunities of Dairy Cooperatives in Ethiopia: Implication to Dairy Sector Transformation

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Abstract

Ethiopia has the largest cattle population in Africa. Despite this, average milk yields are still low, and dairy small farms, as well as those in more remote areas, benefit less from access to modern dairy farming practices. This issue requires a structural transformation of the dairy sector for poverty reduction and welfare improvements-hence the sector has the potential to provide good income opportunities for the poor. This article provides a compiled overview of challenges and opportunities of the dairy sector in Ethiopia, particularly dairy cooperatives, and their role to transform the sector based on the evidence from the empirical literature. The qualitative and quantitative data were used from available literature, and the data were analyzed qualitatively through triangulation and narration. The empirical evidence shows that the potential of the dairy sector is under-utilized. It is a risky venture due to socio-cultural and religious factors. Dairy cooperatives are believed to accelerate the dairy sector through collective resource mobilization by reducing transaction costs and facilitating market linkages. Studies revealed that cooperative membership has a positive impact on milk production and productivity. However, dairy cooperatives have been facing numerous challenges. The challenge of nurturing the dairy industry is not just to address family-level factors. The main challenges that the dairy cooperatives have been facing include poor institutional support, poor infrastructure, weak cooperative managerial skills, lack of trust, poor quality of dairy product, dairy cattle diseases, poor facilities of milk collection centers, increased cost of inputs, and unstable supply and demand of milk and dairy products. Apart from challenges, there are opportunities to transform the dairy sector in Ethiopia. Over the last decade, there is a rapid increase in expenditures on dairy products by urban consumers in Ethiopia, especially in megacities. There is also an increasing trend in the establishment of dairy processing firms and dairy cooperatives. In 2007, there were eight dairy processing companies, and this number increased to 25 during 2017. Currently, the government of Ethiopia has been establishing industrial parks and agro-processing plants-which are central for transforming dairy sectors. The presence of dairy processing firms and the establishment of agro-processing plants are great opportunities for the advancement and transformation of the dairy sector in Ethiopia. To advance such opportunities the government and development practitioners should focus on strengthening the capacity of dairy cooperatives, and other actors through strong institutional support. To this end collaborative action of private sectors, government organizations, and other donor agencies are indispensable.

Keywords: Dairy, Dairy Cooperatives, Ethiopia, Milk Collection Centers, Transformation

Introduction

Dairy production is an important source of cash and nutrients for many households in developing countries (Zezza et al., 2016). Ethiopia holds large potential for dairy development due to its large livestock population, which comprises 59.5 million cattle, 30.70 million sheep, and 30.20 million goat populations (Getabalew et al., 2019; Misganaw et al., 2017). Ethiopia has the largest cattle population in Africa and milk production is by far dominated by small-scale landholders (Chagwiza et al., 2016). During the reference period of 2019, dairy cows are estimated to be around 7.09 million and milking cows are about 12.41 million heads (Central Statistical Agency(CSA), 2019). Despite the largest population of livestock, its productivity and commercialization remains low (Getabalew et al., 2019). The average milk yields are still low (Minten et al., 2020). In the Ethiopian highlands, the average milk yield per cow per day is 2.31 L for indigenous cows and about 10 L for improved dairy cows (Ergano, 2017). However, the CSA report depicts that the average daily milk production of 1.36 liter per cow (Central Statistical Agency(CSA), 2019) during 2019 production season. Regarding total milk production in the country, 3.134 billion liter of milk was produced in 2017. In this production season there were around 60 million cattle (Central Statistical Agency (CSA), 2017). Similarly, about 3.284 billion litter of milk was produced during 2019 production season (Central Statistical Agency(CSA), 2019).

Dairy production in Ethiopia is practiced with view of by wide socio-economic spectrum by farmers in the area ranging from subsistence production to fully commercialized agriculture as it creates full and part- time employment for households' members and the community at large (Megersa et al., 2011). Given considerable potential for smallholder income and employment generation from high-value dairy products, development of the dairy sector in Ethiopia can contribute significantly to poverty alleviation and nutrition in the country (Getabalew et al., 2019). Dairy production has significant contribution in improving food and nutritional security of households, increasing the income level of households and creating employment opportunity (Misganaw et al., 2017). The dairy sector contributes about 16.5% of the national Gross Domestic Product (GDP), 35.6% of the agricultural GDP, 15% of export earnings and 30% of agricultural employment (Getabalew et al., 2020). The production of milk has increased dramatically in recent decades, but the high production cost and low productivity leave substantial room for improvement (Ignowski et al., 2020).

In Ethiopia, there is a rapid increase in expenditures on dairy products by urban consumers (Minten et al., 2020). CSA report reveals that of the total annual milk production, 50 % was used for household consumption, 10 % was sold, only 0.56 % was used for wages in kind and the rest 39 % was used for other purposes (could be for the production of butter, Cheese, and the likes) (Central Statistical Agency (CSA), 2020). Dairy cooperatives contributed for increased production and consumption of dairy products (Bayan, 2018). For example, in Ethiopia, most of the total Cheese produced was used for household consumption that is about 57 percent (Central Statistical Agency (CSA), 2020). Cooperatives can be efficient business institutions to foster rural development and food security (Chagwiza et al., 2016).

This article provides a compiled overview of challenges and opportunities of the dairy sector in Ethiopia, particularly dairy cooperatives, and their role to transform the sector based on the evidence from the empirical literature. The qualitative and quantitative data were used from available literature. Recent literatures in the area of dairy production and dairy cooperatives were reviewed. The inclusion criteria to select the articles were originality, articles published after 2011, and articles published in peer reviewed journals. In addition, literature from the (Central Statistical Agency (CSA) Ethiopia were used to analyze the trends in the consumption of dairy products. Finally, the data were analyzed qualitatively through triangulation and narration.

Review of empirical studies

Determinants to membership of dairy cooperatives

Dairy cooperatives are believed to accelerate the dairy sector through collective resource mobilization by reducing transaction costs and facilitating market linkages. Dairy cooperatives play a significant role in ensuring sustainable supply of raw milk to the dairy industry by coordinating the flow of milk from their members and assisting them by supplying the required dairy farm inputs (Misganaw et al., 2017). Studies revealed that cooperative membership has a positive impact on milk production and productivity (Chagwiza et al., 2016; Francesconi & Ruben, 2012). Dairy production can be improved through the use of improved breeds. Dairy cooperatives are among organizations that deliver breeding services to the members and other farming communities (Rathod et al., 2014). Dairy cooperatives are expected to deliver products at lower price (Bayan, 2018).

The study conducted by Megersa et al. (2011) in Bishoftu reveals that 30% of smallholders consume dairy at home and 68% sell at the market. Among the buyers of the dairy product, 59% are cooperatives (Megersa et al., 2011). Similarly, Misganaw et al. (2017) reported that raw milk is the only dairy product regularly supplied to the local consumers by dairy cooperatives in Aksum and Adwa towns. Milk consumption in Ethiopia shows that most consumers prefer purchasing of raw milk because of its natural fl avor (high-fat content), availability and lower price (Getabalew et al., 2020).

Membership to dairy cooperatives may be influenced by different factors. For example, a study conducted in Thailand shows that education, dairy farming experience, herd size, and distance to milk collection center positively affects membership to dairy cooperatives (Jitmun et al., 2020). Farmers' milk productivity per cow is reduced, on average, by almost 1 L per day or by 26% with each additional hour of travel time (Vandercasteelen et al., 2021). A study conducted in West Shoa of Ethiopia indicates that trust is an important factor influencing the intensity of milk marketing through the cooperatives (Belay, 2020). According to the author, for improving farmers' trust, improving the competency of the management, communicating and sharing of information and democratic election of the management are critical.

In addition, three organizational characteristics may affect the inclusiveness of producer cooperatives: community- orientation versus market-orientation; open versus closed membership; who is represented in the governance of the cooperative (Bijman & Wijers, 2019). When cooperatives evolve from community- orientation towards market-orientation, they are likely to become less inclusive.

Current challenges of dairy cooperatives in Ethiopia

The challenge to foster large scale uptake of technologies and productivity growth in the dairy sector goes beyond addressing household-level factors (Ergano, 2017). Problems with structural elements such as the absence of key actors, limited capacity of existing actors, insecure property rights, cumbersome bureaucratic processes, poor interaction among actors and inadequate infrastructure have all limited dairy innovation (Kebebe et al., 2015). Feed source, housing and floor type, udder health management and insemination determine the production level of dairy cooperatives in Ethiopia (Megersa et al., 2011). Most of the smallholder farmers use family labor for managing dairy cattle. Dairy production in Ethiopia is constrained by feed shortage, disease prevalence and low milk yield of local cows (Tassew & Seifu, 2014).

Dairy farms have negative public health impact (Getabalew et al., 2020) because of the bad odor and existence of some zoonotic diseases. Diseases, unavailability of feed of adequate quantity and quality, lack of marketing facilities and technical assistance are serious concerns indicated by producers (Megersa et al., 2011). Bovine tuberculosis (BTB) and bovine brucellosis are two important milk-borne zoonoses that have been shown to be prevalent to various degrees in Ethiopian cattle. The milking cows of small-holders being members of dairy cooperatives have a low BTB and Brucellosis prevalence compared to farms in large urban areas (Tschopp et al., 2013). These diseases could be imported through purchasing upgraded animals (Holstein and their crosses) in high prevalence areas such as Addis Ababa and its dairy belt, and through the rapid increased use of artificial insemination which aims at increasing the cross-breed population in the area. The dairy cooperatives should keep the disease burden low with appropriate measures (Tschopp et al., 2013).

Inadequate know how about good hygiene practices in the processing of milk and milk products is prevailing in dairy cooperatives (Getabalew et al., 2020). Evidences reveals that milk samples collected from smallholder milk producers, dairy cooperatives, dairy cooperative union, milk processor and consumers were subjected to microbial contamination and does not meet the international milk quality standard (Haile, 2015). Dairy cooperatives also fail to satisfy their members and customers in providing adequate livestock breeding services due to lack of technical skill and inputs to deliver artificial insemination (Rathod et al., 2014). On the other hand, literacy status and dairying experience of smallholder dairy producing households contributed to keep the hygiene of the milk (Lemma et al., 2018).

The absence of milk collection centers nearby smallholder farmers is another challenge. The quality of milk will be deteriorated as the time it takes to the milk collection center increases. Practically, the milk should arrive at the processing places two hours after milking (Getabalew et al., 2020). The milk collection centers are few, not well equipped, and limited in function to collection only rather that serving as center for diary education, services and innovation. The adulteration milk by milk producers before reaching to milk collection centers is a sever challenge in most of the areas (Getabalew et al., 2019).

Moreover, there is lack of private sector inputs, such as artificial insemination technicians, community animal health workers, business development service providers, animal feed suppliers, etc. for milk value chain actors, poorly developed dairy market infrastructure for collection and distribution of milk (Getabalew et al., 2020). Lack of market, low product price and less demand for dairy products especially during fasting times are the major constraints encountered by the dairy cooperatives (Tassew & Seifu, 2014). Similarly, Lemma et al. (2018) elabortated that shortage of feed concentrate and water, milk marketing, health of dairy stock, and manure management(Lemma et al., 2018).

Furthermore, dairy cooperatives face challenges of supply and demand imbalance particularly due to socio cultural and religious aspects. For example, in non-fasting season, Demand is always above the supply (Misganaw et al., 2017). This can be resulted due to lack of milk processing equipment.

Opportunities of dairy cooperatives

Even though the dairy sector faces a number of challenges, it has future bright opportunities to be accelerator of national economy. The global as well as national demand of milk is high (Getabalew et al., 2020) and can be expected to grow because of fast growth rate of the population, high income elasticity of demand of milk and development of social values favors the development dairy sector (Megersa et al., 2011)**.** Distribution into multiple market channels to reach more consumers; institutional market segments (schools, hospitals are also valuable opportunities for the development of the dairy cooperatives (Getabalew et al., 2020).

Table 1 presents the percentage of dairy product consumption and marketing from 2012 to 2018 based on the data extract from CSA. As it is presented, it shows the decrease in the percentage of milk consumption and increase in percentage of milk marketing at producers' level. This may imply that smallholder farmers are showing the tendency to market the milk and milk products. In most of rural area, selling of row milk was perceived that culturally unacceptable and they prefer to consume at their home. This is a good opportunity for diary cooperatives to collect row milk from smallholder farmers.

Table 1: Dairy products consumption and marketing trend (CSA - 2012-2018)

Year	Dairy product consumption			Dairy product marketing		
	Milk	Butter	Cheese	Milk	Butter	Cheese
2012	46.61	61.44	83.34	4.69	34.46	12.96
2013	44.92	60.69	82.22	5.1	34.38	12.95
2014	42.27	61.11	82.33	5.64	34.71	12.72
2015	46.36	59.24	79.89	5.98	35.49	15.22
2016	42.38	56.25	79.93	6.12	38.11	14.88
2017	40.81	74.6	96.42	5.75	38.08	14.5
2018	38.97	59.43	80.07	5.84	35.4	15.35

Besides, there is also an increasing trend in the establishment of dairy processing firms and dairy cooperatives. In 2007, there were eight dairy processing companies, and this number increased to 25 during 2017 (Francesconi & Ruben, 2012). Government policy is good and encouraging for the dairy industry in the current situation. Accordingly, different agro-industries have established in different parts of the country to process row and fresh agricultural products including milk. Dairy cooperatives are the main channels to link the producers with milk processing factories. The establishment of dairy processing agro-industries will contribute its part is solving the current shortage of milk processing facilities and skills that dairy cooperatives have been facing.

Moreover, climatic and agro ecological conditions of Ethiopia is also favoring for diary production in different parts of the country (Getabalew et al., 2020). More specifically, the government identified the dairy belt including Addis Ababa and other mega cities. The population of the country is ever growing and urbanization is also expanding over time. As urbanization increases, the consumption of dairy products increases so that dairy cooperatives can access market for their products.

Conclusions

Dairy production has significant contribution in improving food and nutritional security of households, increasing the income level of households and creating employment opportunity. There is also an increasing trend in the establishment of dairy processing firms and dairy cooperatives. Despite the growing emergence of dairy cooperatives, they have been facing input, infrastructural, cultural, marketing, and institutional challenges. The existing challenges can be overcome by using the opportunities such as the growing demand on milk consumption, the growing interest of different stakeholder in supporting the dairy sector, the government emphasis, and emergence of agro-processing industrial parks in different locations of the country. Currently, the government of Ethiopia has been establishing industrial parks and agro-processing plants-which are central for transforming dairy sectors. The presence of dairy processing firms and the establishment of agro-processing plants are great opportunities for the advancement and transformation of the dairy sector in Ethiopia. To advance such opportunities the government and development practitioners should focus on strengthening the capacity of dairy cooperatives, and other actors through strong institutional support. To this end collaborative action of private sectors, government organizations, and other donor agencies are indispensable.

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Raw Milk Value Chain and Gender Role in Assela and Jimma Milk Sheds, Ethiopia

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Abstract

Having clear picture of the stakeholders and their role in a product value chain is the first step to make any progress. This study was carried out to analyze the raw milk value chain, and gender role in Adama-Assela and Jimma milk sheds, Ethiopia. From the two milk sheds, eight milk producing towns were purposively selected based on dairy production potential and the presence of various raw milk value chain actors in the area. A total of 246 milk producers were selected randomly, whereas 33 raw milk value chain actors were purposively selected based on their availability in the milk sheds. A structured questionnaire for dairy producer and checklist for key informant interview were used to collect data. The collected data were analyzed using the Statistical Package for Social Science. The results show that 90% and 94% of the respondents in Adama-Assela and Jimma milk sheds indicated that the main reason for keeping cattle was for milk production, respectively. About 54% respondents from Jimma milk shed and 20% from Adama-Asela milk shed mentioned traction power as the second most important reason for keeping cattle. The structure of the existing milk value chain revealed that there are some organized role and functions of the milk value chain in Adama-Assela milk shed whereas in Jimma milk shed there is lack of clear roles and functions of all actors that resulted in poorly organized linkage between milk producers and other stakeholder actors of the milk shed. The average daily milk production in Adama-Assela and Jimma milk shed was 8.56 and 5.87 lit/cow/day, respectively. Both men and women played an important role in milk production where barn cleaning, milking, milk processing and selling are done mostly by female, especially wives. Urban milk producers in the two milk sheds kept higher number of improved dairy breeds than peri urban milk producers. In addition, the role of gender diversification and taking the advantage to show their role for the success of the sector as both genders had contribution for sector growth and development along the chains.

Key words: Raw milk, Value chain, Gender role, milk production

Introduction

East Africa is the leading milk-producing region in Africa, representing 68 % of the continent’s milk output (Bingi and Tondel, 2015) and 43% of cow milk (FAO, 2018). Ethiopia, Kenya, and Tanzania are among the biggest dairy producers in Africa. Like the rest of sub-Saharan Africa (SSA), cow milk production is predominant in East Africa (Bingi and Tondel, 2015). The dairy sector is one of the fastest growing agricultural sub-sectors in East African countries, generating significant economic returns and employment opportunities along the value chain (Bingi and Tondel, 2015).

Livestock farming is the most important activities which has great role for large number of populations. According to CSA (2017) report, Ethiopia is home to about 60 million heads of cattle, which is the largest in the content. According to MoARD (2014) and USDA (2016) reports, the livestock sector contributes significantly to the social, cultural and economic values to the country. Despite the potential, the dairy sub-sector is performing well below expected levels. The annual increase in milk production of 1.2% lagged behind the annual human population growth estimated at 3 % (Land O'Lakes, 2010). On the other hand, the livestock sector contributes about 54.53% of the greenhouse gas (GHG) emissions in the country (Telaya et al., 2019).

Ethiopian dairy value chains are mainly based on the milk produced from cow with diverse production systems to reach the consumers through different channels (Shapiro et al., 2017). In Ethiopia, dairy value chain accounts about half million smallholder rural farmers (Mohammed et al., 2009). However, there is a poor development due to weak linkages among different actors in the dairy value chain (Yilma et al., 2011), which resulted in less overall share of milk sold in the formal market (2 %) which is far behind the neighboring countries (15 % in Kenya and 5 % in Uganda) (FAO, 2017).

Dairy production and marketing is one of the areas where both men and women are involved by providing labor for different activities (World Bank et al., 2015). Women play an important role in management of animals and products including feeding, milking, processing and marketing although not all women control the sale of milk and its products (IFAD 2007). FAO (1998) also stated that women are usually responsible for food processing and also make a major contribution to food storage, transportation and marketing but they seldom control the revenue generated. ADBG (2015) reported that, while women contribute significantly to agricultural production, their contributions are not usually decidedly recognized in different ways of documentations. Despite the fact that, women play a significant role in agricultural productivity, they suffer from unequal access to resources, services, information and capacity-building opportunities (Gebremedhin et al., 2016).

The dairy sector has a great an important economic activity in the Adama - Assela and Jimma milk sheds. A significant number of farmers (milk producer) are getting their income and daily protein requirement for their family, especially for children, from dairying. Like other milk sheds, in Adama - Assela and Jimma milk shed fresh and/or raw milk is the most common dairy product followed by others such as butter and cottage cheese. However, there is limited information available regarding the current raw milk value chain characterization in both milk sheds in a changing climate that could be used as first step to bring about the desired improvements in the sector. Hence, there is a need in understanding raw milk value chain and gender role in the dairy sector in the study area. The objective of this study was therefore to characterize the raw milk value chain and gender roles in Adama - Assela and Jimma milk sheds in Ethiopia.

Materials and Methods

Study areas

The study was conducted in Adama - Assela and Jimma milk sheds, selected from eight-milk sheds of Ethiopia, based on milk production potential, and the presence of various raw milk value chain actors who contribute to value addition of milk in the area (Brandsma *et al.*, 2013). From those milk sheds, eight potential milk producing, and major and secondary towns (Adama-Assela, Gonde, Iteya, Sagure, Jimma, Yabu, Serbo and Seka) were identified (Figure 1).

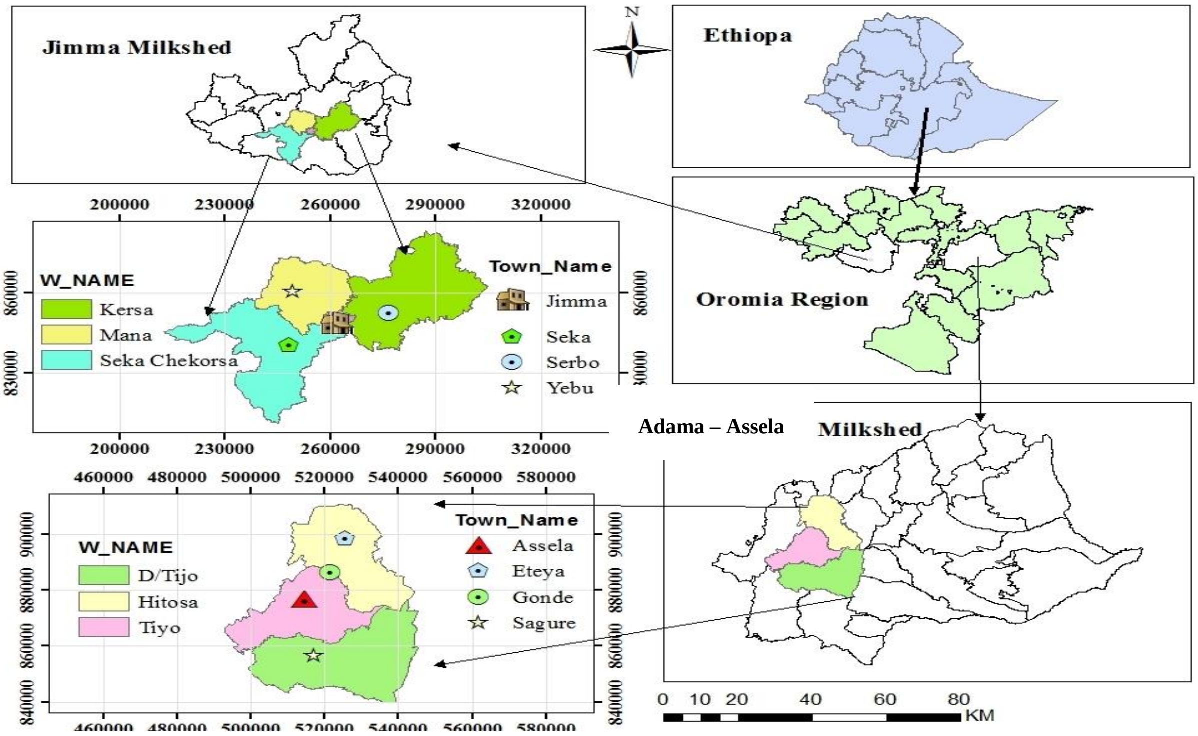


Figure 1: Map of the study areas

Sampling Techniques and sample size

The target populations include individual households involved in smallholder milk production, processing and marketing activities and other actors (milk collectors, processors and retailers) in both milk sheds. The sample size of milk producers was calculated using the formula of Yamane (1967) given as:

$$n = \frac{N}{1 + N(e^2)}$$

Where, n= sample size, N= population size and e= level of precision or error margin.

Finally, a total of 246 milk producers and 33 market actors (13 milk collectors' cooperators, 1 processing plant and 7 retailers) from Adama - Assela milk shed and 1 milk collectors' cooperative and 11 retailers from Jimma milk shed were randomly selected for formal survey.

Data collection methods

Both qualitative and quantitative primary data were collected through face to face interview using semi-structured questionnaire. Additional information was collected from key informant interviews, and personal observations. The questionnaire was used to collect data on household characteristics, purpose of keeping dairy cattle, raw milk value chain actors etc. Literature appraisal including internet, CSA reports, Zonal and district livestock and fishery offices were used for secondary data collection.

Data analysis

Data were analyzed using SPSS, version 20 software package. Statistical significance tests for qualitative parameters were made using chi-square (χ^2) tests. Mapping of the value chain was carried out to visualize, describe and show the chain structures of the major and supporting chain actors.

Actor's gross income was estimated by subtracting the cost price of the product/unit from the sale price (revenue) of that product.

$$Gross\ Income = Revenue - Variable\ Costs$$ (KIT and IIRR, 2008)

Where: income from sold milk was considered as revenue, and costs incurred for feed, hired labour, veterinary drug and breeding cost (AI/ natural bull) were well thought-out as variable cost.

Gross margins (GM) show the percentage of the actor's revenue that is gross profit per unit of produce and were calculated as follows:

$$GM = \left(\frac{Gross\ income}{Sale\ price(revenue)}\right) * 100$$ (KIT and IIRR, 2008)

Added value is the amount of value that each actor in the chain adds. It implies the difference value between the prices incurred by the actor pays to produce the product (to add value) and the price that she or he sells it for and it will be calculated as follows:

$$Added\ Value = Price\ recieved\ by\ actors - Price\ paid\ by\ actors$$ (KIT and IIRR, 2008)

Similar to gross margins, the size of the value share also reflects the number of costs and risks appear in the chain by that actor. **Value share** were estimated by using the following formula:

$$ValueShare = \left(\frac{Added\ value}{Final\ retail\ price}\right) * 100$$ (KIT and IIRR, 200

Results and Discussion

Milk production

Household characteristics - The household characteristics of the two milk sheds are shown in Table 1. The educational status of the respondents did show significant difference across the two milk sheds for primary school (grade 1-4) and preparatory levels. The Peri urban milk producers who had attended grade 1-4 education in Jimma milk shed (33%) were higher than other production systems of the two milk sheds. About 27% of the milk producers in Adama - Assela milk shed had attended either high school and/or higher education (college or university) compared to 16% in Jimma milk shed (Table 1). Urban milk producers in Jimma milk shed (91%) practiced predominantly dairy farming than their Adama-Assela milk shed counterparts. Mixed crop-livestock farming was mainly undertaken in peri urban milk producers than that of the urban, whereas dairy farming is dominant in urban milk producers.

Similarly, Sara *et al.* (2019) reported that 72.5 and 72.5% of the respondents in their study livestock keeping and mixed farming were the primary production systems practiced in both urban and peri urban farmers, respectively.

Table 1: Household characteristics of the respondents in Assela and Jimma milk sheds

Variables	Assela milkshed		Jimma milkshed		Overall	
	Urban	Peri urban	Urban	Peri urban	Assela	Jimma
Sex (%)						
Male	76.5	80.0	81.4	96.2	78.0	90.2
Female	23.5	20.0	18.6	3.8	22.0	8.9
Educational level (%)						
Illiterate	5.9	7.3	4.5	19.0	6.5	13.0
Read and write	5.9	1.8	4.5	6.3	4.1	5.7
Grade 1-4*	8.8[b]	12.7[b]	6.8[b]	32.9[a]	10.6	23.6
Grade 5-8	22.1	25.5	22.7	20.3	23.6	21.1
Grade 9-10	22.1	36.4	22.7	17.7	28.5	19.5
Other ($\geq$ grade 11)*	35.3[a]	16.4[ab]	38.6[a]	3.8[b]	26.8	16.3
Occupation (%)						
Crop and livestock keeping*	23.5[c]	70.9[b]	0.0	100[a]	44.7	64.2
Off-farm and livestock*	23.5	10.9	9.3	0.0	17.9	3.3
Only dairy cattle keeping*	35.3[b]	0.0	90.7[a]	0.0	19.5	31.7
Other activity*	17.6	18.2	0.0	0.0	17.9	0.0

a-c means with different superscripts in the same row among the two milk sheds' production systems differ significantly ($P<0.05$), * denote significant difference between the two milk sheds ($P<0.05$).

Milk production capacity - As indicated in Table 2, the average daily milk yield of cows in Adama-Assela milkshed (8.78 lit/day) was significantly higher than the average daily yield of cows in Jimma milkshed (5.21 lit/day). The difference in milk yield per cow might be associated with the management system, differences in nutritional content of feeds and feed selection and blood level of the animal that the producers hold. Additionally, the impact of proximity to different food complexes that produce agro-industrial by products as animal feed and feed processing plants like Galema feed processing that found in Arsi zone and other feed processing available near the milkshed in Debre Zeit and Kality areas have their own contributions.

The mean milk yield of 8.78 lit/day/cow in Adama-Assela and 5.21 lit/day/cow in Jimma milksheds were lower than the result of Sara (2018) and Yami et al. (2017) who reported 12.01 lit./cow in Ziway-Hawassa milkshed and 10 lit./cow in Lemu-Bilbilo district of Arsi highlands, respectively. However, the current milk yield per day per cow for both milksheds were numerically in line with the result reported in Jimma town (8.52 lit./cow) by Yitaye (2008). Similarly, the report of Belay et al. (2012) in Jimma town for cross bred, Ulfina et al. (2013) for cross bred of western Oromia, Lemma et al. (2004) for Arsi cross bred were slightly comparable with current study which reported 8.52, 6.5 and 5.8 lit /day/cow, respectively. Such difference in milk yield might be attributed to number of factors like differences in nutritional content of feeds, feed selection, breed used and other management given to the animals.

Table 2 - Milk production and proportional use in Assela and Jimma milksheds

Milk production and utilization (lit/day/HH)	Assela Milk Shed		Jimma Milk Shed		Overall mean	
	Urban	Peri urban	Urban	Peri urban	Assela	Jimma
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Milk yield per cow*	10.65±0.03^{a}	6.48±0.36^{c}	8.53±0.40^{b}	3.21±0.30^{d}	8.78±0.24	5.12±0.25
Milk produced/HH	23.90±4.27^{ab}	18.50±4.75^{bc}	36.23±5.31^{a}	7.70±3.96^{c}	21.49±3.19	17.94±3.31
Consumed at home*	1.79±0.11^{a}	1.52±0.12^{a}	1.17±0.13^{b}	b1.04±0.10^{b}	1.67±0.08	1.08±0.08
Provided for neighbor*	0.01±0.03^{c}	0.09±0.04^{bc}	0.26±0.04^{a}	0.11±0.03^{b}	0.04±0.02	0.17±0.03
Marketed	19.97±3.51^{b}	11.48±3.90^{b}	30.80±4.36^{a}	4.70±3.25^{c}	16.17±2.62	14.03±2.72
Stored for processing	1.82±1.11^{a}	4.86±1.23^{a}	1.10±1.38^{b}	1.80±1.03^{b}	3.18±0.83	1.55±0.86
Lost	0.06±0.03^{b}	0.03±0.03^{b}	0.21±0.03^{a}	0.02±0.03^{b}	0.05±0.02	0.09±0.02
Other purpose	0.40±0.39^{b}	0.56±0.43^{b}	2.61±0.48^{a}	0.11±0.36^{b}	0.47±0.29	1.01±0.30

a-d means with different superscripts in the same row among the two milksheds' production systems differ significantly (P<0.05), * denote significant difference between the two milksheds (P<0.05)., HH= household SE= standard error

Milk value chains of Adama - Assela and Jimma milk sheds

As other agricultural products, milk and milk products pass through different marketing agents before reaching the end users (consumer). To develop sustainable dairy value chain through efficient use of the available scarce resources, assessing the main value chain actors with their functions involved in the entire value chain is necessary. The milk value chain consists of many main actors that can generally be categorized into different sub-categories like input providers, direct actors (producers, processors and traders including collectors, wholesalers, retailers and Cafe/Hotel owners) and supporting actors. Based on their structure and roles, the key milk value chain actors and their relationship in Adama - Assela and Jimma milk sheds were illustrated below using value chain mapping (Figures 2 and 3).

Primary Actors - The primary actors of milk value chain identified in Adama - Assela and Jimma milk sheds were input providers (semen (AI), feeds (crop residues, concentrates and industrial by products), forage seeds, veterinary drugs and / or other services etc.), milk producers (urban and peri urban), milk processors (Bokoji milk processing, dairy cooperatives and on farm milk processors), milk market intermediaries (cooperatives, Small and Medium Enterprises (SMEs), kiosks, milk bars, restaurant, hotel, coffee shop etc.) and consumers (urban, peri urban and institutional consumers). This result is in agreement with that of Yami et al. (2017), who also identified six distinct core functions from the inception of milk production through reaching to the final consumer including input supply, production, gathering (bulking), processing, transportation and retail trading at the dairy value chain in Lemu-Bilbilo district of Arsi zone.

Input suppliers - Feed, improved forage seeds, crossbreed cows, semen, veterinary drugs and/or services, milk containers/cans, water, land, labor, housing and training were the major inputs for the dairy producers in both milk sheds. These are categorized in to two categories, namely: purchased and non-purchased inputs. The main purchased inputs included: supplementary feeds (like concentrate, industrial by-products, local brewery by products), improved dairy cows, semen, veterinary drugs and milk containers/cans. Whereas, the non–purchased inputs include family labor, and on farm produced forage grass and hay. However, the crop residues are categorized as both of purchased (for urban milk producers) and non-purchased (for the majority of peri urban milk producers) inputs in the milk shed.

The respondents obtain their crossbred cows through different sources (via buying crossbred heifer, and crossbreeding their local cows by using AI and/or breeding bull). In Adama - Assela milk shed, milk producers obtained their crossbred cows through purchase and/or using AI services provided either by the government, private and/or Community Artificial Insemination Technicians (CAIT). There are also milk producers who obtained their crossbred cows through AI only; hence, there was an opportunity of access to AI services not only from the government but also from non-governmental institutions (FAO) through training CAIT for the area (Table 3). Yami *et al*. (2017) also reported the appreciation of dairy producers for the efforts of FAO in the provision of in kind credit through distribution of improved heifers to selected milk producers. However, in Jimma milk shed milk producers acquired their obtained improved dairy cows mainly through buying from neighbors and/or using government AI, Jimma University and private inseminator (Table 3).

There was a variation in obtaining improved dairy cows and source of semen between the two milk sheds. In Adama - Assela milk shed, the government and CAIT were the main sources of semen supplying actors; whereas, in Jimma milk shed milk producers access improved semen from government, Jimma University and private semen provider.

Table 3: Source of improved dairy cow and AI service in Assela and Jimma milk sheds

Input supplies and services	Assela Milk Shed			Jimma Milk Shed		
	Urban	Peri urban	Overall	Urban	Peri urban	Overall
Source of improved breed (%)						
Buying	13.7	24.4	19.5	35.3	10.6	22.9
Crossing by improved bull	0	1.8	0.8	3.8	26.1	14.8
Crossing by using AI	86.3	72.6	79.4	60.9	63.2	61.5
Source of semen (AI services) (%)						
CAIT	1.5	7.2	4.3	0	0	0
Government	94.1	90.9	92.5	91.8	100	95.9
Private traders	0	0	0	7.3	0	3.6
Others	4.4	1.8	3.1	0	0	0

Similarly, milk producers purchased feeds such as concentrate and industrial by-products from different sources. In Adama - Assela milk shed, the presence of different flour mills (Food complex) and proximity to Addis Ababa (with many agro-industries and feed processing plants) serve as a source of concentrate feed.

On the contrary, in Jimma milk shed there was shortage of concentrate feed providers and there were only private traders who source concentrates from Kality and Bishoftu for retailing in the locality. Members of the dairy cooperative in Jimma town obtained concentrate feeds from their cooperative with fair price. In general, respondent milk producers reported the cost of concentrate feed as a serious problem; especially, in Jimma milk shed not only the cost but also the availability of concentrate feed is a serious problem. This finding agrees with that of Yami *et al*. (2017) who also observed that an increase in the cost of concentrate feed from year to year was unaffordable by milk producers. Producers

Dairy Cooperatives

In addition to urban and peri urban milk producers, dairy cooperatives may serve as the main secondary and tertiary link in the milk value chain of the study areas as they are engaged in milk production, collection, semi-processing and distributions of dairy products. However, due to different factors the number, potential and function of dairy cooperatives were different in the two milk sheds.

In Adama - Assela milk shed, the peri urban milk producers (62%) were significantly higher than urban milk producers (25%). However, in Jimma milk shed only a very few (7%) of urban milk producers were a member of dairy cooperatives. Because of this, milk producers of Adama - Assela milk shed (42%) had significantly better membership option than Jimma milk shed (Table 4). The difference in membership of dairy cooperative between the two milk sheds might be due to access to cooperative, supporting organizations to form a cooperative and willingness of the cooperative to encourage non-member milk producers to join them as a member and the milk producer himself. In Jimma milk shed, there is only one functioning dairy cooperative. However, in Ethiopia, previous studies on dairy development (Holloway *et al.,* 2000; Ahmed *et al.,* 2003) reported that farmers' participation in dairy cooperatives resulted in a significant increase in the volume of milk production and market supply due to improved productivity.

Table 4: Members of the milk production and collection cooperative in percentage

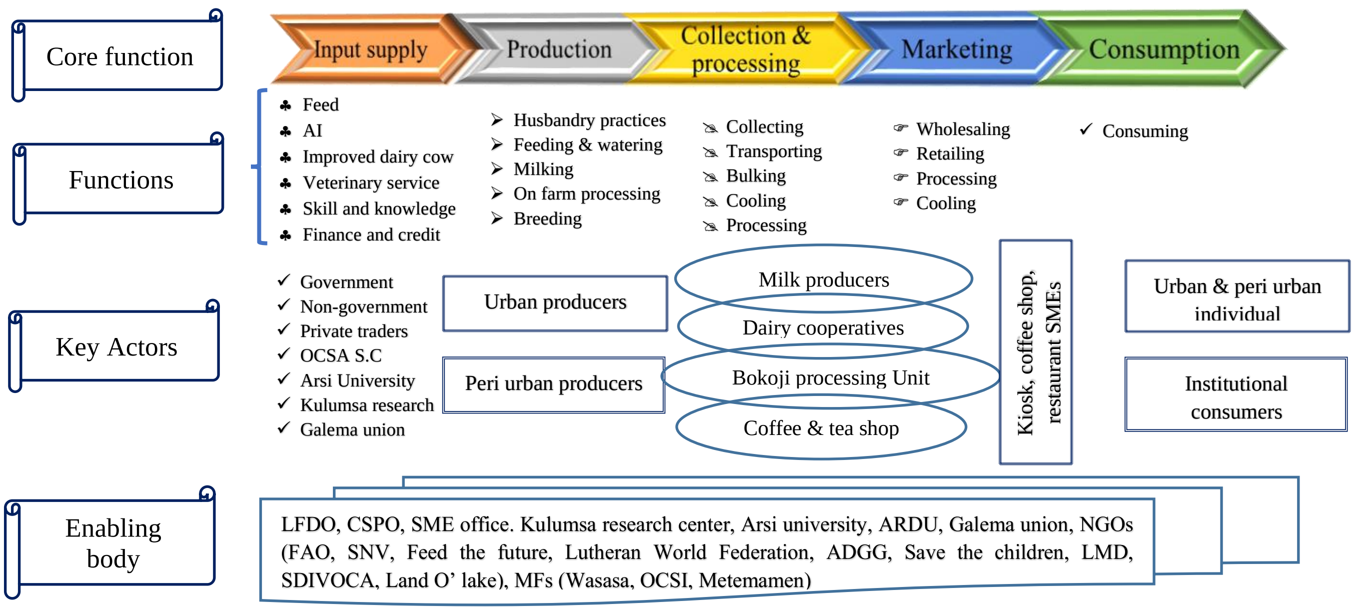
Membership of a cooperative	Adama - Assela milk shed		Jimma milk shed		Overall	
	Urban	Peri urban	Urban	Peri urban	Adama - Assela	Jimma
Yes	25.0	61.8	7.0	0.0	41.5	2.5
No	75.0	38.2	90.7	96.1	58.5	93.3
Chi-square value	16.982*		5.354*		51.151*	

* Along the raw the Chi-square statistic is significant at the 0.05 level

In Adama - Assela milk shed, dairy cooperatives are engaged mainly in bulking raw milk from members and non-members, processing and marketing of processed dairy products. The milk is received at the cooperative milk collection center. However, the dairy cooperative's dairy products were limited mainly to butter, skimmed milk and cottage cheese only (Yami *et al*., 2017). In Jimma milk shed, dairy cooperatives are involved in bulking raw milk from their members only at its collection center in Jimma town and distributes only raw milk to hotel, café and individual consumers in the area. However, making of other milk products (butter and cheese) were rarely practiced and limited to only at the time when milk supply is greater than demand especially during the main fasting time before Christmas and Easter. Bardhan et al., (2012) reported that organizing producers into cooperatives have enhanced their bargaining power and fostered viable linkages among different chain actors for their mutual benefits.

Collectors

Collectors are those actors (cooperatives, licensed individual traders, private collectors/ itinerant traders without license and / or MSEs) engaged in collecting marketable surplus of milk from milk producers and resell to the nearby milk market center, milk processors, retailers and consumers. Figure 2 shows the map of Adama - Assela milk shed value chains. In Adama - Assela milk shed milk producers have an opportunity of suppling the produced milk to different collection centers either of cooperatives, SMEs or individual collector. Especially, milk producers in Sagure town and its area have a chance to deliver raw milk to milk collection centers of the cooperatives that in turn supply to the Bokoji milk processing unit. In this area, there are many cooperatives (Xijo milk, Alaltu, Busha Goba lencha, Ashabaka, Digalu etc.) which are actively participating in raw milk collection. From these actively participating cooperatives, Aleltu and Ashabaqa served as the suppliers to Bokoji milk processing unit with an average supply of 260 liters per day. Like Sagure town a number of milk collection cooperatives were available in Iteya and Gonde areas of Adama - Assela milk shed including Huruta, Ititu milk, Burqa and Elemtu milk cooperative in Iteya and its surrounding and Bilalo, Qonicha, Gara Chilalo, Gora farad, Burqa qacham, Gonde mokro, Dosha and Urji milk collection cooperative in Gonde village and its surrounding. As identified from key informant interview, these labeled cooperatives were most actively participating in milk collection and processing which were established with the support of FAO but they ceased the activities except few of them when FAO stopped its support.



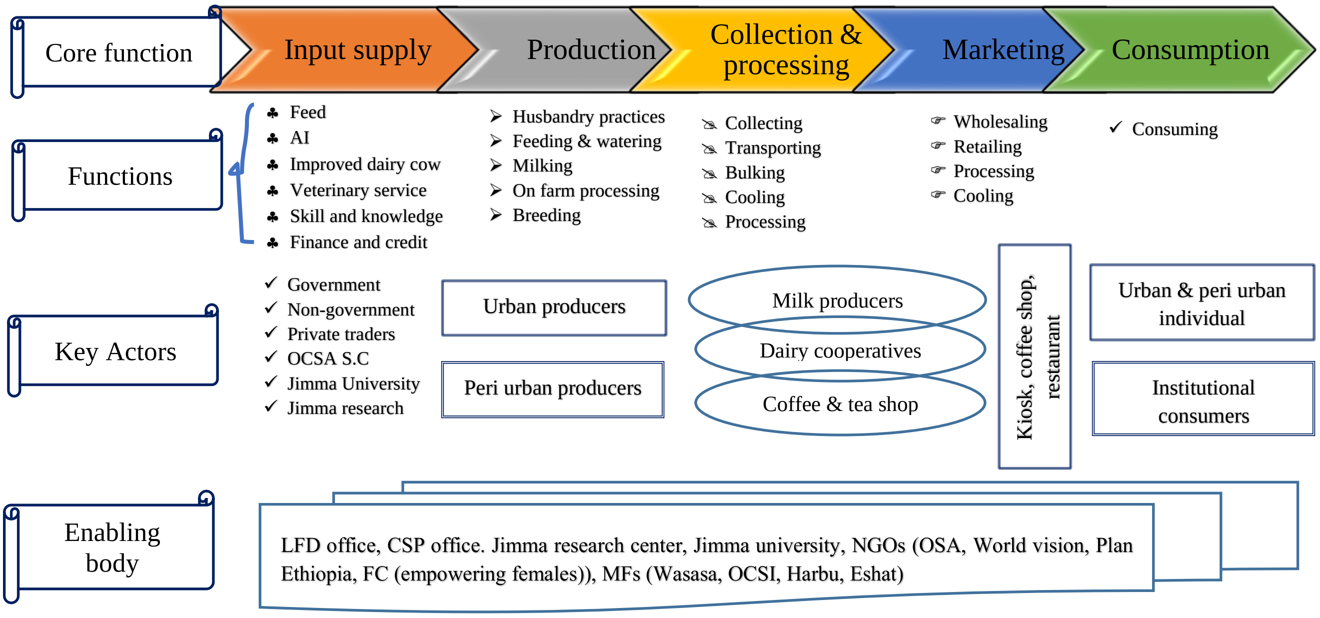
LFDO=Livestock and fishery office; CSPO= Cooperatives Society Promotion office; SME=Small and medium enterprise; ARDU= Arsi Rural Development Unit, ADGG=Africa dairy genetic gain; MF=Micro finances OCSI= Oromia Credit and Saving Institution

Figure 2: Value chain map of Adama - Assela milk shed

Figure 3 shows the map of the Jimma milk shed value chains. In Jimma milk shed there is a problem of milk collection except the milk collection centers of Jimma town dairy cooperative. Though, milk producers of Jimma milk shed sell their milk either directly to individual consumer or through own kiosks at morning and evening; there are also few milk producers who sell milk in their own hotel. Generally, compared to Adama – Assela, milk marketing system in Jimma milk shed was characterized by in efficient and fragmented type of market.

Wholesalers

Cooperatives, union and licensed private collectors/traders, after collecting milk from milk producers, bulked the milk and sold it either to processors, hotels, café and other actors. They were, thus, considered as wholesalers; hence, they are actors, who purchase large volume of milk directly from producers or through local milk collectors and finally resell it mainly to milk retailing shop/kiosks and very rarely to milk processing enterprises and consumers. Such types of wholesalers were available in Adama - Assela milk shed which include different scale of dairy cooperatives and SMEs in Adama - Assela town. However, in Jimma milk shed there is only one cooperative exists and act as a wholesaler by collecting raw milk from its members to process and / or re-sale it to retailers (Coffee/tea marketers, hotels and other actors).



LFDO=Livestock and fishery office; CSPO= Cooperatives Society Promotion office, MF=Micro finances OCSI= Oromia Credit and Saving Institution

Figure 3: Value chain map of Jimma milk shed

Processors

Milk is processed into milk products such as butter, cottage cheese, ghee and skimmed milk. It has been practiced at different levels of the value chain such as on farm, cooperative and private processing plants with traditional, small scale and large scale modern plants. At on farm level of the two milk sheds, processing was mainly practiced in a traditional system. However, at cooperative level, milk was processed using different levels of manual and modern processing technologies including manual and / or electrical cream separator.

In Adama - Assela milk shed, cooperatives were involved in processing activities using manual churners, electrical cream separator, except those collection centers, which are delivering the collected raw milk to Bokoji milk processing. Similarly, the Bokoji milk processing unit located in Bokoji town was installed with the potential of processing 60,000 lit/day, have an opportunity for milk producers of the area when it is with its full potential but currently process much under its capacity (700 lit/day) (Figure 4). However, in Jimma milk shed the majority of milk produced was sold in the form of liquid whole milk unless it was processed in traditional way at household level except the members of Jimma dairy cooperative. In general, the unavailability of small and modern milk processing plants in the Jimma milk shed is the major problem of the area, especially when the demand for raw milk is lower than its supply; and the problem is severe with urban producers of Jimma milk shed during orthodox Christians fasting.

Figure 4: Processed milk products at Adama - Assela milk shed

Retailers

Retailers are part of the value chain who sells milk and milk products to consumers. In both of the milk sheds, cafeterias, hotels, bars, restaurants, individual and cooperatives kiosks/shop were recognized as retailers. Most of the time, they buy milk from milk collectors, processors or directly from producers and sell mostly to urban consumers. In Adama - Assela milk shed, there are more licensed retailers either organized as cooperative or organized as SMEs by government. In addition to those, there are also some illegal retailers who re-sale their own produced milk under small shop/kiosk around their vicinity. In Jimma milk shed, the retailing activities of milk are not well developed like that of Adama - Assela milk shed. The fact that, the produced milk of Jimma milk shed was distributed either by the producer him/herself at farm gate or through own kiosks, hotel, restaurant and cafeteria. In general, these actors are acting as the end intermediary connectors of consumers with other intermediaries when the marketing chain goes via retailers. Previous studies (Brandsma et al., 2013; Sara, 2018) who studied the different chain aspects in milk sheds indicated that retailers are considered as one of the chain actors participating in milk marketing chains.

Consumers

In this context, consumers are those actors who consumed milk directly by the family members of the producers and other urban and peri urban consumers that buy the products through formal or informal marketing systems. In Adama - Assela milk shed, actors that are acting as milk marketing was the source of milk for consumers; while in Jimma milk shed the majority of consumers get raw milk directly from milk producers and kiosks found in Jimma town.

Furthermore, the discussion with key informant and field visit observation found that the consumers mainly complained about the poor quality of milk supplied by producers, which was perceived either adulterated or non-fresh milk. On the other hand, milk producers strongly complained consumers and cafes/hotel owners for their low milk demand and prices during fasting time. This finding corroborates with that of Yami et al., (2017) who identified the contradicting blaming of producers, collectors, wholesalers/retailers and consumers on one another.

Supporting actors

Supporting actors are those actors that provide support services of training, extension, information, financial, research and development services, etc. Access to support services like information, technology and finance determines the success of value chain actors (Martin et al., 2007). Office of Agriculture, Livestock and Fishery development office, Office of Cooperatives Society Promotion, Micro Finance, Research Centers, NGO and Universities were the main supporting actors identified in the two milk shed.

Access to extension services is the most important factor that promotes agricultural production and productivities thereby increasing marketable surplus and ultimately income. Regardless of the milk sheds, huge and extensive investment in promoting extension services, the results of study results revealed that only 46% of the respondent in Adama - Assela milk shed received extension services on milk production with large variability among the sample production system. In contrary, the majority of milk producers (84%) in Jimma milk shed had access to extension services (Table 4). In both milk sheds, government (38 and 76% in Adama - Assela and Jimma milk shed, respectively) play an important role by providing extension services. The variations in access to extension services might be due to availability, perceptions of milk producers and willingness of milk producers.

Marketing Margin

As indicated in Table 5, peri urban milk producers in Jimma milk shed significantly supply lower volume of milk (4.7 lit/day) to the market; however, urban milk producers of Jimma milk shed also considerably supply high volume of milk (30.8 lit/day) than urban and peri urban milk producers of Adama - Assela milk shed. Even though the cost of production (variable cost per cow per year) for urban milk producers of Jimma milk shed was significantly higher, they collected considerably higher gross revenue (daily total sale). In general, the urban milk producers incurred high cost of production than peri urban to supply significant amount of milk to the market. The higher marketable surplus of milk in the urban areas indicates that dairy businesses tended to be more market-oriented due to higher demand for milk.

Table 5: Service provisions of Adama - Assela and Jimma milk sheds

Services	Adama - Assela (%)			Jimma (%)		
	Urban	Peri urban	Overall	Urban	Peri urban	Overall
Access to extension services	33.8	60.0	45.5	79.1	88.2	84.2
Extension service providers						
Government	23.5	49.1	35.0	76.7	76.3	75.8
Non-government organizations	0.0	9.1	4.1	0.0	0.0	0.0
GOV and Private trader's/service providers	10.3	1.8	6.5	0.0	0.0	0.0
GOV, NGO, Coop/union & Private traders	0.0	0.0	0.0	0.0	9.2	5.8
Access to saving and credit	45.6	50.9	48.0	72.1	63.2	65.8
Taking credit services	1.5	3.6	2.4	23.3	15.8	18.3
Availability of veterinary services	80.9	96.4	87.8	93.0	84.2	86.7

Higher total variable cost of production (22,956 EBR/cow/year) than Jimma (16,048 EBR/cow/year), the cost of milk was considerably cheap at Adama - Assela milk shed than Jimma (Table 6). The variation in average selling price and the potential of milk production between the two milk sheds was due to the presence of supporters and different enabling environments such as FAO in Adama - Assela milk shed. The availability of supporting institutions followed by better access to infrastructures (proximity to different in puts) and management activities enabled Adama - Assela milk shed to supply significant amount of milk (2,134 litre per year) with average lactation length of 244 days) that buffer milk supply shortage and make the selling cost of milk lower than that of Jimma milk shed. The average milk yield 2,134 and 1,289 lit/year for Adama - Assela and Jimma milk sheds, respectively was within the lower range of 9,260 and 5,504 lit/year for urban and peri urban dairy farmer in Ziway-Hawassa milk shed (Sara *et al*., 2019). The authors further reported that urban dairy farmers supplied large volume of milk per day to the market (39.2 lit) with the selling price of 18.2 birr/lit than peri urban dairy farmers (20.5 lit/day) with milk prices of 17.7 birr/lit.

Table 6: Total cost of production in urban and peri-urban production of the two milk sheds

Descriptions	Assela milk shed		Jimma milk shed		Milk shed	
	Urban	Peri urban	Urban	Peri urban	Adama - Assela	Jimma
Average marketable milk (lit/day)	19.97[ab]	11.48[bc]	30.80[a]	4.70[c]	16.17	14.03
Average selling price (ETB/lit)*	16.66[c]	14.02[c]	26.11[a]	21.81[b]	15.48	23.35
Daily total sale (ETB)	348.07[b]	209.61[b]	822.48[a]	96.47[b]	286.16	356.18
Milk yield lit/cow/year*	2558.65[a]	1609.08[c]	2103.75[b]	835.56[d]	2134.04	1289.22
Total variable cost ETB/cow/year*	26621.54[ab]	18424.02[b]	31152.20[a]	7635.68[c]	22955.98	16048.10
Total cost of production ETB/lit.	11.18	13.71	13.33	8.53	12.31	10.25

a-d means with different letters of superscripts in the same row among the two milk sheds' production systems differ significantly (P<0.05), * denote significant difference between the two milk sheds (P<0.05).

With regard to milk marketing chains, in Adama - Assela milk shed milk producers, collectors, processors and retailers were identified, whereas in Jimma milk shed there was no any active processor that contributes as a value chain actor and the rest of three actors involved in the milk value chain of the milk shed. In both Adama - Assela and Jimma milk sheds, collectors also act as wholesalers and there were no actors that participate solely as a wholesaler.

As indicated in Table 7, in Adama - Assela and Jimma milk sheds the producer's value share for milk was higher than the other actors. However, retailers in Adama - Assela milk shed had significantly higher gross margin (36.07%) than milk producers in Jimma milk shed (20.48%). As a result of this, retailers had a significant value share (36.22%) and a better gross margin (36.07%) than milk producers in Adama - Assela milk shed, whereas milk producers had 57.33% value share and 20.48% of gross margin. However, in Jimma milk shed milk producers had significantly reasonable share of value in gross margin (56.94%) and value share percentage (76.83%) than other actors. The distribution of value share and marketing share for collector and processor in the Adama - Assela milk shed were slightly similar because cooperatives were participated as this type of actor in the area and also the availability of those actors might be responsible for the lower price of milk selling price in milk shed than Jimma as already shown in Table 5. The value share of 75% for milk producers reported by Godadaw (2018) is in line with that of Jimma milk shed, while it is higher than that of Adama - Assela. The variation observed could be attributed to the cost of production and price of milk. Although milk producers of Adama - Assela milk shed incurred significantly

Table 7: Gross margin and value shares of milk value chain actors in the study areas

	Actors	Production cost	Marketing cost	Revenue	Gross income	Added value	Gross margin (%)	Value share (%)
Adama / Assela	Producers	12.31		15.48	3.17	15.48	20.48	57.33
	Collectors		15.67	16.17	0.5	0.69	3.09	2.56
	Processors		16.71	17.13	0.7	0.54	4.04	2.0
	Retailers		17.26	27	9.74	9.87	36.07	36.22
Jimma	Producers	10.42		24.20	13.78	24.20	56.94	76.83
	Collectors		24.615	30.22	5.605	6.02	18.55	19.11
	Retailers		25.22	31.5	6.28	1.28	19.94	4.06

Gender role and milk production in Adama - Assela and Jimma milk shed

The participation of gender in dairying husbandry activities such as cleaning the barn, milking, feeding dairy animals, feed collection, caring dairy cows and calves, processing, milk transportation and milk selling were the most common dairy farming activities. As illustrated in Table 16 and 17 for Adama - Assela and Jimma milk shed, the participations of gender in different milk production and marketing activities are discussed as follow:

Gender role in cleaning of dairy bran

Regarding participation of gender in barn cleaning, all members of the family at both milk sheds were participating in cleaning dairy barn, but there was difference in degree of participation among the family members. In both urban and peri urban milk producers, barn cleaning was shared among the family members and mostly performed by wives (Tables 8 and 9 for Assela and Jimma milk sheds respectively). In comparison, the female family members were mainly responsible for barn cleaning than male family members.

Table 8: Gender division of labor for dairy farming activities in Adama - Assela milk shed

play	Urban				Peri urban			
	Husband	Wife	Son	Daughter	Husband	Wife	Son	Daughter
Barn cleaning	48.3	70.6	50	41.2	52.7	67.3	52.7	43.6
Milking	22.01	80.9	5.9	27.9	20	81.8	3.6	29.1
Feeding	61.7	47.1	50	41.2	70.9	43.6	61.8	40
Feed collection	85.3	19.1	35.3	4.4	89.1	18.2	41.8	5.5
Keeping/shepherding	14.7	16.2	36.8	19.1	10.9	10.9	45.5	23.6
Treating sick animal	83.8	39.7	4.4	1.5	83	36.4	5.5	1.8
Processing	2.9	60.3	0	16.2	3.6	63.6	0	23.6
Transporting	35.3	26.5	44.1	35.3	34.5	29.1	61.8	34.5
Selling	44.1	66.2	16.2	4.4	56.4	56.4	12.7	9.1

Generally, in both Adama - Assela and Jimma milk sheds, female family members contributed more in cleaning dairy barn than their counter male family members and this finding is supported by the report of Benyam (2016) and Asfaw (2009) which indicated higher proportion of women participated in cleaning of dairy sheds. Generally, wives contributed more than husbands in urban dairy farming activities, while the reverse was true for peri urban dairy farmers where husbands contributed slightly more than wives.

Gender role for milk activities

In Adama - Assela milk shed, wives were predominantly undertaking milking (70.6%) in urban and peri urban (68.3%) milk producers followed by daughters, whereas male family members had lower participation in milking. In Jimma milk shed, wives took the greatest share of milking activity in both urban and peri urban milk producers (70% in urban and 76% in peri urban, respectively). Moreover, in both milk sheds, milking was largely accomplished by wives followed by daughters except at urban milk producers of Jimma milk shed where daughters contributed less to milking. This variation in participation in milking among the family members might be attributed to the awareness, level of production and cultural taboo. Similarly, Beyene (2016) and Fikremariam (2016) also reported in different areas of the country. In contrary to this study, in rural dairy production in Fogera and Bure districts, milking was mostly the responsibilities of adult males followed by women (Belete *et al*., 2010).

Gender role in feed collection and feeding dairy animals

In Adama - Assela milk shed, feeding dairy cow was the responsibility of all family members in both urban and peri urban milk producers. However, feed collection is predominantly undertaken by the household head at both milk production systems followed by boys. This result revealed that at Adama - Assela milk shed feed collection for dairy cows was the responsibilities of male family members, especially the household head (husband).

In Jimma milk shed, a similar trend was observed regarding feeding dairy cow, except the participation of daughters was slightly lower. Correspondingly, feed collection for dairy cow in Jimma milk shed was the duty of male family members; especially the husband and the contribution of daughters was insignificant. Generally, at both Adama - Assela and Jimma milk sheds collecting feed for dairy animals was largely accomplished by male family members, while feeding the animals was the responsibility of all the family members with some disparity in level of contribution. Fikremariam (2016) also reported that feed collection was the main responsibilities of male in both production systems in Dugda district of East Shoa.

Gender role in milk marketing

In Adama - Assela milk shed, wives were more participating in milk marketing than other family members, followed by husbands. To generate revenue, raw milk was transported to different collection centers. In peri urban milk producers of Adama - Assela milk shed, boys are more responsible for transporting raw milk to the collection centers than other family members. In line with our result, FAO (2017) reported that even though women, men and children play a great role in delivering milk to collection points, the greater role was undertaken by men and boys due to the time of collection and remoteness of the collection sites.

However, in Jimma milk shed the majority of respondent milk producers indicated that wives were highly responsibility for raw milk marketing than other family members. Likewise, raw milk transportation was also undertaken by all family members without much variation in labour division.

In contrary to this finding, Zemeda (2015) reported that in relation to gender participation in collection, transportation and selling of milk, males were dominating with 55% over females.

Table *9*: Gender division of labour for dairying activities in Jimma milk shed

Activities	Urban				Peri urban			
	Husband	Wife	Son	Daughter	Husband	Wife	Son	Daughter
Barn cleaning	11.6	72.1	37.2	46.5	15.8	65.8	22.4	60.5
Milking	13.9	69.8	13.9	9.3	15.8	76.3	3.9	21.1
Feeding	65.1	67.4	58.1	41.9	85.5	60.5	48.7	22.4
Feed collection	72.1	30.2	55.8	4.7	90.8	11.8	40.8	3.9
Keeping/shepherding	16.3	25.6	48.8	4.7	34.2	25	43.4	10.5
Treating sick animal	74.4	32.6	11.6	4.7	84.2	25	3.9	0
Processing	2.3	62.8	2.3	27.9	7.9	82.9	2.6	38.2
Transporting	20.9	44.2	51.2	27.9	21.1	43.4	42.1	46.1
Selling	23.3	74.4	16.3	32.6	18.4	76.3	3.9	14.5

Conclusion and Recommendations

The result of this study indicated that milk producers of the two milk sheds kept dairy cattle mainly for milk production. The two milk sheds involved slightly different chain actors and supporters. The main actors involved were input suppliers, producers, collectors, processors, retailers, and consumers. The availability of different cooperatives to collect raw milk was identified at Adama - Assela milk shed. Only one cooperative actively participated in collecting milk from its members at Jimma milk shed and poor development of milk value chain was observed at Jimma milk shed as compared to Adama - Assela. The average daily milk production in Adama-Assela and Jimma milk shed was 8.56 and 5.87 lit/cow/day, respectively. The selling price of milk was higher for milk producers of Jimma milk shed. Regarding gross margin, milk producers of Jimma milk shed obtained greater percentages (57%) than other actors, while 20% for Adama - Assela milk shed was by far lower than Jimma milk shed, and the retailers (36%) of Adama - Assela milk shed. The contribution of gender to milk production was significant. Female family members, especially wives, were mainly involved on activities directly correlated with climate smartness. So they are recognized as essential change agents for climate change mitigation.

Based on the results of this study, the following recommendations are proposed:

- Since the value chain approach is essential to figure out the short comings of different actors, there should be a strategy to alleviate these challenges and using the beefed opportunity available in the sector.
- Place strategies that may include experience sharing between different milk sheds and focus on the profit in the benefit of the climate change to insure the resilience of the sector in a changing climate.

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Parallel Session III

Breeding and Genetics

Synthetic Dairy Cattle Breed Formation in Ethiopia: Lessons and Way Forward

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Abstract

Globally there are about 1.5 billion cattle and 1000 internationally recognized breeds (FAO, 2020). The recent cattle population of Ethiopia is on the other hand 70 million (CSA, 2021) where there are more than 32 breeds. Even though the cattle population in Ethiopia is about 5% of the world's cattle population, their milk productivity is very poor; according to CSA (2021), the milk production of indigenous milking cow was about 1.48 L/day and the lactation length was about seven months. The productivity of crossbreds/synthetic breed dairy cows is, however, 3 to 5 folds of the indigenous ones. The proportion of exotic and/or hybrid cattle population in Ethiopia is however, less than 3%. High population growth, per capita increment of income and urbanization in Ethiopia are potential drivers of milk production improvements; the low milk supply had significant contribution general poor health, stunted growth in children and less analytical ability. In order to ensure improved milk production in Ethiopia, it is important to evaluate available initiatives. Hence, the objectives of this paper were to present technical considerations while implementing synthetic breed formation in Ethiopia and discuss options for synthetic breed formation to improve milk production in Ethiopia. The progresses of crossbreeding and synthetic breed formation were evaluated against worldwide available experiences. In addition, alternative milk productivity improvement scenarios were presented. We conclude that existing national milk production improvement initiatives shall be geared towards synthetic breed formation where tailor made national implementation protocol is needed. We also discussed the merits of importing tropically adapted dairy cattle breeds.

Keywords: Dairy cattle; Level of exotic gene inheritance; Milk; Tropically adapted breed

Introduction

Currently, the global cattle population is estimated to be about 1.5 billion (FAO, 2020). From these, there are more than 1000 internationally recognized breeds. However, their productivity is considerably variable; for example, the breeds on which selection was being conducted for long years had the highest milk production records (the black and white Holstein Friesians produces up to 8735 kg of milk within one lactation period and the red and white Holstein Friesians produce up to 7944 kg of milk within one lactation period (https://veepro.nl/about-us/)); contrary to this, our indigenous cows produce about 300 kg of milk with in one lactation lengths (CSA, 2020). Consequently, the per capita milk consumption in Ethiopia remained low (not more than 40 L). The recent cattle population of Ethiopia was estimated to be about 65 million where 98.2% were indigenous and the remaining were hybrid and exotic breeds that accounted for about 1.62% and 0.18%, respectively (CSA, 2020).

The world health organization recommends 200 L of milk per capita consumption. Ethiopia is far behind this recommendation (taking the current scenario into consideration, at least 150 L of additional milk would have been consumed by Ethiopians). The divergent gap was mainly attributed to the supply shortage of milk in the country.

According to CSA (2020), including milk produced from all types of milk producing animals, about 7 billion L of milk was produced in Ethiopia. On the other hand, taking the human population of the country (at least 110 million) and the WHO recommendation, the country is in the deficit of about 15 billion L of milk annually which can not be fulfilled in the usual way. Hence, increasing the number of high milk-producing cows is required in Ethiopia. In order to increase the number of high milk-producing cows, it is important to consider either crossbreeding or synthetic breed development. For instance, the high per capita milk consumption of Kenya compared to Ethiopia is attributed to the number of high milk producing cows in the country (five million). Compared to the crossbreeding, synthetic breed development is very reliable even though its technical matters are somehow difficult.

Many breeds of animals were formed through synthetic breed development approaches; an article showed that mor than 418 sheep breeds and more than eighty goat breeds were developed through synthetic breed formation in the world (Rasali et al., 2006). Among the cattle breed developed through such methodology Sunandini of India was one. In Ethiopia, the formation of synthetic breed development was started at Holeta agricultural research center before about a decade. The progresses were, however, not satisfactory. Therefore, the present paper was designed with the following objectives:

- To agree on the level of exotic inheritance in the synthetic breed to be formed in Ethiopia
- To present some technical considerations while implementing synthetic breed formation in Ethiopia
- To consider options for synthetic breed formation to improve milk production in Ethiopia

Layout of presenting the results

In this paper, the concept of synthetic breed development, experiences of developing new breeds through synthetic breed formation, alternative scenarios for synthetic breed formation involving different levels of exotic gene inheritance and the alternative way of importing tropically adapted with high milk productive are discussed. Finally, the way forward regarding the synthetic dairy cattle formation in Ethiopia was suggested.

How to choose a breeding program?

There are different means of livestock genetic improvement: within breed selection, between breed selection, crossbreeding and synthetic breed formation. Synthetic breed formation is a special form of crossbreeding. Hence, in order to choose from within breed selection and crossbreeding, the magnitude of the heritability of the traits of interest is an indicator. When the magnitude of the heritability of a trait of interest is considerably high, it means that trait could be improved through selection of superior parents from the within that breed. On the other hand, if the heritability of the trait of interest is considerably low, that trait could be improved through crossbreeding. Before implementing crossbreeding scheme, it would be good idea to check whether the crossbreeding action could improve the trait of interest by greater than 30% of the performance of that trait under the pure breed. The detail methodology of choosing a breeding program while implementing the livestock genetic improvement program is detailed in FAO (2012).

The concept of synthetic breed development

Terms including synthetic breed, composite breed and hybrid are synonymously used. Composite breed has often been used to mean those formed by combining existing breeds (Hammack, 2009). Synthetics or composites are 'new' breeds generated from mixing a number of parental breeds

(Kinghorn et al., 2000). Synthetic breeds are populations formed by crossing two or more existing breeds in specific percentages, followed by intermating of the crosses to maintain the percentages as with formulas. However, a specific intent in creating composites is to maintain the maximum possible levels of heterosis in future generations without additional crossing. This cross starts as follows: two breeds are crossed and males and females of the F1 generation are reciprocally mated. In the 1940s, Winters (1953) at the University of Minnesota pioneered a procedure based on exploiting breed differences for the genetic improvement of performance. Breeding within synthetic populations can retain a high level of heterosis (Bourdon, 2000) without introducing additional breeds (Galukande et al., 2013). The advantage of synthetics is that the population is replaced from within itself and after the initial crossing, no additional breed is needed (Mason and Buvanendran, 1982). Synthetics can be established at any desired breed ratio of the parental breeds (Syrstad, 1996) but it is a long-term process and therefore not able to respond quickly to market or environmental changes (Mason and Buvanendran, 1982).

The global experiences of developing new livestock breed

Many livestock breeds have been formed though synthetic breed formation in different countries. As can be seen in Table 1, up to 49 sheep breeds were formed within one country (UK) and the minimum of sheep breeds formed in this case were seven (Canada). Figure 1 indicates that the number of parental lines used in the formation of synthetic sheep breed. Few sheep breeds were used as parental lines repeatedly. For instance, Merino sheep breed was the most frequently breed where about 175 synthetic sheep breeds had the Merino sheep breed in their blood. In addition to this, there are more 80 synthetic goat breed and considerable number of cattle breeds formed through the synthetic breed formation.

Table 1. Countries that developed seven or mor synthetic sheep breeds globally.

Countries	Number of composite sheep breed formed
UK	49
The Russian Federation	34
Australia	26
Poland	23
China	20
France	18
USA	17
New Zealand	15
Bulgaria	14
Italy	12
Kazakhstan	11
Turkey	10
India, Ukraine, South Africa	9
Germany, the Netherlands	8
Canada	7

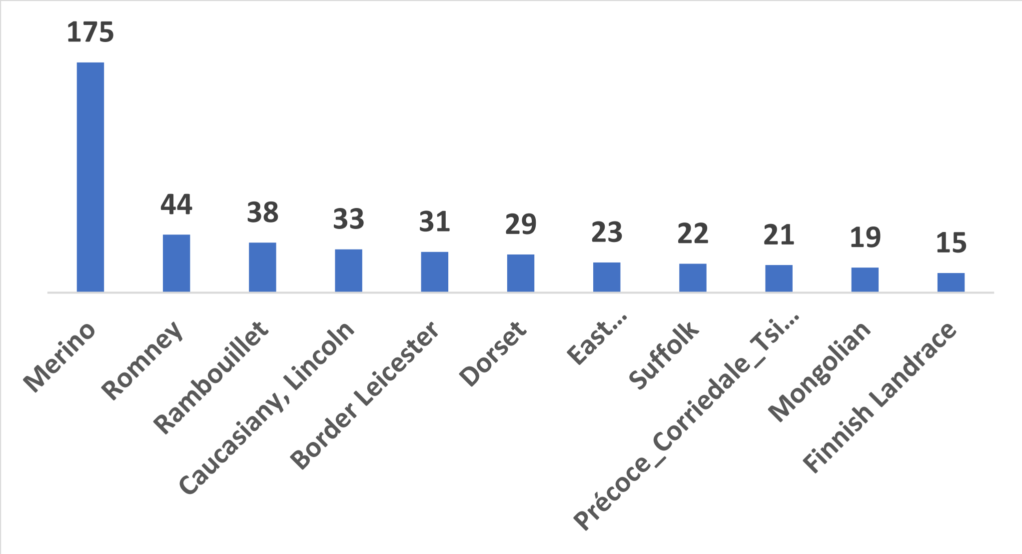

Figure 1: The frequency of pure parental lines used in the formation of synthetic breed in the case of sheep (Source: Rasal et al., 2006).

Alternative scenarios for synthetic breed formation involving different levels of exotic gene inheritance

Various scenarios of synthetic cattle breed formation could be formulated for the case of Ethiopia. Among others, the combination of two things could be considered; the level of exotic gene inheritance and in the breed to be formed under either open nucleus (where the community will be engaged) or under the on-station condition only. The advantages of fixing exotic gene inheritance at 75% than at 50% could have the productivity advantage where animals with high exotic gene inheritance are more productive than those with lesser exotic gene inheritance. As the same time, however, the inputs and management levels required become more intensive whenever the level of exotic gene inheritance is increased; this idea is presented in Table 2.

Table 2. The possible situations of synthetic breed formation

Possible breeding schemes	Level of exotic gene inheritance	
	50%	75%
Station based	Population with 50% gene inheritance will be formed at station (A)	Population with 75% gene inheritance will be formed at station (B)
Village based	Population with 50% gene inheritance will be formed at identified village (C)	Population with 75% gene inheritance will be formed at identified (D)
Open nucleus	Population with 50% gene inheritance will be formed involving both village and station (E)	Population with 75% gene inheritance will be formed involving both village and station (F)

Scenario A: formation of cattle population with 50% exotic gene inheritance at on station condition

Under this scenario, the level of exotic gene inheritance will be fixed to be 50%. Such population will be formed under on station condition to be disseminated to the end users at the end of the day. The implementation of such scenario will not be able to produce the required number of animal population. This is because, such approach will be challenged by the capacity of the farm and the availability of budget. However, the technical matters could be simple because pure exotic breed could be mated with indigenous animals to produce 50% crossbred population.

Scenario B: formation of cattle population with 75% exotic gene inheritance at on station condition

This scenario is the same with scenario A other than fixing the level of exotic gene inheritance at 75%. Even though consideration of population with higher exotic gene inheritance ensures productivity advantage, it is associated with lengthy process as population of 50% required for the formation of this scenario. This scenario may not be feasible because of three facts: (1) provided the situations considered under scenario A, the ultimate population to be formed for dissemination will be minimal; (2) the duration of the synthetic breed formation will be increased by the length of one generation; (3) the inefficiencies related to artificial insemination will be multiplied (for the formation of 50% population and for the formation of 75% population).

Scenario C: formation of cattle population with 50% exotic gene inheritance identifying potential village

For the implementation of this scenario, potential village will be identified; the accessibility, high population of indigenous cattle, availability of Artificial insemination facilities and human capacities will be considered as criteria for identification of the potential villages. This starts with the identification of potential heifers and cows under the identified village and followed by AI of the identified animals. The advantage of this scenario is that it enables to address as many animals as possible; however, it may be limited by the availabilities of implementation facilities including vehicle, semen and semen storage facilities.

Scenario D: formation of cattle population with 75% exotic gene inheritance identifying potential village

This scenario is the same with scenario C except the level of gene inheritance to be considered is 75%. On the other hand, the concerns associated with consideration of 75% exotic gene inheritance discussed under scenario B will hold true for this scenario. Provided that the management levels under village-based scheme is poor, productivity performance of cattle population with 75% exotic gene inheritance under this scenario will less be less likely poor.

Scenario E: formation of cattle population with 50% exotic gene inheritance involving both station and identified villages

The concept of open nucleus breeding program is the use of male animals selected in the specified nucleus for the improvement of the wider population and using the selected female animals from the population of interest in the nucleus; this approach is more suitable for the within breed selection. In the case of synthetic breed formation, two sites maybe assumed like that of the within breed selection: the nucleus and the community. The nucleus site could be where the male side selection could be made for use in the wider community to mate the female dairy animals in the community. Alternatively, the identified nucleus could serve as AI services. The advantage of considering such approach minimizes the problems related with bull shortage and its management for the community, problems related to managements of AI including liquid nitrogen for the preservation of semen. This scenario has high probability of success. On top of providing the male germplasms to through live bull and AI, female crossbred dairy animals will also be injected to the community. The involvement of the on-station component will assist the recording and evaluations of the animals and genetic progresses.

Scenario F: formation of cattle population with 75% exotic gene inheritance involving both station and identified villages

This scenario is the same with scenario E except the level of its exotic gene inheritance, i-e., 75%. As discussed earlier, increasing the level of exotic gene inheritance increases at least one generation interval to the former scenario (scenario E) and the synthetic breed to be formed are also vulnerable to diseases and require intensive management systems. Hence, this scenario has less likely to be materialized.

Technical considerations in the ways of synthetic breed formation

Genetic background: in well-planned efforts to create composite breeds, the genetic background of the foundation breeds should be as broad as possible; this is to achieve increased additive genetic variance and heterozygosity and lower probability for the expression of lethal recessive genes; one can reduce the loss in heterosis by increasing the number of breed combination to three, four or more. The principles of quantitative genetics including: heterosis retention, breed complementarities, reduction in rate of inbreeding and increased genetic variability need to be fully exploited in the course of composite breeds development.

Segregation and inbreeding: In the process of crossbreeding, why the productivity of F2 is less than that of F1? Can F1s could be called synthetic? It is important to consider a large segregating population with sufficient genetic variability, avoiding any possibility of increasing the rate of inbreeding. Desirable morphological characteristics and production performance will not be stable unless the initial crosses are followed by about eight to ten generations of inter se mating. This process is time consuming, and may not be feasible unless the newly formed population consists of genetic combinations, which exceed the performance of the base parental breeds.

Reciprocal mating: In most cases, the process of synthetic breed formation involves fixed breeds from the dam and sire sides; for example, Holestein Friesian cattle breeds are used as the sire line and other indigenous animals are used as dam line in the course of synthetic cattle breed formation. This could be due to the availability of limited number of Holistein Friesian dams in the countries where the synthetic dairy cattle are formed. However, the breed used as sire line one time should be used as dam line the other time in the course of synthetic breed formation.

Operational facilities: Facilities that enable practical breeding operations in the process of synthetic breed formation comprise bull selection, frozen semen production, management and AI.

These aspects need the following: semen quality assessment facilities, continuous supply of liquid nitrogen, a selection index for bull mothers. Synthetic breed formation shall be a national agenda!

Importation of tropically adapted improved breeds

As an alternative to the synthetic breed formation, importing tropically adapted and improved breeds could be considered in the case of Ethiopia. There are breeds with considerably high milk yield potential; Sahiwal cattle breed is one of the tropical Zebu cattle which can be best fit our agro-ecology without extra management cost. Existing evidences indicated that the cows are the heaviest milkers of all zebu breeds and display a well-developed udder; average lactation yield of Sahiwal cows is 2325 kilo grams; the lactation yield ranges from 1600 to 2750 Kg. Moreover, selected herds may have higher productivity; milk yield as high as 6000 lit has been recorded under organized farm conditions. Sahiwal is one of the best dairy breeds in India and Pakistan. Due to its unique characteristics, the breed is exported to wide list of countries and regions. (Asia, Africa and Caribbean). The contribution of the Sahiwal breed to adaptability is well documented in Kenya, Jamaica, Guyana, Burundi, Somalia, Sierra Leone, Nigeria and several ecological zones of Africa. Kenya is the main country in Africa with major resources of Bos indicus Sahiwal cattle and serves as an important source of stock and semen for the continent (Rege et al., 1990). Hence, among other breeds, importation of Sahiwal cattle breed could be considered as alternative to the planned synthetic cattle breed formation in Ethiopia. This germplasm could be imported from Kenya or other nearby country. In general, various ways of improving the milk production should be thought over in Ethiopia including improvement of the existing indigenous animal genetic resources through selection, synthetic breed formation and alternatively, importation of tropically adapted and high milk yielder animals like Sahiwal.

Summary and the way forward

Generally, there are four options for improvement of livestock: within breed selection, between breed selection, crossbreeding and synthetic breed formation. Within breed selection is applied whenever remarkable variability exists for traits under consideration; on the other hand, between breed selection is applied when the performance of a replacer breed excels the other. If a particular breed is imported for a particular production objective, ultimately the existing breed is replaced by the imported one (between breed selection); but this is less likely practical. Crossbreeding is the simplest way of making quick genetic gain but the gain genetics could not be sustained. In fact, synthetic breed formation is a special form of crossbreeding. Hence, synthetic breed formation, could be considered in the case of Ethiopian dairy sector development; in doing so, the exotic gene in heritance to be fixed after a minimum of eight generation, shall be 50% whereas the exotic breed to be used could be Holistein Fresian and the modality under the discussed scenario shall be open nucleus breeding approach. Alternatively, importation of tropically adapted breed known for their high milk productivity shall be considered.

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Morphological Characterization of Indigenous Goat Population in Ethiopia Using Multivariate Analysis

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Abstract

This study was conducted to characterize the indigenous goat population in five zones vis-à-vis South Gondar (S-Gondar), Jimma, Sidama, Gamo, and North Shoa (N-Shoa) representing various agroecological zones of Ethiopia using morphometric traits. Seven morphometric traits were measured from 2540 goats of both sex from various age groups ranging from yearling to four years and above. The traits scored were live weight (LW), body length (BL), wither height (WH), heart girth (HG), rump length (RL), rump width (RW) and ear length (EL). A multivariate canonical discriminant analysis in combination with cluster and discriminant analysis was applied to identify the combination of variables that best differentiate the five goat populations based on morphometric traits. The cluster analyses showed that goats of Jimma tended to group separately whilst those of N-Shoa and S-Gondar as well as Sidama and Gamo clustered closely. The stepwise discriminant analysis indicated that RL followed by RW were the most discriminating variables to separate the five goat populations. The canonical discriminant analysis determined four canonical variables (CAN) of which CAN1 (RL and HG) and CAN2 (RW, EL, and LW) accounted for 80.2 and 14.3% of the total variation, respectively. The canonical discriminant analysis further showed that the Gamo goat is distinct from the other four populations. All Mahalanobis distances among goat population were significant (p<0.0001) being the shortest between Sidama and N-Shoa goats (3.92) followed by that of S-Gondar and Jimma (4.17). The largest distance was noted between N-Shoa and Gamo (68.2) followed by that of Sidama and Gamo goats (53.3). Distances among the other zones were intermediate ranging from 10.7 to 16.2. The respective 99.3, 98.7, 98.6, 97.4 and 95.5%, of the Gamo, Jimma, S-Gondar, N-Shoa and Sidama goats were correctly assigned to their source population with an overall success rate of 98%. The present work revealed that characterization of indigenous livestock based on morphological traits through the application of multivariate analysis is a viable option in regions where molecular tools are inaccessible provided the sample sizes of animal population are large enough to effectively represent the study regions for reliable results. The findings of the study could also be beneficial to strengthen the traditional in situ conservation activities of indigenous goat genetic resources for their sustainable utilization.

Key words: administrative zones; Ethiopia; indigenous goat; canonical discriminant analysis; morphological characterization; morphometric traits

Introduction

Ethiopia is home of 52.5 million goats in which nearly all are of local ecotypes (CSA, 2020/2021). They are reared in a wide range of production systems being adapted to different agro-ecological zones of Ethiopia. A number of studies have been conducted to characterize the indigenous goat population of Ethiopia (Peacock, 1996; Alemu, 2004; Mekuriaw, 2016). The first comprehensive information compiled on physical description and management system revealed that there were 14 goat types in Ethiopia and Eritrea of which eleven are found in Ethiopia (Peacock, 1996). Molecular characterization studies grouped the 11 Ethiopian indigenous goat population into eight distinct genetic entities (Alemu, 2004). However, the Weitzman analysis conducted by the same author indicated that 75% of the total genetic diversity of the Ethiopian goats is present in four breeds. In a more recent study, 309 sample goats representing 13 Ethiopian indigenous goat populations were sequenced to investigate the maternal historical demographic dynamics using molecular characterization (Mekuriaw, 2016). Based on the admixture and phylogenetic network analyses, this author re-grouped the Ethiopian indigenous goat population into seven types. The observed inconsistencies among the findings of different authors suggest that there may be goat population that were not adequately represented in the sampling procedure of previous studies.

In addition to genetic characterization, morphometric measurements have been used to explore the characteristics of several farm animal populations and breeds, which provided useful information in the classification of indigenous animal genetic resources and with reference to their source of origin (FAO, 2012; Melesse et al., 2013; Arandas et al., 2017; Valsalan et al., 2020). Indeed, the outcome of such studies could be further used towards the development of sustainable breed improvement, utilization and conservation programmes. Many analytical tools are available for assessing the phenotypic profile of a breed. In this regard, multivariate analysis of morphological traits has been successfully used to estimate the existence of genetic variations within and between indigenous animal population (Zaitoun et al., 2005; Arandas et al., 2017).

Among others, cluster and canonical discriminant analysis have been reported to be the most suitable methods to describe the relationship between two or more variable sets through linear combinations that are maximally correlated by discovering dominant gradients of variation among groups (Yakubu et al., 2010a,b; Selolo et al., 2015; Arandas et al., 2017). It can discriminate different population types when all measured morphological variables are considered simultaneously and thus helpful in understanding the phenotypic relationship and diversity study in a given livestock population. Moreover, classification of indigenous goat population based on morphometric traits strongly supports the clustering of these animals to the same group similar to using the molecular tools. For example, Hassen et al. (2016) observed higher genetic similarity on two Syrian indigenous goats both at morphological and molecular levels. They conducted characterization studies on three Syrian indigenous goats using molecular data and reported the existence of two genetically similar goat populations, which was further confirmed by the multivariate analysis of the morphological data taken from the same goat types. Thus, characterization of indigenous animal genetic resources using morphological traits could help to validate the findings of molecular based studies provided the number of sampled animals used for a given morphological characterization research is large enough for a reasonable representation of the study population. Since measuring phenotypic traits is relatively cheap and less time consuming, differentiating indigenous farm animals based on their morphological characters would further serve as alternative and affordable option when molecular based characterization studies could not be feasible due to limited resources and lack of capacity.

Although different studies were carried out to characterize the indigenous goat population in Ethiopia (Alemu, 2004; Hassen et al., 2012a,b; Mekuriaw, 2016; Zergaw et al., 2017), there is still limited information on their real genetic potentials that are distributed across various regions of the country with contrasting agro-climatic environments. To the authors knowledge, except Zergaw et al. (2017), no other author has recently classified the goat population of Ethiopia by applying a multivariate analysis (be it cluster, canonical discriminant, factorial or principal component analysis) based on morphological traits. Moreover, morphological distances among the local goat population of the five administrative zones have not been established which could serve as a possible basis for their conservation and genetic improvement programs. The current study was, therefore, conducted to systematically differentiate the indigenous goat population of five zones comprising 11 districts based on their morphometric measurements by applying the procedures of canonical discriminant analysis in combination with cluster and quadratic discriminant analysis.

Materials and Methods

Description of the study area

The study was conducted in five administrative zones comprising South Gondar (S-Gondar), Jimma, Sidama, Gamo and North Shoa (N-Shoa) representing various agroecological zones of Ethiopia. The S-Gondar zone is located in the north central Ethiopia at 11.7746° N, 38.1477° E. Sidama and Gamo zones are situated in the rift valley of southern Ethiopia at 6.7372° N, 38.4008° E and 6° N and 37° E, respectively. The N-Shoa zone is located in Central Ethiopia at 10.0947° N, 39.4864° E. Jimma zone is situated in the wet sub-humid part of southwestern Ethiopia at 7.8144° N, 36.7820° E.

Site selection and sampling techniques

Multi-stage purposive sampling techniques were used to select the study districts, kebeles (the smallest administrative units within a district) and households within each zone. In the first stage, 11 districts were selected purposively from five zones based on goat population size. Accordingly, three districts each from S-Gondar (Libokemkem, Fogera and Farta) and Jimma (Omo nada, Nono benja and Limu seka) zones, two districts each from Sidama (Shebedino and Moricha) and Gamo (Arbaminch zuria and Mirab abaya) zones and one district from N-Shoa zone were selected (Table 1). In the second stage, based on distribution of goat population, 37 kebeles were selected purposively and then proportionally from all zones. Accordingly, nine kebeles each from S-Gondar and Jimma zones, six kebeles each from Gamo and N-Shoa zones and seven kebeles from Sidama zone were selected. In the third stage, the households within kebeles, which possessed at least three matured goats of both sex and had long enough experiences in rearing goat, were randomly selected after setting a minimum screening criterion. Collectively, 2540 goats (722 bucks and 1818 does) were sampled from all zones. The owner's recall method along with dentition classes (pairs of permanent incisors, PPI) were used to estimate the age of goats. Thus, goats with 1PPI, 2PPI, 3PPI and 4PPI were classified in the age groups of yearling, 2-year-old, 3-year-old and 4-year-old, respectively.

Table 1: Sample size of sampled districts, kebeles and households

Zone	Sampled districts	Sampled kebeles	Sampled households	Number of sampled goats		
				Male	Female	Total
South Gondar	3	9	153	153	357	510
Jimma	3	9	210	199	343	542
Sidama	2	7	170	177	353	530
Gamo	2	6	120	151	465	616
N-Shoa	1	6	120	42	300	342
Total	11	37	773	722	1818	2540

Data collection procedures

Data were scored on seven morphometric traits following the descriptor list of FAO (2012) for phenotypic characterizations of goats. Accordingly, the following traits were measured: live weight (LW), body length (BL), wither height (WH), heart girth (HG), rump length (RL), rump width (RW), and ear length (EL). Wooden made ruler fitted with sliding height bars were used to measure wither height. The LW was taken using a suspended weighing scale with 50 kg capacity by placing each animal in self-devised holding harness. All other linear measurements were taken using measuring tapes made of textile material. All measurements were taken in the morning before goats were released for grazing. Measurements were restricted to healthy and non-pregnant goats.

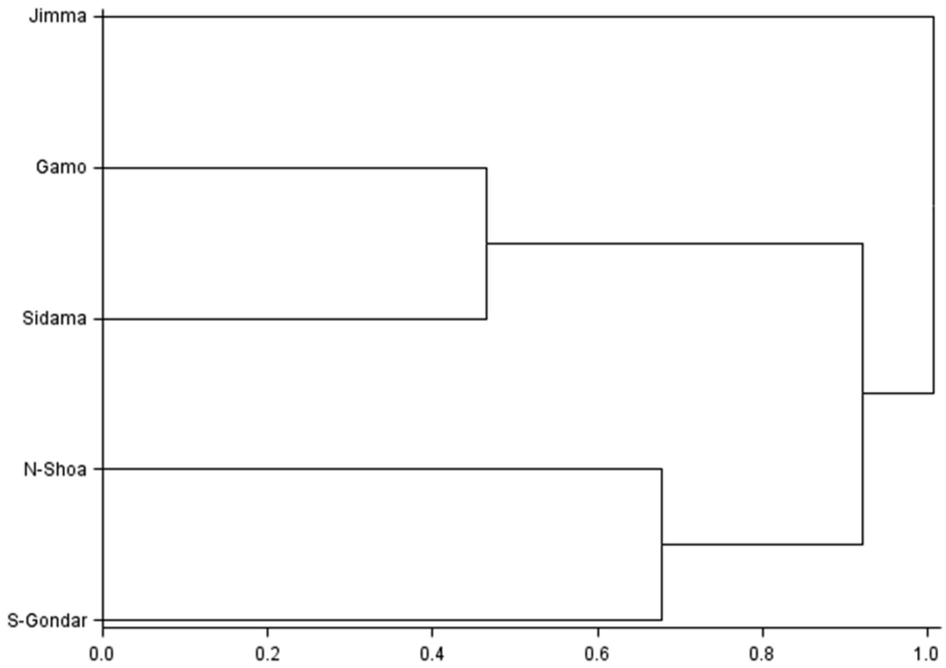
Data analysis

The degree of morphological similarity or diversity among the indigenous goat populations was determined using the procedure of the cluster analysis. Dendrogram was constructed based on distances between the goat populations of the five zones as well as districts within each zone using the average linkage method to group the flocks into their morphological similarity. Moreover, the stepwise discriminant analysis was applied using the STEPDISC procedure to determine the morphometric traits that have the most discriminanting power. The significance of the morphometric variables in discriminating the five goat populations was assessed using the level of significance, F-statistic and partial R^2. Collinearity among the variables used in the discriminant model was further evaluated using tolerance statistics. The canonical discriminant analysis was performed on the identified traits with the highest discriminating power using the CANDISC procedure to compute the Mahalanobis distances between class means, uni- and multivariate statistics and canonical variables with correlations and eigen-values. The TEMPLATE and SGRENDER procedures were used to create a plot of the first two canonical variables in a scatter graph for visual interpretation. Finally, discriminant analysis of the DISCRIM procedure was conducted to determine the percentage classification of goats into their source populations using quadratic discriminant function for unequal covariance matrices within classes after conducting Bartlett's homogeneity test. The cross-validation option was finally applied to evaluate the accuracy of the classification with a minimum bias. All multivariate analyses were performed using the Statistical Software of SAS (2012, ver. 9.4).

Results

The dendrogram (Figure 1a) showed two large clusters: cluster one included Jimma goats as a separate independent group and cluster two incorporated all other goat populations with two sub clusters in which goats of N-Shoa and S-Gondar grouped in one while those of Gamo and Sidama in the second sub cluster.

The dendrogram displaying the minimum distances between the goat populations of districts within zones is presented in Figure 1b. Two distinct groups were identified in which goats of Shebedino, Moricha, Arbaminch zuria, and Mirab abaya districts were clustered in one group and all goats of the other districts in the second. In the first group, goats of Shebedino and Moricha (representing Sidama zone) were further grouped under one sub cluster. Similarly, goats of Arbaminch zuria and Mirab abaya (representing Gamo zone) were grouped under a separate sub cluster. In the second large cluster, goats of Omo nada, Nono benja and Limu seka (representing Jimma zone) were grouped in one sub cluster while those of Libokemkem, Fogera and Farta (representing S-Gondar zone) in a different sub cluster. On the other hand, goats of Hidabu abote (representing N-Shoa zone) were clustered separately as independent sub cluster.



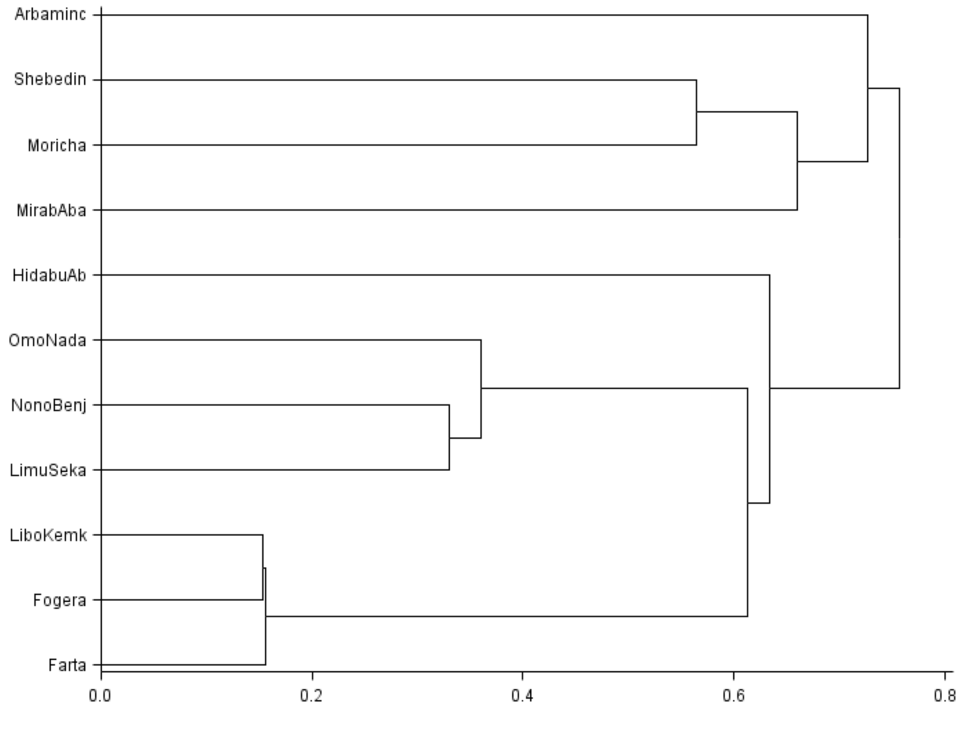


Figure 1a (top). Dendrogram based on average distances between the five indigenous goat populations using morphometric traits, and **Figure 1b (bottom).** Dendrogram classification of indigenous goat population reared in eleven districts of five zones based on morphometric traits; Arbaminc = Arbaminch zuria; MirabAba = Mirab abaya, Shebedin = Shebedino; HidabuAb = Hidabu abote; NonoBenj = Nono benja; Libokemk = Libokemkem

Seven quantitative variables for both sex groups were subjected to the STEPDISC procedure and all of them were identified as suitable discriminating variables in stepwise selection summary of which RL and RW had the highest discriminating power to separate the five goat populations (Table 2). Wilk's lambda test confirmed that all the selected variables had highly significant ($p<0.0001$) contribution to discriminate the total population into separate groups. All the seven variables were then subjected to canonical discriminant analysis using the CANDISC procedure that performed the uni- and multivariate analysis, the Mahalanobis distances and eigen-values of extracted canonical variables. The univariate (ANOVA) statistics testing the hypothesis that class means are equal which validate that each quantitative variable in sampled population is a significant ($p<0.0001$) contributor to the total variation. The goat population difference between zones was tested by the multivariate analysis (MANOVA) and was significant ($p<0.0001$). Wilk's Lambda further tested the hypothesis that assumes zones' means are equal across the goat populations and found to be highly significant, which confirms that differences observed among populations of the five zones were statistically different from zero.

Table 2. Summary of stepwise discriminant analysis for selection of traits

Step	Variables entered	Partial R-square	Pr > F	Wilks' Lambda	Pr < Lambda	ASCC	Pr > ASCC
1	Rump length	0.797	<0.0001	0.203	<0.0001	0.199	<0.0001
2	Rump width	0.631	<0.0001	0.075	<0.0001	0.322	<0.0001
3	Wither height	0.376	<0.0001	0.047	<0.0001	0.390	<0.0001
4	Ear length	0.236	<0.0001	0.036	<0.0001	0.436	<0.0001
5	Body weight	0.091	<0.0001	0.033	<0.0001	0.450	<0.0001
6	Heart girth	0.105	<0.0001	0.029	<0.0001	0.460	<0.0001
7	Body length	0.091	<0.0001	0.026	<0.0001	0.475	<0.0001

ASCC = average squared canonical correlation

Table 3 showed significant Mahalanobis distances between flocks based on morphometric measurements sorted by mean distances. All Mahalanobis distances were significant ($p<0.0001$) being the shortest between Sidama and N-Shoa goats followed by that of S-Gondar and Jimma. On the other hand, the longest distances were noted between N-Shoa and Gamo followed by that of Sidama and Gamo. The third longest distance was observed between Gamo and Jimma goats. The distances among the other zones were intermediate ranging from 10.7 to 16.2.

Table 3. Mahalanobis distances among the indigenous goat population of the five zones based on morphometric traits

Zones	South Gondar	Jimma	Gamo	Sidama	N-Shoa
S-Gondar	0	4.17	41.5	12.4	10.7
Jimma		0	32.2	12.3	16.2
Gamo			0	53.3	68.2
Sidama				0	3.92
N-Shoa					0

All distances are significant at $p<0.0001$

Summary of canonical functions and correlations with eigen-values are presented in Table 4. The canonical discriminant analysis derives a linear combination of the variables that has the highest possible multiple correlation with the groups called the first canonical correlation. Accordingly, the analysis identified four statistically significant ($p<0.0001$) canonical variables (CAN) that accounted for 80.2%, 14.4%, 4.55% and 0.87% of the total variations, respectively, adding to 100% of that total variance. However, among the identified canonical variables, both CAN1 and CAN2 accounted for 94.4% of the total variations indicating a comprehensive representation of the majority of the studied indigenous goat population. Similarly, the respective eigen-values for CAN1 and CAN2 were 8.41 and 1.50, which together accounted for 9.91 (99.1%) of the cumulative variance. Table 5 further displayed the approximate F statistic based on Rao's approximation to the distribution of the likelihood ratio test rejecting the hypothesis that the current canonical correlation and all smaller ones are zero.

Table 4. Summary of canonical correlations, eigen-values and likelihood ratios

Functions	Adjusted canonical correlations	Eigen-values			Likelihood ratio	Approximate F-value	Pr > F
		Eigenvalue	Proportion	Cumulative			
CAN1	0.945	8.38	0.801	0.802	0.0264	555	<0.0001
CAN2	0.774	1.502	0.143	0.946	0.2482	248	<0.0001
CAN3	0.567	0.475	0.045	0.991	0.6211	133	<0.0001
CAN4	0.288	0.091	0.011	1.000	0.9164	56.6	<0.0001

CAN1 = canonical variable 1; CAN2 = canonical variable 2; CAN3 = canonical variable 3; CAN4 = canonical variable 4

Figure 2 shows a plot built with the first two canonical variables illustrating the relationships between goats belonging to different zones. The plot clearly showed that CAN2 discriminates between the Sidama and N-Shoa goats in one group while the CAN1 best discriminates among goats of Gamo zone with those of the other zones. The Jimma and S-Gondar goats fell between the two canonical variables (CAN1 and CAN2). Moreover, values of standardized canonical coefficients (data not shown) indicated that RL and HG dominated CAN1, while RW, EL, and LW showed the largest influence on CAN2. In addition, CAN3 was dominated by WH and CAN4 by BL

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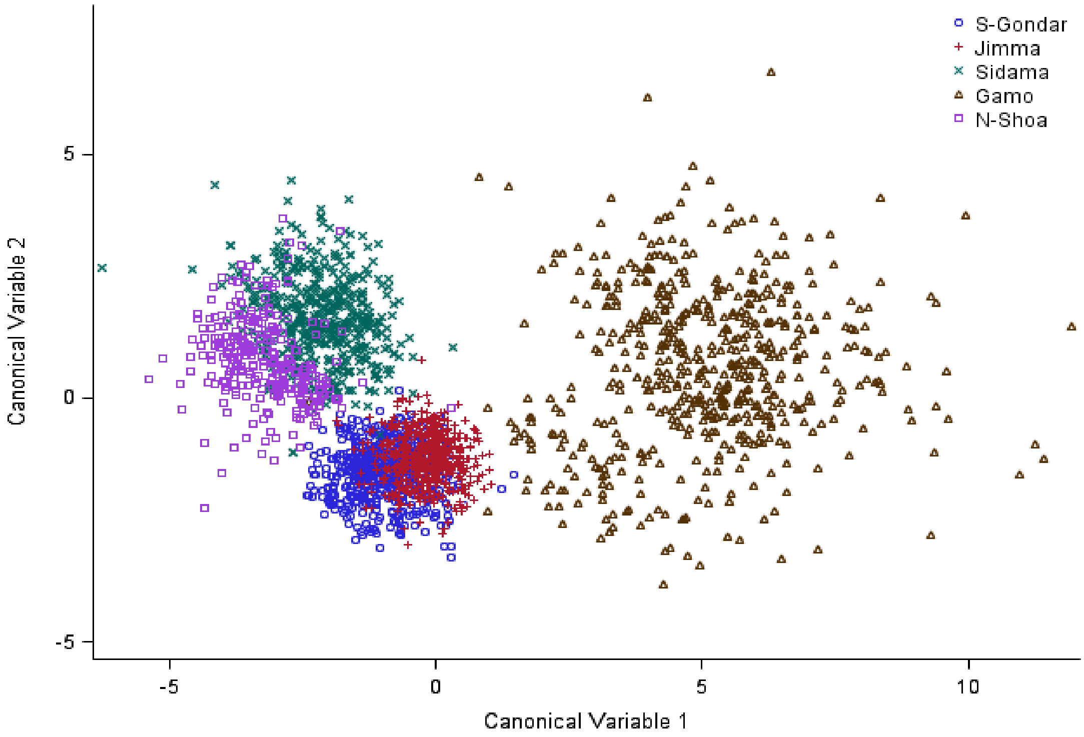

Figure 2. Canonical representation of the goat population in the five zones based on seven morphometric variables

As shown in Table 5, the quadratic discriminant analysis correctly classified most of the individual goats into their respective source population with an overall average of 98.0%. The classification accuracy of the discriminant analysis was further cross-validated and was highly consistent with the observed classification rate with an overall success rate of 97.9%.

Table 5. Percent of individual goats classified into their respective zones & cross-validation of classification based on morphometric variables (values in brackets are number of goats)

Zones	S. Gondar	Jimma	Gamo	Sidama	N. Shoa	Total
Classification						
S-Gondar	98.6	0.78	0.20	0.20	0.20	510
Jimma	0.74	98.7	0.18	0.00	0.37	542
Gamo	0.0	0.18	99.7	018	0.0	565
Sidama	0.0	0.0	0.38	95.5	4.15	530
N-Shoa	0.0	0.0	0.29	2.34	97.4	342
Error count rate	0.014	0.013	0.004	0.045	0.026	0.020
Cross-validation						
S-Gondar	98.4	0.95	0.20	0.20	0.20	510
Jimma	0.74	98.7	0.18	0.00	0.37	542
Gamo	0.00	0.18	99.7	0.18	0.00	565
Sidama	0.00	0.00	0.38	95.3	4.34	530
N-Shoa	0.00	0.00	0.29	2.34	97.4	342
Error count rate	0.016	0.013	0.004	0.047	0.026	0.021
Priors	0.200	0.200	0.200	0.200	0.200	

The quadratic discriminant function further computed the misclassified observations via re-substitution and cross-validation options (Table 6). Accordingly, the misclassification error level among the five goat populations was negligible with an overall error-count estimate of 0.02 (2.0%) for all observations. The error count estimates gave the proportion of misclassified observations in each group being comparatively highest in goats of Sidama and lowest in those of Gamo. The overall error count estimate for cross-validation analysis was also 2.11%, which indicated unbiased estimate for the studied morphometric traits of the five goat populations.

Discussion

Designing genetic improvement schemes for sustainable conservation and utilization of indigenous animal genetic resources should be based on the assessment of the phenotypic characteristics of population reared in various production environments. Ethiopia possesses large and diverse small ruminant populations, which contribute to the livelihood and income of the rural poor and the country at large (Haile et al., 2019). Recent studies conducted by Wodajo et al. (2020) indicated that the respective 78% and 64% of women and men in Ethiopia related the importance of rearing goats with food security as compared with other livestock species.

The cluster analysis identified two distinct groups in which goats of Jimma clustered in one separate group and all the other zones in the second, which were further grouped into sub clusters. The appearance of Jimma goats in one independent cluster could be explained by the fact that they tend to have the smallest body measurements in most morphometric traits that might be attributed mainly to their geographical origin. The classification of Sidama and Gamo goat populations under one sub cluster could be elucidated by their resemblance in LW, HG and RW measurements. Moreover, both goat populations share geographical terrains with medium range of proximity.

The grouping of S-Gondar and N-Shoa goat breeds collectively in one sub cluster might be explained by the fact that these two goat populations tend to have similar phenotypic values for HG, WH and RH traits and could be thus classified as large-sized goat types. These observations have been further substantiated by the results of the canonical discriminant analysis in which the shortest Mahalanobis distances were observed between Sidama and Gamo as well as that of S-Gondar and N-Shoa goat populations. This suggests that goats of Sidama and Gamo, and those of S-Gondar and N-Shoa share similar phenotypic identities, which might have been resulted from non-selection, continuous inbreeding, and admixture events due to migration over several decades. Moreover, the goat populations of Sidama and Gamo as well as those of S-Gondar and N-Shoa are geographically located in relatively midrange distances to each other.

Determining the morphological distances will help to understand the genetic diversity of the indigenous animal population and enable to initiate suitable breeding programmes that are useful for the conservation of the animal genetic resources. In this regard, the Mahalanobis distance is the most commonly used distance measure for quantitative traits of livestock breeds. In the current study, all the Mahalanobis distances were highly significant, indicating the existence of relatively large variations among the morphometric traits of the studied goat population. The significant differences among distances further indicate that differences among the goat populations are important for the classification process.

The observed Mahalanobis distances among the five goat populations in the current study are higher than the findings of Selolo et al. (2015) who reported short distances (0.23 to 1.05) for indigenous goats of South African reared in various agro-ecological zones, which might suggest a much closer relationship among them than observed in the current studied local goat population. Nevertheless, relatively large Mahalanobis distances (22.3) were reported between Damascus and Dhaiwi goat breeds while a moderate value (6.34) was observed between Mountain and Dhaiwi (Zaitoun et al., 2005). Jimcy et al. (2011), Dekhili et al. (2013) and Arandas et al. (2017) have also reported larger distances between indigenous goat population of India, Algeria, Brazil, respectively. Phenotypic variations in a population may arise due to genotypic and environmental effects, and differences in the magnitude of morphological variability under different environmental conditions.

All of the discriminating variables in the present study are similar to those reported by Zergaw et al. (2017) for central highland and Woyto-Guji goats of Ethiopia, Selolo et al. (2015) for South African goat population, Dekhili et al. (2013) for Algerian goats and Yakubu et al. (2010a,b) for Nigerian goat population. Canonical discriminant analysis identifies linear combinations of the quantitative variables that provide maximal separation between classes or groups. The Wilks' Lambda, which presents the ratio of within-group variability to total variability on the discriminating variables, is an inverse measure of the importance of the discriminant functions (Huberty and Olejnick, 2006). In the present study, the value of Wilks' Lambda for the sampled population was 0.0264 (2.64%), which indicates that almost all (97.4%) of the variability in the discriminator variables was because of the differences between the studied populations rather than variation within the population. In this regard, the discriminant analysis carried out gave complementary information in which about 98% of the individual goats were correctly classified to their source population indicating genetic homogeneity within a population rather than between populations (Table 5). Between breed diversity is an important criterion to be considered when ordering priorities for conservation of indigenous animal genetic resources in any genetic improvement programmes. Moreover, the existence of phenotypic variation within and between populations is essential to successfully adapt to frequently changing climatic conditions and to successfully respond to artificial selection.

In the current study, canonical analysis, based on morphometric traits, allowed identification of two canonical variables (CAN1 and CAN2), which added 80.2% and 94.4% of total variation, respectively indicating large reduction in sample space, with little loss (6.6%) to explain the total variation. These observations are in good agreement with those reported by various scholars (Zaitoun et al., 2005; Traoré et al. 2008a; Jimcy et al. 2011; Arandas et al., 2017). In contrary, Selolo et al. (2015) reported a higher value for the first canonical variable that accounted for 91.9% of the variation for South African indigenous goats. According to the studies of Ogah (2013), CAN1 and CAN2 accounted for 59.7 and 40.3% of the total variation in chickens, respectively, which is lower than observed in the current study. Such variations for each canonical variable in the literature might be due to differences in the production environment, genetic make-up of the goats and types of morphological traits included in the study.

The quadratic discriminant analysis correctly classified most of the individual goats into their respective source population with an overall cross-validation rate of 97.9% indicating the homogeneity of goat populations within zones for those morphometric variables included in the discriminant analysis. The proportion of correctly classified individuals gives a measure of the morphological distinctness of the sampled population. The error count estimates among the five goat populations were negligible, which could be explained by the phenotypic relationship between these flocks. This implies that multivariate analysis is an alternative and effective statistical tool to differentiate local farm animal population into separate groups based on their morphological characteristics. Although the measurement of qualitative and quantitative traits is relatively cheap and easy to apply, it has been noted that they are subjected to environmental influences (Hassen et al., 2012b). In the later study, however, Hassen et al. (2016) observed that there were clear morphological variations among the three Syrian goat populations and the analyses of the molecular data validated these observations as well. In another study conducted by Ceccobelli et al. (2016), the genomic results confirmed the morphological observation in the characterization of the three indigenous Italian sheep breeds. These findings suggest the importance of phenotypic traits in the characterization study of indigenous farm animals as alternative approach when molecular based studies may not feasible. Nevertheless, it should be noted that the size of animal populations to be sampled should be large enough and comprehensive to effectively represent the study regions for reliable results.

Consistent with the current findings, 99.4% of West African Dwarf and 100% of Red Sokoto goats of Nigeria were correctly assigned to their source population with an overall success rate of 99.7% (Yakubu et al., 2010a). Conversely, Yakubu et al. (2010b), Dekhili et al. (2013) and Selolo et al. (2015) reported comparatively lower classification rate of goats into their source population with a relatively higher rate of misclassification which might arise from the heterogeneity of the population as a result of admixture and migrations.

In the current study, the error count estimates were comparatively higher in goats of Sidama and N-Shoa than those of other zones were. This might be explained by the fact that the Sidama and N-Shoa goats might be comparatively more heterogeneous than those of the other groups because of admixture and migration. However, it should be noted that the observed error count rate in the current study is much lower than reported by various scholars who used small sample size in their studies. For example, Selolo et al. (2015) and Zaitoun et al. (2005) used about 500 goats while Kurnianto et al. (2013) used 160 which is much lower than the sample size of the current study (N = 2540).

Conclusion

This investigation showed that all the seven morphometric traits had a discriminating power of which rump length and width were identified as the best variables to effectively differentiate the five goat populations. The Mahalanobis distances indicated that the Sidama and N-Shoa goat populations were the closest while those of the N-Shoa and Gamo the furthest. Canonical discriminant analysis indicated that the Gamo goat is distinct from the other four populations. Almost all goats were correctly assigned into their source population indicating phenotypic homogeneity within the population. The multivariate analysis of morphometric traits provided practical basis for differentiating the goat population of the five zones into separate groups using the seven discriminating variables. Thus, characterization of indigenous livestock based on morphometric traits using a multivariate analysis is a viable option in regions where molecular tools are inaccessible provided the number of samples are large enough to comprehensively represent the study region. Moreover, the identified morphometric traits with the highest discriminating power could be considered in any genetic improvement programmes of the five goat populations to attain a better performance.

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Evaluation of Improved Chicken Production Extension Package through Cross-Sectional Survey and On-Farm Monitoring of Exotic Chicken Breeds in Sidama Region

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Abstract

This study was conducted to evaluate the efficiency of the improved chicken production extension package through cross-sectional survey and on-farm monitoring of Sasso and Bovans Brown chicken breeds in selected two districts of Sidama Region. A purposive random sampling procedure was employed to select sample districts and kebeles based on local and exotic chicken populations. The households that rear exotic chickens were stratified into three types of managements visa-a-vise households offering supplementary feed with separate chicken house, those providing supplementary feeds with vaccine and those offering supplementary feeds, separate chicken house with vaccine. Sixty respondents from each category were randomly selected with a total of 180 households for the survey work. Moreover, 50 households were randomly selected from those who were willing to participate on the on-farm performance monitoring. Data were analyzed using GLM procedures. Results indicated that the average chicken breed types per household were local (3.23), crossbreds (3.21) and exotic (6.81). All households offered supplements in which maize grain (31.6%), wheat bran (26.1%) and concentrate (21.6%) were the major feed sources. Newcastle disease (73.8%) was reported as the major constraint in the studied districts. Annual egg productions per hen, age at first egg and mate for cockerels were 81.71, 24.2 and 22.1 weeks, respectively. Number of clutch per year, single clutch days, egg number per clutch and total number of eggs laid per year were 3.15, 28.47, 20.63 and 65, respectively. Regarding on-farm performance monitoring, the total average female body weight of Sasso and Bovans brown chickens at 20 weeks of age was 1724 and 1334g, respectively. The corresponding values for the respective male Sasso and Bovans brown breeds were 2125 and 1415g at the same age. The number of egg production per hen of Sasso and Bovans brown breeds up to 36 weeks of age were 84.0 and 80.4, respectively. Age at first egg for Sasso and Bovans brown was 162 and 158 days and did not differed significantly. The hen-housed egg production for Sasso and Bovans brown breeds was 79.2 and 70.7%, respectively. During the study time, 12 and 10% of mortality was observed for Sasso and Bovans brown breeds, respectively. In conclusion, Sasso breed showed better performance in body weight than Bovans brown and almost the same potential for egg production and can be recommended for further utilization of the two breeds in the study area.

Keywords: body weight; Bovans brown and Sasso chickens; egg production; on-farm monitoring;

Introduction

Poultry production has an important economic, social and cultural benefit and plays a significant role in family nutrition in the developing countries. In most developing countries indigenous chicken kept by households using family labor and locally available feed resources. They are usually kept under scavenging production systems often with very limited application of management interventions to improve flock productivity (Aberra, 2014). In sub Saharan Africa, chicken production is an employment opportunity for the youth, elders and women in the urban and peri-urban area (Aberra, 2014). Improvement of indigenous breeds and ecotypes in developing countries first requires proper documentation of their productive and reproductive performance. Ethiopia is a country where traditional poultry production plays a dominant role in national economy in general and rural economy in particular (Aberra and Tegene, 2011). About 48.1 million total chicken populations in Ethiopia and from which 81.7% comprises indigenous birds, while 10.9% hybrids and 7.4 % are exotic breeds kept for both eggs and meat production purposes (CSA, 2019). Backyard, small scale, and large scale commercial are the three major production system characterization in Ethiopia based on some selected variables such as breed, flock size, housing, feed, health, technology and bio-security. The Ethiopian indigenous chickens are kept under the traditional poultry production system, characterized by lack of purposeful feeding, separate poultry house, small flock sizes, low input and output and periodic devastation of the flock by disease (Aberra, 2014). This author reported that low productivity of local breeds, prevalence of diseases, less availability and poor quality of feeds, limited research and poor extension service, and lack of organized marketing and processing facilities are some of the most important constraints affecting the traditional chicken production system. Although this sector has been contributing substantially to household income and nutrition for majority of poor rural communities, its expansion has been limited by low productivity, poor management practices, high prevalence of diseases and low genetic potential of the stock.

Poultry production as a key to poverty reduction in the rural society. Hence, attempts have been made to introduce different exotic poultry breeds to the smallholder farming systems in Ethiopia with the objective of raising production and productivity (Serkalem et al., 2018, 2019). Different breeds of dual exotic chickens (Rhode Island Red, Australorp and New Hampshire) for both egg and meat production and White Leghorns for egg production were imported to Ethiopia since the 1950‟s (Serkalem et al., 2018). Since then higher learning institutions, research organizations, the Ministry of Agriculture, and Non-Governmental Organizations (NGO‟s) have disseminated many exotic breeds of chicken to rural farmers and urban-based small-scale poultry producers. There has been also a substantial effort to introduce improved hybrid layers of egg type chickens particularly Isa Brown (IB) and Bovans Brown (BB), and dual-purpose hybrid Potchefstroom Koekoek (PK) to smallholder farmers under backyard management into SNNPR (Aman et al., 2017; Serkalem et al., 2018, 2019).

However, lack of recorded data on the performance of chicken and all aspects of management, lack of regular chicken health program and market information makes it difficult to assess the importance and contributions of the past attempts to improve the sector. Besides, most of the exotic breeds studied under the traditional production system in Ethiopia were not high yielding hybrids type used in the international poultry industry. Moreover, the country has no breeding policy and dedicated institute for genetic improvement. As a result, every institution has been introducing any kind of breeds to the country. Therefor there is a need to define the present performance of high yielding layers such as Bovans Brown and dual-purpose hybrid Sasso breed (widely distributed by Ethio-chicken private farm) chickens in selected areas of SNNPR. Accordingly, a systematic study was required to evaluate improved chicken production extension package and on-farm monitoring of Sasso and Bovans Brown breeds under farmer management condition. Thus, the present study was conducted with two-fold objectives: first to assess the performance of management intervention package and its components under the farmer production system and second, to evaluate the production, reproduction and growth performances of Sasso and Bovans brown chicken breeds under different management practices.

Materials and Methods

Description of the Study Area - The study was conducted in two Woredas of Sidama Zone (Wondogenet and Hawassa zuria), SNNPRS. Wondogenet woreda is located in 7° 12’32.14” N latitude and 38°32’14.71” E longitude and elevated at 1723 m.a.s.l. The annual rainfall pattern of the study area varies from 1350 to 1400 mm. The annual minimum and maximum average temperature are 14.36 and 18 °C, respectively. There are three distinct seasons; the main rainy season (June, July, August, September and October); dry season (January, February, and March); small rainy season (October, November, and December). Hawassa Zuria is situated at 7°5’16.36” North and 38°12’58.02” East, has an average altitude of 1650 m.a.s.l. The average temperature varies from a minimum of 16.27 °C to a maximum of 24.9 °C and the annual average minimum and maximum rainfall is 1175 mm and 1200 mm, respectively. It has a bimodal pattern with three distinct seasons; dry (November to February), small rains from March to June, and main rains from July to September.

Sampling techniques and data collections - The study was conducted by using two methodologies, which were survey and on-farm monitoring. Survey data were generated by administrating a structured questionnaire, organizing group discussion, key informants and field observation while quantitative data of on-farm monitoring were recorded in weekly basses.

Survey

A rapid field survey was conducted on the selected sites prior to the actual survey work to explore number of chicken (Sasso, Bovans brown and local), their distribution and management practices of national poultry extension package for improved genotypes in the district. The information regarding distribution and management practices of national poultry extension package also obtained from Animal and Fish Resource Development Office of the woreda. The household survey has been carried out to gather information by interviewing the selected households. The selection of the study area and households were done through a purposive random sampling procedure. Accordingly, Hawassa Zuria and Wondogenet districts were purposively selected based on the potential of poultry population, participating in national poultry extension package at least in the last one and more years and intensity of the distribution of Sasso and Bovans brown breed chickens. The development agents and livestock experts of the Animal and Fish Resource Development Office have actively participated in the selection procedure.

Survey for chicken production was conducted by stratifying the households based on types of management condition. Households that possess Sasso, Bovans brown and local chicken breeds, manage their exotic chickens offering supplementary feed and constructing separate chicken house (BSFH) were the first stratum. Households having Sasso, Bovans brown and local chicken breeds, manage their exotic chickens with offering supplementary feeds and providing vaccine (BSFV) were the second stratum. The third category included households that possess Sasso, Bovans brown and local chicken breeds, manage their exotic chickens with offering supplementary feeds and constructing separate chicken house and providing vaccine (BSFHV). The extension package was for improved genotypes not for local breeds and the survey of this study focused only on the above strata because those management conditions were dominantly applicable in the study area. After communicating with the district’s Animal and Fish Resource Development Office on the issues of practicing national poultry extension package, based on chicken population density and accessibility for transport, two kebeles from Wondogenet district (Wesha Soyama and Kella kebeles) and two kebeles from Hawassa Zuria district (Oudo wetame and Tankaka ounbelo kebeles) were purposively selected for questionnaire administration. Fifteen households per strata was selected randomly from each kebele with a total of 45 households per Kebele and 90 household per district and 180 household per two district were interviewed using a pre-tested questioner (Table 1).

Table 1. Sample size per management condition at each selected kebele

Management condition	Wondogenet district		Hawassa Zuria district		Total
	Wesha Soyama	Kella	Oudo Wetame	Tankaka Ounbelo	
BSFH	15	15	15	15	60
BSFV	15	15	15	15	60
BSFHV	15	15	15	15	60
Kebele Total	45	45	45	45	180

BSFH = breed, supplementary feed and house; BSFV = breed, supplementary feed and vaccine; BSFHV= breed, supplementary feed, house and vaccine

Data were collected using pre-tested semi-structured questionnaires which include household characteristics, flock size and composition, farmers treat preference, source of exotic chickens, frequency and methods of supplementary feeding, season and purpose of supplementation, housing, health and disease control mechanisms, socio-economic aspect of chicken production, labor division, ownership, production and reproduction performance of chicken, selection, culling, and marketing.

Group discussion - One group discussion was undertaken in each district. The groups were composed of women, kebele leaders and key informants who have better knowledge on the present and past socio economic status of the area. Discussions were focused on poultry production system (practices of national poultry extension package), source of exotic breeds, indigenous knowledge on management of breeding, husbandry practices, past and present utility pattern of poultry in the area and major constraints and opportunities of chicken production system using prepared checklist. Secondary data (chicken population size and meteorological data's) were collected from Wondogenet and Hawassa Zuria Woreda office of Animal and Fish Resource Development.

On-farm monitoring

On-farm monitoring has been done in kella kebele of Wondogenet woreda which was selected purposively based on the availability of Sasso and Bovans brown chicken breeds in the hands of most households (intensity of distribution), participating on national poultry extension package and accessibility of the PAs. Based on the information gathered from farmers group discussion, key informants and individual interviews most farmers obtained Sasso (especially provided by Ethio-chicken private farm) and Bovans brown breeds chickens purchasing from, privet farm, local cooperatives, and government through livestock development extension system in the form of cockerels and pullets (45 days old). Accordingly, Sasso and Bovans Brown with 45 days old chickens were selected just after buying from government, through livestock development extension system. A purposive random sampling technique was used to select sample households for farm monitoring. First farmers who had a good experience in chicken production and management and rear both Sasso and Bovans Brown breed in common (and/or only one of them) were selected purposively with the aid of experts, development agents and kebele administrators of the respective kebele. List of farmers who newly taken 45 days old Sasso and Bovans brown pullets/cockerels were obtained from Animal and Fish Resource Development Office. These pullets/cockerels were distributed through livestock development extension system. The list also used as sampling tool to select sampled households.

The on-farm chicken performance testing was designed to compare the performance of two introduced exotic breeds of chicken under two different farmer’s management conditions for evaluating production, reproduction and growth of chicken breeds. The on-farm monitoring was conducted by stratifying the households based on management conditions as stated here above. Then, 27 farmers from strata one (BSFV) and 24 farmers from strata two (BSFHV) with 51 farmers were randomly selected for on-farm monitoring. Then 168 (84 male and 84 female) cockerels and pullets were selected from households. Overall 336 (168 male and 168 female) 45 days old cockerels and pullets of both Sasso and Bovans brown breed chickens were selected randomly. Chickens were grown on station up to 45 days of age under farmer management practices. Out of the selected farmers, 72% were female-headed households and only 28% were male-headed households. This is also an indication of the female's role in the smallholder chicken production system in the study area.

Chicken management and feeds

Chickens in BSFHV management condition were supplemented 20 g concentrate feed/bird/day while chickens in BSFV offered 10 g concentrate feed/bird/day for the whole study period. Besides farmers fed their chickens using locally available feed resources such as maize grain, wheat grain, wheat brain (furishika), leftover of vegetables and animal by-products such as dried cattle blood, bone meal by grinding it into small pieces from local cattle slaughtering areas and some calcium sources of feed such as sand. Chickens were also provided with water as a free choice. The BSFHV management type have separate poultry houses which were constructed with locally available materials but BSFV not construct separate chicken house and their birds spent at night in the main house. Chickens were vaccinated against Newcastle disease, Gumboro, and Marek’s on station with the help of veterinarians. Three days of training were given to the participant farmers and follower development agents at farm level by researchers on chicken production system and their management including feeding, housing, and animal health care as well as data recording systems.

Variables measured

Growth performance traits - Before starting the record, the initial weight of the sampled 45 days pullets and cockerels were measured with weight balance, then male and female chicken body weights were taken for 10, 12, 16 and 20 weeks of age. A weight measurement on males was maintained until the chicken achieves 20 weeks of age.

Egg production performance - Eggs of each management type were collected, recorded and stored separately on a daily basis and weekly egg production data were summarized by farmers and follower development agents as well as researchers up to 36 weeks of age. Egg weight and reproductive performance (age at first egg) data of two breeds were recorded from chickens of the two management types.

Data management and analysis

Survey data

Data collected from each household and kebele were coded and entered into the computer for further analysis. Data collected through questionnaires were analyzed using the Chi Squared procedure of SPSS (SPSS, ver. 20). Simple descriptive statistics such as least squares means and standard error of the mean were applied for quantitative data.

Statistical model for survey

$Y_{ij} = \mu + I_{th} + \epsilon_{ij}$

Where:- Y_{ij} *= The value of the respective variable mentioned above*

μ *= overall mean of the respective variable*

I^{th} *= the effect of* i^{th} *management condition (BSFH, BSFV and BSFHV)*

ϵ_{ij} *= random error term*

On-farm monitoring data

Data collected on on-farm performance quantitative traits were analyzed by two-way ANOVA using Statistical Analysis System (SAS, 2012, ver 9.4) by fitting the genotypes (Sasso and Bovans brown breeds) and management types (BSFV and BSFHV) as main factors and the interactions among them. Mean comparisons were conducted using Tukey's Studentized Range Test and values were considered significant at $p<0.05$.

Model used to analyze the quantitative data

$Y_{ijk} = \mu + A_i + B_j + A_i*B_j + e_{ijk}$, *where:-*

Y_{ijk} *= the observed k variable in the* i^{th} *management and* j^{th} *genotype*

μ *= overall mean of the observed variables*

A_i *= effect due to* i^{th} *management (i = BSFV and BSFHV)*

B_j *= effect due to* j^{th} *genotype of chickens (j = Sasso and Bovans brown)*

A_i*B_j *= effect due to interaction between* i^{th} *management and* j^{th} *genotype*

e_{ijk} *= random residual error*

Results and Discussion

Flock Size and Composition

As shown in Table 2, almost all respondent households keep all groups of birds (except chicken 0-8 weeks of age) together without age separation for local, cross, and exotic breeds. Hens and cocks of exotic strains were dominant in the flock. This is an indication of the increasing desire for farmer's exotic strain preference for egg and meat production. BSFHV and BSFV had significantly more exotic and crossbreed chickens while the number of local chicken in the flock of BSFH relatively higher. This is might be because of farmers who rear chickens in BSFHV and BSFV management condition can supplement more feed to exotic chickens than that of BSFH ones. A similar study reported by Solomon et al., (2013) that 96% of the village chicken producers keep all ages of chicken together, and the flocks were dominated by hens (2.95) and cocks (1.09) for cross and local breeds. The overall flock size of the exotic breed is greater than local breeds in the study area, which is attributed to the access of purchasing it from the private farms. The FGD said that the limits to the number of birds kept by the households were associated with feed resources, disease problems, labor shortage, and nuisance with neighbors. The average flock size of this study compared with that of Fisseha et al., (2010) in the Bure district of the Amhara region.

Table 2. Least square means (±SE) of flock size and composition per household in the study area

Breed	Variable	BSFH	BSFV	BSFHV	Total	P value
Local	Chicks (0-8wks)	1.08±0.06	0.71±0.04	0.43± 0.04	0.74±0.06	0.0974
	Cockerels (8-20wks)	0.47±0.17	0.25±0.18	0.27±0.19	0.33±0.18	0.3384
	Pullets (8-20wks)	0.46±0.21	0.39±0.18	0.21±0.22	0.35±0.35	0.1893
	Hens/layers	1.09±0.09	0.41±0.08	0.63±0.08	0.71±0.09	0.1154
	Cocks(>20wks	1.34±0.17	0.96± 0.17	0.92±0.17	1.11±0.17	0.3097
	Overall	4.43±0.08[ab]	2.72± 0.08[a]	2.46±0.09[a]	3.23±0.08	
Crosses	Chicks (0-8wks)	0	0	0	0	
	Cockerels (8-20wks)	0	0	0.41±0.05	0.14±0.03	0.0036
	Pullets (8-20wks)	0.53±0.06	0.55±0.06	0.76±0.05	0.61±0.06	0.0833
	Hens/layers	1.14±0.14	1.38±0.14	1.44±0.13	1.32±0.13	0.0635
	Cocks (>20wks)	0.85±0.14	1.27±0.14	1.35±0.15	1.16±0.14	0.0599
	Overall	2.52±0.13	3.2±0.13	3.96±0.14	3.22±0.16	
Exotics	Cockerels (8-20wks)	0.71±0.07	1.02±0.06	1.17±0.06	0.97±0.07	0.1587
	Pullet (8-20wks)	0.68±0.08	0.92±0.08	1.26±0.08	0.95±0.08	0.0561
	Hens/layers	1.62±0.14	2.91±0.16	3.23±0.16	2.59±0.15	0.0018
	Cock (>20wks)	1.42±0.15	2.57±0.16	2.91±0.16	2.32±0.11	0.0771
	Overall	4.43±0.09[a]	7.42±0.09[b]	8.57±0.09[b]	6.81±0.09	

Means in the same row with different superscript letters are significantly different (p<0.05) BSFH=breed, supplementary feed and house, BSFV=breed, supplementary feed and vaccine, BSFHV=breed, supplementary feed, house and vaccine and N=number of households interviewed, SE = Standard error

Farmers' breed and trait preferences

The survey results showed that farmers prefer egg production and size, bodyweight/meat production, and physical appearance (Table 3). Majority of interviewee first-rate exotic breeds for egg production and having large body size. The FGD also said that even though exotic breeds were preferred for traits of early maturity, local chickens still selected for mothering ability or high survival rate, less sickness, scavenging ability, and have good meat and egg test. This is in going with the brief of the production performance of Sasso and Bovans brown breed in southern parts of Ethiopia (Aman et al., 2017).

Table 3. Preferred genotypes and reasons for exotic chicken preference (%) in the study area

Variables	BSFH	BSFV	BSFHV	Overall	P value
Preferred genotypes	n= 60	n=60	n=60	N=180	0.6137
Local	13(21.7)	11(18.3)	9(15.0)	16(18.3)	
Cross	15(25.0)	14(23.4)	12(20.0)	56(22.8)	
Exotic	32(53.3)	35(58.3)	39(65.0)	106(58.9)	
Reasons for exotic chicken					
High egg production	34(56.7)	34(56.7)	33(55.1)	101(56.1)	
Large body size (for meat)	19(31.6)	22(36.7)	21(35.0)	62(34.4)	
Large egg size	4(6.7)	3(5.0)	4(6.7)	11(6.2)	
Physical appearance/beautiful	3(5.0)	1(1.7)	2(3.2)	6(3.3)	

BSFH=breed, supplementary feed and house, BSFV=breed, supplementary feed and vaccine, BSFHV=breed, supplementary feed, house and vaccine, N=number of households interviewed

Nearly 94% of Bovans brown chicken used for egg production while 97.5% local farmers prefer Sasso breed for both egg and meat production because of having large body size and capable of producing a large amount of meat. Aberra and Tegene (2011) in southern parts of Ethiopia reported that about 71.4% of chickens raised by the rural community were used for egg production while the rest 28.6% used for meat production purposes. Aberra and Tegene (2011) and Fisseha et al. (2010) reported that local chickens have special meat and egg quality/flavor, hard eggshells, high dressing percentages, and especially low cost with little special care required for production.

Sources of exotic chickens

As shown in Table 4 the major sources of improved chicken in the study area were; Government (Extension), purchasing from cooperatives and/private farms (cooperative poultry farms also give them through credit), purchasing from market, NGO and government organizations in the order of importance in the form of pullets and cockerels. Information assembled from FGD and Animal and Fish Resource Development Office, few model farmers offered exotic breeds by government organizations for research as well as scale-up purpose.

Table 4. Source of exotic chickens (%) in the study area

Variables	BSFH	BSFV	BSFHV	Overall
Government extension	51.3	48.1	43.4	47.6
From Local market	7.6	16.2	15.8	13.2
From local cooperatives	31.5	22.6	26.4	26.8
Given by GO	6.4	7.8	8.8	7.6
Given by NGO	3.2	5.3	5.6	4.7

BSFH=breed, supplementary feed and house, BSFV=breed, supplementary feed and vaccine, BSFHV=breed, supplementary feed, house and vaccine and N=number of households interviewed

Purpose of poultry production

Most farmers in the study area care local and exotic chickens for sale and egg production while few ones look after for home consumption (Table 5). A significant number of farmers keep local chickens for replacement. Similarly Salo et al. (2016) reported as a source of income (55.6%), home consumption and income earning (26.7%). Fisseha et al. (2010) also reported source of income (51%), hatchability (45.0%) and home consumption (44.0%). From the total local egg production bulk of eggs were sold. In contrast to local egg, almost all exotic eggs were spent for sale. This result precisely illustrates that both local and the exotic egg was not used for the same aspire. The local egg was used for reproduction purpose too, whereas exotic egg was used only for income earning which was consistent with the reports of Gelila et al. (2016).

Production and reproduction performances of chicken

The survey revealed that the average age of cock at first mate and hen at first egg was significantly ($P<0.05$) difference among management conditions (Table 6). Chickens reared in BSFV and BSFHV conditions early matured as compared to chickens in BSFH without identifying breed type. Similarly, the average length of a single clutch period was significantly ($P>0.05$) different between management condition. Chickens reared in BSFH management condition had relatively less number of laid days than chickens managed in BSFV and BSFHV condition. This implies that chickens in BSFHV and BSFV had more number of average annual eggs per hen than chickens reared in BSFH management condition. This difference might be due to the effect of vaccine. The current result of age at the first mate of cock and the first egg of hen was comparable with some reports of Aman et al. (2017), Endale et al. (2016) and Fisseha et al. (2010).

Table 5. Production purpose of chicken and egg production (%) in the study area

Purpose	BSFH	BSFV	BSFHV	Overall	P value
Local chicken	n=60	n=60	n=60	N=180	0.342
Replacement	19(31.6)	21(35.0)	22(36.7)	62(34.4)	
Home consumption	11(18.3)	7(11.7)	4(6.7)	22(12.2)	
Sale and egg production	30(50.1)	32(53.3)	34(56.6)	96(53.3)	
Exotic chicken	n=60	n=60	n=60	N=180	0.317
Replacement	-	1(1.6)	2(3.3)	3(1.3)	
Home consumption	4(6.7)	8(13.4)	5(8.4)	17(9.4)	
Sale and egg production	56(93.2)	51(85.0)	53(88.3)	160(88.9)	
Purpose of egg production					
Local	n=60	n=60	n=60	N=180	0.465
Consumption	3(5.0)	2(3.3)	3(5.0)	8(4.4)	
Hatching	23(38.3)	23(38.3)	23(38.3)	93(38.3)	
Sale	34(56.7)	35(58.4)	34(56.7)	135(57.2)	
Exotic	n=60	n=60	n=60	N=180	0.627
Consumption	4(6.7)	5(8.3)	6(10.1)	15(8.3)	
Hatching	-	-	-	-	
Sale	56(93.2)	55(91.7)	54(89.8)	165(91.7)	

BSFH=breed, supplementary feed and house, BSFV=breed, supplementary feed and vaccine, BSFHV=breed, supplementary feed, house and vaccine, N=number of households interviewed

Table 6. Least square means (± SE) of production and reproduction performances of chickens reared in different production conditions

Variables	BSFH	BSFV	BSFHV	Total	P value
Age of cock at first mate (wk)	23.6^{b}±0.94	21.4^{a}±0.94	21.1^{a}±0.94	22.1±0.94	0.003
Age of hen at first laying (wk)	25.7^{b}±0.94	23.5^{a}±0.94	22.8^{a}±0.94	24.2±0.94	0.002
Number of clutch per year	3.2±0.13	3.1±0.13	3.1±0.13	3.2±0.13	0.114
Length of single clutch (days)	26.7^{a}±0.84	28.3^{b}±0.84	30.5^{c}±0.84	28.5±0.84	0.009
Number of eggs per clutch	18.9±1.26	21.0±1.26	22.0±1.26	20.6±1.26	0.096
Number of eggs per hen per year	75.2±3.24	83.6±3.24	86.3±3.24	81.7±3.24	0.088
Number of eggs set for incubation	11.0±1.12	11.9±1.13	12.0±1.12	11.6±1.13	0.118
Number of eggs hatched	10.1±1.13	10.8±1.12	11.0±1.13	10.6±1.12	0.159
Hatchability of eggs set (%)	92.1±5.59	86.5±5.59	92.1±5.59	90.2±5.59	

Means in the same row with different superscript letters are significantly different (p<0.05), BSFH=breed, supplementary feed and house, BSFV=breed, supplementary feed and vaccine, BSFHV=breed, supplementary feed, house and vaccine and N=number of households interviewed, SE = standard error

The result showed that age at first mating and age at first laying were significantly (P<0.05) different among local, exotic, and crossbreeds and higher in local breeds and lower in exotic chickens (Table 7). This implies that exotic chickens have high feed conversion efficiency and fast growth rate, which was responsible for early maturity than others. Similar results were reported by Aman (2017) for Sasso chicken breeds. Length of the single-clutch period and the number of egg per clutch were significantly different (P< 0.05) among local and cross breeds and was higher in a cross than in local breeds. The annual egg production performance per hen was significant (P<0.05) difference between a local, cross and exotic breeds and higher in exotic and lower in the local breed. Crossbreed chickens had higher producing ability, larger body size and faster growth rate as compared to local chicken. This result was comparable with that of Addisu et al. (2013) who reported comparable values.

Table 7. Least square means (±SE) of production and reproduction performance traits of different breed chickens

Variables	Local	Cross	Exotic	P value
Average age of cock at first mate (week)	24.59^{a}±0.62	22.29^{b}±0.62	20.94^{c}±0.62	0.0000
Average age of hen at first laying (week)	26.54^{b}±0.41	24.83^{a}±0.41	22.17±0.41	0.0000
Average number of clutch per year	3.29±0.37	2.65±0.37	-	0.0132
Average length of single clutch period (week)	26.52^{a}±1.36	29.2^{b}±1.37	-	0.0033
Average number of eggs per clutch (number)	15.23^{a}±1.15	24.8^{b}±1.14	-	0.0005
Average number of eggs per hen per year	49.87^{a}±2.21	73.55^{b}±2.21	114.5^{c}±2.53	0.0000
Average number of eggs sets	11.13±0.14	12.16±0.14	-	0.0032
Average number of egg hatched	9.74±0.17	11.15±0.14	-	0.0892
Hatchability rate (%)	86.27±5.92	91.76±5.59	-	0.0687

Least squares means with different superscripts with in a row are significantly different (p<0.05), SE=standard error of the mean

On-farm performance evaluation of Sasso and Bovans brown chickens

Body weight of female chickens

In the study area, the performance of chicken's body weight and gain at 10, 12, 16 and 20 weeks of age were highly significant (P<0.05) among managements (Table 8). In BSFHV, both Sasso and Bovans brown breeds achieved higher body weight performance than BSFV. This difference with in the same breed might be due to breed by management interactions at 10, 12, and 20 weeks of age and management differences. This result also agreed with Tomas et al. (2017) who narrated that the average body weight of female chicken of Bovans brown breed at the age of 20 weeks was 1347g.

Table 8. Least square means (±SE) of genotype, management and their interactions on female body weight

Breed	Age in weeks	BSFV	BSFHV	Overall mean	Sources of variation: Breed	Mgt	M*B
Sasso	6	463±2.8	459±2.8	461±2.8	.0000	NS	NS
Bovans brown	6	317±2.8	303±2.8	310±2.8			
Sasso	10	847±2.9	943±2.9	895±2.9	.0000	.0000	.0000
Bovans brown	10	550±2.9	597±2.9	573±2.9			
Sasso	12	1044±3.1	1212±3.2	1128±3.2	.0000	.0000	.0000
Bovans brown	12	752±3.1	1036±3.2	894±3.2			
Sasso	16	1322±3.2	1617±3.3	1469±3.2	.0001	.0000	NS
Bovans brown	16	926±3.2	1264±3.3	1095±3.2			
Sasso	20	1505±3.2	1943±3.1	1724±3.3	<.0001	< .0001	.0014
Bovans brown	20	1240±3.2	1429±3.1	1334±3.3			

*BSFV = Breed, supplementary feed and vaccine, BSFHV = Breed supplementary feed, housing and vaccine, B*M =Breed by management interaction, Mgt= management and SE= standard error*

Sasso and Bovans Brown male chicken breeds presented higher body weight at the age of 10, 12, 16 and 20 weeks than the same chicken breeds in BSFV (Table 9). Shumuye et al. (2017) reported that the average body weight of the male Koekoek chicken under the farmer management condition was 1300, 1900 and 2500g at 5 months, 8 months and yearling age, respectively, which are comparable with the current findings.

Table 9. Effect of genotype, management, & their interactions on male body weight (LSM ±SE)

Breed	Age in weeks	BSFV	BSFHV	Overall mean	Sources of Variation		
					Breed	Mgt	M*B
Sasso	6	460±3.3	467±3.3	463±3.3	.0001	NS	NS
Bovans brown	6	307±3.3	313±3.2	310±3.3			
Sasso	10	897±3.4	1167±3.4	1032±3.2	.0001	.0001	.0001
Bovans brown	10	718±3.2	720±3.3	718±3.2			
Sasso	12	1180±3.3	1383±3.3	1282±3.4	.0001	.0001	.0001
Bovans brown	12	827±3.3	1157±3.3	992±3.4			
Sasso	16	1537±3.4	1820±3.5	1678±3.3	.0001	.0001	NS
Bovans brown	16	1060±3.3	1347±3.4	1203±3.4			
Sasso	20	2006±3.5	2243±3.3	2125±3.3	.0000	.0000	.0000
Bovans brown	20	1267±3.2	1563±3.2	1415±3.3			

BSFV = Breed, supplementary feed and vaccine, BSFHV = Breed supplementary feed, housing and vaccine, B*M =Breed by management interaction, Mgt= management, SE= standard error

Egg production and reproductive performances

The total egg production performance up to 36 weeks of age and age at first egg in the study area were significantly (P <0.05) different among management conditions (Table 10). Both Sasso and Bovans Brown genotypes had higher average egg production performance in BSFHV than BSFV management condition throughout the experimental period (up to 36 weeks of age). The current result of egg production performance was lower than those observed by Serkalem et al. (2018), who reported 133, 117 and 138 eggs for Sasso, Bovans Brown and Koekoek chicken breeds, respectively.

Table 10. Effect of genotype, management and their interactions on egg production up to 36 weeks of age , age at first egg and egg weight (LSM ± SE)

Parameters	Breeds	BSFV	BSFHV	Overall mean	Sources of variation		
					Breed	Mgt	M*B
Egg production per hen	Sasso	71.4±1.8	89.3±2.1	80.3±1.8	NS	.000	NS
	Bovans Brown	73.3±1.8	94.4±2.2	83.8±1.8			
Age at first egg in days	Sasso	170±2.6	153±2.4	162±2.2	NS	.000	NS
	Bovans Brown	167±2.6	148±2.5	158±2.4			
Egg weight (g)	Sasso	60.5±0.4	62.1±0.4	61.3±0.43	.000	NS	NS
	Bovans Brown	49.8±0.4	51.2±0.4	50.5±0.43			

*BSFV = Breed, supplementary feed, vaccine, BSFHV = Breed, supplementary feed, housing and vaccine, B*M =Breed by management interaction, Mgt= management and SE= standard error*

Age at the first egg of the current result concurred with that of Serkalem et al. (2018) who observed 155, 157, 174 and 238 days for Sasso, Bovans Brown, Koekoek and local breeds respectively. Tomas et al. (2017) reported that Bovans Brown female birds achieved its sexual maturity at 146.0 and 163.8 days of age under intensive and backyard management, respectively. The egg production performance and age of chicken at first egg were not significant (P>0.05) different among breeds. This implies that management difference was the only factor of variation rather than genotype and management by genotype interaction effect in the study area. The current result of egg weight was similar with that reported by Serkalem et al. (2018) for Bovance brown (49.5g), Sasso (53.8g) and Keokeok (43.9g).

Survivability and mortality rates

Chickens survive more in BSFHV than BSFH management conditions and this difference might be due to variation in management and breed by management interaction effect. As shown in Table 11, the overall survivability of Sasso and Bovans Brown chickens was 88% and 90%, respectively. The survivability of the two breeds decreased linearly from 9 up to 36 weeks of age. It was relatively low at 30, 33, and 36 weeks of age. Survivability reduced when the age of birds increased which might be related to poor management at peak production.

Table 11. Effect of genotype, management, and their interactions on survivability (LSM ±SE)

Breed (%)	Weeks	BSFV	BSFHV	Total mean	Sources of variation		
		N=168	N=168	N=336	Breed	Mgt	M*B
Sasso	8	95±2.3	95±2.3	95±2.3	NS	NS	<.0001
Bovans brown	8	99±3.3	99±3.2	99±2.3			
Sasso	14	91±2.3	95±2.3	93±2.3	NS	.0007	<.0001
Bovans brown	14	96±2.3	98±2.3	97±2.3			
Sasso	20	90±1.8	94±1.8	92±1.8	NS	.0003	<.0001
Bovans brown	20	95±1.8	97±1.8	96±1.8			
Sasso	26	89±2.1	93±2.1	91±2.1	NS	NS	.0000
Bovans brown	26	93±2.2	95±2.2	94±2.2			
Sasso	30	88±1.9	90±1.9	89±1.9	NS	NS	.0000
Bovans brown	30	91±1.9	93±1.9	92±1.9			
Sasso	36	87±2.3	89±2.3	88±2.3	NS	NS	.0000
Bovans brown	36	89±2.3	91±2.3	90±2.3			

*BSFV = Breed, supplementary feed and vaccine, BSFHV = Breed supplementary feed, housing and vaccine, Mgt = management, B*M =Breed by management interaction, SE= standard error*

Both Sasso and Bovans Brown breeds had a similar pattern of mortality along the course of the experiment. The overall mortality of Sasso and Bovans Brown breeds up to 36 weeks of age were recorded to be 12% and 10%, respectively. Mortality was almost nil at weeks 9 and 12 in both breeds while it increased linearly starting from week 18 up to 36. This might be an effect of failing the offering of balanced ration at peak production period. Because at this particular time birds need adequate and balanced supplementary feeds for maintenance as well as production requirement.

Conclusion

The exotic chicken were preferred over local and cross breeds for their high egg production, large body, and egg size. The Sasso breed had higher body weight and body weight gain compared to Bovans brown. The production and reproduction potentials of chicken were highly affected by the full management intervention package. Farmers who rear their chickens in BSFHV management condition had relatively higher productivity than those who had exercised some elements of management intervention package. Besides, both Sasso and Bovans Brown chicken breeds were preferred for a few treats like age at first egg and total egg production performances while the Sasso breed has shown high body weight and body weight gain performances than Bovans Brown and local breeds under farmer management conditions. The survivability of the two exotic breeds was almost similar and it only depended on the management conditions.

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The Influence of Different Factors on Reproductive and Productive Performances of Dairy Farm: The Case of Holeta Agricultural Research Center

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Abstract

Even though the cattle population of Ethiopia is increasing, the per capita milk consumption was less than 20 L. If the WHO recommendation, i.e., 200 L/head/year, is targeted, Ethiopia needs about 22 billion more litters of milk annually. In order to fill this gap, professionals focus on production of crossbred animals or more productive animals and overlook correcting the reproduction related problems. Hence, the present study was designed with the objective of investigating factors affecting reproductive and productive parameters using sizable data set collected at Holeta Agricultural Research Center (HARC). This work was based on few reproduction and production data collected at HARC dairy research farm during 1976 to 2019. The effect of years of productions, breeds and mating types were investigated on reproduction and production traits including number of services per conception (NSPC), Age at first calving (AFC), lactation milk yield (LMY) and lactation length (LL) were investigated. The overall number of services per positive conceptions (NSPC), which is frequently used as an indicator of fertility in a dairy farm, was 1.9±1.36 for dairy cows at HARC. Significantly smaller NSPC was required for crosses compared with local dairy animals in HARC; smaller NSPC was also required during the early periods of research system compared to the other categories. The overall mean of AFC for the dairy herds at HARC was 41 months. The AFC for local animals were about ten months later than the AFC for crossbred animals which could be due to the genetic improvement to the crossbred animals. The overall lactation milk yield at HARC was 1697L where the effects of breed, years of production and parity had significant effect on it. Local animals had about a third of lactation milk yield of crosses and significantly shorter lactation lengths than the crosses. It is concluded that reducing the number of services per conception should get due attention in addition to using crossbred animals for milk production than local ones.

Keywords: Borana cattle breed; commitment in research; crossbred animals; Horro cattle breed; Number of services per conception

Introduction

In Ethiopia, livestock is a major source of animal protein, power for crop cultivation, means of transportation, export commodities, manure for farmland and household energy, security in times of crop failure, and means of wealth accumulation (Management Entity, 2021). In Ethiopia, livestock is a major source of animal protein, power for crop cultivation, means of transportation, export commodities, manure for farmland and household energy, security in times of crop failure, and means of wealth accumulation (Management Entity, 2021). The dairy production system of Ethiopia is predominantly extensive, with indigenous breeds and low-input/low-output husbandry practices. The productivity of this sub-sector is constrained by several factors, including poor genetics, low reproductive performance, poor quality and varying seasonal availability of feed, high disease incidence and parasite challenges, and low accessibility to services and inputs. Milk production averages only 1.46 liters per day per cow (CSA, 2021). Holeta agriculture is one of the oldest research centers working on dairy research where its main objective was to characterize and recommend crossbred animals with different exotic gene inheritance in the central highlands of Ethiopia.

Even though the cattle population of Ethiopia increased to about 70 million heads (CSA, 2020), the annual per capita milk consumption in the country was estimated to be less than 40 L where the world health organization (WHO) recommendation was 200 L. The low per capita milk consumption in Ethiopia is attributed to the prevailing insufficient supply of milk in the country. The low supply of milk, on the other hand, were due to large number of indigenous animals whose milk production is substantially low and insignificant number of crossbred animals whose milk production is more than three folds of the indigenous one. If the WHO recommendation is targeted, Ethiopia needs about 22 billion more litters of milk annually as of the year 2021. Such divergent gap could not be filled through usual approaches; rather, different approaches as indicated in national research strategy should be followed and implemented. In order to fill the gap, designing and implementation of appropriate crossbreeding program for specific agro-ecologies was put as short, medium, and long-term strategies among others (EIAR, 2017).

Most commonly, researchers and other stakeholders put their attention on crossbred production itself and overlook the contribution of correcting reproductive constraints and institutional and professional commitments. In an ideal situation, in a farm it would be possible from one cow in one year (365 days) to obtain one viable calf, though, with the rapid increase of the level of productivity, often in farms arises a situation that the first service after calving is belated and, in some cases, it needs to be repeated. To ensure the profitability of dairy farming and to keep the cost of milk production as low as possible, farmers need to pay attention not only to the possibilities of increasing the cow milk productivity, but also of preventing the problems that affect cow longevity and productivity (Hansen, 2000).

Institutional and professional commitments also have high contributions towards the productivity improvement of dairy animals. In the present work, about 48 years data were used to investigate the reproductive and milk productive performances of dairy animals maintained at Holeta Agricultural Research Center. Earlier studies focused either on subset of the data from the same farm or on crossbred animals only. In the current work, data collected from 1976 to 2019 were used by categorizing the data into different years of data collection that could clearly indicate the institutional commitment and associated professional commitments. Years before 1993 were those times where the 'derg' regime was ruling the country and the remaining two categories including 1994 to 2000 and 2001 to 2019 were associated to the early and current times for the present ruling party. In addition, the performances of local cows including Borana, though their data size was not as large as that of crossbred animals were investigated. Hence, the present work was designed with the objective of investigating factors affecting reproductive parameters like number of services per conception and age at first calving and productive parameter like lactation length and lactation milk yield.

Materials and Methods

The study area

The current work was conducted at Holeta Agricultural Research Center (HARC). HARC is located in the central highlands of Ethiopia at 29 km west of Addis Abeba ($9^0$00'N latitude and $38^0$30'E longitude) with an altitude of 2400 meters above sea level. The average annual rainfall is 1100 mm and average annual temperature is 15^0C with minimum 6^0C and maximum 24^0C, respectively

(Yohannes et al., 2016). The average relative humidity is 60% (Gebregziabher et al., 2013). The effect of years in ranges, breeds and mating types were investigated on reproduction and production traits including number of services per conception (NSPC), Age at first calving (AFC), lactation milk yield (LMY) and lactation length (LL) were investigated.

Animal management at the Holeta Agricultural Research Center

The research animals were managed based on breed, pregnancy, lactation stage, sex, and age. Uniform feeding and management practice were adopted for all animals within each category. During the daytime, animals were allowed to grazing from 8:00 to 16:00 hrs. Natural pasture hay was provided as additional feed during the evening. Concentrate mixture composed of wheat middling (32%), wheat bran (32%), noug (*Guizocia abyssinca*) cake (34%) and salt (2%) was supplemented based on their body weight, productivity and physiological stages. But since the last three years, balanced concentrate ration replaced the aforementioned concentrate details. Milking cows, heifers and calves were supplemented with concentrate mixture at the rate of 4, 1 - 1.5 and 0.25 – 1 kg, kg per day respectively depending on the availability of the supplemental feed. The research animals had free access to clean tap water all the time.

Calves were allowed to suckle their dams immediately after birth for about four days to receive colostrum. Weighing and ear tagging of the new born calves were also conducted within 24 hrs after birth. After four days, calves were taken into calve rearing pen and continue to feed the recommended amount of whole milk for 98 days through artificial rearing system (bucket feeding). Milking had been practiced by hand until 2001. In 2002, milking machine has been installed and since then cows had been milked with milking machine twice per day (in the morning and in the evening). The animal management was also supported with vaccinations against major diseases (anthrax, black leg, and foot and mouth diseases) and treatment to control any incidence of diseases.

Breeding program

Pure Borana dams were mated with pure Friesian semen to produce 50% F_1 crosses while 50% F_1 is backcrossed with pure Friesian semen to produce the 75% first generation. The later generations F_2 (50% F_1 X 50% F_1), F_3 (F_2 X F_2) and 75% second generations were produced by the inters mating of 50% male and 50% female and 75% male and 75% female. The Borana heifers/cows used for crossbreeding were bought and brought from Borena pastoralists in the southern Ethiopia (their center of origin) and reared on station and inseminated randomly with semen from National Animal Genetic Improvement Institute (NAGII) (the then a national Artificial insemination Center) and Worldwide sire (WWS) to produce the required generations. Seasonal breeding has been undertaken until 2000. Since then, the mating practice was changed and undertaken throughout the year using AI (Artificial Insemination) which was brought from locally recruited crossbreed bulls or pure Friesian semen from NAIC and WWS. Sometimes, natural service was used when animals become repeated breeders with AI. In addition to herdsmen, teaser bulls were reared with cows for heat detection. Cows detected in heat were mated using AI by qualified technicians. Cows not seen after services for longer were diagnosed for pregnancy after 60 days of services.

Data management and analysis

Data collected and entered into computer since 1976 (about 48 years' data) were obtained from the Holeta dairy research data record unit. The data collected from 1976 to 2019 were used by categorizing the data into different years of collection that could clearly indicate the institutional commitment and associated professional commitments. Years before 1993 were those times where the 'derg' regime was ruling the country and the remaining two categories including 1994 to 2000 and 2001 to 2019 were associated to the early and current times for the present ruling party. In addition, the performances of local cows including Borana, though their data size was not as large as that of crossbred animals were investigated. Four traits including number of services per conception (NSPC), Age at first Calving (AFC), Lactation Milk Yield (LMY) and Lactation Length (LL) were investigated against different genetic groups (local and crosses), different years of production, parities of animals, and mating types (for NSPC only) and presented.

Model for NSPC

$$Y_{ijk} = \mu + B_i + Y_j + M_k + E_{ijkl}$$

Where Y_{ijk} is the response variable NSPC, μ=overall mean for the NSPC and B_i, Y_j, M_k and E_{ijkl} were classes two categories of breed, three years of production, two types of mating, and error factors, respectively.

Model for AFC

$$Y_{ijk} = \mu + B_i + Y_j + E_{ijkl}$$

Where Y_{ij} is the response variable AFC, μ=overall mean for the AFC and B_i, Y_j and E_{ijk} were two categories of breed, three years of production and error factors, respectively.

Model for LMY and LL

$$Y_{ijk} = \mu + B_i + Y_j + P_k + E_{ijkl}$$

Where Y_{ijk} is the response variable LMY and LL, μ=overall mean for the LMY and LL and B_i, Y_j, P_k, E_{ijkl} were two categories of breed, three years of production, seven categories of parity, and error factors, respectively.

Results and discussion

Number of services per conception

The overall number of services per positive conceptions (NSPC), which is frequently used as an indicator of fertility in a dairy farm, was 1.9±1.36 for the data analyzed at Holeta dairy research. This NSPC was significantly ($p<0.05$) affected by breed and different categories of mating years whereas the effect of mating type had non-significant effect ($p>0.05$) on the NSPC. Significantly smaller NSPC was required for crosses compared with local dairy animals in the study area (1.8 (for crosses) vs 1.9 (for local)); the dairy cows also required smaller NSPC during the early periods of research system compared to the other categories (Table 1). Variable findings were reported regarding the NSPC of dairy cattle at Holeta agricultural research center; Yohannes et al. (2017) reported 1.2 to 2.37 NSPC from the same farm but based on relatively smaller data size; Kefale et al. (2018) on the other hand reported about 1.75 NSPC both are in agreement with the present finding which used relatively larger data size. In agreement with the present finding, the NSPC for Latvian Brown (LB) and Holstein Black and White (HBW) breed cows based on the data from the Latvian Agricultural Data center ranged from 1.71 to 1.94 (Lāsma et al., 2017). The NSPC often indicates the problems with cow reproductive system, which has a negative impact on farms profitability (LeBlanc, 2007;

Honarvar et al., 2010) and often results in culling from herd (Sewalem et al., 2008). This trait is affected by different external factors, for example, the content of ration and its suitability for cows' physiological needs, the frequency of feeding (Butler et al., 2006), housing system in the farm, season and weather conditions, the work quality of veterinary staff and the correct observation of heat (Nabenishi et al., 2011). The main environmental factor that affects NSPC is the heat detection system in the farm. If heat detection is done properly and insemination process follows with a good execution, it can improve the effectiveness of insemination (Wall et al., 2003).

Table 1. Least squares means and standard errors of number of services per conceptions for local and crossbred dairy cattle at Holeta dairy research

Factors	Number of observations	Least square means ± SE
Overall	6628	1.9±1.36
Breed		***
Cross	5063	1.8±0.02
Local	1565	1.9±0.04
Years of production		***
1976 – 1993	1479	1.8±0.04
1994 – 2000	1236	1.9±0.04
2001 – 2019	3913	1.9±0.03
Mating type		NS
Artificial insemination	3402	1.9±0.03
Bull services	3170	1.9±0.03

Age at first calving (AFC)

The overall mean of AFC for the dairy herds at Holeta Agricultural Research Center was 41 months (Table 2). The AFC for local animals were about ten months later than the AFC for crossbred animals indicating highly significant difference ($p<0.005$) which could be due to the genetic improvement to the crossbred animals. The AFC from earlier years in the research periods had significantly longer probably due to the involvement of high proportion of indigenous animals. Kefale et al. (2018) reported an overall of AFC of about 37 months using data of the same farm. The difference of about three months was due to the fact that the focus of Kefale et al. (2018) was only on the crossbred animals while we investigated indigenous animals as well. Similar to our find, different classes of year also had significant effect on AFC in the reports of Kefale et al. (2018).

Table 2. Least squares means and standard errors of Age at first calving (Months) for local and crossbred dairy cattle at Holeta dairy research

Factors	Number of observations	Least square means ± S E (months)
Overall	1461	41.0±9.79
Breed		***
Cross	1380	46.8±4.90[b]
Local	81	56.3±5.03[a]
Years of production		***
1976 – 1993	538	59.3±4.93[a]
1994 – 2000	246	48.3±4.98[b]
2001 – 2019	677	47.2±4.95[b]

Least square means with different letter are significantly different.

Lactation milk yield and lactation lengths

The overall lactation milk yield at Holeta Agricultural Research Center was 1697 L where the effects of breed, categories of year and parity had significant effect ($p<0.05$; at least) on it (Table 3). In the same fashion, the overall lactation length was about 338 days. The effect of breed, categories of year and parity was significant ($p<0.05$; at least) on the lactation length of dairy animals investigated (Table 3). Local animals had about a third of lactation milk yield of crosses and significantly shorter lactation lengths than the crosses. Lactation length was significantly shorter for the years since 2001 on wards than the former years. Lactation milk yield was significantly the highest amounting about 1976 L during the years from 1976 to 1993 which could be associated with the commitments both at individual and institution level which was lacking by these days. Even though higher parities had significantly the shortest lactation length, the highest lactation milk yield was associated with the later parities. Regarding the longevity of breeding females, hence it should be not debatable to maintain in the production as long as the productivity is not hampered. The lactation milk yield reported in this study was smaller than the reports of Yohannes et al. (2017) from the same farm may be due to the fact that local animals were considered in the present work.

Table 3. Least squares means and standard errors of Lactation milk yield (L) and lactation lengths (days) for local and crossbred dairy cattle at Holeta dairy research

Factors	N	Lactation length (days)	Lactation milk yield (L)
	4172	337.7±98.76	1696.5±596.95
Breed		***	***
Cross	3766	347.8±1.95	1828.0±11.83
Local	407	288.3±5.03	659.5±30.44
Years of production		***	***
1976 – 1993	954	338.9±4.01a	1976.2±24.37[a]
1994 – 2000	958	327.1±4.24a	1211.3±22.60[b]
2001 – 2019	2361	314.0±4.56b	1544.1±19.80[c]
Parity		***	***
1	149	338.9±4.00[a]	941.8±24.21[a]
2	910	327.1±4.24[a]	1150.7±25.65[b]
3	698	314.0±4.56[a]	1290.8±27.57[c]
4	532	317.7±5.02[a]	1325.0±30.34[c]
5	378	314.8±5.73[a]	1304.2±34.65[c]
6	260	315.7±6.67[a]	1309.1±40.29[c]
≥7	344	297.9±5.87[b]	1385.1±35.45[c]

** Number of observations; least square means with different letters in the same column are significantly different.*

Conclusion

The effect of mating type did not show significant effect on the NSPC where this trait was significantly affected by breeds and different years of production. The less productivity of the local dairy animals was also revealed by the smaller lactation length and lactation milk yields. It was concluded that reducing the number of services per conception should get due attention in addition to using crossbred animals for milk production than local ones.

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Characterization of Indigenous Sheep Populations Based on Morphological Traits and Body Indices Reared in Central Rift Valley of Ethiopia

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Abstract

The study was conducted in Adamitulu-Jidokombolcha (ATJK), Bora, Asasa and Kofele districts situated at the Central Rift Valley of Ethiopia to describe the genetic diversity of sheep populations based on their morphological characteristics and body indices. Qualitative data were collected from 523 ewes on coat color pattern, coat color type, hair coat type and presence or absence of horn. Seventeen morphometric traits were also collected from the same number of animals, which included live weight (LW), body length (BL), height at withers (WH), heart girth (HG), rump height (RH), chest depth (CD), chest width (CW), rump length (RL), rump width (RW), head length (HL), head width (HW), ear length (EL), canon circumference (CC), canon length (CL), tail length (TL), tail circumference (TC) and neck length (NL). Twenty-one structural and functional related indices were computed from the morphometric traits. Results revealed that brown and white coat color were the dominant hair coat type being (P<0.05) different across districts. High proportions of Sheep from Kofele and Asasa districts were characterized by long and course hair coat types while those of ATJK and Bora with short and smooth hair coat types. The district effect was highly significant for most morphometric traits studied except for RL, RW, and HL. Sheep populations reared in Kofele district had higher (P< 0.01) LW, BL and TL values compared with the rest of the three districts. The regression analysis indicated that LW can be predicted by fitting HG, BL and RH in the regression model. The functional and structural indices indicated that most of the traits varied (P<0.05) across the districts. Accordingly, the Kofele sheep had the highest (P<0.05) compact index than those reared in the other districts suggesting that they are a meat phenotype. The highest values for body index (BI), body frame index (BFI), area index and weight were also observed in Kofele sheep being different (P<0.05) from those of the Asasa district. The overall value of BI classified the sheep population as medigline, which well corresponds to the value of BFI by describing the sheep as meat type. The Bora sheep had higher (P<0.05) balance index than Kofele sheep, which suggest that they can climb hills and descend valleys effectively. The width slop index was also higher in Bora sheep than those of Asasa and Kofele, indicating this sheep type is narrow at the fore quarter compared to the hind quarter. The Asasa sheep had higher (P<0.05) proportional index than the Kofele sheep indicating their body tends to be rectangular, which is a characteristic of meat type breeds. In conclusion, the morphological traits in combination with the body indices indicated the existence of phenotypic variations among the studied sheep populations suggesting the opportunity of genetic improvement through selection within the local sheep.

Keywords: *central Rift Valley; districts; indigenous sheep; morphological traits; body indices*

Introduction

Sheep rearing is one of the most important means of livelihood and food security for majority of the rural population, especially in developing countries (Gizaw*et al., 2008)*. Given its proximity to the Arabian Peninsula, Ethiopia is considered as a genetic corridor for the introduction of livestock species including sheep to the African continent (Muigai and Hanotte, 2013). There are 14 traditional sheep populations and nine identified sheep breeds (Gizaw et al., 2007) and with a population of around 42.91 million heads of sheep out of which about 71% and 29% are females and males, respectively (CSA, 2020/21).

The 14 Ethiopian sheep populations are broadly categorized according to their tail phenotypes as thin tailed (one breed), fat-tailed (11 populations), and fat-rumped (two populations) (Gizaw et al., 2007). Study conducted by Edea et al. (2018) using a high-density genome-wide SNP analyses on five local sheep revealed that Ethiopian sheep populations are roughly clustered according to their geographic distribution and tail phenotype. Accordingly, short fat-tailed, long fat-tailed and fat-rumped sheep are distributed in very cool high altitude, mid to high-altitude, and arid low-altitude, respectively. Despite their large population and diversity, the performances of indigenous sheep populations in Ethiopia are relatively low. Various studies indicated that the adult live weights of indigenous sheep population of Ethiopia are far below than improved sheep breeds (Melesse et al., 2013; Wagari et al., 2020). The low productivity of the indigenous sheep may be due to different factors among which poor genetic makeup and nutrition are the most determining factors. On the other hand, the indigenous sheep populations are still reproducing and producing under adverse environmental conditions and are still the main stay of income generation for many smallholder farmers. Hence, understanding the genetic diversity of the indigenous sheep population is particularly relevant to search for specific traits related to their adaptation to diverse agro-climatic zones.

Morphometric characterization of different livestock breeds have been recognized as the preliminary approach for the sustainable use of animal genetic resource (FAO, 2012). To identify the type and function of sheep or goat breeds, functional and structural indices could be calculated from morphometric traits (Chacón et al., 2011; Khargharia et al., 2015; Barragán, 2017). These indices are combination of several linear body measurement traits that are used to assess the type, weight, and function of the breeds of animals and further enhance the ability of breeders to select potential breeding stock in the existing production system (Chacón et al., 2011). Such indices provide tested empirical values, which are limited in the use of single measurements. The current study was therefore conducted to systematically differentiate the populations of indigenous sheep reared in four districts of central rift valley of Ethiopia based on their morphological traits and body indices.

Materials and Methods

Site selection and sampling techniques

The study was conducted in four districts drawn from two zones of Oromia, Ethiopia. First, the relevant secondary information was gathered from Livestock and Fishery Development office. Based on the collected information, multi-stage purposive sampling techniques were used to select the representative districts, kebeles (the smallest administrative units within a district), and households within each kebele. In the first stage, four districts namely Adami Tulu-JidoKombolcha (ATJK), Bora, Asasa, and Kofele were selected purposively from two zones based on their potential for sheep production. In the second stage, based on distribution of sheep population, 3 kebeles from each district (total of 12 kebeles) were selected purposively. In the final stage, the households within kebeles who possess at least three matured sheep of both sexes and had long enough experiences in rearing sheep, were randomly selected based on proportional to the population size to selected kebeles. Collectively, 523 ewes were sampled from the four districts. The agro-climatic characteristics of the studied districts and number of sampled ewes are provided in Table 1. The owner’s recall method along with dentition classes (pairs of permanent incisors, PPI) were used to estimate the ages of sheep. Thus, sheep with 1PPI, 2PPI, 3PPI and 4PPI were classified in the age groups of yearling, 2-year-old, 3-year-old, and 4-year-old, respectively (Ebert and Solaiman, 2010).

Table 1. Agro-climatic characteristics and sample size of households and sheep across each district

Districts	GPS coordinates	Altitude (m.a.s.l)	Agro-ecology Coverage	Annual rainfall (mm)	Sampled ewes
ATJAK	07º 55’ N, 39º45’ E	1643	90% LL, 10% ML	700	89
Bora	8°39′ N, 39°5′ E	1880	85% LL, 15% ML	800	85
Kofele	07º 00’ N, 38º 45’E	2695	90% HL, 10% ML	2500	178
Asasa	07°06′ N, 39°12′ E	2367	35% HL, 65% ML	1970	171

LL = lowland <1500 m a.s.l; ML = midland =1500-2300 m a.s.l; HL = highland >2300 m a.s.l

Data collection procedures

Qualitative traits

The qualitative traits were assessed through visual observation and were evaluated based on the descriptor list of FAO (2012). The following qualitative traits were observed and recorded: coat color pattern, coat color type, hair coat type and presence or absence of horn.

Morphometric traits

Data were scored on 17 morphometric traits following the descriptor list of FAO (2012) for phenotypic characterizations of sheep. Accordingly, the following traits were measured: live weight (LW), body length (BL), wither height (WH), heart girth (HG), rump height (RH), chest depth (CD), chest width (CW), rump length (RL), rump width (RW), head length (HL), head width (HW), ear length (EL), canon bone circumference (CC), canon bone length (CL), tail length (TL), tail circumference (TC) and neck length (NL). Wooden made ruler fitted with sliding height bars were used to measure withers height. The LW was taken using a suspended weighing scale with 100 kg capacity of 0.2 kg precision by placing each animal in self-devised holding harness. All other linear measurements were taken in the morning before sheep were released for grazing by using measuring tapes made of textile material. Measurements were also restricted to healthy and non-pregnant sheep.

Structural and functional indices

To assess the type and function of indigenous sheep populations in the study area, structural and functional related indices were computed from the morphometric traits according to (Chacón et al. 2011; Khargharia et al. 2015 and Barragán 2017) (Appendix Table 1).

Data analysis

Qualitative data were analyzed following the frequency procedures of SPSS version 20.0. Chi-square test was then employed to test for independence between the categorical variables. The morphometric data were subjected to GLM procedures of Statistical Analysis System (SAS 2012, ver. 9.4) to determine effects of class variables (district and age). When F-test declared significant, adjusted multiple least square means were compared with Tukey test.

Model used for the analysis of morphometric traits:

$$y_{ij} = \mu + A_i + D_j + A_i*D_j + e_{ij}$$

where y_{ij} *= the response of dependent variables,* μ *= overall mean,* A_i *= the effect due to* i^{th} *age group (i = 1PPI, 2PPI, 3PPI, 4PPI),* D_j*= the effect due to* j^{th}*district (j = ATJK, Bora, Asasa, Kofele)* A_i*D_j *= effect due to interaction of* i^{th} *age with* j^{th} *district* e_{ij} *= random residual error*

The live weight of the sheep within age groups was predicted using stepwise multiple regression procedure with the following model:

$$Y_j = \alpha + \beta_1X_1 + \beta_2 X_2 + \ldots\ldots.. \beta_{17}X_{17} + e_j$$

Where Y_j *= the response variable (body weight),* α *= the intercept,* $\beta_1 \ldots, \beta_{17}$ *= regression coefficients of the variables* $X_1 \ldots, X_{17}$*,* $X_1 \ldots., X_{17}$ *= the explanatory variables (BL, WH, CG …) and* e_j*= random error*

Results

Qualitative traits

The results of the qualitative traits of sheep reared across the studied locations are presented in Table 2. The chi-square test for assumption of equal proportion of categorical variables in sheep populations sampled from four districts indicated that all the variables considered in this study (coat color pattern, coat color type, hair coat type, horn presence) were found to significantly (P<0.001) differ within the samples sheep population. Accordingly, plain coat color patter had more proportion across sheep reared in Bora, Asasa and Kofele districts with nearly similar proportions. Sheep populations of ATJK had high proportion of patchy coat color pattern with more than half of sampled sheep. The most preferred coat color type was brown with white dominant followed by a mixture of brown with white brown dominant and creamy white. Black coat and grey coat colors had the least preference among the wide ranges of hair coat colors and this was confirmed by small proportions of animals exhibiting black and grey coat color in the sampled population. Black coat color type had higher proportion in sheep populations reared in Kofele and Asasa districts as compared to the other two districts. Sheep population reared in Kofele and Asasa districts had higher proportion of long and course hair coat type while those in ATJK and Bora districts showed higher proportion of short and smooth hair coat types. More than half of the sampled sheep populations in ATJK and Asasa district were horned as compared to those of Kofele and Bora which were characterized by the low proportions of presence of horns.

Table 2. Proportion (%) of qualitative traits in sheep populations across the four districts

Category of traits	ATJK	Bora	Kofele	Asasa	Overall	X^2
Coat color pattern						44.7*
Plain	28.1	57.6	57.3	59.6	38.8	
Patchy	58.4	32.9	30.9	27.5	49.1	
Spotted	13.5	9.4	11.8	12.9	12.0	
Coat color type						84.4*
White	11.2	9.4	7.9	5.8	8.0	
Creamy white	22.5	25.9	8.4	5.3	12.6	
Brown	18.0	20.0	5.1	7.0	10.3	
Black	2.2	0.0	6.2	5.3	4.2	
Grey	4.5	2.4	2.8	4.1	3.4	
White & black, Wd	4.5	5.9	2.8	7.0	5.0	
Brown & white Brd	16.9	15.3	23.0	29.8	22.9	
Brown & white Wd	15.7	16.5	38.8	30.4	28.5	
Black & white Bd	4.5	4.7	5.0	5.3	5.0	
Hair coat type						**201***
Short and smooth	78.7	80.0	19.1	12.9	37.1	
Long and course	21.3	20.0	80.9	87.1	62.9	
Horn						22.1*
Present	60.7	42.4	40.4	62.0	51.2	
Absent	39.3	57.6	59.6	38.0	48.8	

***Significantly different across the districts, ATJK=Adami Tullu Jidokombolcha districts, Wd = white dominated, Brd = brown dominated and Bd = black dominated*

Morphometric traits

Least-squared means of morphometric traits, as well as the significance of the district and age effects, are presented in Table 3. The LW and most of the other linear body measurements was highly significant across the study areas. District had no effect (P>0.05) on RL, RW and HL in the sampled sheep population. Sheep populations reared in Kofele district had higher values (P< 0.01) for LW, BL and TL compared to the rest of the three districts. On the other hand, the Asasa sheep population had lower values (P< 0.01) for BL, CC and TC traits compared with the other sheep populations. In the sheep population studied, age was found to strongly influence (P < 0.01) most morphometric traits except for RL, CBC, CL and TC. There was wide variability as the age of the animals increased for body measurements such as BW, HG and CD. In contrast, RL, RW, HL, CC, and CL were less influenced by age and showed less variation as age advances.

Table 3. Least square means of the morphometric traits as affected by district and age (N = 523)

Traits	Districts				Age (months)			
	ATJK	Asasa	Bora	Kofele	1PPI	2PPI	3PPI	4PPI
Live weight	26.0^{b}	25.9^{b}	25.9^{b}	28.1^{a}	23.6^{d}	25.2^{c}	27.8^{b}	29.0^{a}
Heart girth	70.0^{b}	68.6^{bc}	70.2^{ab}	71.5^{a}	67.0^{d}	68.9^{c}	71.6^{b}	72.8^{a}
Wither height	61.9^{ab}	61.2^{b}	62.4^{a}	62.7^{a}	61.1^{c}	61.9^{bc}	62.3^{ab}	62.9^{a}
Body length	62.0^{b}	59.4^{c}	62.2^{b}	63.9^{a}	60.3^{c}	61.2^{bc}	62.6^{ab}	63.5^{a}
Rump height	63.5^{ab}	62.5^{b}	63.9^{a}	64.3^{a}	62.9^{b}	63.2^{b}	63.9^{ab}	64.3^{a}
Chest depth	30.4^{ab}	29.3^{c}	30.2^{bc}	31.1^{a}	29.1^{c}	30.1^{bc}	30.6^{b}	31.3^{a}
Chest width	17.6^{ab}	17.9^{a}	17.2^{b}	17.9^{a}	17.0^{b}	17.9^{a}	17.7^{a}	18.0^{a}
Rump length	19.6	19.5	19.4	19.7	19.1	19.6	19.6	19.8
Rump width	17.0	16.6	17.2	16.9	16.4^{b}	17.1^{ab}	17.0^{ab}	17.1^{a}
Head length	16.5	16.4	16.7	16.4	16.2^{b}	16.4^{ab}	16.6^{ab}	16.8^{a}
Head width	10.9^{ab}	10.6^{b}	10.6^{b}	11.1^{a}	10.4^{b}	10.8^{ab}	11.0^{a}	11.1^{a}
Ear length	11.2^{b}	11.7^{a}	11.2^{b}	11.9^{a}	11.0^{b}	11.4^{ab}	11.7^{a}	11.8^{a}
CC	6.99^{a}	6.56^{b}	6.93^{a}	6.79^{a}	6.83	6.93	6.72	6.79
Canon length	12.3^{a}	11.9^{b}	12.4^{a}	12.1^{ab}	12.1	12.2	12.2	12.2
Tail length	32.6^{b}	32.7^{b}	31.7^{b}	34.8^{a}	29.6^{c}	34.9^{a}	33.0^{b}	34.2^{ab}
TC	16.8^{a}	14.4^{b}	17.0^{a}	16.6^{a}	16.0	16.1	16.0	16.6
Neck length	22.6^{ab}	22.4^{b}	22.6^{ab}	23.2^{a}	22.2^{b}	22.3^{b}	23.0^{ab}	23.3^{a}

a-d Means with different superscript letters between districts and age groups are significant
CC = canon circumference, TC = tail circumference

Multiple regression analysis

Table 4 shows the results of the regression analysis and coefficient of determination for sheep population studied in different dentition categories. Heart girth was consistently selected and entered into the model staring from step one procedure of stepwise regression and then throughout due to its larger contribution to the model than other variables. In the prediction of body weight the multiple stepwise regressions found only two explanatory variables to be significant (P< 0.01) for all dentition groups. As shown in Table 4, for dentition one and two only HG and RH were significantly contributed to the model and together yielded an R2 value of 58% and 70%, respectively. The dentition group of three and four, HG and BL were selected with R2 values of 61% and 57%, respectively. When the data was pooled, the HG and BL were selected and contributed to the model and together yielded R2 value of 66%. The coefficient of determination (R2) indicated that HG succeeded in explaining most of the variations in predicting LW as compared with the other linear body measurements.

Structural and functional indices

The results pertaining to the structural indices of the sheep reared in the studied locations are presented in Table 5. The results indicate that the body index (BI) values of the sheep varied across the studied locations with higher (P<0.05) values recorded among those reared at Kofele. The body frame index (BFI) values were higher (P<0.05) among the sheep raised at Kofele while those of the sheep population in ATJK and Bora have no significant different.

Table 4. Linear regression equations for the estimation of live weight from linear body measurements and their determination coefficients

Age group	Prediction models	R^2	C(P)	P-value
1PPI	-15.13 + 0.58HG	0.46	61.13	0.001
	-37.83 + 0.39HG + 0.56RH	0.58	39.75	0.001
2PPI	-27.81 + 0.78HG	0.64	51.58	0.001
	-46.02 + 0.70 HG + 0.37RH	0.70	31.58	0.001
3PPI	-32.20 + 0.84HG	0.59	22.53	0.001
	-34.86 + 0.73HG + 0.16BL	0.61	17.20	0.01
4PPI	-26.97 + 0.77 HG	0.54	45.20	0.001
	-32.00 + 0.66 HG + 0.21BL	0.57	29.20	0.001
Overall	-29.39 + 0.80 HG	0.64	112.32	0.001
	-33.16 + 0.70 HG + 0.18BL	0.66	79.84	0.001

HG = heart girth; RH = rump height; BL = body length

Table 5. Structural and functional indices of sheep populations as affected by district

Structural/functional indices	ATJK	Bora	Asasa	Kofele	Overall	CV (%)
Cephalic index (CpI)	66.0	63.7	65.0	67.4	65.5	2.98
Body index (BI)	88.8^{ab}	88.7^{ab}	86.7^{b}	89.5^{a}	88.4	1.22
Body frame index (BFI)	1.00^{ab}	1.00^{ab}	0.97^{b}	1.02^{a}	0.99	1.51
Compact index (CI)	4.19^{b}	4.15^{b}	4.21^{b}	4.46^{a}	4.25	2.73
Proportional index (PrI)	99.9^{ab}	100^{ab}	103^{a}	98.2^{b}	101	1.59
Pelvic index (PI)	87.2	88.7	85.9	86.139	87.0	1.68
Transverse pelvic index (TPI)	26.8	26.9	26.6	26.3	26.6	1.43
Longitudinal pelvic index (LPI)	30.8	30.5	31.1	30.6	30.7	2.39
Relative depth of thorax (RDI)	49.1	48.4	48.0	49.6	48.7	2.08
Thorax development index (TDI)	1.13	1.12	1.12	1.14	1.13	1.18
Dactyl thoracic index (DTI)	9.99	9.90	9.58	9.51	9.75	3.03
Dactyl costal index (DCI)	40.0^{ab}	40.6^{a}	36.9^{b}	38.0^{ab}	38.9	3.62
Body ratio index (BRI)	0.98	0.98	0.98	0.98	0.98	0.84
Conformation/baron index (ConI)	79.4	79.1	77.2	81.6	79.3	2.71
Area index (AI)	3847^{ab}	3885^{ab}	3640^{b}	4014^{a}	3847	2.89
Relative cannon thickness (CTI)	11.3	11.1	10.7	10.8	11.0	3.76
Balance index (BaI)	0.63^{ab}	0.65^{a}	0.62^{ab}	0.59^{b}	0.62	2.62
Pictorial index (PtI)	1.99	1.97	1.95	2.02	1.98	2.11
Width slop index (WSI)	0.97^{ab}	1.01^{a}	0.94^{b}	0.95^{b}	0.96	2.16
Height slope index (HSI)	1.60	1.47	1.36	1.58	1.50	27.4
Fore leg index (FLI)	31.5	32.2	31.9	31.7	31.8	2.55
Weight	27.7^{ab}	28.0^{ab}	26.2^{b}	29.6^{a}	27.9	5.30

a-cMeans with different superscript letters between districts are significant, ATJK = Adamitulu-Jidokombolcha

The values of the compact index (CI), area index (AI) and weight were varied among the sheep reared across the studied areas with higher ($P<0.05$) values among those reared at Kofele. Proportional index (PrI) and balance index (BaI) were also significant ($P<0.05$) with lower value at Kofele sheep population. The results further indicated that the dactyl costal index (DCI), balance index (BaI) and width slop index (WSI) were higher among the sheep raised at Bora district. Sheep population of Asasa had higher values for BI, BFI, DCI, area index and weight.

Discussion

Qualitative traits

The predominant coat color patterns were plain and patchy with different proportions of appearance. Plain coat color pattern was the dominants and observed in the three districts except at ATJK districts. This result agrees with Mesfin (2015) for sheep breeds around Woleyita zone and Melesse et al (2013) for sheep population in southern regional state that report plain coat color pattern was the dominant in the respective study sites. Similar to this study, Wossenie (2012) reported that Hararghe Highland sheep had coat color pattern plain (52.2%) and patchy (47.8%) with the most frequently observed predominant coat color being light brown (35.3%), light brown with white patch (29.1%) and white (23.9%) and Bosenu (2012) reported that out of the sampled 155 ewes, 57.42% were plain, 38.71% patchy and 3.8% had spotted coat pattern which was almost in good agreement with the current study. The patchy coat color have higher proportion in Kofele, while sheep population of Asasa, ATJK and Bora districts have higher plain coat color pattern than those found in the Kofele district. This may be agro-ecological impact as well as both natural and society selection.

The most dominant hair coat color of sheep in the study area were Brown & white with white dominant followed by Brown & white with brown dominant, Creamy white and Brown. This was more or less comparable with the study of (Mesfin, 2015) in Woleyita zone. The results were in good agreement with the findings of Tibbo and Ginbar (2004) and Edea et al. (2010) for Horro and Bonga sheep. While black coat color mostly unwanted color due to less market demand across all the districts. Pure white coat color was unwanted color in both Kofele and Asasa due to less resistance for cold air condition and disease caused due to evil eyes ”YesewuAyin”. Previous reports noted that black coat color was generally less preferred color in most parts of Ethiopia (Zewdu et al 2012). According to Stone et al. (1992), coat thickness alters the quantity of metabolizable energy necessary for maintenance, as the difficulty in liberating latent body heat causes the body to use compensatory mechanisms which lead to energy generation. Yeates (1954) showed that thin, smooth skin was associated with resistance to heat stress and that thick skin would be a survival threat in environments where the temperature was above 40.5°C. Finch et al. (1984) also showed that thick hairy skins were associated with resistance to body heat dissipation. Tropical breeds of animals have a highly pigmented skin and a white or light colored coat, which is a consequence of natural selection. This helps to protect the tissues under the skin of the animal from short wave ultraviolet radiation which easily penetrates the thin skin of temperate animals (Silva et al. 2003). Gebremedhin et al. (2008) studying coat color differences in Angus cattle found that white cattle sweated more and had lower body temperatures than black-coated animals. Coat length and thickness are important traits linked to animal adaptation in the tropics, where longer hair is linked to animals more affected by heat stress (Yeates 1955).

The findings to the hair coat type indicated that the most common hair coat color is long and course type with statistically different ($P<0.05$) across districts. This was comparable with that of Solomon (2008) who reported that the Arsi-Bale, Bonga and Afar sheep were characterized by hairy fiber hair. The sheep in Kofele and Asasa were characterized by having long and course hair type. Whereas sheep found in ATJK and Bora districts possess short and smooth hair type. This may related to the agro-ecology of the study areas, the first two districts were found in highland altitude and the second two districts were found in mid-altitude. Hair coat type and coat color were adaptation mechanisms by which the animal adapt to the environment they live in (Mechael, 2013)

Most of sheep populations in all districts were characterized by the presence of horns, which concurs with the findings of Tibbo and Ginbar (2004), Getachew et al. (2010) and Mechael (2013). In contrary, Solomon, (2008) and Edea et al., (2010) reported that both the rams and ewes among the Bonga and Horro sheep breed were polled. Generally, the studied sheep populations were reared in geographically different areas without frequent mixing of the breeding animals, which also contributes to the phenotypic divergences among them. Thus, larger differences in qualitative phenotypic traits imply larger distances among the population.

Morphometric traits

The results pertaining to the morphometric traits show that there were differences in skeletal dimensions and body weight of the sheep across ages and districts and the results are in accordance with the reports of Amelmal (2011) and Michael (2013). The body weight of the sheep population as observed in the present study were in close accordance with the findings of Duguma et al.(2017) for Afar breed of sheep. The average values were, however, lower than those reported by Markos and Ginber (2004) for Bonga ewe reared in Keffa, Sheka and Bench communities; and Gizaw et al (2007) for Gumuz ewes in Amhara communities. This may ascribed that the skeletal dimension was grossly influenced by the mineral available to the livestock especially calcium and phosphorus (Dele, 2014).The skeletal dimension also influences the muscle attachment area thereby influencing the body weight and the stability of the animals (Banerjee, 2015). One must have in mind that the field work was done during the driest season, so animals were not certainly in their best corporal condition. Thus, changes in environmental and nutritional conditions primarily affect the muscles and the fat, in that order (Cost et al., 2014). Sheep of Kofele district possessed the heaviest body weight and longest linear body measurement traits than the other three districts. This may suggest that sheep population in Kofele district have an environment that favors sheep keeping.

The overall chest girth values of ewes obtained from the current study were comparable to those reported by Sisay (2002) for mature female rift valley and central highland sheep. However, chest girth value reported by Tibbo et al. (2004) for Horro yearling sheep were lower than observed in the current study of the same age. In contrary, chest girth values reported by Mengiste (2008) for Washera yearling sheep were greater than which observed in the current study of the same age. These variations might be explained by the fact of differences in the genotype and production environments in which animals have been reared (Getachew et al., 2010). The height at withers and body length in ewes observed in this study were comparable to those reported by Gizawu et al. (2007) for Gumuz sheep and Sisay (2002) for central highland and north-western highland sheep. The height at withers of ewes was also in line with the findings of Mengistie et al (2011) for Gumuz ewes and Tibbo et al. (2004) for Horro and Menz ewes. The ear length of sheep reported/obtained in the study areas has similarity with the observations of Taye et al. (2010) and Abegaz et al. (2011). The ear length in the present study was longer than that of reported for Abergelle ewes (Seare et al., 2007).

Body weight and most of body linear measurements in this study showed significant variability in an increasing trend as animal age advances. This implies that growth patterns of the animal might be explained well by body dimension measurements. Accordingly, animals in dentition group of 3 and 4 had higher values than those between 1 and 2 dentition categories. This shows that younger animals (in dentition one and two) were still growing compared to animals at advanced age. This result is in line with that of Jemal et al. (2018) who reported similar results on Dorper, local sheep and their crossbred sheep population in northeastern Amhara region. Body weight, height at withers, chest depth and chest girth significantly increased as the age advances which implies that there was is linear increase in their body size or skeletal size (Jemal et al., 2018).

Prediction of body weight from morphometric traits

Assessment of body weight is important both for commercial purposes and also from the veterinary point of view where the dosages of the medicines are usually provided based on the body weight

(Fasae et al., 2006). The weights of the animals are also correlated with the skeletal dimensions, as weight of the bones comprises a bulk of the weight of the animals (Afolayan et al., 2006).Thus, the wider and the longer the bones, the higher are the weight of the animal (Atta and El kahidir, 2004).The study indicates that the accuracy of the prediction improves when higher numbers of traits were taken into account (Kahi and Nitter, 2004). However, under the field conditions, a reasonable balance between accuracy and numbers of traits to be included have to be decided as there were hardly any restraining mechanisms available (Zewdu, 2008). The inclusion of body length in assessment of weight of a ewe has been reported (Michael, 2013). Taking into account the assessment of body weight, the chest girth have been reported as a viable predictor in several studies (Zewdu, 2008; Tesfaye, 2008; Gizawu et al., 2007 and Kedjela, 2010) which makes it one of the most popular and easily measurable trait. The present results indicated that morphological measurements could be used fairly for prediction of body weight. However, the use of body measurements to predict body weight should be considered with care due to multi-collinearity, which has been shown to be associated with unstable regression estimates (Ogah, 2011).

Body indices

Morphometric indices are used to describe the size and proportion of an animal, which are the relationship among various linear body measurements (Khargharia et al., 2015). The indices were calculated from morphometric measures of body size and are generally used for the estimation of proportions and conformation of animals (Pares Casanova et al., 2013). Calculating of structural indices can thus, serve as useful tool to assess the balance between aesthetics and production potential of animals (Banerjee, 2015). The values pertaining to the BFI in the current study was in close accordance with the results of Salako (2006) for West African Dwarf sheep and Banerjee (2015) for Garole sheep.

The result of BI of current study was higher than reports of Pare´s-Casanova et al. (2013) for Zambian fat tail sheep and Banerjee (2015) for Garole sheep in west India. Body index is used to determine an animal’s proportions (Cerqueira et al., 2011). A lower BI value for an animal indicates that it is closer to being rectangular and is indicative of better conformation for meat production (Cerqueira et al., 2011). The BI value can be influenced by both genetic and non-genetic factors (Chaco´n et al. 2011). The findings indicate that the sheep populations studied were of medigiline type,(BI value range from 80 to 120) as well as BI values were well corresponds to the value of BFI by describing the sheep as meat type exhibiting a square body frame which is in agreement to those reported by Pare´s-Casanova et al. (2013) and Banerjee, (2015). The compact index showed that the animals were suitable for meat production, and they had good thoracic development. This was an important criterion for animals in terms of fitness and good respiratory system, especially in high altitude of Kofele and Asasa. Studied sheep populations were relatively narrower at the fore quarter than the hindquarter. This agrees with the report of Banerjee (2015) and Chaco´n et al. (2011) who reported that sheep under their study have narrower forequarter. The BRI indicates that those sheep populations were low in the front (the hind region is taller than the fore region) which agrees with the result of Banerjee (2015) who reports that Garole sheep breed in India show a characteristic of shorter forequarter than hindquarter.

The baron index in this study were low, which indicate that the sheep population can traveled long distance (Cerqueira et al., 2011). This trait is very important for Ethiopian environment where animals travel long distance in searching of feed and water. The WSI was higher among the sheep reared at Bora district. The WSI indicated that the chest of studied sheep populations was wider than the pelvic girdle, indicating that the animal has well sprung ribs with enough space for large lung space which is in agreement with results of Salako (2006) for West African Dwarf and Yankasa sheep. The study also indicated that HSI of sheep population is aligned towards the front and that the back of the sheep was higher than the front of the sheep. The DTI provides information about conformation and whether an animal is more appropriate for meat or milk production (Bravo and Supelveda, 2010; Cerqueira et al., 2011; Khargharai et al., 2015). Relatively low values of DTI (lower than 10) were obtained for the studied sheep population, which means these sheep types are of relatively light in their body size making them well adapted for walking longer distances

(Markovic et al., 2019). Thorax development index was important for the animals in terms of their fitness, good thorax development, and capacity of the respiratory system, especially for breeds reared at higher altitudes (Esquivelzeta et al., 2011; Chacon et al., 2011). The pelvic index (PI) is used to determine the proportionality of the hindquarters and could be related to reproductive capability (Cerqueira et al., 2011).

Conclusion

Significant variations were observed both in qualitative and quantitative morphometric parameters of sheep across the studied locations. Stepwise regression analysis shows that chest girth was selected first, which explain more variation than any other linear body measurement traits. Variation in estimators and accuracy for body weight using linear measurements would be expected, as sheep studied were raised under varying environments and under different nutritional regimes. This variation is very important for genetic improvement through selection in open nucleus and community-based selection. From the results of body indices, the sheep population in the study districts could be characterized as meat phenotype.

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Appendix Table 1. The body measurement indices and their calculation

Name of body measurement index	Calculation
Body index	(Body length / thoracic girth) * 100
Cephalic index	(Head width / head length) * 100
Cranial index	(Head width / head length) * 100
Dactyl–thoracic index	(Cannon perimeter / thoracic girth) * 100
Depth index	Chest depth / withers height
Foreleg length	Withers height - chest depth
Height index	Withers height / body length
Height slope	Withers height – rump height
Pelvic index	(Hip width / hip length) * 100
Relative cannon thickness index	(Cannon perimeter / withers height) * 100
Rump-length index	(Hip length / body length) * 100
Weight index	Body weight x withers height
Length index	Body length/wither height
Width slope	Hip width/chest width
Balance	(Rump length * hip width)/ (chest depth *Chest width)
Cumulative index	(Weight /breed average weight) **+** length index **+** balan
Transversal pelvic (TPI)	Rump width/withers height * 100
Longitudinal pelvic (LPI)	Rump length/withers height*100
Proportionality (PRI)	Withers height/body length*100

Describing the Indigenous Goat Populations of South Gondar Based on Morphometric Features and Zoometric Indices: The Primary Step for Conservation

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Abstract

This study was conducted to describe the indigenous goat populations of South Gondar, Ethiopia based on morphometric traits and body indices. Multi-stage purposive sampling technique was applied to select the study districts, kebeles, and individual households. To this effect, morphometric measurements were taken from 512 goats (153 male and 359 female) drawn from three districts (Farta, Fogera and Libokemkem). Twenty structural indices were computed from morphometric measurements. Data on morphometric traits were subjected to GLM procedures of the Statistical Analysis System (SAS, 2012, ver. 9.4) by fitting district, sex and age as fixed effects while structural indices were analyzed by fitting district and sex as main effects. Results indicated that age at first kidding and kidding intervals was 13.6 and 8.39 months, respectively, with an average litter size of 1.54 kids. Sex affected (p<0.001) all quantitative traits except ear length (EL), rump width and canon circumference being higher in bucks than in does. The effect of age was significant (p<0.001) for all morphometric traits except for EL resulting in a linear increase with advancing age in both sexes. Except for EL and scrotal circumferences, all quantitative traits were (p<0.01) affected by district of the goats rearing. Accordingly, goats of Fogera district had higher live weight (LW), heart girth (HG), height at withers(HW), body length (BL), chest width (CW), rump height, rump length (RH) and teat length (TL) than those of Libokemkem district. Goats of the Fogera district had also the highest LW and HG compared with those of Farta. Conversely, the goats from Farta district had higher (p<0.01) rump width, body length, teat length, rump length, chest width, chest depth, and paunch girth than those of Libokemkem. Goats at Libokemkem district were inferior in most of the studied morphometric traits. Heart girth (HG) was identified as best predictors of LW in both sexes. Structural indices indicated that the goat populations could be characterized as meat phenotype with short legs being well adapted to midland altitudes. In conclusion, goats reared in the region could have a genetic potential for meat production with very good prolificacy. The goats from Fogera district were particularly better in most morphometric traits suggesting their suitability for meat production. However, further on-station research is recommended to verify their potentials as meat animal in the region.

Keywords: body indices, indigenous goat, morphometric traits, reproductive traits, South Gondar

Introduction

Ethiopia is home of about 52.5million goats in which nearly all of them are of local breeds (CSA, 2020/2021).They are reared in a crop-livestock and agro-pastoral farming systems, and are widely distributed across different agro-ecological zones of Ethiopia (Gizaw et al., 2010; Hassen et al., 2012; Dea et al., 2019). Goat meat production in Ethiopia had increased by 2% between 2005 and 2012 and expected to further increase in the upcoming years due to increased domestic and export demand for goat meat (Getachew and Fadiga, 2014). Moreover, in areas where there is a financial and physical limitation for resources to keep large ruminants, goat milk production is valued the most. Recent studies conducted by Wodajo et al. (2020) indicated that the respective 78% and 64% of women and men in Ethiopia related the importance of rearing goats with food security as compared with other livestock species.

The characterization of local animal genetic resources (based on morphological traits) plays a very fundamental role in classification of animals based on their size and shape (Melesse et al., 2013). It presents the primary step to be undertaken for the sustainable utilization of the available animal genetic resources through conservation(Melesse et al., 2021; Tade et al., 2021). Data obtained from such studies could also provide valuable information on the suitability of animals for selection (Mwacharo et al., 2006). Moreover, structural and functional indices could be calculated from quantitative data that are obtained from any morphological characterization studies. These indices are the combinations of several linear measurements that could offer estimation of an animal's structural conformation and functional trends as compared to individual measurements alone (Salako, 2006; Chacón et al., 2011).

Characterization studies conducted by various scholars have reported the existence of phenotypic variations among Ethiopian goat populations between and within these goat ecotypes (Hassen et al., 2012; Gatew et al., 2015; Dea et al., 2019; Melesse et al.,2021). However, there is limited characterization studies conducted to describe the genetic potentials of indigenous goat populations found in Amhara Regional State in general and that of South Gondar zone in particular. For example, Hassen et al. (2012) conducted a morphological characterization study on indigenous goats in the representative zones of Amhara Region. Although South Gondar zone was one of them, the respective potential districts for goat production were not adequately represented in the study. In addition, reports dealing with structural and functional indices of goat populations in Ethiopia are generally scanty except those works reported by Chiemela et al. (2016) and Dea et al. (2019) for goats reared in specific locations with very few sample size. To the authors' knowledge, there is no information in the literature reporting on the structural indices of local goat populations in south Gondar. As a result, the potential of local goats as meat, dairy and dual-purpose phenotypes has never been reported using structural indices. Therefore, the aim of this study was to systematically characterize the indigenous goat populations of South Gondar region, Ethiopia based on morphometric traits and structural indices.

Materials and Methods

Sampling procedure

First, the relevant second hand information was collected from Agriculture and Rural Development office of South Gondar zone, Ethiopia. Based on the obtained information, multi-stage purposive sampling techniques were applied to select the study districts, kebeles (the smallest administrative units within a district), and individual households. In the first stage, three districts namely Farta, Fogera and Libokemkem were selected purposively according to their goat production potential. The number of goats raised in the respective Farta, Fogera and Libokemkem districts were 45,634, 41, 326 and 61,770. In the second stage, based on the distribution of goat's population, three kebeles from each district were selected purposively. In the third stage, the households within kebeles were selected who possess at least five matured goats of both sexes and have long enough experiences in rearing goat.

The number of goats tested, by region of rearing, sex and age are presented in Table 1. For morphological characterization, a total of 512 goats were sampled of which of which 153 and 359 were males and females, respectively. The owner's recall method along with dentition classes (pairs of permanent incisors, PPI) were used to estimate the ages of the goats. Consequently, goats with 1PPI, 2PPI, 3PPI and 4PPI were classified in the age groups of yearling, 2-year-old, 3-year-old and 4-year-old, respectively (Ebert and Solaiman, 2010). Each animal was further identified by its sex and sampling site.

Table 1. Number of goats tested, by district, sex and age

Age of the goats	Districts					
	Farta		Fogera		Libokemkem	
	Males, N=50	Females, N=102	Males, N=52	Females, N=104	Males, N=51	Females, N=153
1 – 2	18	26	20	26	20	40
2 - 3	15	21	14	25	14	38
3 - 4	11	22	10	27	11	37
> 4	6	33	8	26	6	38
Total	50	102	52	104	51	153

Data collection procedures

Morphometric traits - Data on 14 morphometric traits were collected according to the descriptor list of FAO (2012) for phenotypic characterizations of goats. Accordingly, the following traits were measured: live weight (LW), body length (BL), height at withers (HW), heart girth (HG), chest depth (CD), chest width (CW), paunch girth or abdominal circumference (PG), rump height (RH), rump length (RL), rump width (RW), ear length (EL), fore cannon circumference (FCC), teat length (TL) and scrotal circumference (SC). All measurements were taken using plastic tape while LW using a suspended weighing scale with 50 kg capacity by placing each animal in a self-devised holding equipment. All measurements were taken early in the morning prior to feeding.

Structural and functional indices - To assess the type and function of indigenous goat populations in the study area, 20 structural and functional related indices were computed from the morphometric traits according to the methods of Chacón et al. (2011), Khargharia et al. (2015) and Barragán (2017). The following structural and functional indices were calculated according to method suggested from those authors.

Statistical analysis - Data on morphometric traits were subjected to GLM procedures of Statistical Analysis System (SAS, 2012, ver. 9.4) by fitting district, sex and age as fixed effects while structural indices were analyzed by fitting district and sex as main effects. When F-test declared significant, means were separated by Duncan multiple range test. Correlations of morphometric traits were computed for each sex separately using Pearson correlation coefficient. Moreover, stepwise regression procedure of SAS was used to regress LW on morphometric traits to determine the best-fitted regression equation for LW prediction in both sexes.

Results

Reproductive traits

According to the respondents, the overall mean age at first mating for males was 7.76 months (Table 2). The overall mean age at first kidding was 13.6 months. There were significant differences ($p<0.05$) among districts in kidding interval of does in which goats of the Libokemkem district had the shortest than those of the Fogera. The reproductive lifespan of does from Libokemkem district was ($p<0.05$) higher than those of the Farta and Fogera districts. However, the shortest lifespan was observed in bucks raised in Farta district and differed ($p<0.05$) with those of the Libokemkem.

Table 2. Average maturity ages (in month) and reproductive lifespan (in year) of goats reared in three districts

Parameters	Farta	Fogera	Libo-kemkem	Overall mean	SEM
Age at first mating of bucks	7.88	7.80	7.59	7.76	0.11
Age at first kidding	13.8	13.7	13.5	13.6	0.12
Kidding intervals	8.39^{ab}	8.51^{b}	8.27^{a}	8.39	0.07
Litter size	1.47	1.49	1.65	1.54	0.08
Average reproductive lifespan of does	7.63^{a}	7.76^{a}	8.16^{b}	7.85	0.11
Average reproductive lifespan of bucks	5.65^{a}	6.00^{ab}	6.35^{b}	6.00	0.13

a,b - Row means with different superscript letters are significant at $p<0.05$; SEM = standard error of the mean.

Morphometric traits

As presented in Table 3, district had significant effect on all morphometric traits except EL and SC. Accordingly, goats of the Fogera district had higher ($p<0.05$) LW, BL, HG, HW, CW, HR, RL and TL than those of Libokemkem. The values for BL, CD, CW, PG, RL, RW and TL for goats of Farta districtwere larger ($p<0.05$) than those of the Libokemkem. The goats of the Fogera districthad the highest LW and HG as compared to those of Farta and Libokemkem districts, while the goats at Farta had the highest CD, PG and RW. The FCC in goats of the Farta and Libokemkem districtswas higher ($p<0.05$) than that of Fogera. The effect of sex was significant ($p<0.001$) for all morphometric traits except RW, FCC and EL being higher in males than in females. Age had also significant ($p<0.001$) effect on all linear body measurement traits except for EL. Accordingly, most mophometrical traits increased ($p<0.05$) with age of both sex groups. The overall coefficient of variation (CV) ranged from 1.27% in HW to 11.8% in FCC. Relatively higher CV was also observed in RW, EL and TL.

Phenotypic correlations among the morphometric traits

Phenotypic correlations between traits are shown in Table 4 for males and females separately. Regarding females, all morphological traits showed significant correlations; however, the EL (similar as in males) showed a different behavior being insignificant with other traits. In both male and female goats, LW was strongly and positively correlated ($p<0.001$) with all morphometric traits except EL. In female goats, the magnitude of the correlation of LW with HG, BL and HW was exceptionally high ranging from 0.93 to 0.96. Similarly, in male goats, the degree of association of LW was highest with HG (0.95), HW (0.94) and BL (0.91).

Moreover, positive and strong associations were observed in female goats between BL and HW, CD and HR whereas in male goats, it was among PG, HW, HG and CD traits all being highly significant ($p<0.001$). Height at withers was also positively correlated with HG, HR and CW while in males it was associated with HG, HR and CD ($p<0.001$). Although insignificant, EL of female goats was negatively correlated with FCC and RL whilst in males it correlated negatively with CW, HR, RL, RW and SC. A positive correlation of SC with RL ($p<0.05$) and RW as well as PG ($p<0.01$) was also observed. An interesting positive and strong correlation of TL was further observed with LW, HW, CD and HR amid similar values ranging from 0.80 to 0.82.

Prediction of live weight from morphometric traits

Multiple linear regression models that are developed for predicting the LW of goats from morphometric traits are presented in Table 5. Stepwise multiple regressions were used to predict LW from morphometric traits, which had a significant positive correlation with this variable. The small C (p) indicates precision and small variance in estimating the population regression coefficients while the coefficient of determination (R^2) represents the proportion of the total variability explained by the model. R^2 increased as new variable was added to the model resulting in reduced C (P) value. However, when new variables are added to the model, it might increase the error and becomes impractical to use at farmer's management level. In the current study, the regression analysis indicated that HG could accurately estimate LW of female and male goats when weighing scales are not available or affordable to smallholder farmers with limited income.

Table 5. Multiple linear regression analysis indicating models fitted to predict body weight from linear body measurement traits in male and female goats

Sex	Model	I	β1	β2	β3	R^2	C/(p)
Male	CG	-64.35	1.30			0.90	267
	CG+BL	-57.45	0.84	0.434		0.96	28.3
	CG+BL+HW	-56.41	1.26	0.349	0.279	0.98	5.76
Female	CG	-59.08	1.225			0.92	889
	CG+BL	-54.06	0.75	0.48		0.95	33.0
	CG+BL+HW	-51.2	1.17	0.417	0.155	0.96	1.18

CG = Chest girth; BL= body length; HW = Height at wither; I = intercept

Table 3. Effect of sex, age and district on live weight (kg) and morphometric traits (cm) in indigenous goat populations

Traits	Overall Mean	CV, %	District				Sex			Age				
			Farta	Fogera	Libok	Pr>F	M	F	Pr>F	1PPI	2PPI	3PPI	4PPI	Pr>F
LW	28.6	3.83	28.6^{b}	29.0^{a}	28.4^{b}	<0.001	30.0	28.0	<0.001	25.1^{d}	27.4^{c}	30.5^{b}	32.5^{a}	<0.001
BL	60.4	2.14	60.7^{a}	60.6^{a}	59.9^{b}	<0.001	61.2	60.0	<0.001	57.3^{d}	59.2^{c}	61.8^{b}	64.1^{a}	<0.001
HW	68.0	1.27	68.0^{ab}	68.1^{a}	67.9^{b}	0.033	68.8	67.6	<0.001	65.2^{d}	67.1^{c}	69.4^{b}	71.1^{a}	<0.001
HG	71.5	1.52	71.3^{c}	71.9^{a}	71.5^{b}	<0.001	72.5	71.1	<0.001	68.9^{d}	70.8^{c}	73.0^{b}	74.3^{a}	<0.001
CD	30.1	3.04	30.5^{a}	30.2^{b}	29.8^{c}	<0.001	30.8	29.8	<0.001	27.5^{d}	29.3^{c}	31.5^{b}	33.0^{a}	<0.001
CW	15.7	4.80	15.8^{a}	15.8^{a}	15.5^{b}	0.001	16.3	15.4	<0.001	14.1^{d}	15.5^{c}	16.4^{b}	17.2^{a}	<0.001
PG	75.7	2.60	76.4^{a}	75.9^{b}	74.9^{c}	<0.001	77.4	74.9	<0.001	71.9^{d}	74.2^{c}	78.1^{b}	79.6^{a}	<0.001
HR	70.7	1.56	70.7^{ab}	70.9^{a}	70.5^{b}	0.004	71.3	70.5	<0.001	68.0^{d}	70.0^{c}	72.2^{b}	73.4^{a}	<0.001
RL	16.0	4.94	16.1^{a}	16.0^{a}	15.8^{b}	0.001	15.7	16.1	<0.001	15.0^{d}	15.7^{c}	16.4^{b}	17.2^{a}	<0.001
RW	13.0	9.58	13.5^{a}	12.8^{b}	13.0^{b}	<0.001	13.1	13.0	0.939	11.2^{c}	13.3^{b}	14.0^{a}	14.2^{a}	<0.001
FCC	7.88	11.8	8.00^{a}	7.69^{b}	7.94^{a}	0.007	7.88	7.88	0.900	7.20^{d}	7.69^{c}	8.11^{b}	8.72^{a}	<0.001
EL	14.6	7.26	14.7	14.6	14.5	0.220	14.7	14.5	0.080	14.5	14.6	14.6	14.6	0.670
SC	22.9	4.42	22.8	23.0	22.7	0.310	-	-	-	21.9^{c}	23.1^{b}	23.7^{a}	23.9^{a}	<0.001
TL	3.70	6.93	3.74^{a}	3.73^{a}	3.65^{b}	0.007	-	-	-	3.03^{d}	3.49^{c}	4.02^{b}	4.23^{a}	<0.001

a-d - Row means with different superscript letters within the same class are significant at $p<0.05$;
Libok= Libokemkem,M = male, F= Female, LW= live weight, BL= body length, HW= height at withers, HG= heart girth, CD= chest depth, CW= chest width, PG= paunch girth, HR= height at rump, RL= rump length, RW= rump width, FCC= fore canon circumference, EL= ear length, SC= scrotal circumference, TL = teat length.

Table 4. Phenotypic correlations among morphometric traits in males (above the diagonal line, N = 153) and in females (below the diagonal line, N=359). Correlations higher than 0.80 are in bold

	LW	BL	PG	EL	HW	HG	CD	CW	FCC	HR	RL	RW	SC
LW	1	**0.91*** **	0.78	0.06ns	**0.94*** **	**0.95*** **	**0.87*** **	**0.81*** **	0.42***	**0.83*** **	0.55***	0.62***	0.54***
BL	**0.94*** **	1	**0.81*** **	0.07ns	**0.86*** **	**0.81*** **	**0.83*** **	0.78***	0.41***	0.77***	0.51***	0.58***	0.53***
PG	**0.80*** **	0.79***	1	-.05ns	0.76***	0.73***	0.78***	0.72***	0.29**	0.73***	0.48***	0.54***	0.42**
EL	0.05ns	0.07ns	0.02ns	1	0.03ns	0.05ns	0.01ns	-.01ns	0.02 ns	-.01ns	-.04ns	-.01ns	-.02ns
HW	**0.93** **	**0.89*** **	**0.81*** **	0.03ns	1	**0.90*** **	**0.85*** **	**0.83*** **	0.43***	**0.88*** **	0.55***	0.67***	0.54***
HG	**0.96*** **	0.84***	0.76***	0.02ns	**0.89*** **	1	**0.82*** **	0.77***	0.37***	**0.81*** **	0.49***	0.59***	0.51***
CD	**0.87*** **	**0.86*** **	**0.84*** **	0.03ns	**0.86*** **	**0.82*** **	1	**0.82*** **	0.42***	**0.80*** **	0.56***	0.63***	0.55***
CW	**0.80*** **	0.76***	0.72***	0.10ns	**0.80*** **	0.77***	0.79***	1	0.48***	**0.80*** **	0.57***	0.62***	0.53***
FCC	0.52***	050***	0.47***	-.01ns	0.51***	0.50***	0.52***	0.46***	1	0.38***	0.28**	0.32**	0.19ns
HR	0.86***	**0.83*** **	0.79***	0.03ns	**0.93*** **	0.82***	**0.84*** **	0.78***	0.48***	1	0.47***	0.65***	0.49***
RL	0.71***	0.69***	0.58***	-.01ns	0.71***	0.65***	0.68***	0.60***	0.43***	0.67***	1	0.56***	0.29*
RW	0.56***	0.52***	0.57***	0.04ns	0.56***	0.57***	0.61***	0.57***	0.39***	0.55***	0.40***	1	0.42**
TL	**0.82*** **	0.79***	0.62***	0.01ns	**0.82**	0.77***	**0.80*** **	0.76***	0.20ns	**0.81*** **	0.64***	0.57***	-

Correlations higher than or equal to 0.80 are in bold (p<0.001); *** = p<0.001; ** = p<0.01; * = p<0.05; ns = not significant; LW= live weight, BL= body length, HW= height at withers, HG= heart girth, CD= chest depth, CW= chest width, PG= paunch girth, HR= height at rump, RL= rump length, RW= rump width, FCC= fore canon circumference, EL= ear length, SC= scrotal circumference, TL= teat length.

Structural and functional indices

As shown in Table 6, district had significant effect only on longitudinal pelvic index (LPI), girth index (GI), dactyl costal index (DCI) and balance index (BaI). Accordingly, goats of the Farta districthad higher LPI and GI values than those of the Libokemkem. Moreover, DCI and BI values were larger in goats of the Farta than that of the Fogera district. The effect of sex was significant for DCI, BaI, height slope index (HSI), LPI, body ratio index (BRI), conformation index (ConI), GI and compact index (CI). Female goats had larger ($p<0.05$) BaI, DCI, HSI and LPI values than males, whereas males were better in BR, ConI, GI and CI indices than females.

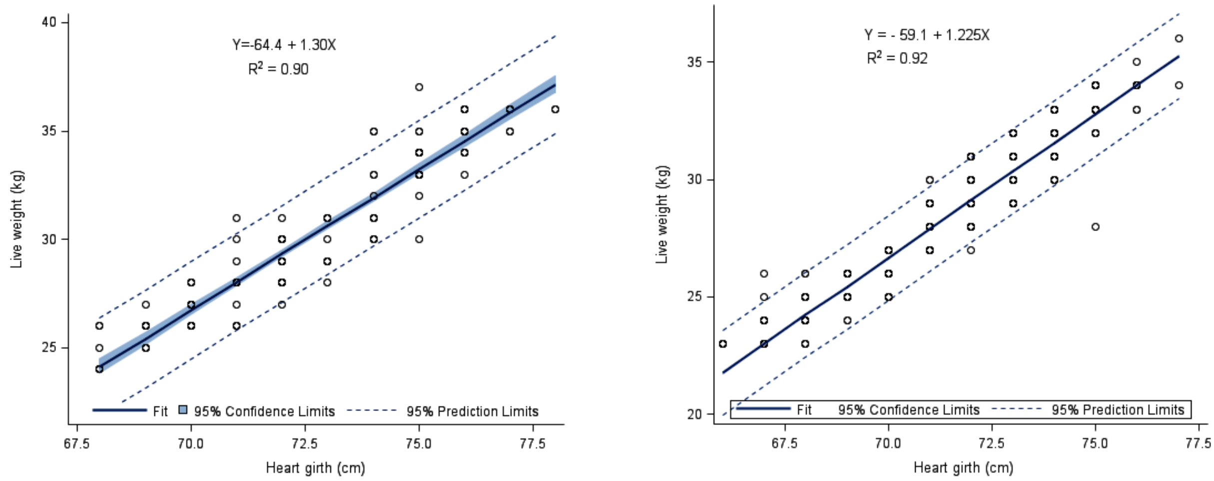

Figure 1. Live weight (Y) prediction of south Gondar bucks (left) and does (right) by fitting heart girth (X) in the regression model

Table 6. Structural and functional indices of goat populations as affected by district and sex

Structural/functional indices	District			Sex		Overall
	Farta	Fogera	Libok	Male	Female	mean
Body index (BI)	85.3	84.4	84.2	84.9	84.4	84.6
Body frame index (BFI)	0.893	0.893	0.886	0.894	0.887	0.890
Compact index (CI)	4.27	4.34	4.28	4.47[a]	4.13[b]	4.30
Proportional index (PrI)	89.4	89.0	88.6	89.3	88.8	89.0
Pelvic index (PI)	84.3	80.1	83.6	84.4	80.9	82.7
Transverse pelvic index (TPI)	20.1	18.7	19.2	19.4	19.3	19.3
Longitudinal pelvic index (LPI)	22.9[a]	22.5[ab]	22.1[b]	22.2[b]	22.8[a]	22.5
Relative depth of thorax (RDI)	44.9	44.7	44.3	45.2	44.0	44.6
Thorax development index (TDI)	1.048	1.055	1.053	1.053	1.051	1.052
Dactyl thoracic index (DTI)	11.2	10.7	11.0	11.0	11.1	11.0
Dactyl costal index (DCI)	49.8[a]	48.2[b]	50.7[a]	48.1[b]	51.0[a]	49.6
Body ratio index (BRI)	0.963	0.961	0.965	0.968[a]	0.958[b]	0.963
Conformation/baron index (ConI)	75.3	76.5	76.0	77.2[a]	77.7[b]	75.9
Area index (AI)	4213	4216	4188	4358	4054	4206
Relative cannon thickness (CTI)	11.8	11.3	11.9	11.6	11.6	11.6
Balance index (BaI)	0.450[a]	0.419[b]	0.429[ab]	0.410[b]	0.457[a]	0.433
Pictorial index (PtI)	1.853	1.846	1.833	1.859	1.828	1.844
Width slop index (WSI)	0.193	0.178	0.183	0.186	0.183	0.184
Girth index (GI)	1.074[a]	1.060[ab]	1.054[b]	1.071[a]	1.054[b]	1.063
Height slope index (HSI)	2.63	2.64	2.63	2.35[b]	2.92[a]	2.63

a-d Means with different superscript letters across the column within a group are significant; Libok= Libokemkem

Body (BI), Body frame (BFI), proportionality (PrI), pelvic (PI), transversal pelvic (TPI), relative depth of thorax (RDI), dactyl thorax (DTI), thorax development (TDI), pictorial (PtI), area (AI), width slope (WSI) and relative cannon thickness (CTI) indices were similar across districts and sex groups. Although not significant, goats of the Fogera districthad relatively lower PI than other goat populations. Similarly, bucks had higher PI and AI values than females. The thorax development index (TDI) was similar among goats of the Fogera and Libokemkem districtswhile it was lowest in goat population of the Farta district.

Discussion

Reproductive traits

The overall mean age at first kidding in the current study was 13.6 months, which is slightly higher than that of Chanie et al. (2014) who reported 12.2 months of age for local goats. According to reports of Abegaze (2014), age at first kidding for does reared in north-western lowland of Ethiopia were 12.4 months which was lower than observed in the current study. Gatew et al. (2015) reported an extended age of first kidding ranging from 15.9 to 20.2 months for local goats. The possible reasons for such differences among local goats might be due to variations in ecotype, production systems, incidence of diseases and availability of feed resources. Kidding interval is one of the important reproductive traits that influence the general performance of farm animals. The average kidding interval in the current study is in line with that of local goats reported by Muluneh et al. (2016). Sheriff et al. (2019) established a kidding interval of 7.2 to 7.8 months for goats in north-west Ethiopia, which is slightly lower than observed in the present study. The reproductive life spans of male and female goats in the study area were 6.35 and 8.2 years, respectively, which indicate that goats stayed in reproduction for an extended period providing services to their owners. This finding is slightly lower than reported by Sheriff et al. (2019) for Arab and Oromo goats in north-west Ethiopia. The overall average litter size in the current study was 1.54, which may suggest the practice of selecting female goats for improved litter size. The finding is higher than that of Asefa et al. (2015) who reported a litter size of 1.33 in Eastern Ethiopia.

Morphometric traits

The goats of the Fogera district had the highest LW and HG values as compared to those of Farta and Libokemkem. However, goats at Farta district were superior in CD, PG and RW to those of the Fogera and Libokemkem districts while the goats at Libokemkem district were inferior in most of the morphometric traits to those of Farta and Fogera goats. Such variation in quantitative traits might be due to difference in the management practices among the communities and availability of feed and water resources. Moreover, such differences might be explained by the existence of disparity in the genetic makeup of these ecotypes particularly between the Libokemkem and the other two goat populations. This calls for molecular based study to provide proof of existence of dissimilarity among the studied goat populations. Male goats were found to be heavier than the females, which is in good agreement with that of Seid et al. (2016) and Dea et al. (2019) who reported similar findings in goats reared in Western highland (Wollega zone) and Southern lowland (Gamo zone) parts of the country, respectively. In contrary, Jeda and Asefa (2016) established that females goats raised in Eastern Ethiopia had higher LW than those of bucks. These inconsistencies might be attributed to age differences of both sexes in which the data were collected. Moreover, such conflicting results might be because of negative selection practiced by the farmers as fast growing male kids are being sold at earlier age. The LW of male and female goats increased as dentition class increased from 1PPI to age group 4PPI. Such changes are explained by the skeletal muscle development as the age of the animal advances. Moreover, a steady increase in live weight with age indicates the absence of critical feed shortage in the study region.

Ear length of goats reared in the lowland Gamo zone as reported by Dea et al. (2019) was lower than observed in the present study (12.7 vs. 14.6 cm). However, the EL reported for midland Gamo goats reported by the same authors were similar to that of the present study (14.3 vs. 14.6 cm). Goat's ear length is crucial in adaptation of various climatic environments. Correlation of EL with other traits showed a different behavior being insignificant in both sexes. Moreover, EL was not affected by age in both sexes. These observations may suggest that the EL development is less dependent on the size of the animal. The SC is an important trait that is closely associated with the testicular growth and sperm production capacity of domestic animals. Gatew et al. (2015) found relatively higher SC values for bucks in eastern Ethiopia than observed in the current study (27 vs. 23 cm). Since SC size is dependent on the maturity of the animal, the differences could be related to the age of bucks when data were collected. This has been supported by the present observation in which SC consistently increased with advancing age. Moreover, SC showed a significant positive correlation with the body weight (Table 5), which substantiated the dependency of SC on the body development of the animal. Consistent with the current results, Raji and Ajala (2015)observed a significant effect of body weight on SC for West African Dwarf buck. As SC is an indirect measurement of testicular size, knowing the increased size of testis may be used as indicator in the onset of active spermatogenesis and, hence, the possibility of using bucks for breeding at an earlier age than normally recommended. Such knowledge might be particularly essential if young bucks are not kept together with the does for reasons related to control of inbreeding.

Live weight was strongly and positively correlated with some of morphometric traits particularly with HG, HW and BL in both sexes (Table 5). Thus, LW can be predicted based on physical measurements taken from either of the traits by fitting to the regression model. Moreover, other morphometric traits were found to be positively and significantly correlated with each other, which suggests that selection for one of the traits will result in the improvementof the other traits particularly those that might be more difficult or expensive to measure in filed conditions under smallholder production system. The stronger the correlation the higher would be the response to selection in breeding goal trait which is evident in the present study. Thus, selection for correlated traits as observed in the present study might be be suitable genetic improvement strategy in local goats provided the heritability of such traits under selection are reasonably high. Teat length positively affected milk production capacity of does (El-Gendy et al., 2014). Merkhan and Alkass (2011) reported 3.6 cm TL for Iraqi Black and Meriz goats, which is comparable with the current observations (3.7 cm). However, Alemayehu et al. (2015) reported lower TL (3.4 cm) for goats reared in West Amhara region of Ethiopia. The type of breed, feed availability, season, and health conditions of animals might explain such differences. Teat length significantly increased with the age of the does. Although not significant, similar patterns were observed by Merkhan and Alkass (2011) for the Iraqi goats. Since TL is highly and positively correlated with LW, HR, HW and CD (Table 4), then selection of female goats based on this trait will result in a better milk production provided the breeding goal is to enhance milk production.

Structural indices

Morphology of an animal expresses a strong relationship with productive potential, since it contains the structure, which supports the biological functionality of the animal (Alpak et al., 2009). Based on the results of BI, goats in south Gondar could be classified as brevigline. The TDI was slightly above 1.0 indicating a smaller thoracic capacity, which suggests that south Gondar goats are inherently adapted to mid altitude rather than in higher elevations. The PI serves as a racial diagnostic index and is used to determine the proportionality of the hindquarters and thus, related to the reproductive capacity of female goats (Cerqueira et al., 2011). According to the current result (PI=82.7), the goats' rump is described as a convex curve, with a predominance of the rump length over the width. Chacón et al. (2011) reported lower PI (76.0) for Cuban Creole goats while Dea et al. (2019) found much higher values for lowland Gamo goats than observed in the current findings. Such variations might be due to differences in breed and environment effect as well as age and sex of goats when the morphometric measurements were taken.

Proportionality index relates the body height to the body length and designates the shape of a given animal populations (Barragán, 2017). A PrI value less than 100 indicates that the animal's body tends to be rectangular which is a characteristic of meat phenotype, while greater than 100 denotes a square shape, which is an attribute of dairy phenotype (Barragán, 2017). In the current study, the lower PrI (89.0) would classify the south Gondar goat populations as meat type. The DTI helps to classify animals as hypermetric (large format), eumetric (medium format), or elipometric (small format). According to the current DTI result (11.0), the goats in the study region could be classified as eumetric possessing characteristics of medium meat type. The CI, LPI and CTI values further substantiated that goats in the study region to be suitable for meat production. Nevertheless, the south Gondar goat populations showed low aptitude for meat production when assessed by RDI and TPI that serve to estimate the meat aptitude of a given breed (Arredondo-Ruiz et al., 2012; Barragán, 2017). The CI of bucks in the current study is significantly higher than that of females suggesting the former being more suitable for meat production than the latter.

The RDI indicates that south Gondar goats are characterized by relatively short leg that is close to the ground, which may suggest to their adaptation to flat land and mountain terrains. In the present study, the PtIvalues are similar across districts and sex groups indicating that they possess comparable adaptations with short legs as already confirmed by RDI values. The BFI in the current study was 0.89 which indicates that the goats in the study area possess longer body frame with respect to their height at withers suggesting that goats in the study area may possess good space for the development of internal organs and carcass yield. The BRI in the present study is less than 1.0, which suggests that south Gondar goats are lower at wither than they are at the rump. This has been clearly demonstrated in female goats in which they had significantly lower BRI value than the bucks. The HSI has further validated this observation where the value is positive in both sexes being significantly lower in males than in females.

Conclusion

Goats in south Gondar region of Ethiopia demonstrated impressive prolific aptitude by producing above average litter size. Goats of the Fogera districthad the largest body weight and heart girth values than those of the other two districts. Goats reared in Libokemkem district were inferior in most of the studied quantitative traits. Male goats were superior in all traits than females except for rump width, canon circumference and ear length. Heart girth can be used as reliable predictor of body weight in male and female goats. The structural and functional indices indicated that the goat populations of south Gondar can be characterized as meat type with short legs. Further studies are recommended to validate their meat production and prolific potentials under a controlled environment.

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Appendix Table 1. Formula used for assessing structural indices

Indices	Formula	Description
Height slope (HIS)	Height at wither - rump height	
Depth index	Chest depth/ height at wither	
Length index(relative body index)	Body length/height at wither*100	
Body index (BI)	Body length/ heart girth *100	When >90 animal long line, between 0.86 to 0.88 mideline and less than 0.85 it is brevigline
Proportionality (PRI)	Height at wither/body length*100	
Pelvic index (PI)	Pelvic width/rump length*100	
Transverse pelvic index (TPI)	Pelvic width/rump height*100	
Longitudinal pelvic index (LPI)	Rump length/rump height*100	
Relative depth of thorax index (RDI)	Chest depth/ height at wither)*100	
Dactyl depth/thoracic index(DTI)	Cannon bone circumference/heart girth*100	May not be more than 10.5 in light animal up to 10.8 in intermediate ,up to 11 in light meat animal and up to 11.5 in heave meat type
Area index (AI)	Height at wither*body length	
Thoracic development(TDI)	Heart girth/height at wither	Values above 1.2 indicating good thorax development
Body ratio	Height at wither/ rump height	If the withers are lower than the rump, the animal is low in front and vice versa
Conformation/baron index (ConI)	Heart girth^2/height at wither	
Relative cannon thickness index (CTI)	Cannon circumference/height at wither*100	
Pectoral Index (PI)	((HW + HR)/2)/(HW-CD))	This index also indicates thoracic development; when the back height is less than the sternum height, the animal is considered “far from ground”
Balance(Bal)	(Rump length × rump width)/ (chest depth × chest width)	
Girth index (GI)	Paunch girth/ Heart girth	
Width slope(WSI)	Hip width/chest width	
Dactyl-costal (DCI)	Cannon bone perimeter/chest width*100	

Parallel Session IV

Food Safety and Quality

Presence of *Salmonella enterica* and Some Contamination Indicator Bacteria on Beef of Ethiopian Abattoirs

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Abstract

Salmonella continues to be a major food safety and public health threat. In the present study, a total of 150 of beef were examined for the pathogens over a 2-year study (May 2019 through February 2021). The aims of this study were to evaluate the prevalence of Salmonella enterica and its antibiotic resistance profiles, and the contamination level in beef at three abattoirs (SH01, SH02 and SH03), Ethiopia. The detection methods of Salmonella enterica were adapted from the U.S. Food and Drug Administration's Bacteriological Analytical Manual. Additionally, agglutination kit, MALDI Biotyper and RT PCR assay were used for confirmation. The Coliform and E. coli populations were quantified by plating onto E. coli*/coliform petrifilms. All isolates were evaluated for susceptibility to a panel of 13 antimicrobials using disk diffusion method as described in CLSI. A total of 45 S. enterica were identified using MALDI Biotyper. The invA gene was detected in all of the isolates with Ct value ranged from 17.61 - 27.74. The overall prevalence of Salmonella enterica at animal level was 22.7 % (95% CI, 16.0 - 30.0). However, based on the sampling points, Salmonella enterica was detected in 13.3% (95% CI, 8.0 - 18.7) hides; 12.0% (95% CI, 7.3 - 17.3) pre-evisceration; and significantly lowest prevalence of 4.7% (95% CI, 1.3 - 8.0) post-evisceration samples (P < 0.05). The prevalence of Salmonella enterica on beef samples was not different by abattoirs (P > 0.05). Nevertheless, prevalence of Salmonella enterica was significantly higher during wet season (P = 0.011). The overall mean log ± SD of E. coli, coliform and total coliform counts were 4.55±0.99, 4.91±1.13 and 4.98±1.09, respectively. All Salmonella enterica isolates (100%) were susceptible to the 5 antibiotics tested. However, about 20% of the Salmonella enterica isolates were found to be multi drug resistant. The most frequently detected resistance was to Tetracycline (28.9%), followed by Streptomycin (22.2%), Sulfisoxazole (20.0%) and Ampicillin (17.8%). The high prevalence of Salmonella enterica, E. coli and coliform on beef in abattoirs highlight the need to implement interventions and improve sanitation procedures. Thus, applying strict sanitation measures at the abattoirs in Ethiopia is crucial to reduce the risk of carcasses contamination.*

Key words: *Salmonella enterica, Abattoir, Antimicrobial resistance, Contamination, Beef, Ethiopia*

Introduction

Foodborne disease (FBD) is a global public health concern. It remains a significant source of human disease (Jacob *et al.*, 2010; Ahmed *et al.*, 2014; Havelaar *et al.*, 2015; Ferrari *et al.*, 2019). Biological hazards are responsible for 70% of the global burden of foodborne diseases (Havelaar et al. 2015). The most frequent causes of foodborne illness were diarrheal disease agents, among the diarrheal disease agents, especially non-typhoidal *Salmonella enterica* (NTS) were important burden in all sub-regions (Havelaar et al. 2015). A study by (Majowicz et al. 2010) found that, globally, *Salmonella* infection is responsible for an estimated 93.8 million cases of human gastroenteritis and 155 000 fatalities annually. *Salmonella enterica* is also the second most frequently reported zoonotic agent in the European Union (EU) after thermotolerant Campylobacter (EFSA and ECDC 2015). Whereas, in the USA, *Salmonella enterica* is estimated to cause 1.2 million cases of gastroenteritis, 23,000 hospitalizations, and 450 deaths each year (Scallan et al. 2011). The burden of bacterial foodborne disease, including disease caused by NTS, is disproportionately higher in African regions compared with other parts of the world (Havelaar et al. 2015).

Foodborne illnesses are often attributed to the consumption of contaminated food; however, animal source foods (ASFs) are the leading point of exposure to foodborne pathogens (Havelaar et al. 2008; Pires et al. 2009; Hoffmann et al. 2017; Finstad et al. 2012; Ferrari et al. 2019; Grace 2015). Among the ASFs, meat is regarded as a high-risk food owing to their abundant ingredients that could favor the growth of microorganisms (Scharff. et al. 2009). Fresh foods such as beef and its products have been vehicles implicated with transmission of *Salmonella enterica* (H. Xu et al. 2019; Sallam et al. 2014; Finstad et al. 2012; Brichta-harhay et al. 2008; Bosilevac et al. 2019; Laufer et al. 2015). Although the data on key bacterial pathogens is limited in Ethiopia, studies in the country have shown that *Salmonella* spp. are highly prevalent in meat and its products (Kore et al. 2017; Gebremedhin et al. 2021; Alemu and Zewde 2012; Hiko et al. 2018; Zelalem et al. 2019).

The contaminating *Salmonella* in meat was complex and becoming more serious as source of contamination in meat is more and more diverse (Z. Xu et al. 2020). Bacterial contamination of carcasses during the slaughtering process can originate from multiple sources such as the animal's skin and dung, equipment, environment, and personnel (Kh et al. 2012; Hauge et al. 2012; Buncic et al. 2014; Ali et al. 2010). However, the initial microbial load in the gastrointestinal tract and cross-contamination during the slaughtering process are the key contributors of carcass contamination (Arthur et al. 2007; J L Vipham et al. 2015; Akbar et al. 2014; Brichta-harhay et al. 2008). Besides, studies highlighted that pathogens contamination and their occurrences in meat are affected by seasonal variation (Jessie L. Vipham et al. 2012; Z. Xu et al. 2020).

In spite high bacterial contamination of beef in in meat processing plants and retails, the emergence and spread of antimicrobial resistance among zoonotic *Salmonella* has become a public health threat (Z. Xu et al. 2020; Sallam et al. 2014; Ribot et al. 2002). In most developing countries, misuse and overuse of antibiotics has contributed to the increasing trend of multi-resistance in *Salmonella* (Ed-dra et al. 2017). The increased number of human salmonellosis cases might also linked with antimicrobial resistant *Salmonella* (Cui et al. 2016; Barbosa and Levy 2000). Thus, Antimicrobial-resistant *Salmonella enterica* are classified as critical-priority pathogens by the World Health Organization (Tacconelli et al. 2018; Monte et al. 2019).

In Ethiopia, the poor sanitary conditions and abattoir facilities, lack of food safety standards, weak regulatory structure, poor food safety knowledge and practices of meat handlers, and custom of raw meat consumption might increase the risk of *Salmonella* infection (Muleta and Ashenafi 2001; Zelalem et al. 2019; Girma 2015; Delesa 2017). Generally, the food safety practices and microbiological contaminants present in meat plants have been poorly investigated in low-income countries (Casas et al. 2020). The Previous reports on the prevalence, distribution and antimicrobial resistance pattern of *Salmonella* serovars at beef in Ethiopian abattoir (Wabeto et al. 2017; Kore et al. 2017; Hiko et al. 2018) are useful. However, information which assessed the occurrence of *Salmonella enterica* on beef at various seasons (wet vs. dry) with different sampling points (hide, pre-evisceration and post-evisceration) and loads of bacterial contamination of beef at abattoir in Ethiopia is limited. The aim of this study was therefore to determine the prevalence of *Salmonella enterica* and its antimicrobial resistance and level of indicator bacteria on beef samples collected from abattoir.

Materials and Methods

Study design

A cross-sectional study design was used and samples were collected from stunned animals at three abattoirs facilities. Collectively, these abattoirs are providing the highest slaughtering service in Ethiopia. Moreover, the processing facilities are well situated to collect specimens from cattle representing different agro-ecological ranges across major cattle-producing areas. The sample collection was conducted at different seasons i.e., wet (June through September, 2019) and dry (December, 2019 through February, 2020) as identified by (Goshu et al. 2007). The names of the abattoirs have been withheld for confidentiality and coded as SH01, SH02 and SH03.

Sample size

The sample size required for this study was based on expected prevalence of *Salmonella* on beef determined according to Thrusfield (2007). The previous study in Ethiopia indicated 10% pooled prevalence of *Salmonella* on beef in Ethiopia (Zelalem et al. 2019). Therefore, using 10% expected prevalence, 95% confidence interval and 5% type I error, and the number of animals required for sampling from beef slaughtering facilities was estimated to be 138. To increase the precision of the estimate, the sample size was inflated. Thus, grand total of 150 animal heads/carcasses were used to collect samples. The sampling proportion allocation for each site was calculated based on abattoir's minimum beef slaughtering capacity/day. Thus, SH01 (78), SH02 (32) and SH03 (40) slaughtered animals were sampled and a total of 75 animal heads were sampled in each season.

Sample collection

Beef samples (n = 150) were collected according to the U.S. Department of Agriculture's Food Safety and Inspection Service (USDA-FSIS) Directive 117 10,300.1, Rev. 1, Section VII, A, 12 (USDA - FSIS 2013). Sampling was carried out using Sani-stick sponge (LABPLAS, Quebec, Canada) hydrated with 10 mL of buffered peptone water (BPW; Becton Dickinson, Franklin Lakes, NJUSA) and sterile plastic templates covering 250 cm^2 area of the region (Narváez-bravo et al. 2013). Each slaughtered animal was sampled randomly during the time of sample collection. For each animal slaughtered/carcass, sampling was carried out at three steps in the processing line: hide (P1), pre-evisceration (P2), and post-evisceration (P3). In each sampling point, swabbing was carried out at three regions, *i.e.,* midline, fore shank and hind shank. After swabbing, only the sponge was placed back into the original sterile bag. Finally, the bags were labeled and transported using iceboxes containing frozen freezer packs (2 - 8°C) and samples were processed within 24 hours.

Sample preparation

Each bag containing a spongy swab was hand-stomached thoroughly for about a minute as described by (Bosilevac et al. 2019)**,** and the sample homogenate was used for microbial analysis as described below.

Detection and enumeration of *E. coli*, coliform and total coliform

From the initial rinse bag, 1mL was taken before the addition of enrichment media into the bag and tenfold serial dilution was made and 1mL of each dilution was dispensed onto labeled *E. coli*/Coliform Count Plates (ECC; 3M Petrifilm Count Plates: St. Paul, MN - USA) in duplicate. Then, the plates were incubated at 35° ± 2.0°C for 24 ± 2.0 hr in a horizontal position with the clear side up in stacks not exceeding 20 plates. After incubation, the petrifilm plates were examined for *E. coli*, coliform, and total coliform growth. According to AOAC Official Methods (998.08 and 991.14) (Curiale et al. 2002), blue to red-blue colonies on ECC associated with entrapped gas, regardless of size or intensity of color, were confirmed as *E. coli*. The red colonies closely associated (within one colony diameter) with entrapped gas were counted as coliform. Whereas both the red and blue colonies associated with gas at 24 hours were counted as total coliform. The petrifilm plates were re-incubated for about 24±2hr to detect any additional *E. coli* growth. The bacterial count was recorded on excel sheet and log transformed and reported as LogCFU/cm^2. The enumeration result was interpreted and benchmarked with different standard sets for the microbiological safety of meat.

Isolation and identification of *Salmonella enterica*

Samples were analyzed for the presence of *Salmonella enterica* following USDA-FSIS MLG. 4.10 method (USDA-FSIS 2019). Thus, in each bag, 50 ± 1 mL of Tryptic soya broth (TSB; Hardy Diagnostic, Santa Maria, CA - USA) was aseptically added using bottle - top dispenser (VWR, Labmax) and samples were hand-stomached for one minute. Sponge bags were incubated at 42 ± 1°C for 15-24 hr. An aliquot of 0.5 ± 0.05 mL of the sample was transferred into 10 mL Tetrathionate (TT) broth (HiMedia, Mumbai, India) and 0.1 ± 0.02 mL into 10 mL Rappaport-Vassiliadis soya (RVS) broth (HiMedia, Mumbai, India). The tubes containing the selective enrichments were incubated at 42 ± 0.5°C for 22-24 hr.

After incubation, the contents of the tubes were carefully mixed using a digital vortex mixer and a 1µL loopful of the selective enrichment medium was streaked onto a 60 x 15 mm plate of Xylose Lysine Tergitol-4 agar (XLT- 4; Hardy Diagnostic Santa Maria, CA, USA) and Brilliant Green Sulfur agar (BGS; HiMedia, LBS Marg, Mumbai, India). Plates were incubated at 35 ± 2°C for 18-24 hr. After incubation, well isolated black colonies (H_2S positive) or pink colonies with or without black center or yellow and clear colonies with dark centers from XLT-4 agar, and pink and opaque colonies with a smooth appearance surrounded by a red color from BGS agar were tested for agglutination using Wellcolex™ color *Salmonella* rapid latex agglutination Kit (Remel, Dartford, Kent, DA2 6PT UK). Colonies that tested positive in the agglutination test were recorded as presumptive positives for *Salmonella enterica*.

Collection of *salmonella* isolates

If agglutination reaction is positive, the same colony was streaked onto 60 x 15 mm plate of Tryptic Soy Agar (TSA; Hardy Diagnostics, Santa Maria, CA-USA), and incubated at 35° ± 2.0°C for 24 ± 2.0 hr. The isolated colony was transferred into conical tube containing 10 ml Tryptic soya broth (TSB; Hardy Diagnostic, Santa Maria, CA - USA) and incubated at 35 ± 2°C for 18-24 hr. The TSB inoculated broth was then used to create a lawn of *Salmonella* culture onto TSA using a sterilized cotton swab. The TSA plates then were incubated at 35 ± 2°C for 18-24 hr. After incubation, the lawn was harvested using a sterile 10µL loop and transferred the growth into cryobeads (Key Scientific Products INC, Stamford, TX-USA) following manufacturer instruction. The cryobeads were labeled and closed tightly. Finally, the cryobeads were stored at -80° ± 2.0°C at the National Animal health Diagnostic and Investigation Center (NAHDIC), Ethiopia for further analysis.

MALDI Biotype identification of isolates

The analysis was carried out following the instruction of MBT compass. Thus, isolates were first grown at 37°C for 18 - 48 hrs on Tryptic Soy Agar (TSA; Hardy Diagnostics, Santa Maria, CA-USA). Direct transfer sample preparation procedure was employed. Hence, from each sample, an isolated colony was smeared as a thin film directly onto a sample position of clean MALDI target plate using a sample applicator. 1 µL of bacterial test standard (BTS) solution was added onto the assigned BTS quality control (QC) position. 1 µL bacterial test standard (BTS, # 8255343, Bruker Daltonik GmbH) was also transferred to the same target plate. 1 µl HCCA matrix solution (Bruker Daltonik GmbH) was added onto each sample and BTS QC position. Then the MALDI target plate was air- dried for few minutes. Finally, identification was performed by MALDI Biotyper (Bruker Daltonik Gmb, Bremen, and Germany) and the plate was read and interpreted using inbuilt data base.

PCR confirmation *Salmonella* isolates

The RT PCR confirmation of isolates was completed at National Animal Health Diagnostic and Investigation Center, Ethiopia. All isolates previously stored in cryobeads were streaked for growth onto a TSA plates. Plates were incubated at 37° ± 2.0° C for 24 ± 2.0 hr. The extraction of DNA from the bacteria was performed by boiling method as previously described elsewhere (Bonke et al. 2012). The cells were lysed by heating for 10 min in Eppendorf Thermomixer Compact at 100^{o}C. The lysate was then centrifuged at 14,000 rpm for 5 min, and 50 µl of the supernatant was transferred in a sterile Eppendorf tube and stored at -20^{o}C for further use. Up to 2.5 µl of the collected supernatant per 25 µl PCR reaction was used.

The real time PCR reaction mixture (25 µL) contained 2.5 µL of DNA template, 0.5 µL invA probe, 1 µL invA Primer mix, 12.5 µL iQ Multiplex Powermix (2x mix contains dNTPs, 11 mM MgCl2, iTaq DNA polymerase), and 8.5 µL dd H_2O. The mixture was then dispensed with the correct volume (25 µl) in each well in the plate. The PCR program was set with the following conditions: Initial denaturation at 95^{o}C for 10 min, 45 cycles of denaturation at 95^{o}C for 15 s, and annealing and extension at 60^{o}C 50 seconds. *Salmonella* Typhimurium (ATCC 14028) was used as a positive control strains and nuclease free distilled water (Integrated DNA Technologies, Coralville IA, USA) as a negative control. Finally, isolates were confirmed using Real-Time PCR (AB Applied Biosystem 7500 Fast System, Sequence Detection Software Version 1.4) targeting specific *Salmonella* genus-specific invA gene. The primers, probe and its descriptions are listed in Table 1.

Table 1. Prımers and probe used in isolation and identification of *Salmonella enterica*

Amplified	Oligonucleotide sequence (5′-3′)	# bases	MW	ODs	nmol
invA	invA-F 5′d CGTGTTTCCGTGCGTAATA 3′	19	5791.66	5.20	30
	invA-R 5′d GCCATTGGCGAATTTATG 3′	18	5512.50	5.19	30
*inv*A-Pr	5′d FAM-ATTATGGAAGCGCTCGCATT-BHQ-1 3′	20	7202.79	2.25	10

Antimicrobial susceptibility test

The antimicrobial susceptibility test of *Salmonella enterica* isolates (n = 45) was determined using a Kirby-Bauer disk diffusion assay according to the standards and interpretive criteria described by the Clinical and Laboratory Standards Institute CLSI M100, 30^{th}.ed (CLSI 2020). About 4 - 5 colonies of each isolate were inoculated into sterile tube containing 5 mL sterile distil water. The suspensions were homogenized using vortex mixer. Then, the suspensions were adjusted to the turbidity of 0.5 McFarland standards using Densitometer (DEN-1, CAMBS, England) and streaked onto Mueller Hinton II Agar (MHA, BD). Antimicrobial disks (Oxoid, Hants, UK) were dispensed onto the surface of the inoculated agar plates and the plates were incubated at 37°C for 16 to 18 hr. The following 13 antimicrobials were tested: Ampicillin (AMP, 10 µg), Amoxicillin-clavulanate (AMC, 20/10µg), Gentamycin (CN, 10µg), Streptomycin (S, 10 µg), Tetracycline (TE, 30 µg), Ciprofloxacin (CIP, 5 µg), Nalidixic acid (NA, 30 µg), Meropenem (MEN, 10µg), Trimethoprim - sulphamethoxazole (SXT, 1.25/23.75µg), Chloramphenicol (C, 30µg), Trimethoprim (W, 5µg), Sulfisoxazole (S3, 250/300 µg), and Ceftriaxone (CRO, 30µg). The results were recorded as susceptible (S), intermediate (I) or resistant (R) by measuring the inhibition zone diameter according to the interpretative standards of CLSI. An isolate was considered multidrug resistant when it was resistance to three or more antibiotics belonging to different antibiotic classes. The reference strain of *E. coli* ATCC 25922 was used as quality control to monitor the precision and accuracy of susceptibility testing.

Data Analysis

The data was analyzed using Statistical Package for the Social Sciences (SPSS) 23.0 software (IBM Corp, USA). The prevalence of *Salmonella enterica* at 95% Confidence Interval was determined for all samples, by sampling point (hides, pre-evisceration and post- evisceration), season (wet and dry) and abattoirs (SH01, SH02 and SH03). The results of microbial counts (CFU/cm^2) were converted into log10 and descriptive statistics were used to calculate mean, standard deviation, minimum and maximum values of samples. For each bacteria detection level / prevalence, a chi-squared analysis (Fisher's exact test) was used to test for differences among abattoirs, sampling points and seasons. The microbial counts were compared across the abattoirs using one way ANOVA. P value ≤ 0.05 was considered statistically significant. Additionally, a chi-square test was also employed to compare the resistant and susceptibility isolates against the antibiotics. A probability of $p < 0.01$ was considered statistically significant.

Results

The overall prevalence of *Salmonella enterica* on hides, pre-evisceration and post-evisceration across abattoirs is shown in Table 2. Of the 150 beef cattle, a total of 450 sub swab samples were collected. Forty-five *Salmonella enterica* were identified using MALDI Biotyper and invA gene was detected in all of the isolates with Ct value ranged from 17.61 - 27.74 (provided supplementary data). The overall prevalence of *Salmonella enterica* at animal level was 22.7 % (95% CI, 16.0 - 30.0). However, based on the sampling points, *Salmonella enterica* was detected in 13.3% (95% CI, 8.0 - 18.7) hides; 12.0% (95% CI, 7.3 - 17.3) pre-evisceration; and 4.7% (95% CI, 1.3 - 8.0) post-evisceration samples. Chi-square analysis indicated that the prevalence of *Salmonella enterica* on beef samples was not different by abattoirs ($P > 0.05$). Also, in prevalence of *Salmonella enterica*, no significance difference ($p > 0.05$) was observed between hide and pre-evisceration samples. However, the *Salmonella enterica* positives samples were significantly lower in post-evisceration than both sampling points ($P < 0.05$).

Additionally, Fisher's exact test indicated that the prevalence of *Salmonella enterica* on beef samples was significantly higher during wet season (P = 0.011).

Table 2. Overall *Salmonella enterica* prevalence for abattoirs and sampling points of the carcass

Abattoir [a]	Sample size	% *Salmonella enterica* prevalence (95% Confidence interval)			
		Carcass	Hide	Pre-evisceration	Post-evisceration
SH01	78	21.8 (12.8 - 32.1)	10.3 (3.8 - 17.9)	15.4 (7.7 - 24.4)	6.4 (1.3 – 11.5)
SH02	40	27.5 (15.0 - 42.5)	20.0 (7.5 - 32.5)	12.5 (2.5 – 22.5)	2.5 (0.0 – 7.5)
SH03	32	18.8 (6.3 - 31.3)	12.5 (3.1 - 25.0)	3.1 (0.0 – 9.4)	3.1 (0.0 – 9.4)
Total [b]	150	22.7 (16.0 - 30.0)	13.3 (8.0 - 18.7)	12.0 (7.3 – 17.3)	4.7 (1.3 – 8.0)

[a] Chi-square analysis indicated that the overall prevalence of *Salmonella enterica* was not different by abattoirs (P = 0.346).
[b] A chi-square analysis depicted that *Salmonella enterica* positive samples was not different between hide and pre-evisceration (p = 0.728). On the other hand, *Salmonella enterica* positives samples of pre-evisceration vs. post-evisceration (p = 0.022) and hide vs. post- evisceration (p = 0.009) was significantly different.

The descriptive statistics of hygiene indicator bacteria was presented in Table 3. The overall mean log ± SD of *E. coli*, coliform and total coliform counts were 4.55±0.99, 4.91±1.13 and 4.98±1.09, respectively. The majority, 77.6% (73.8 - 81.5) of the samples were contaminated by *E. coli* with enumeration ranged from 2.57 to 8.76 log CFU/cm^2. Besides, the coliforms were detected in 76.2% (72.2 - 80.2) of the samples with range of 1.32 to 8.58 log CFU/cm^2. It was also observed that about 89.1% (86.0 - 91.6) of the samples were contaminated with total coliforms with a range of 2.57 to 8.76 log CFU/cm^2.

The *E. coli* contamination of beef in SH02 was significantly lower as compared to other abattoirs (ANOVA, P < 0.05). Also, the coliform contamination of beef in SH02 was significantly lower (ANOVA, P < 0.05) as compared to SH01. No significance difference (ANOVA, P > 0.05) in *E. coli*, coliform and total coliform contamination of beef was observed between SH01 and SH03 abattoirs. Whereas the beef samples from SH02 abattoir had significantly lower total coliform contamination than SH03 abattoir (ANOVA, P < 0.05). The Fisher's exact test analysis indicated that significantly higher number of samples were detected positive for *E. coli* during wet season (P = 0.001). Nevertheless, the coliform occurrence was significantly (P = 0.027) higher during dry season. No significant difference (P > 0.05) in contamination of *E. coli* and coliform was observed among sampling points. However, significance difference (P < 0.05) in contamination of total coliform was observed among the sampling points in which hide samples showed the highest contamination. In this study it was noted that about 76% of *Salmonella enterica* were detected from *E. coli* positive samples which imply that fecal contamination may pose a serious risk in beef processing.

The *Escherichia coli* ATCC 25922 which was used as quality control was within the acceptable range of sensitivity. Antimicrobial resistance was generally low among *Salmonella* isolates in this study as presented in Table 4. Approximately 44% of the isolates were susceptible to all antibiotics tested. All *Salmonella enterica* isolates (100%) were susceptible to the 5 antibiotics tested. Whereas 37.8% isolates were resistant to at least one antibiotic and 11% to 2 antibiotics. The most frequently detected resistance was to Tetracycline (28.9%), followed by Streptomycin (22.2%), Sulfisoxazole (20.0%) and Ampicillin (17.8%). In addition, about 20% of the *Salmonella enterica* isolates were found to be multi drug resistant with 15.6% to 3 antibiotics and 4.4% to 5 antibiotics (Table 5).

Table 3. The enumeration of *E. coli*, coliform, and total coliform from beef swab samples of abattoirs (n = 150)

Abattoir	Sample source	N	Sampling point	#Sub-samples	Log10 Mean bacterial counts ± SD (log_{10} CFU/cm^2)								
					ECC			CC			TCC		
					Mean ± SD	Max	Min	Mean ± SD	Max	Min	Mean ± SD	Max	min
A02	beef	78	Hide	78	4.72±0.92	6.42	3.05	5.13±1.13	6.77	3.05	5.20±1.12	6.90	3.05
			Pre-evisceration	78	4.37±0.91	7.08	3.18	4.65±1.42	7.04	1.32	4.76±1.20	7.34	3.05
			Post-evisceration	78	4.61±1.11	7.02	2.51	5.17±1.18	7.02	3.05	5.08±1.20	7.32	2.88
A02	Beef	40	Hide	40	4.66±1.09	6.59	3.18	5.08±1.03	6.89	3.53	5.16±1.07	6.99	3.53
			Pre-evisceration	40	3.91±0.83	5.90	2.57	4.42±0.63	6.02	2.88	4.50±0.67	6.22	2.57
			Post-evisceration	40	3.99±0.71	5.83	3.05	4.44±0.73	6.45	3.18	4.57±0.90	6.45	2.57
A03	Beef	32	Hide	32	4.80±0.72	6.01	3.53	5.10±0.93	6.68	3.80	5.24±1.01	7.30	3.53
			Pre-evisceration	32	4.67±0.15	6.42	3.62	4.93±1.07	6.61	3.05	5.12±0.96	6.61	3.42
			Post-evisceration	32	5.15±1.22	8.76	3.57	5.13±1.34	8.58	3.18	5.24±1.27	8.98	3.72
Total		**150**		**450**	**4.55±0.99**	**8.76**	**2.57**	**4.91±1.13**	**8.58**	**1.32**	**4.98±1.09**	**8.76**	**2.57**
					77.6% (73.8 – 81.5)[a]			76.2% (72.2 – 80.2)[b]			89.1% (86.0 – 91.6)[c]		

n: Number of animals sampled; ECC: *E. coli* count; CC: Coliform count; TCC: Total coliform count and SD: Standard deviation

[a] the *E. coli* detection rate in samples

[b] the coliform detection rate in samples

[c] the total coliform detection rate in samples

TABLE 4. Antibiotics resistance profiles of the *Salmonella enterica* isolated from beef samples of abattoirs

Antibiotics	Antibiogram pattern of *Salmonella enterica* (n = 45)		
	S n (%)	**I** n (%)	**R** n (%)
Ampicillin (AMP, 10 µg)	37 (82.2)	0 (0.0)	8 (17.8)
Amoxicillin-clavulanate (AMC, 20/10 µg)	45 (100)	0 (0.0)	0 (0.0)
Gentamycin (CN, 10 µg)	45 (100)	0 (0.0)	0 (0.0)
Streptomycin (S, 10 µg)	29 (64.4)	6 (13.3)	10 (22.2)
Tetracycline (TE, 30 µg)	32 (71.1)	0 (0.0)	13 (28.9)
Ciprofloxacin (CIP, 5 µg)	44 (97.8)	1 (2.2)	0 (0.0)
Nalidixic acid (NA, 30 µg)	43 (95.6)	2 (4.4)	0 (0.0)
Meropenem (MEN, 10 µg)	45 (100)	0 (0.0)	0 (0.0)
Trimethoprim - sulphamethoxazole (SXT, 1.25/23.75 µg)	43 (95.6)	0 (0.0)	2 (4.4)
Chloramphenicol (C, 30µg)	45 (100)	0 (0.0)	0 (0.0)
Trimethoprim (W, 5µg)	42 (93.3)	0 (0.0)	3 (6.7)
Sulfisoxazole (S3, 250/300 µg)	36 (80.0)	0 (0.0)	9 (20.0)
Ceftriaxone (CRO, 30 µg)	45 (100)	0 (0.0)	0 (0.0)

n - number of isolates, R- resistant**,** I – intermediate, S – susceptible

Table 5. Multidrug resistance *Salmonella enterica* isolates from beef samples

Antibiotics	**No of isolates (%)**
AMP, S, TE, SXT, W, S3	2 (4.4)
S, TE, S3	7 (15.6)

Discussion

This study demonstrated that alarmingly high prevalence (22.7%) of *salmonella enterica* was detected at animal level slaughtered in abattoirs. However, earlier studies conducted in Ethiopian abattoir facilities indicated low rates of *Salmonella* contamination of beef, with prevalence varying from 2% to 9% (Alemu and Zewde 2012; Kore et al. 2017; Kebede et al. 2016). Also, lower prevalence (8.5 %) of *Salmonella* spp. was reported from beef carcasses in Brazil (Iglesias et al. 2017). The potential differences in *Salmonella* contamination levels might be attributed to different factors like the sampling procedure, detection method, hygienic practices, and season as described by (Siriken, Al, and Erol 2020). The significant increase *in Salmonella enterica* prevalence on beef in Ethiopia where meat is consumed as raw is a potential health threat. Besides, high incidence of *Salmonella enterica* was observed from hide (13.3%) and pre-evisceration (12.0). In contrast, higher proportion of *Salmonella* was isolated from hides of cattle in China 20 % (Dong et al. 2014), and in Ethiopia 31 % (Sibhat et al. 2011).

No significance difference in *Salmonella enterica* detection rate in between hides and pre-evisceration samples which suggested that poor practices of hide removal and potential transfer of pathogens from hide to carcass. It is however difficult to make conclusion on transfer of the pathogens but many studies have shown that hides are a key sources of *Salmonella* contamination in beef (Narvaez-Bravo et al. 2013; Brichta-Harhay et al. 2011). None of the abattoirs sought for this study had pathogen reduction interventions or decontamination treatments in place. Thus, processing establishments in Ethiopia requires of good hygiene practices like the use of hide wash, acid or action to inactivate *Salmonella* on hides then by reducing the rate of meat contamination later on in the processing.

Meanwhile, the presence of *Salmonella enterica* during wet season is significantly higher in the study. The aggravating factors regarding increased *Salmonella enterica* prevalence during wet season might be due to the variation of fecal shedding, animal hygiene status, climate and feed. Corroborating the results reported here, different studies indicating strong seasonal patterns of *Salmonella* prevalence in meat (Z. Xu et al. 2020; Jessie L. Vipham et al. 2012). Therefore, this baseline finding reminds the need of seasonal based intervention to ensure meat safety in the sector. However, replicates of the current study need to be conducted during different seasons to fully address seasonality and its effects on *Salmonella* prevalence.

The overall mean log of *E. coli* and total coliform counts were 4.55 and 4.98, respectively. Despite the variation of factors, study conducted in Brazilian slaughterhouses reported a lower mean count of *E. coli* and total coliform (<3.5 log CFU/cm^2) with significantly lower bacterial loads during pre-evisceration and post-evisceration (Camargo et al. 2019). It was further noted that significantly higher number of samples were detected positive for *E. coli* during wet season (P = 0.001). The result is in accordance with those previously reported studies in Korea and Argentina where seasonal variation was observed on the detection and loads of *E. coli* and coliform from meat samples (Lasta et al. 1992; Kim and Yim 2016).

In the present study, no significant difference (P > 0.05) in contamination of *E. coli* and coliform was observed among sampling points. In contrary, Camargo et al. (Camargo et al. 2019) reported that significantly higher no of *E. coli* and coliform counts were recovered from hide samples. The similarity of microbial loads over steps of slaughtering line attributed from poor hygiene practice, abattoir environments, knives, and other cutting machines (Hauge et al. 2012; Buncic et al. 2014). Moreover, the lack of strict hygiene practice during slaughter operation will result in buildup of meat and fat residues on tools and meat contact surfaces that cause microbial accumulation and recontamination of carcasses over the production lines (Gill and McGinnis 2004). Additionally, the compromised hygiene status might be linked with poor operators' food safety knowledge and attitudes reported by previous study at the same slaughtering facilities (Zelalem et al. 2021).

Currently, there is no specific regulation on the permissible range of microbial loads on beef carcass in Ethiopia. The majority of the samples analyzed w not in the acceptable ranges as compared to other standards. For instance, according to the European Commission Regulation (EC) No. 1441/2007 limits of *E. coli* for carcasses of cattle after dressing (m = 1.5 log CFU/cm^2 and M = 2.5 log CFU/cm^2 (European Union Commission regulation 2007), none of the pre-evisceration and post-evisceration samples were in the acceptable ranges of microbial load (<1.5 log CFU/cm^2). *E. coli* testing on beef carcasses is used as an indicator of hygiene practice in different stage of beef chain (USDA-FSIS 1996). As, *E. coli* populations are indicators of fecal contamination, all the abattoirs included in this study would have failed to prevent fecal contamination as the load and detection rate of *E. coli* was recorded high on beef samples. Besides, the occurrence of *E. coli* on beef is a public health concern as some strains are associated with the production of shiga toxins that cause foodborne illness in humans (Gyles 2007; Pennington 2010).

Antimicrobial resistance is causing a community health care crisis worldwide. The expanded utilization and misuse of antimicrobial agents in food animal production and humans resulted in drug resistance (CDC, 2013). Interestingly, in the present study, very high percentage (> 95%) of the *S. enterica* was sensitive to naldixic acid, ciprofloxacin, and ceftriaxone. In similar trend, all isolates recovered from beef cattle feedlots in South Texas demonstrated susceptibility to ceftriaxone, ciprofloxacin and nalidixic acid (Xie et al. 2016). The advantage here that is that ceftriaxone (an extended-spectrum cephalosporin), nalidixic acid (a quinolone) and ciprofloxacin (a fluoroquinolone) are common choices to treat salmonellosis in humans (Chiappini et al. 2002; Chen et al. 2013). However, about 37.8% *S. enterica* were resistant to at least one antibiotic. In contrast, study conducted on imported beef in Jordan demonstrated very high percentage (93.0 %) of the *Salmonella enterica* resisted to at least one antimicrobial (Obaidat 2020).

Additionally, 20% of the *Salmonella enterica* isolates were found to be multi drug resistant. Nevertheless, a high percentage (70 %) of MDR was exhibited by *Salmonella enterica* isolates from beef cattle in Mexico (Delgado-Suárez et al. 2019). Although the number of MDR *Salmonella enterica* relatively low in this study, it is still a public health concern as MDR *Salmonella* serovars are considered to be more virulent than non-MDR *Salmonella* (Dong et al. 2014). The most frequently detected resistance was to Tetracycline (28.9%), followed by Streptomycin (22.2%), Sulfisoxazole (20.0%) and Ampicillin (17.8%). In agreement with this finding, it was reported that the most common *Salmonella enterica* multidrug-resistance pattern were observed against ampicillin, streptomycin, sulfamethoxazole, and tetracycline (CDC 2007). Additionally, a systematic review and meta-analysis study in Ethiopia demonstrated a 25% ampicillin resistance of *Salmonella* were isolated from meat and its product (Zelalem et al. 2019).

Conclusion and Recommendation

In conclusion, the data presented in this study at three abattoirs demonstrated that the beef samples were highly contaminated with *Salmonella enterica* with some isolates exhibited a multidrug resistance to commonly used antibiotics. Thus, the high prevalence of *Salmonella enterica* may underscore a public health threat where in Ethiopia eating raw meat is a tradition. The *Salmonella enterica* were more prevalent on hides of animals presented for slaughtering. It was also identified that the prevalence of *Salmonella enterica* was affected by seasons. Additionally, the detection rate and loads of *E. coli*, coliform and total coliform were recorded high on beef samples which may signify insufficient sanitary conditions in abattoirs. Moreover, the study gives an insight on the current status of beef contamination at abattoirs in Ethiopia. Therefore, there is a need to implement good hygiene practices and appropriate intervention to reduce *Salmonella* contamination of beef at abattoirs.

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Physico-Chemical, Sensory and Microbiological Qualities of Homemade Yoghurt using Commercial Starter Culture

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Abstract

*This research was initiated with the objectives of evaluating the physico-chemical, sensory and microbiological qualities of four homemade yoghurt treatments. Fresh morning milk was collected from Andassa Livestock Research Center farm, thoroughly mixed, transported to Bahir Dar University for yoghurt preparation. The milk samples were mixed at 800rpm for three minutes and filled in to coded cups of 300ml capacity. The four yoghurt treatments were pasteurized milk inoculated with starter culture containing thermophilic yoghurt culture (YoFlex®) at 42^{o}c (T1), pasteurized milk inoculated with plain yoghurt at 42^{o}c (T2), pasteurized milk inoculated with plain yoghurt at room temperature (T3) and unpasteurized milk inoculated with plain yoghurt at room temperature (T4). The treatments were subjected to physico-chemical and microbial count laboratory analysis and sensory evaluation, on the 1st, 7th, 14th and 21st day of storage. The analysis was done in duplicate and the design was a 4*4*2 factorial design. The results obtained showed that the mean moisture content of the treatment yoghurt ranged between 86.52 and 88.26%, without showing significant difference between each other. The entire treatment yoghurt seems to have a relatively long shelf-life because of the high acidity value of 4.3-4.5 recorded. Mean titratable acidity level of the yoghurt ranged from 0.86 to 0.94 compared to the mean titratable acidity level of 0.67 - 0.95 recorded for good quality traditional yoghurt in the area. The total solid content of the yoghurt treatments ranged between 6.8 and 7.3. Relatively higher fat content of 9.88-10% was obtained from both yoghurt treatments T1 and T2. The result of microbiological analysis ranged from <0.1 – 11420 (*10^2 cfu/ml) of Coliforms and 0 – 834 (*10^2 cfu/ml) of yeast and mold count. All the yoghurt treatments studied fit into acceptable range set for good quality yoghurt throughout the storage periods. Based on the panelist's sensory evaluation the yoghurt treatment T4 ranked first in acceptance followed by T1. Testing different types of commercial starters in the area, their affordability and accessibility in the market seems to be the future direction of research.*

Keywords: *Microbiological, Pasteurized, Sensory, Starter Culture and Yoghurt*

Introduction

Dairy products constitute an important group of foods. They are known to contain balanced levels of protein, fat, carbohydrate, and calcium. They also make an important contribution to vitamin intake (Igbabul et al., 2014). The consumption of milk and a dairy product is common in the world. Yoghurt is a coagulated milk product obtained by lactic acid fermentation through the action of *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (Bourlioux and Pochart, 1988), and is a popular product throughout the world (Mohammed and Mohamed, 2017). According to FDA (2013) yoghurt is defined as a food produced by culturing one or more of dairy ingredients i.e. cream, milk, and skim milk, used alone or in combination with a characteristic bacterial culture that contains lactic acid producing bacteria (Tamime, 2006).

Yoghurt is a valuable healthy food for both infants and elderly persons. For children, it is a balanced source of protein, fats, carbohydrates, and minerals. For senior citizens who usually have more sensitive colons or whose intestines have run out of lactase, yoghurt is also a valuable food (Igbabul et al., 2014). A number of human studies have clearly demonstrated that yoghurt containing viable bacteria (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus*) improved lactose digestion and eliminated symptoms of lactose intolerance, thus these cultures clearly fulfill the current concept of probiotics (Mohammed and Mohamed, 2017). Regular consumption of yoghurt is thought to be beneficial in the strengthening of the immune system, improvement in lactose digestion, blood glucose management (Yaday et al., 2007) and the reduction of constipation, diarrhea, colon cancer, inflammatory bowel disease and allergies (Adolfsson et al., 2004). The beneficial health effects of yoghurt have partly linked to the proteolysis products, produced during fermentation and storage in particular, a group of peptides can lower the blood pressure in hypertensive patients (FitzGerald et al., 2004).

During the manufacturing process of industrial/commercial fermented dairy products, such as yoghurt, pasteurization of the milk is a prerequisite process-step before inoculation of the milk with fermentative starter cultures. This process destroys pathogenic and spoilage micro flora from the products (Tamime, 2006) making the fermented milk safer for consumers. In principle, worldwide, there is no any difference between manufacturing of homemade and factory-made yoghurt (Akin and Rice, 1994). The shelf-life of yoghurt is 1 day at 25 to 30°C and 5 days at 7°C or 10 days at 4°C according to the Turkish standards for plain yoghurt (Hayaloglu et al., 2007). The easiest and least expensive way of obtaining a starter culture is to purchase plain yoghurt at a grocery store/supermarkets. It should be plain– no fruit added. To maintain a culture, save a small portion of yoghurt (1 cup is enough for a 1-gallon batch) to use as a starter culture for the next batch (Hutkins et al., 2006).

Based on FAO (2005), dry season synthesis report in Ethiopia, 28.6 million liters of milk per year is wasted at the farm level. This covers 1.3 to 6.4% of the value of available milk at the farm level and the total value of post-harvest milk losses per year amounted to 14.2 million US dollars. For both on-farm level and in the market chain, milk losses are largely in form of spoilage, spillage, and "forced home consumption" (including by calves and humans) over and above normal household consumption (Tezira *et al.,* 2005). The biggest challenge for smallholders in Ethiopia is to prevent the milk from spoilage during fasting periods, and distance to milk cooperatives and cities. This situation warrants the production of market yoghurt with safe procedures. The objectives of this study were to evaluate

- the physico-chemical, and microbiological qualities of homemade yoghurt using different commercial starter culture.
- the sensory parameters of homemade yoghurt using different commercial starter culture

Materials and Methods

Preparation of homemade yoghurt - Adequate volume of fresh morning cow's milk was collected from Andassa Livestock Research Center dairy farm. The milk collected from different lactating animals, was thoroughly mixed and transported to Bahir Dar University using stainless still milk container. Yoghurt was prepared according to the procedure suggested by Hutkins, (2006). Soon after arrival at the university, the milk was homogenized at 800rpm for three minutes and the homogenized milk was filled in to coded cups each with 300ml capacity. The experiment was made by four treatments, four analysis intervals and the analysis were done in duplicate (4*4*2 factorial design). The milk was pasteurized at 80^{o}c for 30 minutes and cooled down to 45^{o}c. A total of four experimental treatments presented below were prepared through inoculation of the milk samples with either starter culture (containing thermophilic yoghurt culture (YoFlex®) (17mg for 300ml milk) or plain yoghurt (2% i.e. 6ml) at 42^{o}c or at room temperature until coagulation occur. The treatment yoghurts were stored in refrigerator at 4^{o}c. These were subjected to chemical and microbiological quality analysis on the 1^{st}, 7^{th}, 14^{th} and 21^{st} days.

Experimental treatments

- Treatment 1. Pasteurized milk inoculated with starter culture at 42^{o}c
- Treatment 2. Pasteurized milk inoculated with plain yoghurt at 42^{o}c
- Treatment 3. Pasteurized milk inoculated with plain yoghurt at room temperature
- Treatment 4. Un pasteurized milk inoculated with plain yoghurt at room temperature

Chemical and microbial analyses - The yoghurt produced were subjected to analysis of pH, moisture, titratable acidity, total solid, fat and protein contents, using the procedure suggested by AOAC (2005). Microbiological analysis of the treatment yoghurt was done for coliforms, yeast and molds according to the Compendium methods for the microbiological examination of foods as suggested by APHA, (2001). For the determination of coliform count (CC) and yeast and mold count (YMC), Brilliant Green Bile broth and potato distress agar were used. One gram of the yoghurt samples was dissolved in 9 mL of sterilized distilled water and serial dilution was made from 10^{-2} to 10^{-5} rate. All parameters were analyzed in duplicates. The analysis was conducted in collaboration with Bahir Dar University Faculty of Chemical and Food Engineering.

Determination of titratable acidity: NaOH as a base (titrant) and a color indicator (phenolphthalein) was used to determine the end point of the acid-base reaction. And the following formula was used to calculate the total acidity.

Titratable acidity = (Volume of titrant × N × 90 ÷ weight of sample × 1000) × 100.

Where; N = normality of titrant; 90 = Equivalent weight for lactic acid

Determination of fat percentage: to determine the fat percentage in yoghurt, 10ml sulfuric acid (98% concentration) was used for dilution of 11.3gram sample; and 1ml amyl alcohol was used to separate the fat. All the ingredients were shacked well to avoid the yoghurt droplet. Then the solution was kept in water bath (65-70^{o}C) for 5 minutes. Then the solution was centrifuge under 1000 RPM for 4 minutes and it was so wait for 3 minutes in water bath (65-70^{o}c).

pH measurement: pH meter was used to directly measure the pH of yoghurt samples.

Sensory evaluation

The sensory evaluation was done in order to check the texture, flavor, taste and overall acceptability of the treatment yoghurt by four untrained panelists. The Panels were from Andassa Livestock Research Center, Woreta ATVET College and Bahir Dar University staffs and the treatment samples were randomly presented at room temperature. The panelists were given a five Likert scale values (1 = excellent; 2 = good; 3 = acceptable; 4 = bad; 5 = insupportable) aimed at testing, appearance/color, texture/smell, flavor/test, and overall acceptance of the fresh coded samples of the treatment yoghurt, stored for 1, 7, 14 and 21 days. Panelists were asked to keep the yoghurt in the mouth for 12 seconds before scoring for flavor/test parameter. Water was used for rinsing mouth between samples (International Dairy Federation, IDF, 2002). For 14th day analysis, taste was not conducted due to fasting. The characteristics of the sensory evaluations considered for:

- **Appearance/color:** involves the filling and the surface of the product, color, visible purity, presence of foreign matters, spots of mold, and seepage/leakage of whey and phase separation.
- **Texture/smell:** the evaluation involves thickness, stickiness and coarseness. Evaluation can be made by blending the product with a (black) spoon before evaluating the sample in the mouth.
- **Flavor/test:** The evaluation of flavor is made by smelling and tasting the product.

Statistical Analysis

The data obtained were computed as mean and analyzed by Analysis of Variance (ANOVA) of SPSS. Likert scale values for sensory evaluation were analyzed by index method. Index was computed with the principle of weighted average according to the following formula.

Index = $R_n*C_1+R_n-1*C_2…. R_1*C_n/\sum R_n*C_1+ R_{n-1}*C_2….R_1$

Where,

R_n = Value given for the least ranked level (example if the least rank is 5th rank, then R_{n-5}, R_{n-1}=4 and … R_1= 1)

C_n = Counts of the least ranked level (in the above example, the count of the 5th rank = C_n, and the counts of the 1st rank = C_1)

Results and Discussion

Physico-chemical property

Moisture percentage - The results of the mean chemical properties of the treatment are presented in Table 1 and 2. According to the results presented, the moisture content of the treatment yoghurt ranged between 86.52 and 88.26%, without showing significant difference between each other. Numerically lower moisture content of 86.52% was recorded from the treatment yoghurt containing pasteurized milk inoculated with starter culture at 42^{o}c (T1). The moisture content of the current study indicated a decreasing trend from day one to 14. A moisture content of 78.2 – 87.1% was reported by (Joseph and Joy, 2011) for yoghurt samples collected form market in Nigeria.

pH content - The current result showed that lower pH of 4.22 (T1) to higher value of 4.53 (T2) was reported in the current study. The pH value of the current study was in line with the report of Joseph and Joy (2011) which was 3.7 – 4.33. The treatment yoghurt seems to have a relatively long shelf-life because of the high acidity value ranging between 4.3 and 4.5 as reported by Lourens-Hattingh and Viljoen (2002).

Table 1. Physico-chemical properties of yoghurt across different analysis days

Analysis day	Moisture %	pH	Titrable acidity	TSS	Fat %	Protein %
Day 1	87.75	4.44	0.91	7.71	7.85	2.86
Day 7	87.53	4.24	0.78	6.60	8.44	2.97
Day 14	86.37	4.68	0.94	6.69	9.50	3.03
Day 21	87.84	4.23	0.92	7.21	9.50	2.85

Titratable acidity - Titratable acidity is an approximation of the total acidity in a substance. It determines how much of a base (NaOH) is required to neutralize an acid. The base, also known as the titrant, is of known concentration. Comparable mean Titrable acidity level of 0.85 and 0.86 was recorded from T1 and T2, respectively. Titratable acidity for Ergo (yoghurt) collected from small scale, large scale and research center was reported to be 0.85, 0.67 and 0.95, respectively (Zelalem and Bernard, 2006). Considerably lower titrable acidity content was reported to be 0.22 – 0.5% (Joseph and Joy, 2011) in yoghurt samples collected from market. While considerably higher titrable acidity (1.22) was reported by Silva and Rathnayaka (2014).

Total solid - As shown in Table 2, the total solid (TSS) recorded from the treatment yoghurts followed the same trend as that of titratable acid. Mean total solid of 6.8 was recorded from T1 and T2. Higher level of total solid (12.9 – 21.8) (Joseph and Joy, 2011), and 22.89 (Silva and Rathnayaka, 2014) was reported for market collected yoghurt samples.

Fat and protein percentage - In the current study, the fat content ranges from 7.23 to 10%. Lower fat content (1.88 – 4.0%) for yoghurt samples collected from market in Nigeria was reported (Joseph and Joy, 2011). According to USDA (2001), yoghurt with less than 0.5% fat content should be labeled as" not fat yoghurt", those with fat content within the range of 0.5-2.0% before the addition of bulky should be labeled "low fat yoghurt" and those with fat content above 3.25% should be labeled "yoghurt". Based on this classification, the yoghurt made for this activity was labeled as yoghurt.

Table 2. Physico-chemical properties of yoghurt across different treatment groups

Parameters	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Moisture %	86.52	87.17	88.26	87.53
pH	4.22	4.54	4.43	4.41
Titrable acidity	0.86	0.85	0.94	0.92
TSS	6.8	6.8	7.3	7.3
Fat %	9.88	10.00	8.19	7.23
Protein %	2.85	3.03	2.90	2.92

Microbial properties - The results of the microbial quality of the treatment yoghurt are presented in Table 3. The microbiological analysis indicated that the result of the analysis ranged from <0.1 - 11420 ($*10^2$ cfu/ml) for coliforms and 0 – 834 ($*10^2$ cfu/ml) for yeast and mold count. Values ranging from 0.25 to 0.37 cfu/ml for coliform count was reported by Zelalem Yilma (2014) in Jimma town. Mean value of 8 cfu/ml was also reported by the same author. The coliform count was decreased across the working days. The result showed that T1 had lower coliform and yeast and mold count which might be due to the use of commercial starter culture. The coliform count was decreased across the working days which might be due to the absence of hand and other materials contaminations. Serhan (1999), suggested that satisfactory yoghurts contain more than l08 cfu ml^{-1} of the starter organisms, <1 coliform cfu/ml, <1 mold cfu/ml and <10 yeasts cfu/ml (fruit-containing yoghurts may contain up to 100 yeasts ml^{-1} and remain of satisfactory quality). Based on this, T1, T3 and T4 satisfy the stated values in different days of analysis.

Table 3. Microbial properties of yoghurt across different analysis days and treatments

Analysis days	Coliform (*10^2 cfu/ml)	Yeast and Mold (*10^2 cfu/ml)	Treatments	Coliform (*10^2 cfu/ml)	Yeast and Mold (*10^2 cfu/ml)
Day 1	7668.13	416	Treatment 1	0.7	0.031
Day 7	2402.78	26.85	Treatment 2	5548.75	38.06
Day 14	269.53	40.68	Treatment 3	2517.5	260.25
Day 21	395.65	44.44	Treatment 4	2669.13	229.63

Sensory evaluation **-** The results of the sensory quality (appearance, texture, and flavor) are crucial for consumer acceptance. The sensory evaluations of the treatment yoghurt are presented in Table 4. Based on the panelists sensory evaluation result, T4 ranked first in overall acceptance followed by T1. This might be attributed to unpasteurized milk resembles the natural appearance and flavor of homemade yoghurt done traditionally.

Table 4. Sensory evaluation index value (rank) between treatments across analysis days

Day	Treatments	Appearance/color	Texture/smell	Flavor/test	Overall acceptance
1	1	0.263 (1)	0.263 (1)	0.222 (4)	0.25 (2)
	2	0.225 (4)	0.258 (2)	0.274 (1)	0.241 (4)
	3	0.227 (3)	0.257 (3)	0.272 (2)	0.242 (3)
	4	0.258 (2)	0.225 (4)	0.258 (3)	0.258 (1)
7	1	0.261 (1)	0.246 (1)	0.230 (4)	0.261 (1)
	2	0.253 (2)	0.24 (3)	0.253 (3)	0.253 (2)
	3	0.25 (3)	0.220 (4)	0.279 (1)	0.25 (3)
	4	0.230 (4)	0.246 (1)	0.276 (2)	0.246 (4)
14	1	0.5 (1)	0.5 (1)	Due to fasting test was not conducted	
	2	0.466 (2)	0.533 (2)		
	3	0.466 (2)	0.533 (2)		
	4	0.461 (4)	0.538 (4)		
21	1	0.235 (4)	0.294 (1)	0.235 (3)	0.235 (4)
	2	0.263 (1)	0.263 (2)	0.210 (4)	0.263 (1)
	3	0.25 (3)	0.25 (3)	0.25 (2)	0.25 (3)
	4	0.263 (1)	0.210 (4)	0.263 (1)	0.263 (1)

Conclusion

Safe yoghurt production and marketing increases the well-beingness and healthy lifestyle of the consumers, helps to reduce wastage of milk and provides job opportunities for cooperatives, youths and women found in and around urban areas. Market price of fresh milk is very low during Christian Orthodox fasting times. During this occasion preparation of yoghurt in a safe and standard way is mandatory. Even though there was no standard set for yoghurt in Ethiopia, the treatments used in this study satisfies the standards set for yoghurt in different countries like USA. Based on the organoleptic analysis, it is best to use the yoghurt before 14 days kept in refrigerator. The results obtained indicated that using commercial starter can help small scale milk producers and cooperatives to form standard yoghurt for sale and use. The yoghurt treatment prepared from pasteurized milk inoculated with starter culture at 42^{o}c (T1) can be widely demonstrated for cooperatives and small-scale dairy producers.

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Physicochemical Properties and Microbial Quality of Raw Cow Milk Produced by Smallholders in Bench Maji Zone, Southwestern Ethiopia

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Abstract

The study was conducted in Bench Maji Zone, Southwestern Ethiopia, aimed to assess physicochemical properties and microbial quality of raw cow's milk produced by smallholders in the areas. A total of Forty-five samples of raw cow's milk were collected from Mizan Aman, Debub, and Shei Bench Woredas. All of the samples were collected using the proportional random sampling method. Physicochemical properties data and the transformed microbial count values were analyzed using the General Linear Model (GLM) procedure. The overall mean of pH value, specific gravity (SG), titratable acidity (TA), fat, protein and ash were 6.477±0.273, 1.028±0.010, 0.190±0.023, 6.024±0.763, 3.980±0.414 and 0.795±0.056, respectively in three woredas. The mean values for pH, SG, TA, fat, protein and ash contents of milk samples collected from Mizan. Aman were 6.153±0.114, 1.022±0.016, 0.215±0.010, 5.867±0.586, 3.844±0.475 and 0.780±0.050, respectively. The mean values for pH, SG, TA, fat, protein and ash contents of milk samples collected from Debub Bench Woreda were 6.647±0.200, 1.031±0.002, 0.174±0.018, 5.973±0.730, 3.954±0.402 and 0.815±0.047, respectively. The milk samples obtained from Shei Bench Woreda had 6.627±0.128, 1.031±0.001, 0.177±0.013, 6.233±0.940, 4.140±0.320 and 0.791±0.066 for pH, SG, TA, fat, protein and ash contents, respectively. Significant differences (P<0.05) were found in pH, specific gravity, titratable acidity, fat, protein and ash contents between the sources of milk samples. The overall mean of total bacterial count (TBC), coliform count (CC), spore-forming bacterial count (SFBC) and yeast and mould count (YMC) were 7.091±0.342, 5.100±0.288, 6.341±0.371 and 3.902±0.477, respectively in three woredas. The average (±SD) TBC, CC, SFBC and YMC of milk samples obtained from Mizan Aman were 7.235±0.277log_{10}cfu/ml, 5.203±0.230log_{10}cfu/ml, 6.489±0.258log_{10}cfu/ml and 4.001±0.588log_{10}cfu/ml, respectively. Whereas, milk samples obtained from Debub Bench Woreda had 7.222±0.156log_{10}cfu/ml, 5.187±0.211log_{10}cfu/ml, 6.307±0.195log_{10}cfu/ml and 3.944±0.346log_{10}cfu/ml for TBC, CC, SFBC and YMC, respectively. On the other hand, the corresponding values for Shei Bench Woreda samples were 6.817±0.381log_{10}cfu/ml, 4.911±0.324log_{10}cfu/ml, 6.221±0.542log_{10}cfu/ml and 3.762±0.468log_{10}cfu/ml, respectively. TBC, CC, SFBC and YMC of milk samples obtained from Mizan Aman were significantly higher (P<0.05) than milk samples obtained from Debub and Shei Bench Woredas. Therefore, it was concluded that the physicochemical properties were adequate as compared to the standard level whereas, the microbial quality of raw cow's milk produced by smallholders in the areas were poor and this suggests the need for enriched hygienic practices and educating the public on safety issues and personal hygiene in milk handling.

Keywords: Bench Maji, Microbial quality, physicochemical properties, Raw cow milk.

Introduction

Milk's biochemical composition is complicated, and it has a high-water activity. Because of its high nutritional value, raw milk serves as an excellent medium for microbial development, which decreases milk quality and shelf life. Consumer demand for safe, high-quality milk has placed a substantial burden on dairy producers, retailers, and manufacturers to produce and market safe milk and milk products (Degraaf *et al.*, 1997; Mennane *et al.*, 2007). Adverse environmental conditions have a significant impact on the quality of milk and milk products. Raw milk is easily fermented and ruined during storage if it is not cooled or kept in places where the temperature is hot and humid. However, due to a lack of dairy infrastructure in rural areas, such storage facilities are few, and cooling systems are impractical (Teshome *et al.,* 2014). Due to a lack of refrigeration facilities at the farm and household level in developing tropical countries with high ambient temperatures, raw milk will easily spoil during storage and transportation (Godefay and Molla, 2000). Milk is an essential food source for both humans and animals. Raw milk is a suitable substrate for microbial development, which decreases milk quality and shelf life due to its high nutritional content. As a result, milk and milk products must be handled with extreme caution to avoid spoiling and foodborne disease (Degraaf et al., 1997).

Muriuki and Thorpe (2001) claim that the great majority of milk produced outside of urban areas is processed into milk products at home using conventional technology. Traditional milk production, processing, and storage are common in the research area. Traditional milk products are poor in quality due to absence of refrigeration and clean water, as well as a lack of training about how to handle milk and milk products safely. Despite the fact that milk production is an important part of the community's livelihood in Bench Maji Zone, there is no documented data on the physicochemical characteristics and microbiological quality of raw cow's milk produced by smallholders. The objective of this research was to evaluate the physicochemical properties and microbiological quality of raw cow's milk produced by smallholders in the Bench Maji zone.

Materials and Methods

Description of the study area

The Ethiopian Southern Nations, Nationalities, and Peoples Region State has more than 13 zones, including the Bench Maji zone. The zone is located in Ethiopia's southwest part and is divided into ten Woreda and one administrative town. Mizan-Teferi, the administrative seat of the Bench Maji zone (BMZ), is located 561 kilometers from Addis Ababa and 830 kilometers from Hawassa, the regional capital. It is bordered on the north by Keffa Zone, on the east by Debub Omo, on the south by Sheka Zone, on the west by Gambela, and on the south by the South Suddan Republic (BMZFED, 2015).

Agro-ecologically, the BMZ is divided into three sections: 52 percent lowland (1500 masl), 43 percent mid altitude (1500-2300 masl), and 5% highland (>2300 masl). The elevation varies between 500 and 3,000 meters above sea level. At $34^0 45'$-$36^0 10'$ East and $5^0 40'$-$7^0 40'$ North, the Bench Maji zone can be located. The average annual temperature is between 15.1°C and 27.5°C, with annual rainfall ranging between 400 and 2,000 mm (BMZFED, 2015). Majority of the population depend on crop production, animal production and beekeeping. The main livestock species reared in the zone are cattle, sheep, goats, poultry and equines. About 367,853 cattle, 170,400 sheep, 92,905 goats, 11,922 horses, 2,921 donkeys, 310,931 chicken and 27,055 beehives are estimated to be found in the zone according to the report of CSA (2020/21).

Sources of data and sampling techniques

A total of 45 home milk samples (5 from each kebele) were collected in the morning from nine Kebeles that were purposefully chosen (three kebeles from each Woreda and town). The households were chosen based on secondary data collected from each woreda and kebele. The proportional random sampling approach was used to acquire all samples. Morning milk samples were obtained aseptically twice from each kebele at various times. Approximately 300 ml of milk sample was aseptically collected from producers' bulk milk containers and transferred into sterile glass bottles during collection. After that, the samples were tagged and placed in an icebox before being transferred to the laboratory for analysis. The analysis was completed three to four hours after the sample was taken.

Research Design

A laboratory-based experiment was conducted to evaluate the physicochemical characteristics and microbiological purity of raw cow's milk produced by smallholders in the Bench Maji Zone. A total of 45 samples of raw cow's milk were obtained from Mizan town, Debub, and Shei Bench Woredas in the morning.

Physicochemical Quality of Milk

PH value

The pH of the milk samples was tested in the laboratory using a digital pH meter, according to O'Connor's protocol (1995).

Specific gravity

A glass cylinder was properly filled with fresh milk samples (100 ml capacity). The lactometer was then placed into the milk while being held by the tip. The lactometer was left to float freely until the balance was attained. Following that, the lactometer reading at the lower meniscus will be taken. A thermometer was also placed into the milk sample at the same time, and the temperature of the milk was recorded (O'Mahony, 1998). The following formulas were used to calculate the specific gravity of the milk.

$$\text{Specific gravity} = (L/1000) + 1$$

Where, L = corrected lactometer reading at a given temperature, i.e., for every degree above 15.56 ^{0}C, 0.2 were added to the lactometer reading but for every degree below 15.56 ^{0}C, 0.2 were subtracted from the lactometer reading.

Titratable acidity of milk

The Association of Official Analytical Chemists technique was used to determine the titratable acidity of the milk samples (AOAC, 1990). Three to five drops of 1 percent phenolphthalein indicator were pipetted into nine ml of milk sample in a beaker. After that, the milk samples were titrated with 0.1N NaOH solution until they retained a faint pink tint. The titratable acidity expressed as % lactic acid was finally calculated using the following formula.

$$\text{Titratable acidity \%} = \frac{\text{N/10 NaOH (ml)} \times 0.009}{\text{Weight of milk sample}} \text{x } 100$$

Crude protein determination

The Kjeldahl method was used to determine the total protein content of the milk samples (AOAC, 1990). Five grams of milk were warmed in a water bath at 38°C and placed into a Kjeldahl flask for digestion. The flask was filled with 15 grams potassium sulphate, 1.0 ml copper sulphate solution, and 25 ml concentrated sulphuric acid, which was gently mixed. In a digestion block, the digestion was carried out until a clear solution developed. After that, it was set aside to cool to room temperature.

Distillation was accomplished by placing digesting flasks in the distillation machine and filling them with 30 mL distilled water and 75 mL 50 percent sodium hydroxide solution. The ammonia was then distilled, and 50 mL of 40 percent boric acid solution was added until a blue color developed, using bromocresol green indicator. Finally, a burette was used to titrate the sample with 0.1 N hydrochloric acid solution until a faint pink color solution was generated, and the burette reading was obtained to the nearest 0.01 ml. The above process was followed for the blank test, only water was utilized instead of the test sample. The percentage of nitrogen in the milk samples was calculated as follows:

$$\%N = \frac{(Vs - Vb)\ \text{HCl consumed} * \text{NHCl} * 1.4007}{\text{sample weight}} \times 100$$

$$\%CP = \%N * 6.38$$

Where, % N is percentage nitrogen by weight, Vs is volume of HCl used for titration of a sample, Vb = volume of HCl used for titration of the blank, % CP = percentage of crude protein

Determination of fat content of milk

The Gerber method was used to determine the fat content. Milk samples (11 ml) were combined with commercial sulfuric acid (10 mL) with a specific gravity of 1.82 and dispensed into the butyrometer, which was then closed with a rubber cork. After using a butyrometer stopper to close the butyrometer, the contents were shaken and inverted numerous times until the acid consumed all of the milk samples. The butyrometer was then immersed in a 65°C water bath for five minutes. The samples were centrifuged at 1100 rpm (rotations per minute) for five minutes (Richardson, 1985). Finally, the samples were returned to the water bath for 5 minutes at 65°C, and the fat percentage was recorded from the butyrometer reading (Richardson, 1985).

Determination of ash content

Gravimetric analysis was used to evaluate the ash content of the milk samples. The dried milk samples used to determine total solids content were burned in a muffle furnace at 550°C for four hours until they were carbon-free (heating continued until black color faded or the ash residue looked grey to white), then transferred to desiccators to cool down. Finally, the ash content was calculated according to Richardson 1985.

Calculation:

$$\%Ash = \frac{\text{Residue weight}}{\text{Sample weight}} \times 100$$

Microbial analysis

The determination of colony-forming units (CFUs) of total bacteria, coliform bacteria, spore-forming bacteria, yeast, and mould using suitable conditions is part of the microbiological analysis of milk samples. All microbiological analysis media were sterilized prior to use according to the manufacturer's instructions.

Total bacterial count

Appropriate decimal dilutions that would yield the expected total number of colonies on a plate, i.e., between 30 and 300 colonies, were chosen for the total plate count (Richardson, 1985). Before pouring, the standard plate count (SPC) agar was cooled to 45°C. One mL of milk sample was added to a sterile test tube with nine mL peptone water and thoroughly mixed up to a serial dilution of 10^{-7}. The total bacterial count was determined by incubating surface plated duplicate decimal dilutions of milk samples for 48 hours at 32^0C on standard plate count agar (Oxoid, UK). Finally, a colony counter was used to count the colonies (Schutt Count Plus D-37079, Germany).

Coliform count

One mL of milk sample was added to a sterile test tube with nine mL peptone water and thoroughly mixed up to a serial dilution of 10^{-7}. On Violet Red Bile Agar (Pharma, US), duplicate adequate decimal dilutions were surface plated and incubated at 32^0C for 24 hours, and typical dark red colonies on uncrowned plates were regarded coliforms and counted. Then, four to five typical colonies from each plate were transferred and incubated in tubes containing 2 percent Brilliant Green Lactose Bile Broth as a confirmatory test (Oxid, UK). The presence of coliforms was determined by the formation of gas during 48 hours of incubation at 35°C (Richardson, 1985).

Spore-forming bacteria count

The spore-forming bacteria were counted using plate count agar according to McLandsborough's recommendations (2005). Milk samples were heated in a water bath at 80°C for 10 minutes, and quantities of 0.1 ml of appropriate dilutions were surface plated using plate count agar as for the standard plate count. Colonies were counted after 3 days of incubation in an inverted position at 30^0C.

Yeast and mould count

Milk samples were serially diluted in the same way that total bacterial count samples were, but the dilutions were surface plated on Potato Dextrose Agar (PDA) (Oxoid, Pvt. Ltd. MU 096: UK). After that, the dry plates were incubated for 3 to 5 days at 25°C. Yeasts and molds were counted as colonies having a blue-green tint (Yousef and Carlstrom, 2003).

Statistical Analysis

Before statistical analysis, data from microbial counts were converted to logarithmic values (log10). Then, data on the physicochemical properties and the transformed microbial count values were analyzed using the General Linear Model (GLM) procedure of SAS (SAS, 2009). Mean separation was carried out using the Least Significant Difference (LSD) technique when analysis of variance shows significant differences between means and differences were considered significant at $p < 0.05$.
The following model was used for the analysis of the physicochemical properties and microbial quality of milk:

$$Yij = \mu + \alpha i + eij$$

Where, Yij = The value of the respective variable mentioned above on the I Woreda (i=3, Mizan Aman, Bench and Shei Bench), μ = Overall mean of the respective variable, αi = The effect of i^{th} Woreda (Mizan Aman, Debub and Shei Bench) on the respective variable, eij = The error term

Results and Discussion

Physicochemical properties of raw cow milk

The physicochemical properties of raw cow milk samples collected from milk producers in study areas were shown in Table 1. The mean pH value of raw milk samples was significantly different ($P < 0.05$) among Woredas. On the other hand, there was no marked difference between milk samples collected from Debub and Shei Bench. The pH value of milk samples collected from Mizan Aman town was more acid than those of the Debub and Shei Bench Woredas. This might be due to variations in the milk hold equipment, age of milk, and handling techniques. The pH of milk samples collected from Mizan Aman town was significantly ($P < 0.05$) lower than the pH of milk obtained from Debub and Shei Bench Woredas (Table 1). The average (±SD) pH of milk samples obtained from Mizan Aman town (6.153 ± 0.114) were not within the normal pH range indicating that there were bacterial growths in the milk samples. However, the average pH value of milk samples obtained from Debub Bench (6.647 ± 0.200) and Shei Bench (6.627 ± 0.128) (6.67 ± 0.03) were within the normal pH range of fresh cow milk indicating that the milk was most probably obtained directly from households shortly after milking. Fresh cow milk has a pH value that ranges from 6.6 to 6.8 (O'Connor, 1995 and FAO, 1999). The pH values higher than 6.8 indicate mastitic milk and pH values below 6.6 indicates increased acidity of milk due to bacterial multiplication (O'Connor, 1995). Consequently, the low pH of milk collected from Mizan Aman town might probably be due to the production of acid resulting from bacterial growth and multiplication in the milk samples. There was a significant difference in milk specific gravity among Mizan Aman, Debub and Shei Bench Woredas (Table 1). However, there was no marked difference between milk samples collected from Debub and Shei Bench Woredas. The specific gravity of normal milk ranges from 1.027 – 1.035 g per ml with a mean value of 1.032 g per ml (Tamime, 2009). FAO (1988) also reported that the specific gravity of normal milk ranges from 1.028-1.033 gram per milliliter. In the current study, the result of milk samples collected from Debub and Shei Bench Woredas within the ranges of Tamime (2009) and FAO (1988) findings. Conversely, the result of milk samples collected from Mizan Aman town did not exist within a range of Tamime (2009) and FAO (1988) findings. This might be indicating the adulteration of milk with water. According to O'Connor (1993) the higher value of specific gravity (1.035) indicates skimming off fat whereas, the lower value than normal value of specific gravity of milk (1.020) is indicative of addition of water. Similar on-farm result of specific gravity of 1.030 was reported by Zelalem and Ledin, (2001). Furthermore, adulteration of milk with water that was usually done in order to increase the quantity of milk lowers milk's specific gravity while addition of solids such as flour or sugar into milk and removing the butterfat increases the specific gravity of milk beyond 1.035 gram per milliliter (O'Connor, 1995; Omoree*et al*., 2005).

Table 1. Mean (±SD) physicochemical properties of raw cow's milk samples collected from three Woredas (n=45)

Variables	Woredas			
	Mizan Aman (n=15)	**Debub Bench (n=15)**	**Shei Bench (n=15)**	**Overall mean**
pH value	6.153±0.114^{b}	6.647±0.200^{a}	6.627±0.128^{a}	6.477±0.273
Specific gravity	1.022±0.016^{b}	1.031±0.002^{a}	1.031±0.001^{a}	1.028±0.010
TA(%LA)	0.215±0.010a	0.174±0.018b	0.177±0.013b	0.190±0.023
Fat	5.867±0.586	5.973±0.730	6.233±0.940	6.024±0.763
Protein	3.844±0.475	3.954±0.402	4.140±0.320	3.980±0.414
Ash	0.780±0.050	0.815±0.047	0.791±0.066	0.795±0.056

Means followed by different superscript letters within a row are significantly different (P<0.05), TA = Titratable acidity, LA= Lactic acid, n= number of samples

The mean titratable acidity was significantly different (P < 0.05) among milk samples collected from Mizan Aman, Debub and Shei Bench Woredas (Table 1). On the other hand, there was no marked difference among milk samples collected from Debub and Shei Bench Woredas. In the current study, the milk samples collected from three areas had a titratable acidity value of greater than 0.16% which indicates that the milk samples were kept at room temperature for longer period of time and under poor handling practices until they were sold and/or consumed. Normal fresh milk has an apparent acidity of 0.14 to 0.16% as lactic acid (O'Connor, 1995). The titratable acidity milk obtained from Mizan Aman town was significantly (P < 0.05) higher than that of Debub and Shei Bench Woredas (Table 1). The higher titratable acidity of raw milk samples collected from Mizan Aman town may be due to bacterial growth and longer storage of the milk before sale. Asaminew and Eyassu (2011) reported higher acidity for milk samples collected from individual farmers (0.23 ± 0.01% lactic acid) in Bahir Dar Zuria Woreda.

There was no significant difference (P > 0.05) in fat content observed among three study areas. The average fat content of milk obtained from three areas (5.867 ± 0.0.589, 5.973±0.730 and 6.233±0.940% of Mizan Aman, Debub and Shei Bench Woredas, respectively) were greater than the earlier findings of Mansson *et al.* (2003), Janštová *et al.* (2010) and Teklemichael (2012) who reported a fat content of 4.3%, 3.79±0.18% and 3.862±0.412%, respectively for milk produced in dairy farms. According to European Union quality standards for unprocessed whole milk, fat content should not be less than 3.5% (Tamime, 2009). Consequently, the average fats content (6.024 ± 0.763%) were observed from three areas were within the recommended standards. Only high-quality raw milk can be used to make high-quality milk products. The hygienic quality of milk is critical for smallholder producers who want milk that is safe and suitable for its intended use. Because the fat content of milk is a determining factor in the price paid per liter of milk. As a result, the current result is fantastic news for smallholder raw cow milk producers.

Protein content of milk obtained from Mizan Aman, Debub and Shei Bench Woredas were 3.844±0.475, 3.954±0.402 and 4.140±0.320, respectively (Table 1). There was no marked difference (P>0.05) among milk samples three areas. The average protein content of raw milk obtained from Mizan Aman, Debub and Shei Bench Woreda*s* were higher than the earlier findings of Abd Elrahman *et al*. (2009) who reported a protein content of 3.48% for milk produced in dairy farms. Correspondingly, Fikrineh *et al.* (2012) reported lower protein content (3.46 ± 0.04%) for milk samples collected from households producing local and crossbred cows. According to European Union quality standards for unprocessed whole milk, total protein content should not be less than 2.9%, (Tamime, 2009). Therefore, the average proteins content (3.980±0.414%) observed from three areas were within the recommended standards. Because the protein content of milk is a determining parameter in determining the price paid per liter of milk. As a result, the current result is fantastic bulletin for smallholder raw cow milk producers.

Ash content of raw milk obtained from Mizan Aman, Debub and Shei Bench Woredas averaged 0.780±0.050, 0.815±0.047 and 0.791±0.066, respectively (Table 1). The ash contents of milk samples collected from three sampling areas was not significantly (P<0.05) different. The ash content of cow milk remains relatively constant 0.7 to 0.8% and it is influenced by breed, stage of lactation and feed of the animal (O'Connor, 1995). The composition of milk can vary depending on breed of the animals, interval between milking, completeness of milking, stage of lactation, feed of the animal, age and health status of the milking cows. Microbial activities such as degradation of proteins and lipids of milk can also change the composition of milk (O'Connor, 1995).

Microbial Quality of Raw Cow Milk

Total bacterial count

The mean total bacterial count was significantly different ($P < 0.05$) among milk samples collected from Mizan Aman, Debub, and Shei Bench Woreda*s* (Table 2). On the other hand, there was no marked difference among milk samples collected from Mizan Aman and Debub Bench Woreda*s*. The total bacterial count obtained in this study is generally high compared to the acceptable level of 1×10^5 bacteria per ml of raw milk (O'Connor 1994). The total bacterial count obtained from Mizan Aman and Debub Bench was significantly higher ($P < 0.05$) than milk samples collected from Shei Bench Woreda (Table 2). This might be due to further contamination of the milk during transportation, use of poorly cleaned milk containers, and absence of a cooling system. In general, a higher total bacterial count of milk samples obtained from study areas could be attributed to improper cleaning of the udder and milking containers before and after milking, failure to use a separate towel for each cow, improper cooling system, and milk contamination from the hands of producers.

Table 2. Mean (±SD) microbial counts (log10 CFU/ml) of raw cow's milk samples collected from three Woreda (n=45)

Variables	Woredas			
	Mizan Aman (n=15)	Debub Bench (n=15)	Shei Bench (n=15)	Overall mean
TBC	7.235±0.277a	7.222±0.156a	6.817±0.381b	7.091±0.342
CC	5.203±0.230a	5.187±0.211a	4.911±0.324b	5.100±0.288
SFBC	6.489±0.258a	6.307±0.195ab	6.221±0.542b	6.341±0.371
YMC	4.001±0.588	3.944±0.346	3.762±0.468	3.902±0.477

Means followed by different superscript letters within a row are significantly different (P < 0.05), TBC=Total bacterial count, CC= Coliform count, SFBC= Spore forming bacterial Count, YMC= Yeast, and mold count, n= number of samples

In the present study, the total bacterial count of raw cow milk collected from three areas was lower than that reported by Ahmed *et al.* (2008) who found a high total bacterial count of (9.089 ± 0.281 log_{10}CFU/ml) in milk samples collected from dairy farms of Khartoum State. However, the total bacterial count obtained from Mizan Aman and Debub Bench was higher than that reported by Debebe (2010) who found a total bacterial count of $6.98 \pm 0.15 log_{10}$CFU ml^{-1} milk samples collected from milk producers (Table 2). The mean total bacterial count of raw cow's milk (7.091 log_{10}CFU/ml) obtained in this study was lower than the earlier findings of Zelalem (2010), Haile *et al.* (2012), and Teklemichael (2012) who reported a total bacterial count of 9.10 log_{10}CFU/ml for milk samples collected from different parts of Ethiopia, 10.28 log_{10}CFU/ml from distribution containers (at selling point) and 9.137 log_{10}CFU/ml from vendors, respectively. Milk produced under hygienic conditions from healthy cows should not contain more than 5×10^4 bacteria per milliliter (O' Connor, 1993). Higher total bacterial count observed in the present study could probably be due to lack of knowledge about clean milk production, use of unclean milking utensils and plastic containers for collecting and keeping milk, initial contamination of the milk samples either from the udder of the cow or the milkers' hand and the poor hygienic quality of milking area.

Coliform count

The mean coliform count was significantly different (P<0.05) among milk samples collected from Mizan Aman, Debub, and Shei Bench Woredas (Table 2). On the other hand, there was no marked difference among milk samples collected from Mizan Aman and Debub Bench Woredas. The coliform count obtained from Shei Bench Woreda was significantly lower (P<0.05) than milk samples obtained from Mizan Aman and Debub Bench Woredas (Table 2). The overall mean of coliform count observed in raw cow's milk samples collected from Mizan Aman, Debub, and Shei Bench Woredas were 5.203±0.230, 5.187±0.211, and 4.911±0.324 log_{10}CFU/ml, respectively (Table 2). The coliform count obtained in the current study was greater than that reported by Abdalla and Elhagaz (2011) who found coliform counts of 2.23±0.136 log_{10}cfu/ml from milk samples collected at Khartoum State dairy farms. On the other hand, Zelalem and Bernard (2006) obtained a higher coliform count of 6.57 log_{10}CFU/ml for raw cow's milk collected from different producers in the central highland of Ethiopia. In the current study area, some animals are kept in a muddy barn and hygienic conditions were poor. This possibly has exposed the milk to a high risk of contamination, which in turn increases the microbial count. The existence of coliform bacteria in high proportion is suggestive of unsanitary conditions or practices during production or storage.

According to the European Union standards for total bacterial and coliform counts of raw milk should be less than 10^5 and 10^2CFU/ml, respectively (Fernandes, 2009). The present study showed that the coliform count of all milk samples exceeds the standards given for raw milk by European Union and US regulations. Generally, the presence of high numbers of coliforms in milk indicates that the milk has been contaminated with fecal materials, unclean udder and teats of cow's, inefficient cleaning of the milking containers, poor hygiene of milking environment, contaminated water, and cows with subclinical or clinical coliform mastitis can all lead to elevated coliform count in raw milk (Jayarao*et al.,* 2004).

Spore forming bacterial count

Mean spore-forming bacterial count (SFBC) was significantly different (P<0.05) among milk samples collected from three study areas (Table 2). However, there was no marked difference between Mizan Aman and Debub Bench Woredas. Likewise, there was no significant difference between Debub Bench and Shei Bench Woredas. The mean SFBC of raw cow's milk obtained in this study (6.3411±0.371log_{10} CFU/ml) was agreed with the earlier finding of Teklemichael (2012) who reported a spore-forming bacterial count of6.392±0.154log_{10} CFU/ml from milk vendors in Dire Dawa town. However, the lower SFBC (4.703 ± 0.069 log_{10} CFU/ml) was reported by Teshome *et al*. (2014) for milk samples collected from Shashemene town. Numerically higher SFBC in milk samples obtained from Mizan Aman may indicate that there was poor environmental sanitation and poor handling practice at the production and selling sites. It could also be associated with the spores which transferred from feed, feces, bedding material, and soil into milk. As a result of these factors, daily milk production and eventual milk marketing require special consideration to ensure hygienic and acceptable milk delivery to the consumers.

Yeast and mould count (YMC)

The overall mean of YMC was 4.001±0.588, 3.944±0.346, and 3.762±0.468 log_{10} CFU/ml for milk samples collected from the Mizan Aman, Debub, and Shei Bench Woredas, respectively. The mean value of yeast and mold counts was not significantly different (P<0.05) among milk samples collected from three study areas (Table 2). However, numerically the YMC of Mizan Aman town was higher than the milk samples obtained from Debub and Shei Bench Woredas. Teshome *et al.* (2014) reported higher overall mean Yeast and mold counts of 4.206 ± 0.082 for milk samples collected from small-scale milk producers, small shops, hotels, and dairy cooperative milk collection centers. Numerically the higher YMC observed in milk obtained from Mizan Aman town might be attributed to contamination from air, containers, or poor personal hygiene of milk handler. Furthermore, the presence of a high number of yeast and mold in milk indicates that the milk has been contaminated with soil, dust specks, air, and other contaminants as a result of poor raw milk handling practices. Similarly, differences in initial contamination during production, additional contamination during post-harvest handling, and differences in milk holding temperatures and time during storage and transportation could all contribute to this variation.

Conclusions

The physical properties and chemical composition of the collected raw cow milk samples were within the recommended levels of European Union and FAO established quality standards. However, the observed microbial quality of milk produced at three study areas was poor. This might be due to the poor hygienic condition of the milking environment (absence of separate area for milking and failure to clean milking areas regularly), absence of cooling system, the poor sanitary condition of the milk containers, poor udder and teats cleaning practice, failure to use a separate towel for each cow, use of plastic buckets, keeping the milk at room temperature and poor personal hygiene of the milkers. In general, the microbial quality of raw cow milk produced by three areas does not meet the international standards set by regulatory agents and thus could pose health hazards to the consumers. Therefore, this suggests the need for enriched hygienic practices and educating the public on safety issues and personal hygiene in milk handling. It would be of great interest if further investigations are to be carried out to identify and isolate different species of microorganisms that might cause public health importance.

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Determinants of Pasteurized Milk Purchase Probability and Intensity of Addis Ababa Consumers

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Abstract

Dairy product consumption in Ethiopia is by far lower than its neighboring East African countries as well as the amount recommended by the World Health Organization. Moreover, consumers in Ethiopia usually depend on raw milk. However, raw milk consumption has a risk of zoonotic disease transmission. One strategy to reduce such risk is through shifting to pasteurized milk consumption. Studies that guide policy makers on factors that determine pasteurized milk consumption are scanty in Ethiopia. This paper analyzed the determinants of pasteurized milk purchase probability and intensity (amount) in the Ethiopian capital Addis Ababa using survey data of 384 sample urban consumers, and with an underlying focus on bovine tuberculosis (bTB), a zoonotic disease that can be milk-borne. Both descriptive statistics and a Heckman's two step selection model were used to analyze the data. The descriptive results show that 73% of the sample households purchased/consumed pasteurized milk with an average annual consumption of 76 liters per household, corresponding to 24 liters per person in milk consumption units for pasteurized milk purchasers. The Heckman's two step selection model result indicated that Orthodox Christian households consumed less pasteurized milk than average, which could be associated with frequent fasting seasons for these consumers. The model results further revealed that older household heads were positively associated with the probability of consuming pasteurized milk. The model results also revealed that households having children in their family had higher probability of purchasing pasteurized milk. Households who perceive that pasteurized milk is expensive (high price) had higher probability of purchasing but they purchased less amount. The model results further indicated that the influence of social peer, households' emotional values such as 'feeling good when consuming pasteurized milk' and epistemic value (their attitude to try new and different products) had positive impact on both the probability and intensity of purchasing pasteurized milk. Furthermore, conditional value (availability of pasteurized milk) had a positive impact on the probability of purchasing pasteurized milk. Therefore, addressing demographic, socio-economic, and consumption value variables would be important factors to be considered when designing 1) policies that target nutritional improvement based on dairy products, and 2) public health-related policies that target zoonotic diseases.

Keywords: pasteurized milk, Heckman two step model, milk, zoonosis.

Introduction

Consumption of dairy products is necessary to fulfill adequate intake levels of nutrients recommended for human beings to develop the immune system of the body (Huth *et al*., 2006; Thorning *et al*., 2016). Dairy products are good sources of many essential minerals and vitamins, besides providing with dietary energy, protein, fat, and carbohydrate (FAO, 2013). Many countries make dairy an important food group when preparing food-based dietary guidelines (FBDG) (Herforth *et al*., 2019). The daily recommended dairy product intake per capita has been set to at least 500 milliliters of milk in the FBDG available for most developed nations (WHO, 2003).

Despite the significant contribution of milk and dairy products to human diets, the average global per capita consumption of milk during 2014-2018 was only 85kg/year or 232 milliliters/day which was by far lower than the recommended intake (FAOSTAT, 2020). However, there is a great variation in dairy consumption between developed and less developed countries, with the top three countries with the highest average annual per capita consumption during 2014-2018 being Montenegro (355kg), Finland (353kg), and Albania (311kg). In contrast, the annual per capita milk consumption in developing countries was less than 50kg/year during the same period. In several East African countries, namely Uganda, Ethiopia, Djibouti, and Rwanda, the annual per capita milk consumption was very low and recorded at only 38kg, 30kg, 26kg, and 14kg, respectively, while much higher per capita consumption was recorded in Sudan (95kg) and Kenya (76kg) during the same period (FAOSTAT, 2020).

Fresh dairy products are the most commonly consumed dairy products, accounting for more than 50% of the total consumption in 2018 across the globe (OECD/FAO, 2018). This figure was very high in Sub-Saharan African countries with more than 90% of dairy products consumed fresh in 2016 (OECD/FAO, 2016). Fresh dairy products refer to unprocessed or only slightly processed (pasteurized or fermented) milk but exclude processed dairy products such as butter, cheese, skim milk powder, whole milk powder and, casein and whey (OECD/FAO, 2018). Consumption of fresh milk, especially raw milk has been recognized as a continuous risk factor for zoonotic diseases such as bovine tuberculosis caused by Mycobacterium bovis through consumption of raw milk (Doran *et al*., 2009). One of the strategies to reduce this risk is consuming processed fresh milk such as pasteurized milk and dairy products derived from pasteurized milk due to the fact that consuming raw milk and products derived from it is a continuous risk factor for zoonotic diseases (CDCP, 1999; Cohen, 2000; FDA, 2020, Jay-Russell, 2010; Lejeune and Rajala-Schultz 2009).

Nevertheless, unlike the developed nations who set a strict regulation to prohibit sale and consumption of raw milk and its derivatives long times ago, public health regulations of such kind are lacking in developing countries including Ethiopia. On the other hand, informal milk marketing that involves high level of direct raw milk sell to consumers in large cities including Addis Ababa is common (Tadele *et al*., 2021) despite dairy processing factories that also provide pasteurized milk is highly concentrated in large cities (AddisBiz, 2021). However, both the farm and herd level prevalence of tuberculosis, that can be transmitted through consumption of raw milk in and surroundings of Addis Ababa is high. For instance, Elias *et al*. (2008) found 23.7% and 43.4% animal and herd level prevalence, respectively in Addis Ababa. Wondewosen *et al*. (2010) found 34% and 54% animal and herd level prevalence, respectively in Addis Ababa. Two years later, Rebuma *et al* (2012) found 30% and 50% animal and herd level prevalence, respectively in farms in and around Addis Ababa with 50kms radius. Recent study by Gizat *et al*. (2021) showed 31% and 61% animal and herd level prevalence, respectively in and surroundings of Addis Ababa.

In the absence of regulations that prohibit raw milk marketing and with high prevalence of tuberculosis in Addis Ababa and surrounding, pasteurized milk consumption is an important strategy from the public health perspective. However, empirical findings on pasteurized milk consumption status and determinant factors of the probability of participating in purchase and intensity of purchase is generally lacking. The objective of this paper was therefore to investigate the determinants of the probability and intensity of pasteurized milk purchase.

Materials and Methods

Description of the study area

The study was conducted in Addis Ababa, the capital city of Ethiopia, with a total population estimated at three million people (Addis Ababa city Mayor Office, 2018). Administratively, the city is divided into 11 sub-cities that are further divided into 117 districts (also known as Woredas). This study covered four of the ten sub-cities, namely Bole, Kirkos, Kolfe Keraniyo, and Gulele, and from which 11 districts were selected: three districts each from Bole and Kolfe Keraniyo, and two districts each from Kirkos and Gulele sub-cities (Figure 1).

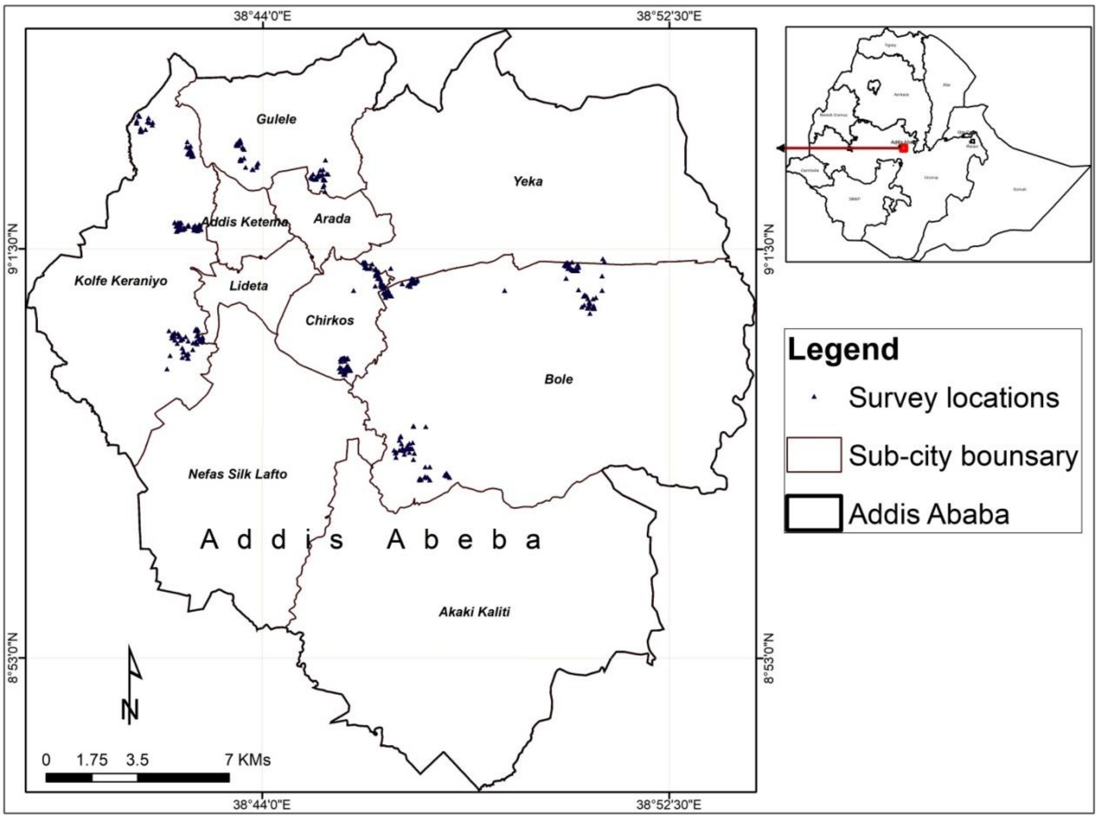

Figure 1. Map of Addis Ababa city and its 10 sub-cities, of which Bole, Kirkos, Kolfe Keraniyo, and Gulele were the study areas.

Sampling procedure

To obtain a representative sample size of the dairy product consumers, the sample size determination formula by Kothari (2004) was used:

$$N = \frac{Z^2pq}{e^2} = \frac{(1.96)^2\,(0.5)(0.5)}{0.05^2} = 384 \qquad (1)$$

Where N is the sample size needed, Z is the inverse of the standard cumulative distribution that corresponds to the level of confidence, *e* is the desired level of precision, *p* is the estimated proportion of an attribute that is present in the population, and $q = 1\text{-}p$. The value of Z is found from the statistical table which contains the area under the normal curve of 95% confidence level. In the determination of sample size, setting the value of p=0.5 and hence q=0.5 yields the maximum optimum sample size while any other combination of the values of p and q yields less sample size using the Kothari formula. Therefore, using 0.5 for the values of p and q and *e* =0.05 the Kothari formula gives a total of 384 samples to sufficiently represent the dairy product consumers' population in the selected study areas assuming a 95% confidence level and ±5% precision. To identify the study samples a multi-stage stratified random sampling procedure was used. Addis Ababa city was purposively selected due to three reasons. First, it is a metropolitan city where high potential for dairy products consumption is expected from the demand side. Second, there is a high supply of dairy products in the city from domestic production of urban and peri-urban dairy producers of the Addis Ababa milk-sheds and there are dairy processing industries in the city. Lastly, dairy products importing companies are available in the city. Then, the city was stratified into four strata using the population density, geographical location, and the level of development of the sub-cities. Based on this, Bole was selected to represent the eastern, northeastern, and southeastern sub-cities stratum composed of three sub-cities, sparsely populated and highly developed sub-city whereas Kirkos was selected from the central part representing four sub-cities, less developed and highly populated sub-city. Kolfe Keraniyo was selected from the southwestern and western sub-cities representing two sub-cities with a medium level of both development and population density. Finally, Gulele sub-city was selected from the northern part of the city having a medium level of development and population density.

After the selection of the four sub-cities, the number of districts to be selected was determined based on the number of districts available in each sub-city. Since ten or more districts are available in each sub-city, the districts and sample households were randomly selected from each district using systematic random sampling from the households list available in the department of basic events in each district. The allocation of the number of samples for each district was based on probability proportional to population size as summarized in Table 1.

Table 1. Description of the sample households by sub-city and districts

Sub-city	District	Number of households/districts	Sample size	% of sample
Bole	Woreda 4	5166	39	10.2
	Woreda 8	6013	42	10.9
	Woreda 12	12120	53	13.8
	Subtotal	23299	134	34.9
Kirkos	Woreda 3	3341	34	8.8
	Woreda 8	3230	32	7.9
	Subtotal	6571	66	17.2
Gulele	Woreda 4	2529	30	7.8
	Woreda 9	2041	28	7.3
	Subtotal	4570	58	15.1
Kolfe keraniyo	Woreda 5	8605	49	12.8
	Woreda 10	6024	44	11.5
	Woreda 15	3935	33	8.6
	Subtotal	18564	122	31.8
Total			384	100

Data collection

Well-trained and experienced enumerators having university first Degree were recruited and given training on the content of the questionnaire and on how to approach sample households. The questionnaire was pretested before the actual data collection was conducted and feedbacks were included in the final questionnaire. The questionnaire was designed based on Mullins *et al*. (1994) and Rahnama and Rajabpour (2017). The questionnaire included household, socio-economic and demographic characteristics, awareness and perception on dairy products consumption, detailed dairy product purchase and consumption practices such as place, frequency, quantity, and reason for buying dairy products, and an average annual price of each dairy product they purchase. The questionnaire also contains household background variables economic variables such as monthly income. Consumption value variables measured in five-point Likert with carrying 1-5 points with 1 strongly disagree and 5 strongly agree to the statements represent functional, social, conditional, emotional and epistemic value variables. Data collection was performed from January to February 2019 using CAPI (computer-assisted personal interview) laden with Census Survey Processing System (CSPro 7.1). In most cases, the household head was used for the interview while spouses were used in some cases to give the information of the household.

Data analysis

Both descriptive and econometric models were used to analyse the data. Econometric model used in this study was the Heckman selection model, the specification of which is given in subsequent section.

Empirical model specification

Pasteurized milk consumers make two types of decisions: The first is whether or not to purchase it whereas the second is on the quantity of purchased one they decide to purchase. Several econometric models are available to handle such decisions, of which Tobit (Tobin, 1958), Heckman two-stage (Heckman, 1979) and Craggit double hurdle (Cragg, 1971) are commonly used. However, each of the models has their own strengths and weaknesses. The Tobit model has two drawbacks. The first is that it cannot separate the participation and intensity of participation decisions as it assumes both equations are affected by the same factors. However, this cannot be always true. The second drawback is that it assumes zero corner solution which may not hold true as the zero value of the intensity of participation equation may not be necessarily the corner solution rather can be due to a discrete choice of not to participate in the adoption decision. Therefore, Heckman two stage and the Craggit double hurdle models could be the best candidates.The Heckman two-stage sample selection model can solve the drawbacks of the Tobit as the participation and intensity of participation decisions are successively regressed in this modelling approach. In the Heckman selection model, the zero observations in the dependent variable are assumed to be discrete choices not to participate and only positive quantities are expected in the intensity (second) equation once a consumer decides to participate in pasteurized milk purchasing. That is, the second stage does not have a room for a corner solution in the intensity decision, which may not always be true, which is a shortcoming of the Heckman selection model. The alternative model for this is the Craggit model formulated by Cragg (1971) and further developed by Jones (1989). This model is more flexible and designed to solve the drawbacks of both the Tobit and the Heckman two stage models. However, to decide whether the Tobit, the Craggit or the Heckman selection model better fits for the data at hand, formal testing procedures are available. To choose between the Tobit and Craggit models a log likelihood ratio test can be used.

Similar procedure can be done to choose between the Heckman and the Craggit model. The difference between the Heckman and the Craggit double hurdle models is that the former assumes there is no zero observation in the dependent variable of the second stage once the first stage is passed whereas the later still considers that there might be a possibility of zero observation. In this study, once the consumers decide to participate in purchasing pasteurized milk, there is no possibility that the quantity purchased (the intensity) can be zero which means the probability that the first assumption of the Heckman selection model holds true is high. Another difference between the two is that the Heckman two stage selection model assumes the dependence of the hurdles whereas the Craggit double hurdle model assumes the independence of the hurdles (Rufino, 2016). If this holds true, the Heckman is better than Craggit double hurdle model for it corrects the sample selectivity bias. The way to undertake the empirical comparison of the Craggit and the Heckman two stage models suggested by Rufino (2016) is by evaluating the phenomenon of dependence/independence of the hurdles. That is, the likelihood-ratio test reported at the bottom of the Heckman two stage model output is an equivalent test for Ho: $\rho = 0$. It is computationally the comparison of the joint likelihood of an independent probit model for the selection equation (first hurdle) and a truncated regression model of the intensity equation (second hurdle). If a p-value is less than 0.05, the use of Heckman sample selection model instead of the Craggit model is justifiable.In order to choose between the Tobit model and Craggit model, a likelihood ratio (LLR) test that compares the double hurdle model with the Tobit model was used. Following Greene (2012), the LLR can be given as:

$$LLR = 2 * [Log_{\text{Craggitmodel}} - Log_{\text{Tobitmodel}}] \quad (2)$$

However, to choose between the Heckman and the Cragit model, the Heckman model itself provides Null hypothesis of independence of the error terms and it is enough to evaluate the result provided under the model output to choose between the Heckman and the Craggit model.

In this study after evaluating the appropriateness of all the three models, the Heckman's two-steps selection model was chosen to be appropriate. Heckman's sample selection model is based on two latent dependent variable models and has developed a two steps estimation procedures model that corrects for sample selectivity bias (Heckman, 1979). Moreover, Heckman's two steps estimation procedures are appropriate in that there are two decisions involved, such as participation in purchasing of pasteurized milk and the intensity of purchase. The first step of Heckman two steps model, 'the participation equation', attempts to capture factors affecting participation decision. The selectivity term called 'inverse Mills ratio' (which is added to the second step outcome equation that explains factors affecting the level or intensity) is constructed from the first equation. The inverse Mill's ratio is a variable for controlling bias due to sample selection (Heckman, 1979). The second step involves the Mills ratio to the intensity (level of participation) equation and estimating the equation using Ordinary Least Square (OLS). If the coefficient of the mill's ratio (lambda) is significant, then the hypothesis of the unobserved selection bias is confirmed. Moreover, with the inclusion of extra term (Mill's ratio), the coefficient in the second step selectivity corrected equation is unbiased (Zaman, 2001).

Specification of the Heckman two steps procedures, which is written in terms of the probability of participation and intensity, is:
The participation/the binary probit equation

$$Y_{1i} = X_{1i}\beta_1 + U_{1i} \qquad U_{1i} \sim N(0, 1) \tag{3}$$

$Y^*=1$ if $Y_{1i} > 0$ (3.1)

$Y^*=0$ if $Y_{1i} \leq 0$ (3.2)

Where Y_{1i} is the latent dependent variable which is not observed,
X_{1i} is vectors that are assumed to affect the probability of participation,
β_1 is vectors of unknown parameter in the participation equation, and
U_{1i} are residuals that are independently and normally distributed with zero mean and constant variance
The observation equation/the intensity equation

$$Y_{2i} = X_{2i}\beta_2 + U_{2i} \qquad U_{2i} \sim N(0, 1) \tag{4}$$

Y_{2i} is observed if and only if $Y^* = 1$. The variance of U_{1i} is normalized to one because only Y^*, not Y_{1i} is observed. The error terms U_{1i} and U_{2i} are assumed to be bivariate, normally distributed with correlation coefficient ρ, β_1 and β_2 are the parameter vectors.

Y_{2i} is regressed on explanatory variables, X_{2i}, and the vector of inverse Mill's ratio (λ_i) from the selection equation by Ordinary Least Square (OLS).

Where, Y_{2i} is the observed dependent variable
X_{2i} is factors assumed to affect intensity equation
β_2 is vector of unknown parameter in the intensity equation
U_{2i} is residuals in the intensity equation that are independently and normally distributed with mean zero and constant variance.

$$\lambda_i = \frac{f(XB)}{1-F(XB)} \tag{5}$$

f (Xβ) is density function and 1- F (Xβ) is distribution function.

Results and Discussion

Demographic characteristics of the sample households

Tables 2 and 3 present the descriptive results of the continuous and discrete variables included in the Heckman econometric model, respectively. The result shows that the average age of the pasteurized milk purchasing household head was 47 years while the average of the non-purchasers was 50 years and the age of the overall sample was 48 years. The household head makes a household level decision and his/her age, a proxy for experience, is a crucial factor to consume pasteurized milk. In this study, there is no significant difference between the average age of the purchasing and non-purchasing households (Table 2).

Table 2. Mean difference of continuous variables between purchasers and non-adopters of pasteurized milk

Variables	purchasers (n=282)	Non- purchasers (n=102)	Total sample (n=384)	t-test
Age of head	47.42 (14.87)	50.01(16.27)	48.11 (15.27)	-1.45
Family size (CU[a])	3.72 (1.64)	3.40 (1.45)	3.64 (1.60)	1.75*
Consumption value [b]				
Price (expensive)	4.35 (0.86)	4.52 (0.70)	4.40 (.82)	-1.8*
Taste	3.88 (1.00)	4.02 (1.01)	3.92 (1.00)	-1.2
Social value	3.09 (1.05)	2.74 (1.13)	2.99 (1.08)	2.8***
Emotional value	4.01(0.50)	3.93 (0.64)	3.99 (0.54)	1.3
Conditional value	2.77 (1.15)	2.45 (1.23)	2.68 (1.18)	2.3**
Epistemic value	3.48 (0.86)	3.27 (1.00)	3.42 (0.90)	2.0**

,and *** means significant at 10%, 5% and 1% level of significance, respectively.*
Note: Figures in parentheses indicate standard deviations, aConversion factor for consumption unit (CU) is: 0.35 for male and female of age <2years, 0.6 for male and female of age 3-10 years, 0.8 for male and 0.7 for a female of age 10-15 years, 1 for male and 0.8 for a female of age 16-50 years and 0.8 for male and 0.65 for a female of age >50years (Leegwater et al., 1991); b1=strongly disagree, 2=disagree, 3=indifferent, 4=agree, and 5=strongly agree.

The sample households were on average, composed of 3.6 family members (converted into consumption units). However, the average family size of the purchasing households was significantly higher (3.7) than the non-purchasing households (3.4) at 10% level of significance (Table 2). The result of the household background further indicated that 78.9% of the sample households were Orthodox Christians, 27% of the heads of the sampled households had at least completed 12[th]-grade education level, 43% had children of age seven years or below, and 77% were aware that consuming raw milk is a risk factor for zoonotic diseases, with significant differences between the proportion of the two groups with respect to religion variable at 5% and no significant difference between other variables (Table 3).

Monthly income of the sample households

Income is one of the important factors that affect consumption of dairy products. The result indicated that only 10% of the households had a monthly income of at least 8,000ETB ($289 at 0.036 average exchange rate of 2018) per household, while the majority (59%) had an average monthly income of less than 4000ETB followed by those earn an average monthly income of 4000-8000ETB (31%). There is no significant difference between the purchasers and non-purchasers of pasteurized milk in all income categories (Table 3).

Characteristics of the sample households in terms of consumption value variables

In terms of the consumption values that the respondents attribute for pasteurized milk (using a 1-5 Likert scale), the result indicated that the sample households tended to agree to the consumption value indicators of functional values of taste and price, and emotional value with a significant mean difference between the two groups in terms of functional value price. On the other hand, the sample households were found to be neutral on the indicator for social value and did slightly disagree on conditional value with significant mean differences between the two groups in terms of both variables. The average sample households did slightly agree on epistemic value with a significant mean difference between the two groups.

Table 3. Percentage difference between purchasers and non-purchasers of pasteurized milk (discrete variables)

	Purchasers (n=282)		Non-purchasers (n=102)		Overall (N=384)		X^2 value
	Freq.	%	Freq.	%	Freq.	%	
Orthodox (Yes=1)	215	76.24	88	86.27	303	78.91	4.53**
Education of head ≥ 12 grade completed (Yes=1)	80	28.37	22	21.57	102	26.56	1.77
Children <7 years (Yes=1)	124	43.97	41	40.20	165	42.97	0.44
Aware on risk of raw milk (Yes=1)	218	77.30	77	75.49	295	76.82	0.14
Income <4000 (Yes=1)	164	56.16	63	61.76	227	59.11	0.40
Income 4000-8000 (Yes=1)	89	31.56	31	30.39	120	31.25	0.05
Income > 8000 (Yes=1)	29	10.28	8	7.84	37	9.64	0.51

Pasteurized milk purchase and consumption characteristics

As shown in Table 4, on average a sample household consumed 75.6 liters of pasteurized milk in a year which is equivalent to 24.3liters of milk consumption per person converted into milk consumption unit. The figure is higher than the previously reported by Minten et al. (2020) as 10.2kg of dairy products in Addis Ababa.

Table 4. Annual pasteurized milk consumption in Liter of the pasteurized milk purchasers (N=282)

Variable	Mean	Std. Dev.	Minimum	Maximum
Consumption per household	75.64	69.4	36	365
Consumption per consumption unit	24.3	25.7	4.31	158.7

Table 5 presents the purchase frequency of pasteurized milk by the sample households. The result showed that the majority of the consumers (20%) were infrequent purchasers, who purchases once a month, followed by those who purchase twice a month (15% and once a week (15%). The reason why consumers purchase pasteurized milk infrequently can be due to the fact that it has longer shelf life as compared to the raw milk and hence once they purchase, they can use it for a week or two until they go for the second purchase.

Table 5. Frequency of buying pasteurized milk

Frequency	Frequency	Percent
Daily	22	5.7
Three- six times a week	30	7.8
Twice a week	26	6.8
Once a week	56	14.6
Twice a month	59	15.4
Once a month	76	19.8
Only for holidays	14	3.7
Not at all	101	26.3
Total	384	100

Place of buying pasteurized milk is presented in Figure 2. The result showed that pasteurized milk is mainly purchased from milk and dairy selling shops followed by modern dairy retailing shops such as mini market and supper market in Addis Ababa. The result further indicated that consumers who purchased pasteurized milk at common (shops those sell any commodity) was more than 10%.

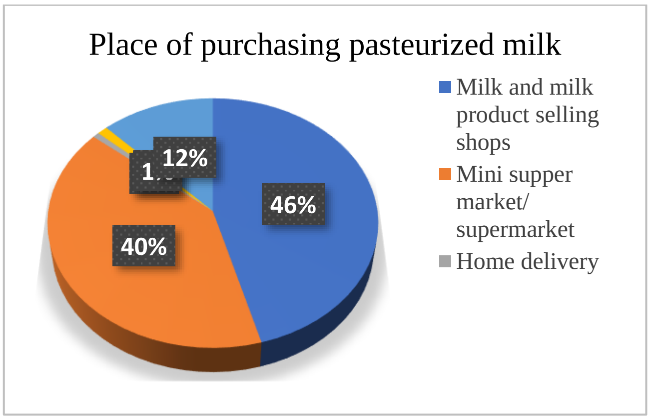

Figure 2. Place of purchasing pasteurize milk in Addis Ababa

As shown in Table 6, the main reason for preferring pasteurized milk was its easily availability followed by it safe to consume. However, characteristics related to longer shelf life and being unadulterated received less importance for preferring pasteurized milk.

Table 6. Main reason for preferring pasteurized milk

Main reason for preferring	Frequency	Percent
Easily availability	212	75.2
Safe to consume	46	16.3
Unadulterated	5	1.8
Freshness	4	1.4
Long shelf-life	3	1.1
Low price	3	1.1
Other, specify	9	3.2
Total	282	100

Pasteurized milk consumption disaggregated by the household members showed that the majority (80%) of the sample households reported that the pasteurized milk is consumed by all the family member while 15% of them reported that it is consumed mainly by children (Table 7).

Table 7. Intra-household pasteurized milk consumption

Who consumes mainly?	Frequency	Percent
All family members	225	79.8
Only children	42	14.9
Children and women	9	3.2
Patients	6	2.1
Total	282	100

Determinants of pasteurized milk purchase probability and intensity

Table 8 presents the estimation results of the Heckman's two step selection model. Before estimating the results using the Heckman model, two alternative candidate models namely Tobit and Craggit models were evaluated using the log-likelihood ratio test against the Heckman model. First, to choose between the Tobit and Craggit models, the Tobit model was rejected based on the LR value of 71.95 as compared to the critical value of X^2 26. 119 at 0.05 and 14 degrees of freedom. Second, to choose between the Craggit and Heckman model, the LR test of independence eqns. (rho = 0): chi2(1) = 31.14 Prob > X^2 = 0.0000 under the Heckman selection model was in favor of the use of Heckman and suggesting for the rejection of the Craggit model as suggested by Rufino (2016). Therefore, the result reported in this study was based on the Heckman's two step selection model. The first step of the Heckman procedure captures factors affecting participation decisions in the purchase of pasteurized milk while the second step explains factors affecting the intensity of purchase. The intensity of purchase was attributed to the quantity of pasteurized milk purchased by the consumers.

Table 8. Parameter estimates of the Heckman Two-step selection model

	Probability of purchase equation		Intensity of purchase equation	
Variables	Coef. (SE)	ME	Coef. (SE)	ME
Religion-orthodox	0.016 (0.14)	0.031	-0.352* (0.205)	-0.107
Age of head	0.002*** (0.0004)	0.002	-0.006 (0.005)	-0.002
Education	0.014 (0.015)	0.010	0.069 (0.177)	0.022
Children	0.03** (0.13)	0.035	-0.116 (0.153)	-0.038
Family size in CU	0.004 (0.004)	0.001	0.066 (0.05)	0.022
Income 4000-8000ETB	0.01 (0.015)	0.012	-0.043 (0.168)	-0.014
Income>8000ETB	0.023 (0.023)	0.032	-0.19 (0.271)	-0.065
Awareness on risk	0.012 (0.014)	0.010	0.041 (0.173)	0.014
Expensive (price)	0.042*** (0.007)	0.053	-0.242** (0.112)	-0.079
Functional value-taste	-0.002 (0.006)	0.003	-.0112 (0.081)	-0.036
Social value	0.029*** (0.006)	0.021	0.179*** (0.062)	0.058
Emotional value	0.098*** (0.011)	0.082	0.351*** (0.135)	0.114
Conditional value	0.012*** (0.004)	0.012		
Epistemic value	0.034*** (0.007)	0.027	0.158* (0.082)	0.052
/athrho			1.638*** (0.366)	
/lnsigma			-2.27*** (0.065)	
rho			0.927*** (0.051)	
sigma			0.103*** (0.007)	
lambda			0.096*** (0.011)	

Number of obs.=384, Selected =282, Nonelected = 102 Wald chi2 (14) = 18892.11, Prob > chi2=0 Log likelihood = 114.93, Prob > chi2 = 0.0000
*LR test of indep. eqns. (rho = 0): chi2(1) = 31.14 Prob > chi2 = 0.000, y = E(probability|Zg>0) (predict, ycond) = 0.99158328, y = Pr(intensity) (predict, psel) = .73744954, ***p<0.01, **p<0.05, *<0.1*

According to the Heckman two-steps model results illustrated in Table 8, the coefficient estimates for the factors affecting participation of consumers in the purchase decision of pasteurized milk were presented along with marginal probabilities while the intensity of purchasing has been provided along with corresponding marginal effects. In both cases, most of the coefficient estimates are statistically significant. The Wald Chi-square test for the Heckman model was highly significant (P<0.000) suggesting a strong explanatory power.

The model result revealed that religion-orthodox was negatively associated with the intensity of purchasing pasteurized milk. Compared to other religion groups including Muslims and Protestants, the quantity of pasteurized milk is reduced by 0.107 liters, keeping other things constant. A recent study conducted in Ethiopia on the effect of Orthodox Christianity religion on milk consumption confirmed that Orthodox Christians fasting adversely affects milk consumption in Ethiopia (D'Haene *et al*., 2019). This calls for supplying pasteurized milk with longer shelf length such as UHT milk so that consumers purchase and consume after fasting period.

The model results further indicated that age of the household head was positively related to the probability of purchasing pasteurized milk at 1%. Based on the marginal probability coefficient, as age of the household head is increased by one year, the probability of the household to participate in purchasing pasteurized milk would be increased by 0.2%, ceteris paribus. This suggests that age, a proxy for experience, is useful in consuming pasteurized milk that is safer to consume as compared to consuming raw milk which is risky for consumption. The result also indicated that households who have children of age seven or less had 3.5% higher probability of purchasing pasteurized milk compared to those who did not have children. This is because milk is an important food for children. This result is in line with the findings by Fu *et al*. (2014) and Fu and Florkowski (2016) who found positive and significant relationship between the presence of children and the likelihood of consuming whole-milk, yoghurt, low-fat milk and butter in Poland.

The model result showed that households who had higher score (strongly agree) to a statement that pasteurization is expensive (high price) were found to have higher probability of participation in the purchase of pasteurized milk but lower intensity of purchase. As the score is increased by one point from 1-5 scale, their probability of purchasing pasteurized milk is increased by 4.2% but the quantity of purchase is decreased by 0.053liters, keeping other variables constant. The implication is that households try to purchase pasteurized milk but the higher price hinders them from expanding their purchase. Therefore, by improving the processing capacity and efficiency of milk processing plant so that they reduce cost, it would be important to supply pasteurized milk at affordable price to attract consumers purchase of higher quantity.

The Heckman selection model result also indicated that the influence of social peers such as friend, families, neighbors had a positive impact on both the probability of participation in and the intensity of purchasing pasteurized milk at 1%. As score of agreement to statements indicating the influence of social peers increased by one point along a five-point Likert scale (from strongly disagree to strongly agree), the probability of participating in purchasing pasteurized milk and the quantity of purchasing would be increased by 2.1% and 0.058liters per year, ceteris paribus. Previous findings also reported positive impact of social peer on dairy product consumption (Rahnama and Rajabpour (2017). Similarly, the result also showed that emotional value had a positive impact on both the probability and intensity of purchasing pasteurized milk at 1% with a marginal value of 0.082 and 0.114, respectively. The result suggested that as the score of statements indicating emotional values such as 'consuming dairy products is interesting, makes them feel good, relaxed and gives them pleasure' is increased by one point (from strongly disagree to strongly agree), the probability of participation in and the intensity of purchasing pasteurized milk would increase by 8.2% and 0.114 liters per year, respectively, keeping other things constant. This finding is consistent with previous findings (Johansen *et al*. 2011; Rahnama and Rajabpour, 2017).

Conditional value (availability) of pasteurized milk was found to have a positive impact on the probability of participation in purchasing pasteurized milk at 1%. The marginal effect value indicated that as a household's score for statement indicating availability of pasteurized milk is increased by one point along the one to five Likert scale from strongly disagree to strongly agree, the probability that they are participated in purchasing pasteurized milk would be increased by 1.2%, keeping other things constant. The result is in agreement with a study by Johansen *et al*. (2011) who reported a positive association between conditional value of consumers and motivation for choice of calorie-reduced dairy products that are perceived to be healthier than the whole milk.

Lastly, the result of the model also revealed that epistemic value (knowledge) was positively influenced both the probability and intensity of purchasing pasteurized milk. The marginal effect value indicated that as a households' response to statements indicating knowledge of new models or products is increased by one point along the one to five Likert scale (from strongly disagree to strongly agree), the probability of participation in and the intensity of purchasing pasteurized milk would be increased by 2.7% and 0.52 liters, respectively, ceteris paribus. The results imply that households with higher epistemic value tended to purchase dairy products that are safer to consume than raw milk products. The result is in line with previous finding of Rahnama and Rajabpour (2017) who found positive relationship between epistemic value and consumption of dairy products in Iran.

Conclusion and Policy Implications

In this paper, we investigated determinant factors of purchase probability and intensity of pasteurized milk in Adds Ababa, the capital city of Ethiopia using Heckman two-step selection model. The result showed that the majority of the sampled households were participated in purchasing pasteurized milk. Religion (Orthodox Christianity) had adverse impact on the intensity of consuming pasteurized milk implying that policies that support establishment of pasteurized milk with long shelf life such as UHT milk (that can be stored for more than six months) would be effective to increase the intensity of purchase of dairy products by such religion groups. Experience (proxied by age of head) was also an important factor to boost the probability of purchasing pasteurized milk. The implication is that awareness creation on the importance of pasteurized milk and informing the risk of consuming raw milk from the public health perspective would be important. This can be done through the Ethiopian health and nutrition institute using appropriate medias. Availability of children in the family had higher probability of purchasing pasteurized milk which is important to improve the nutritional need of the growing children in one hand and pasteurized milk is more safer to feed children as compared to the raw milk on the other hand. In addition to variables related to the demographic background, consumption value variables such as functional value (price), social value (influence of the social group) emotional value (feeling good and relaxed when consuming pasteurized milk), conditional value (availability), and epistemic value (attitude to try new and different things) were found to have significant impact on pasteurized milk purchase decision. The policy implication is that attracting more investors to invest in milk processing factories so that they can produce at large quantity and hence reduce price for consumers would have a positive impact on the quantity of pasteurized milk purchased in large cities such as Addis Ababa. Furthermore, addressing demographic variables such as religion, age, children, and consumption value variables including functional, social, conditional, emotional and epistemic values would be important factors to be considered when designing policies that target nutritional improvement based on dairy products, and public health-related policies that target zoonotic diseases as well.

Acknowledgement

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Parallel Session V

Feed and Nutrition

Challenges of Shifting from Free Grazing to Adoption of Cut-and-Carry Feeding System in North-Western Ethiopian Highlands

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Abstract

Free grazing is a common practice in Northwestern highlands of Ethiopia. Unmanaged free grazing increases land degradation and soil erosion. This study was conducted in Burie and Farta districts in Northwestern Ethiopia to assess the socio-economic and institutional factors that affect shifting from free grazing to cut-and-carry system. For this study four kebeles were selected, two kebeles per district, and data were collected employing different methods. Formal survey, informal survey and observations were conducted in these selected kebeles. For the formal survey, data were collected from 180 respondents that were selected through systematic random sampling method. Descriptive statistics, binary logistic regression and multinomial logistic regression were used to analyze the data. Farmers' awareness creation through trainings, availability of adequate feed resource per household, fear that the communal grazing lands will be taken by the government and total land holding per household had a significant effect on the farmer's willingness to adopt or to continue adopting the cut-and-carry system. Total land holding per household, family size in school, fear that the communal grazing lands will be taken by the government and availability of adequate feed resource per household had a significant effect on the adoption of the cut-and-carry system. To make the cut-and-carry system implemented and to control land degradation, the communities that adopted or are willing to adopt the cut-and-carry system should be given communal land ownership certificates. The production of fewer and more productive animals encourages the adoption of the system. This practice should be implemented in those areas that have more land holding per household and have feed shortage problems.

Keywords: Cut-and-carry system, Communal grazing lands, Free grazing, adoption, Ethiopia

Introduction

The contribution of natural pastures or grazing lands as livestock feed resources in Ethiopia is high. The main feed resources for livestock production in the country are natural pasture, crop residues, improved pastures, forage crops and agro-industrial by products (Mengistu, 2004). The contribution of these feed resources varies from area to area depending on agro-ecology, type of crops produced and other factors. Currently, as the human population is increasing, the grazing lands are being converted to crop lands to feed the ever-increasing human population in the country in general and in Amhara Region in particular (Mengistu *et al*., 2017; Tegegne and Assefa, 2010). The size of the communal grazing lands in the highlands of Ethiopia is decreasing due to crop land expansion (Kebede *et al*., 2016). This resulted in overgrazing, soil erosion and land degradation. Based on different studies in the country, the contribution of natural pasture is decreasing from its earlier contribution of 90% to the current contribution of 57% as livestock feed resource in the country (Mengistu *et al*., 2017; Tegegne and Assefa, 2010).

Free grazing is a common practice in the highlands of Amhara Region. Unmanaged free grazing exacerbates land degradation and soil erosion. According to Desta *et al.* (2000), deforestation and overgrazing are among the direct factors that cause land degradation in Amhara Region. These are caused by the ever-increasing human population in these areas. According to Benin and Pender (2002), unrestricted use and access of grazing lands will result in overexploitation and degradation of the resource. Free grazing on crop land after harvest results in soil compaction and the need for frequent tillage (Meseret, 2016). In addition, free grazing has a negative impact on soil and water conservation practices. Physical and biological soil and water conservation practices will be damaged by trampling animals. The communal grazing lands in the highlands of Ethiopia are low in forage productivity and the nutritive value of the forage that is produced on these lands is low. In addition, free grazing makes improved livestock breeding difficult (BDU CAES, 2015).

The adoption and implementation of cut-and-carry system increases forage productivity and reduces the degradation of communal grazing lands (Rossiter, 2017). According to this source, irrespective of age exclosure establishment increase vegetation cover, biodiversity levels and infiltration rates. According to Mulugeta and Achenef (2015), after the adoption of exclosures there was regeneration of grasses reduction of soil erosion. According to the above source, animal grazing, thieves, shortage of grazing land and conflicts between adjacent peasant associations are the main challenges for the adoption of exclosures. Collective action can play a significant role in the sustainable utilization of grazing lands (Benin and Pender, 2002). Restricting access and use by the community on these lands will reduce land degradation by eliminating overexploitation. This in turn will result in improved availability and quality of forage in the long run. According to Hailu (2016), establishing enclosures on communal grazing lands is effective in restoring degraded soils. Other studies also show that exclosures are better options to restore degraded communal grazing lands (Mekuria and Aynekulu, 2011; Manaye, 2017).

To reduce land degradation, the government has been pushing for the banning of free grazing in Ethiopia and especially in Amhara National Regional State. But this system is still prevalent in most parts of Amhara National Regional State (BDU CAES, 2015). Establishment of cut-and-carry systems in communal grazing lands reduces land degradation and enhances forage productivity. To avoid free grazing and to make the cut-and-carry system adopted by smallholder livestock keepers in rural areas assessing the major factors that affect the adoption and implementation of cut-and-carry system is crucial. There is no adequate published information regarding the factors that affect the adoption and implementation of the cut-and-carry system in rural areas in the country. Therefore, this study was conducted to fill this gap in the country. The objective of this study was to assess the socio-economic and institutional factors that affect shifting from free grazing to cut-and-carry system.

Methodologies

Description of the study areas - This study was conducted in Farta and Burie districts, located in Northwestern Ethiopian Highlands (Figure 1 & 2). Based on secondary data and consulting district office of livestock experts, four *kebeles* (lowest administrative units in Ethiopia) were selected for the study; two *kebeles* per district. The selected *kebeles* for the study are Awuzet and Atta *kebele* from Farta District; and Alefa and Zeyew Shiwun *kebele* from Burie District (Table 1). The study was conducted in 2016 and 2017.

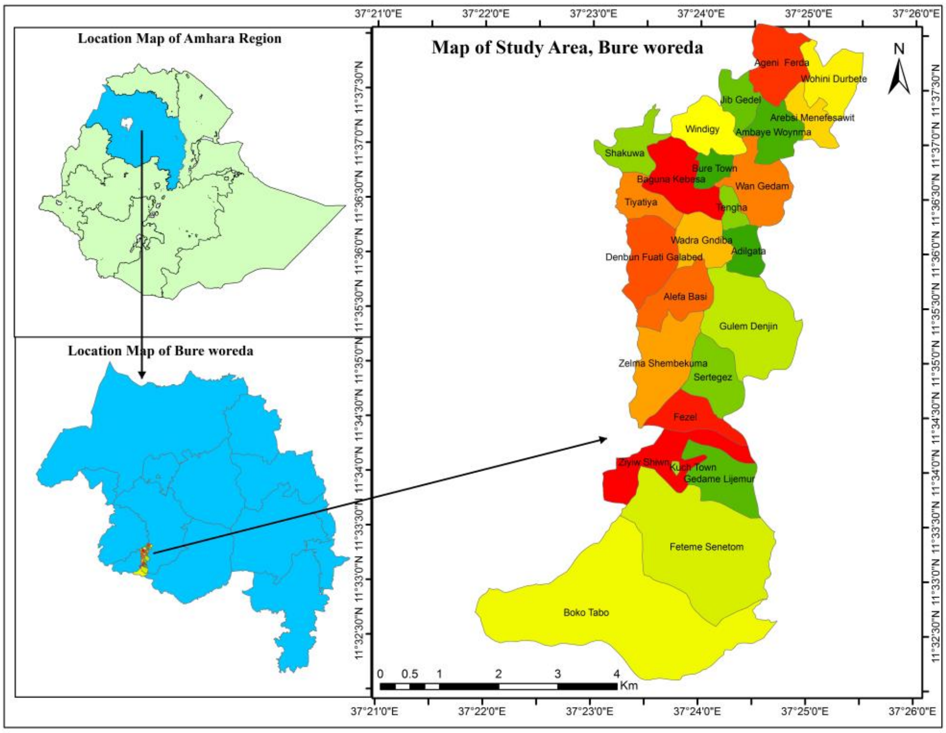

Figure 1. Location of the study kebeles in Ethiopia and Amhara Regional State (Burie District)

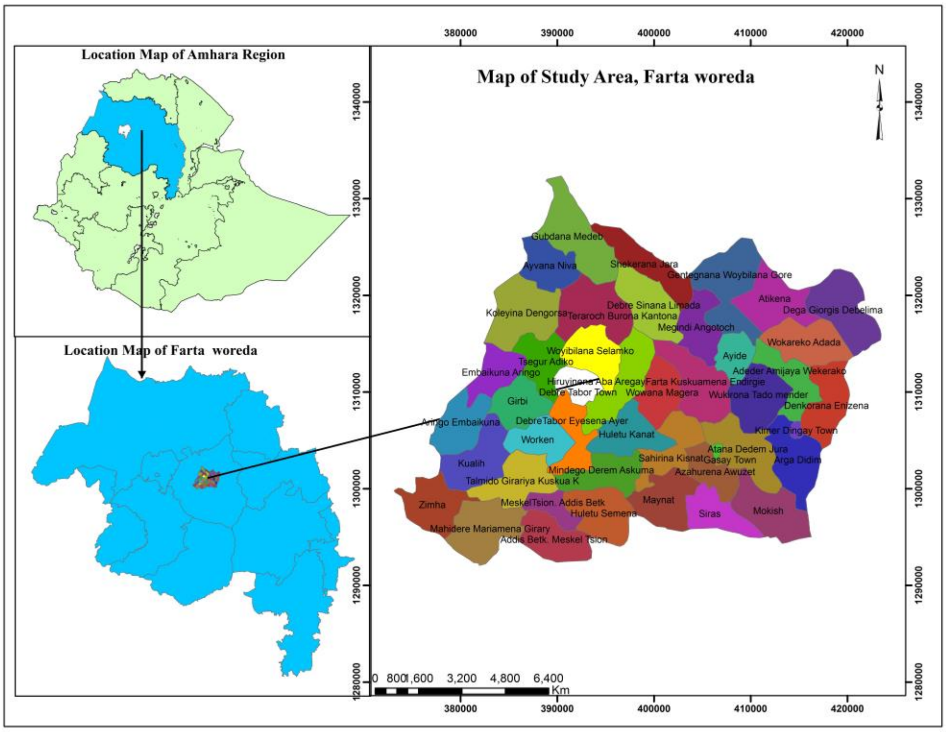

Figure 2. Location of the study kebeles in Ethiopia and Amhara Regional State (Farta District)

Table 1. *Kebeles* selected for the study in Farta and Burie districts

District	Selected *kebele*	Tethering of animals	Adoption of cut-and-carry system	Adoption level
Farta	Awuzet	Yes	Yes	Full
Farta	Atta	No	No	None
Burie	Zeyew Shiwun	No	Yes	Partial
Burie	Alefa	No	No	None

Sampling and data collection - At the beginning of the study, secondary data were collected from different sources. Based on the secondary data and consulting district office of livestock experts, four *kebeles* (lowest administrative units in Ethiopia) were selected for the study; two *kebeles* per district. The selected *kebeles* for the study are Awuzet and Atta *kebele* from Farta District; and Alefa and Zeyew Shiwun *kebele* from Burie District (Table 1). One kebele per district adopted the cut-and-carry (Awuzet and Zeyew Shiwun) and the other kebele per district did not adopt the cut-and-carry system (Atta and Alefa). The selected kebeles in Farta district represent the Dega agro-climatic zone and those selected kebele in Burie District represent Woina Dega agro-climatic zone in Amhra Region. Informal and formal surveys were conducted in the selected *kebeles* following the guidelines of Roeleveld and Broek (1996). Checklists were prepared and used for the informal survey study. Individual, key informant interviews and focus group discussions were conducted in selected *Gotes* (part of a *kebele*) within the *kebele* that were near to FTCs and have better experience on the study objectives. Focus group discussion was conducted in these Gotes involving different community groups. After the completion of the informal survey, questionnaire was prepared based on the informal survey result. The questionnaire prepared was pretested before administration. Orientation on how to fill the questionnaire and on the data collection process was given to the enumerators. Respondents for the formal survey were selected from these Gote residents list by systematic random sampling method. A total of 180 respondents were interviewed for the formal survey: 45 respondents from each kebele. The formal survey data from the selected respondents was collected by these enumerators. The statistical analysis was done by using IBM SPSS (version 24) statistical software. Descriptive statistics were used to summarize the data. Moreover, ANOVA and LSD were done for mean comparison and mean separation, respectively. In addition, binary and multinomial logistic regressions were used to test the effect of different independent variables on the dependent variable. Before binary and multinomial data analysis the data were assessed on sample size and multicollinearity.

Results and Discussion

Household characteristics

The livelihood of the farmers living in the study *kebeles* is based on mixed farming (87.0%), crop production (10.2%), livestock production (0.6%) and other activities (2.2%). The mean age, family size and land holding of the household heads interviewed are 44, 4.6 and 1 ha, respectively (Table 2). Farmers in Zeyew Shiwun kebele have significantly higher ($P<0.05$) land holding per household than the other kebeles. The mean livestock holding (in TLU) per household is 3.1 (Table 3).

Table 2. Mean age of respondents interviewed, family size and land holding in the study *kebeles*

Kebele	Age (Mean ± SD)	Total family size (Mean ± SD)	Land holding (ha) (Mean ± SD)
Awuzet	45.2±15.59	4.6±1.50	0.7±1.24[bc]
Atta	50.4±11.02	4.4±2.10	0.4±0.24[c]
Zeyew Shiwun	39.9±11.62	4.3±1.98	1.8±1.07[a]
Alefa	40.5±10.53	5.0±1.91	1.0±0.59[b]
Average	44.0±12.96	4.6±1.89	1.0±1.04

Table 3. Mean livestock number per household in the study *kebeles*

Kebele	Cattle	Sheep	Goat	Donkey	Horse	Mule	Equines	TLU*
Awuzet	2.3	2.7	0.0	0.04	0.42	0.36	0.82	2.5
Atta	3.2	2.8	0.25	0.57	0.30	0.11	0.98	3.1
Zeyew Shiwun	4.7	0.9	0.0	0.89	0.0	0.0	0.89	3.8
Alefa	3.8	0.64	0.02	0.09	0.0	0.11	0.20	2.9
Average	3.5	1.8	0.07	0.4	0.18	0.15	0.72	3.1

*TLU = A tropical livestock unit is the equivalent of one bovine animal of 250 kg live weight. Conversion factor (head to TLU); Cattle = 0.7; sheep = 0.1; goats = 0.1; horses = 0.8; mules = 0.7; donkeys = 0.5. (ILCA, 1990).

Factors affecting the adoption of the cut-and-carry system

1. Awareness on cut-and-carry system and commitment of local authorities and experts

For the adoption of the cut-and-carry system awareness creation is crucial. Most of the respondent farmers (72.6%) got training on the importance of adopting the cut-and-carry system and the disadvantages of free grazing in the study *kebeles* (Table 4). If farmers are not aware of the importance of adopting the cut-and-carry system they tend to continue and use the traditionally accepted way of using the communal grazing lands, i.e. free grazing. There is a relationship between farmers awareness and their tendency for the adoption or continuation of the cut-and-carry system of feeding (χ^2 = 17.06, P<0.05) (Table 5 and 12). In addition to awareness, commitment of local authorities and experts on the adoption of the cut-and-carry system is crucial. If there is weak commitment from local authorities and experts the adoption of the cut-and-carry system will be low. Furthermore, experience sharing tours to best practice areas on cut-and-carry system is also crucial. Before the adoption of the cut-and-carry system in the study areas in Farta and Burie districts there was experience sharing tours to best practice areas. Farmers believe by seeing new practices. So, experience sharing tours have a great impact for the adoption of the cut-and-carry system. In addition, commitment of local authorities and experts for the adoption of the cut-and-carry system has a great impact. Generally, involvement of several stakeholders in the implementation of the cut-and-carry system from different government and other sectors is essential. Several stakeholders were involved during the implementation of the cut-and-carry system at Awuzet kebele in Farta District.

Table 4. Percentage of farmers who got training on the advantages of adopting the cut-and-carry system and the disadvantages of free grazing in the study *kebeles*

Kebeles	Yes	No
Awuzet	91.1%	8.9%
Atta	53.8%	46.2%
Zeyew Shiwun	60.5%	39.5%
Alefa	86.4%	13.6%
Total	72.6%	27.4%

Table 5. The effect of farmers' awareness on their willingness to adopt or continue the adoption of the cut-and-carry system

		Got training on the cut-and carry system and free grazing	
		Yes (%)	No (%)
Want to adopt or continue the adoption of the cut-and-carry system	Yes	88	58
	No	12	42
		N = 115	N = 40

2. Size of the communal grazing land owned and human density in the area

Generally, awareness alone is not the only factor that affects the adoption of the cut-and-carry system. It is difficult to adopt the cut-and-carry system after awareness creation due to different factors. The size of the communal grazing land area and population pressure also affects the adoption of the cut-and-carry system even though farmers have adequate awareness on the importance of the cut-and-carry system (Table 6). If the communal grazing land area is small and the population pressure high, farmers tend not to adopt the cut-and-carry system. This is due to the fact that if the communal grazing land area is small and the population pressure high, farmers will not get adequate forage from the cut-and-carry system. This is due to the equal division of the forage produced from the communal grazing lands among all households in the area (among livestock owners and non-livestock owners). In addition, in high population pressure areas the farmers will not get adequate crop residues from their crop land as their land holdings are small (Table 2).

Table 6. Hypothetical communal grazing land share per household and human density in the study *kebeles*

Kebele	**THH***	**Communal grazing land (ha)**	**Communal grazing land share per HH (ha)**	**Human density (Persons ha^{-1})**
Awuzet	1613	1.18	0.20	1.56
Atta	1557	1.13	0.12	2.27
Zeyew Shiwun	795	2.66	0.32	1.32
Alefa	718	2.27	0.36	2.43

*THH = Total number of households per kebele

3. Ownership of equines, goats and crossbred cattle

Feeding equines and goats creates problems for the adoption of the cut-and-carry system. Equines need more feed compared to other animals. Farmers do not have adequate feed to feed these animals tethered in and around home when the cut-and-carry system of feeding is adopted. About 62% of the respondents said that the cut-and-carry system of feeding is difficult to feed equines. Equines are widely distributed in the study areas as they are mostly used for transportation of goods. Equine rearing households prefer free grazing over the cut-and-carry system. In addition, goats are browsers and need shrubs and trees to feed on. About 48% of the respondents said that the cut-and-carry system of feeding is difficult to feed goats. Ownership of crossbred cattle in cut-and-carry system adopting kebeles is relatively higher than non-adopting kebeles (Table 7). In Farta District, most of the farmers rear crossbred cattle. The mean number of crossbred cattle reared per household in Awuzet kebele is significantly higher ($P<0.05$) than other kebeles. It is possible to get adequate livestock products from a smaller number of crossbred cattle when it is compared with more indigenous animals. The crossbred animals produce more milk per animal than the indigenous cattle. Crossbred animals also fetch better prices on market.

Table 7. Mean number of crossbred cattle holding per household in the study kebeles

Kebele	**N**	**Crossbred cattle (Mean ± SD)**
Awuzet	39	0.97 ± 1.06^{a}
Atta	40	0.28 ± 0.88^{b}
Zeyew Shiwun	45	0.07 ± 0.45^{b}
Alefa	45	0.02 ± 0.15^{b}
Average	169	0.31±0.78

4. The inclusion and forage share of non-livestock holding farmers in the system

Inclusions of non-livestock holding farmers in the forage share of the cut-and-carry system hinders the adoption of the cut-and-carry system. Most livestock holding farmers do not want the inclusion of non-livestock holding farmers in the cut-and-carry system in high population density areas. This is due to its reduction of the amount of forage they get for their livestock from the communal grazing lands after the cut-and-carry system adoption.

5. Labour shortage to keep livestock and forage shortage to feed animals

In the mixed crop-livestock system labour shortage affects the adoption of the cut-and-carry system. In the mixed crop-livestock system labour is needed for both crop and livestock production. In the study areas most of the children are students (Table 8). The cut-and-carry system demands more labour compared to free grazing system. More labour is needed to mow grass from the grazing land, to feed and water animals indoors. In those areas that adopted the cut-and-carry system and tethering of animals (Awuzet kebele) there is work burden on women to feed and manage the animals in addition to the women daily household activities. Those areas that focus on crop production and rearing more animals per household will encounter severe labour shortage problems after the adoption of the cut-and-carry system. Presence of adequate forage for livestock per household negatively affects the adoption of the cut-and-carry system (Table 9). Most of the farmers in the cut-and-carry system adopting kebeles (Awuzet and Zeyew Shiwun) reported that they have encountered feed shortage problems for their livestock (Table 9). This may be due to the share of the available forage from the cut-and-carry system among all the households in these kebeles (among livestock owners and non-livestock owners).

Table 8. Mean family size in agriculture and in school in the study *kebeles*

Name of *kebele*	Family size (Mean±SD)	Family size in agriculture (Mean±SD)	Family size in school (Mean±SD)
Awuzet	4.6±1.50	2.1±0.53	2.3±1.55
Atta	4.4±2.10	2.1±0.77	2.4±1.42
Zeyew Shiwun	4.3±1.89	2.2±0.78	1.6±1.80
Alefa	5.0±1.91	2.2±0.80	2.4±1.54
Average	4.6±1.87	2.1±0.73	2.1±1.61

Table 9. Percentage of farmers who have adequate feed for their livestock in the study kebeles

Kebeles	Have adequate feed			
	No (%)	Yes (%)	N	Percent (%)
Awuzet	97.7	2.3	45	96
Atta	60.0	40.0	42	44
Zeyew Shiwun	82.2	17.8	44	79
Alefa	72.1	27.9	44	38
Total	78.0	22.0	175	63

6. Farmers fear that the communal grazing land will be taken by the government

Those farmers who adopted or willing to adopt the cut-and-carry system fear that the communal grazing land may be taken by the government and used for other purposes (Table 10). It is feared that the land will be taken by the government and given to the youth and investors. On average, about 63% of the respondents said that if the cut-and-carry system is adopted the land will be taken by the government and used for other purposes (Table 10). As indicated in table 10, those kebeles that had adopted the cut-and-carry system had higher percentages of fear on the communal grazing lands to be taken by the government and used for other purposes.

Table 10. Percentage of farmers that said the communal grazing land will be taken by the government when the cut-and-carry system is adopted in the study *kebeles*

Name of *kebele*	N	Percent (%)
Awuzet	45	96
Atta	42	44
Zeyew Shiwun	44	79
Alefa	44	38
Total	175	63

7. Total cattle number and size of land holding per household

Households that have a large number of cattle are against the adoption of the cut-and-carry system. This condition is especially common in high population pressure areas (Table 11). Having a large number of cattle per household demands more forage and labour to feed and manage the animals if the cut-and-carry system is adopted. In addition, these households are better beneficiaries of the communal grazing lands if the cut-and-carry system is not adopted. If the cut-and-carry system is not adopted the communal grazing lands are used mainly by livestock rearing farmers only. Therefore, they do not want to lose this benefit. So, they do not want the cut-and-carry system to be adopted. In those areas that adopted the cut-and-carry system fully (Farta District, Awuzet *kebele*), those farmers who had a large number of cattle before the adoption of the cut-and-carry system had reduced their indigenous cattle number per household and shifted to the rearing of a smaller number of crossbred cattle per household due to labour and feed shortage problems (Table 3). The farmers who are living in Awuzet kebele have more crossbred animals per household when compared with other study kebeles (Table 7). More land holding per household positively affects the adoption of the cut-and-carry system. This may be due to the availability of land to the production of more crop residues and allocation of private grazing lands for livestock production.

8. Net stocking rate and human density in the area

When the net stocking rate is higher it negatively affects the adoption of the cut-and-carry system. This is because after the adoption of the cut-and-carry system farmers will not get adequate forage for their animals. If the cut-and-carry system is adopted they have to share the forage produced form the communal grazing lands equally among the households living in the area. This condition is observed in the cut-and-carry system adopting kebeles in the study areas. If the communal grazing land is decreased too much and used for other purposes, this will result in higher net stocking rates and the lower adoption of the cut-and-carry system in high population pressure areas (Table 11). The net stocking rates of the study *kebeles* that adopted and not adopted the system was 14.1 and and 26.7 TLU ha^{-1} for Awuzet and Atta *kebeles* in Farta District, respectively. There is also high human population density in those *kebeles* that did not adopt the cut-and-carry system (Table 6).

Table 11. Livestock density, net stocking rate and percentage of the communal grazing land in the study *kebeles*

kebele	Livestock density (TLU ha^{-1})	Net stocking rate (TLU ha^{-1})	Percentage of the pasture land in the kebele (%)
Awuzet	1.61	14.12	11.4
Atta	1.37	26.70	5.1
Zeyew Shiwun	0.71	8.62	8.2
Alefa	1.12	10.14	11.1

Binary and multinomial logistic regression analysis

Several factors affect the farmers' willingness to adopt or continue adopting the cut and carry system (Table 12). Training on the advantages and disadvantages of cut-and-carry system and free grazing, availability of adequate feed resource per household, fear that the communal grazing land will be taken by the government after the adoption of the cut-and-carry system and total land holding per household are the main ones. Trainings are essential to increase the farmers willingness to adopt or to continue adopting the cut-and-carry system. Previously, trainings were given to farmers on the advantages of cut-and-carry system and the disadvantages of free grazing. There was a relationship between farmers' awareness creation and their willingness for the adoption or continuation of the cut-and-carry system (Table 5). According to Asmame and Abegaz (2017), a study conducted in northern highlands of Ethiopia, education, training and extension service positively and significantly affects the adoption of land management practices. According to Atnafe *et al*. (2015), contact with extension workers and training affect the adoption of soil and water conservation methods by farmers. Education level and frequency of contact with development agents positively and significantly affects the adoption of land management practices (Saguye, 2017). Collective action is successful when users have adequate knowledge on sustainable yield of the common-pool resource (Wade, 1987).

Presence of adequate feed for livestock negatively affects the adoption of the cut-and-carry system. Those farmers who lack adequate feed for their livestock are willing to adopt the cut-and-carry system (Table 12). In addition, feed shortage for livestock per household is also observed in those areas that adopted the cut-and-carry system (Table 9). As lack of feed for livestock affects the adoption of the cut-and-carry system in a sustainable manner, adequate feed production per household is crucial. The introduction of improved forages in the cut-and-carry system adopting areas is important. The result of this study is in agreement with other studies. According to Gebremedhin *et al*. (2001), restricted grazing lands are least established in areas where there is adequate livestock feed. According to the above source, restricted grazing lands are more effective in areas where there is severe feed shortage and closer to markets.

Currently, there are cases in Amhara Region where the communal grazing lands are given for the youth and investors and used for different purposes. Farmers are uncertain on the fate of the communal grazing land after the cut-and-carry system is adopted. Those farmers who had adopted and willing to adopt the cut-and-carry system had a fear that the communal land will be taken by the government and used for other purposes (Table 12, 13 and 14). This factor affects the adoption of the cut-and-carry system greatly. This condition is more pronounced in the cut-and-carry system adopting kebeles. The percentage of farmers who said the communal grazing land will be taken by the government is higher in those kebeles that adopted the cut-and-carry system than those that did not adopt the cut-and-carry system (Table 10). So, farmers prefer free grazing from cut-and-carry system due to this condition. According to Asmame and Abegaz (2017), land tenure security affects the adoption of land management practices. According to Atnafe *et al*. (2015), the greater the risks of losing the right, the less likely the farmers tend to invest and conserve the productive capacity of the land. In addition, land tenure status affects the adoption of soil and water conservation methods. According to Rossiter et al. (2017), issuance of land titles increases the adoption of excolures in Lake Tana Sub-basin. So, to alleviate this problem communal grazing land ownership certificates should be issued and handed over to the cut-and-carry system adopting communities or kebeles. This makes the farmers more certain of their ownership of the communal grazing lands and assists in the adoption of the cut-and-carry system easily. In addition, awareness creation work should be conducted.

Size of land holding per HH also affects the adoption of the cut-and-carry system (Table 12). Those households that have more land will get more crop residues for their livestock. In addition, they can allocate private grazing land for their livestock. So, feed shortage will not be a problem for these farmers to adopt the cut-and-carry system. So, the cut-and-carry system is more preferably adopted in those areas where farmers have more land holding per household.

Table 12. Factors affecting farmers' willingness to adopt or continue adopting the cut-and-carry system in the study areas

Variable	B	S.E.	Wald	DF	p	OR	95% C.I. for OR	
Got training	1.39	0.68	4.23	1	0.04*	4.01	1.07	15.04
Feed resource adequate	- 1.73	0.68	6.58	1	0.01*	0.18	0.05	0.67
Fear (land will be taken by govern)	2.83	0.68	17.34	1	0.00*	16.99	4.48	64.47
Total land holding (ha)	0.96	0.48	4.00	1	0.045*	2.60	1.02	6.64
Total TLU number	- 0.10	0.16	0.37	1	0.54	0.91	0.66	1.24
Total equine number	- 0.31	0.43	0.50	1	0.48	0.74	0.32	1.72
Total family size in school	0.06	0.20	0.10	1	0.76	1.06	0.72	1.58
Labour shortage	- 0.83	0.66	1.60	1	0.21	0.44	0.12	1.58
Constant	- 0.43	0.78	0.30	1	0.58	0.65		

Note: *Significant at $p<0.05$; Log likelihood = 84.104; omnibus test of model coefficients (chi square = 67.92 and p = 0.00); Hosmer and Lemeshow test (chi square = 5.55, df = 8, p = 0.698); Pseudo R^2 (Cox and Snell R square = 0.366; Nagelkerke R^2 = 0.566).

There are several factors observed that affect the adoption of the cut-and-carry system in the study areas. Total equine number per household, total land holding per household, total family size in school, fear that the communal grazing land will be taken by the government if the cut-and-carry system of feeding is adopted and availability of adequate feed resources per household are the main ones (Table 13). Furthermore, labour shortage also influenced the full adoption of the cut-and-carry system in the study areas (Table 14). This factor is related to total family size in school. Furthermore, type of animal owned by the household affects the adoption of the cut-and-carry system. Ownership of equines affects the adoption of the cut-and-carry system (Table 13). Equines need more forage compared with other animals. About 62% of the farmers said that it will be difficult to feed equines if the cut-and-carry system is adopted. Farmers who own equines prefer free grazing to exist.

Table 13. Factors affecting the adoption of the cut-and-carry system in the study areas

Variable	B	S.E.	Wald	DF	P	OR	95% C.I. for OR	
Total TLU number	0.06	0.17	0.12	1	0.73	1.06	0.76	1.48
Total equine number	0.82	0.41	4.06	1	0.04*	2.27	1.02	5.04
Total land holding (ha)	1.81	0.51	12.55	1	0.00*	6.13	2.25	16.72
Total family size in school	- 0.71	0.20	12.16	1	0.00*	0.49	0.33	0.73
Total crossbred cattle number	0.38	0.33	1.33	1	0.25	1.46	0.77	2.78
Got training	- 0.50	0.80	0.39	1	0.53	0.61	0.13	2.89
Labour shortage	- 0.87	0.61	2.02	1	0.16	0.42	0.13	1.39
Fear (land will be taken by govern)	4.37	0.88	24.97	1	0.00*	79.20	14.25	440.03
Feed resource adequate	- 3.81	0.86	19.78	1	0.00*	0.02	0.00	0.12
Constant	- 1.91	0.90	4.45	1	0.04	0.15		

Note: *Significant at $p<0.05$; Log likelihood = 84.104; omnibus test of model coefficients (chi square = 67.92 and p = 0.00); Hosmer and Lemeshow test (chi square = 5.55, df = 8, p = 0.698); Pseudo R^2 (Cox and Snell R square = 0.366; Nagelkerke R^2 = 0.566).

There were different factors observed that affect the full adoption of the cut-and-carry system in the study areas. Ownership of crossbred cattle per household, total family size in school and total land holding per household (ha) are the main ones (Table 14). Rearing crossbred cattle enhances the full adoption of the cut-and-carry system (Table 12). Rearing more crossbred cattle per household increases animal productivity and income. Crossbred cattle are the main cash income sources for their owners. This practice is especially common in Farta District. According to Shimelse *et al.* (2017), livestock number has a negative and significant effect on the establishment and management of exclosures in Tigray Region. Large cattle number per household demands more forage, labour and water if the cut-and-carry system is adopted. Those farmers who had a large cattle number have reduced their animal number after the adoption of the cut-and-carry system due to feed and labour shortage problems (Farta District, Awuzet kebele). They are currently rearing more productive crossbred cattle per household (Table 7). According to Addisu and Sibhat (2015), to reduce grazing land degradation adjustment of livestock holding with the available feed resources is essential. In traditional crop production, more cattle number is needed for different purposes. More cattle are needed for ploughing, trampling the land at planting (tef and finger millet), threshing and transportation of the harvest. Technologies and practices are needed that reduce draft power. This will result in the reduction of unproductive animals per household in the study areas.

The study areas are mixed crop-livestock systems. In these areas crop production is practiced. Traditional crop production by its own nature is labour intensive. According to Asmame and Abegaz (2017), family members are a source of labour and family size affects the adoption of land management practices. Size of household affects the adoption of soil and water conservation methods (Atnafe *et al*., 2015; Saguye, 2017). In the current study, about half of the family members (50%) are students. So, labour from children is not available for crop and animal production purposes especially during the dry season. It negatively affects the adoption of the cut-and-carry system (Table 14). So, to make the cut-and-carry system adopted in these areas introduction of labour-saving technologies is essential.

High population density affects the adoption of the cut-and-carry system. In areas where the the population pressure is high, the adoption of the cut-and-carry system will be low. In these areas the farmers are not willing to adopt the cut-and-carry system. This is due to the fact that the farmers who have livestock will not get adequate forage for their animals after the adoption of the cut-and-carry system. As the non-livestock holding farmers share the forage of the cut-and-carry system, the forage the livestock owners get will be less. In Atta kebele, the communal grazing land area is small and the communal grazing land share per household is low (Table 6). Based on previous study, there is a decline in grazing land area from 18.1% to 4.1% in Eastern part of Lake Tana from 1986 to 2011 (Sibhat *et al*., 2015). This condition affects the adoption of the cut-and-carry system. According to Benin and Pender (2012), collective action for grazing land management will be more effective in area where there are large areas, and the population pressure is low. According to Wade (1987), collective action in the use of common-pool resources will be effective when the net collective benefit is high. This condition affects the adoption of the cut-and-carry system.

Table 14. Factors affecting the full adoption of the cut-and-carry system in the study areas

Variable	B	OR	P
Full adoption vs. Partial adoption			
Got training	1.77	5.85	0.14
Fear (land will be taken by govern)	2.97	19.40	0.09
Labour shortage	- 1.26	0.29	0.12
Total crossbred cattle number	- 1.69	0.19	0.01*
Total family size in school	- 0.69	0.50	0.01*
Total land holding (ha)	4.49	89.5	0.0*
Total equine number	- 0.36	0.70	0.58
Total TLU	0.23	1.26	0.43
Full adoption vs. Non-adoption			
Got training	0.38	1.46	0.75
Fear (land will be taken by govern)	5.23	186.3	0.0*
Labour shortage	- 1.30	0.27	0.04*
Total crossbred cattle number	- 1.0	0.37	0.01*
Total family size in school	0.25	1.29	0.23
Total land holding (ha)	2.25	9.44	0.02*
Total equine number	- 0.82	0.44	0.13
Total TLU	0.18	1.20	0.48

Note: *Significant at $p<0.05$; Log likelihood = 167.187; Pseudo R^2 (Cox and Snell R square = 0.684; Nagelkerke R^2 = 0.777).

High population density also affects the adoption of the cut-and-carry system in another way. In high population pressure areas, the size of the communal grazing land is small. This results in high net stocking rates and lower availability of forage per household (Table 6 and 11). This affects the adoption of the cut-and-carry system. In high population pressure areas if the cut-and-carry system is adopted, farmers will not get adequate forage for their animals. High population density will result in low land holding per household and high net stocking rate per area of communal grazing land (Table 7 and 11). According to Benin and Pender (2002), collective action for grazing land management may be effective in areas where there is a large area and the population pressure is low. Population growth has a negative impact on the utilization of restricted grazing lands. According to Gebremedhin *et al.* (2001), high population pressure reduces the establishment of restricted grazing lands. So, it is important to keep the size of the communal grazing lands from decreasing in size and used for other purposes. There is a need to make the traditional crop production more productive in order to retard the reduction of the grazing land that is being devoted to crop production as the human population increases.

Conclusions

To make the cut-and-carry system adopted in the study area and to alleviate land degradation the following measures are necessary. Training on the advantages and disadvantages of free grazing and cut-and-carry system should be conducted. Fear that the communal grazing land will be taken by the government and used for other purposes is prevalent in those communities who adopted and who are willing to adopt the cut-and-carry system. So, to alleviate this problem awareness creation on this issue should be conducted and communal grazing land ownership certificates should be issued and delivered to rural communities. The cut-and-carry system is feasible in those areas that have more land holding per household and encounter feed shortage for their livestock. To make the cut-and-carry system fully adopted rearing of more productive (crossbred cattle) is essential. It is possible to reduce the cattle number per household by rearing more productive animals (crossbred cattle) without decreasing livestock productivity in high livestock population areas. This practice makes the cut-and-carry system adopted easily by rural communities especially in high population pressure areas. Those farmers who have more children in school and have labour shortage problem are less willing to fully adopt the cut-and-carry system. This may be due to labour shortage for livestock production if the cut-and-carry system is adopted. To alleviate this problem technologies that save labour in food crop and livestock production should be introduced in the study areas.

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Evaluation of Feeding Regime Based on Natural Pasture Hay Supplemented with Vetch or Different Oilseed Cakes Protein Supplements on the Performance of Lactating Jersey Cows

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Abstract

A study was conducted to evaluate the effect of four different protein supplements (vetch hay (VH), Noug seed cake (NSC), cottonseed cake (CSC) and linseed cake (LSC) based on a natural pasture hay (NPH) basal diet on the performance of 20 lactating Jersey cows. The study was conducted in a randomized complete block design with 5 replications. The study lasted one full lactation (305 days). The supplements were a mixture of wheat bran (WB) with either of the protein supplements formulated to be iso-nitrogenous and fed at about 30% of the entire diet. Treatments were T1 = NPH ad libitum + Concentrate (16% WB and 84% VH); T2= NPH ad libitum + Concentrate (79% WB and 21% NSC); T3= NPH ad libitum + Concentrate (71% WB and 29% CSC); T4= NPH ad libitum + Concentrate (78% WB and 22% LSC). Total DM intake was 9.96, 10.75, 11.06 and 11.61 kg/day for T1, T2, T3, and T4, respectively and deferred only between T1 and T4. Crude protein (CP) intake was lower for T1 (5.74 kg/day) than other treatments (7.31 to 7.55 kg/day). Apparent digestibility of DM and CP was similar among treatments. Daily body weight gain followed the trend of DM intake and ranged 0.12 kg/day (T1) to 0.21 kg/day (T4). Milk yield was 5.74, 7.42, 7.31 and 7.55 kg/day for T1, T2, T3, and T4, respectively and was lower for T1 than other treatments. Except protein content of milk, other milk composition (fat, lactose, ash and total solids) were similar among treatments. Partial budget analysis showed that supplementation of vetch hay and noug seedcake (NSC) was found to be an economically feasible option. Vetch hay due to its effect of lowering production cost, can be used as an input in buffering the increasing cost of production on relatively lower capital owning farmers.

Key-words: Vetch hay, Oil seedcakes, Milk yield, Milk composition, Jersey cow, Partial budget

Introduction

Increasing urban population and rising real income, changes in lifestyles and food preferences are expanding the demand for milk and milk products in Ethiopia. Consequently, production of dairy products falls below demand and the country is dependent on imports of milk and milk products (FAO, 2012). Thus, undertaking appropriate interventions to enhance the supply of milk and milk products is central to fulfil domestic demand and benefit from the sub-sector through export. Such interventions among others include the supply of improved genotype and availing appropriate feeding systems that will support the potential productivity of the animals (Tekleab, 2009, EIAR, 2016). Moreover, factors like urbanization, shrinkage of grazing land and labor shortage are shifting the dairy production system from more number of less productive local cattle holding to maintaining a few and highly productive pure or cross breed dairy cows (Tekleab, 2009) which leads to the growing practice of stall-feeding (Funte *et at.*, 2010).

Getachew and Gashaw (2001) noted Holstein Friesian and Jersey as exotic dairy breeds with wide acceptance, while IAR (1986) recommended Jersey crosses for their relative advantage over crosses of Holstein Friesians where nutrition is a limiting factor. As such Holeta Agricultural Research Center (HARC) of Ethiopia is producing and disseminates pure Jersey dairy cows and their crosses with indigenous Boran cattle as part of its on farm dairy productivity improvement research activity. Such improved genotypes have increased milk production in Ethiopia by four fold as compared to local breeds (Defait, 2018). Nevertheless, the dissemination of high yielding dairy animals to smallholder farmers alone cannot solve issue of productivity, unless supported by appropriate feeding system and management practices that can satisfy the demand of the improved animals. Generally, animals are maintained predominantly on fibrous feeds such as harvested natural pasture hay and crop residues (Yosef *et al.*, 2011; Selamawit, 2017), and a comprehensive package to support the performance of such improved genotypes appears to be lacking (Tekleab, 2009).

Improved nutrition of cow can be achieved by producing better quality forages on-farm, or by appropriate supplementation with forage legumes such as vetch (Getnet and Ledin, 2001) and locally available agro-industrial by-products like oil seed cakes (Khalili *et al.*, 1994; Dawit and Solomon, 2009) due to their high protein contents. Forage legumes like vetch may offer good opportunities for increasing milk production (Getnet and Ledin, 2001). However, the comparative nutritional and economic advantage of vetch over convention protein supplement oil seed cakes has not been well investigated. Therefore, the objective of this study is to assess the comparative supplemental effect of vetch and three oil seed cakes (noug seedcake, cotton seedcake and linseed cake) on the performance and profitability of lactating Jersey cows.

Materials and Methods

Experimental site

The experiment was conducted at Adea-berga dairy research station of HARC found in West Shewa Zone of Oromia regional state of Ethiopia. The area is located 70 km south west of the capital Addis Ababa. Adea-berga dairy research station is situated in the central highlands of Ethiopia at 9^0 16’N latitude and $38^0$23’E longitude and at an altitude of 2500 meters above sea level (Direba *et al*., 2015). The annual temperature and rainfall ranges from 18°C to 24°C and 1000 to 1225 mm, respectively (Tamirat *et al*., 2016).

Experimental feeds and sample preparation

Natural pasture hay was harvested from Adea-berga dairy research station pastureland, field-cured, baled and stored in a roofed hay barn of the station. The vetch hay was grown at Adea-berga dairy research station using the recommended agronomic practice. Vetch seeds (Lana variety of *Vicia dasycarpa*, common name woolly-pod vetch) with a minimum germination rate of 75% was sown at seeding rate of 30 kg/ha at 2 mm soil depth. The grown vetch forage was harvested for hay at 50% flowering stage, field-cured, baled and stored in a roofed hay barn of the station. The supplement ingredients (wheat bran, noug seed cake (NSC), cotton seed cake (CSC), and linseed cake (LSC)) and mineral sources were purchased from Addis Ababa and the surrounding markets.

Experimental animals and management

Pure lactating Jersey cows were used for this experiment that lasted one entire lactation season (305 days). The cows were kept in-door and individually stall-fed in a well-ventilated barn with concrete floor and appropriate drainage slope and gutters. Before the commencement of data collection, animals were accustomed to the experimental condition for two weeks. The concentrate feeds were a combination of wheat bran with either of vetch hay, NSC, CSC and LSC and was formulated on iso-nitrogenous basis to contain the required CP of 197 g/kg to be supplemented for the lactating Jersey cows (ARC, 1990).

Treatment diets were planned to constitute 70:30 roughage to concentrate ratio, containing 95.3 g/kg CP to satisfy the requirements of lactating Jersey dairy cows (ARC, 1990). The total dry matter amount to be fed to the animals were initially estimated based on body weight, milk yield and milk butter fat content of the experimental cow (ARC, 1990) from the available records of the animals in the farm. This was used to determine the amount of supplement to be offered to the animals to attain the proposed iso-nitrogenous 95.3g/kg CP of the entire diet. Once the study commenced, the basal natural pasture hay was provided *ad libitum* allowing 20% refusal from previous day’s intake which was adjusted on weekly basis. Consecutively, the supplement amount was determined and adjusted on the basis of the basal diet intake so that the supplement intake becomes about 30% of the entire feed intake. The supplemental feeds were offered in two equal halves at 0400 and 1600 hours. Animal had free access to water and mineral source (common salt).

Experimental design and treatment

The experiment was conducted using twenty Jersey cows in a randomized complete block design (RCBD) with four supplement treatment diets. The experimental animals were blocked into five groups of four animals each on the basis of their parity (first to fifth parity). Animals within a block were randomly assigned to the four treatments. Treatment diets used in this experiment were natural pasture hay fed *ad libitum* and supplemented with a mixed diet prepared from 16% wheat bran and 84% vetch hay (T1); 79% wheat bran and 21% NSC (T2); 71% wheat bran and 29% CSC (T3); and 78% wheat bran and 22% LSC (T4).

Feeding trial

For each animal, daily feed offered and refused were measured and recorded. Intake was then calculated as the difference between feed offered and refused. Samples of feed offered was collected from batches of feeds, while refusals were collected every day for each animal and pooled on treatment basis for chemical composition.

Body weight of the cows were measured using fixed cattle weighing scale monthly. Body weights change was calculated as a difference between final and initial body weights. Average daily gain (ADG) was determined by dividing body weight change with number of experimental days. Body condition of the dairy cows was scored using a 1 to 5 scale (where 1= emaciated, 5= over conditioning) (Elanco, 2009) fortnightly. Animals were hand milked twice a day in the morning and afternoon and the yield was recorded. After thoroughly mixing 100 ml of the pooled milk of the two milking was sampled for chemical analysis.

Digestibility trial

Digestibility trial was conducted in the middle of the lactation period (days 161 to 167). Apparent digestibility of experimental diets was determined using total fecal collection methods for a period of 7 consecutive days on the same animals. Faeces collections, was undertaken by scooping faeces into plastic buckets as soon as the animals defecate. Urinal contamination was minimized by frequent washing of the concrete floor with high pressure running water using a plastic water hose. Individual cow's faeces were weighed every morning at 0800 hour before fresh feeds was offered to the animals. After weighing, the faeces from each cow was thoroughly mixed and 1% of the faces voided was taken and placed in polyethylene bag and kept in a deep freezer (-20 ^{o}C) until the end of the collection period. At the end of the digestibility trial, the collected fecal sample from each animal was thoroughly mixed, thawed to room temperature and sub sampled, weighed and dried at 60 °C for 72 hour. During the digestibility period, amount of feed offered and refused was recorded daily. Feed samples from each feed offered and refusals from each animal were taken daily to make a composite sample by feeds and refusals by treatments. Apparent digestibility of DM and nutrients were determined using the following formula:

$$\text{Apparent Nutrient Digestibility} = \frac{\text{Nutrient intake} - \text{Nutrient excreted in faeces}}{\text{Nutrient intake}} \text{X } 100$$

Laboratory analysis

Samples of feeds, refusal and faeces were partially dried in a draft oven at 65^{O}C for 72 hours, and ground to pass through 1 mm mesh sieve for subsequent chemical analysis. The standard procedures of AOAC (1990) was used to determine dry matter (DM), total nitrogen (N) and ash content of the samples. Organic matter (OM) content was determined as hundred minus ash. Crude protein (CP) was calculated as N x 6.25. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and permanganate lignin (PL) was analysed following the procedures of Van Soest and Robertson (1985). Milk samples were analyzed for milk protein and fat (O'Connor, 1995), lactose and solid non-fat (O'Mahony, 1988) and ash (Richardson, 1985).

Partial budget analysis

Partial budget analysis was carried out based on cost of feed input and milk output. The price of hay was determined based on selling price of balled hay in the surrounding market, while the prices of feed ingredients of concentrate mixtures was determined based on their purchase prices from the market. The milk price was fixed based on the selling price during the study period. Treatments were compared on the basis of feed cost per kg of milk yield; amount of profit obtained (net return (NR) = total revenue (TR) - total cost (TC)); benefit cost ratio (income per feed cost (TR/TC)); Rate of Return=NR/TC; and Gross Ratio=TC/TR.

Statistical analysis

Data were subjected to ANOVA using the GLM procedure of SAS (SAS, 2008). Significant difference among treatment means were separated using Tukey HSD test. The model used for data analysis was: $Y_{ijk} = \mu + B_i + T_j + e_{ij}$;
where; Y_{ijk}= dependent variables, μ= overall mean, B_i= block effect (Parity), T_j= treatment effect, and e_{ij}= random error.

Result and Discussion

Chemical composition of feed ingredients

The chemical compositions of feeds ingredients used in this study is given in Table 1. The basal diet had a CP content that may not satisfy the maintenance requirement of ruminants (McDonald *et al*., 1994). The basal diet was also high in NDF content that may depress intake of ruminants (Van Soest, 1994). This suggest for the need to supplement the basal diet used in this study to satisfy the performance requirement of dairy animals like the ones used in this study. The chemical composition values of wheat bran and the four protein supplements that the current study is comparing (vetch hay, NSC, CSC and LSC) is within the range of previously reported values for major Ethiopian feeds (Seyoum *et al*., 2007) .

Table 1. Chemical composition of feed ingredients used for the study and treatment refusals for natural pasture hay (g/kg DM)

Chemical composition	Experimental feed ingredients						Natural pasture hay refusal			
	NPH	WB	VH	NSC	CSC	LSC	T1	T2	T3	T4
DM	923	914	930	929	949	924	918	914	937	908
OM	939	947	904	902	935	925	929	906	920	939
CP	51	165	205	321	281	318	61	53.3	58	59
NDF	761	541	524	429	478	376	747	747	776	800
ADF	472	172	448	291	282	230	449	486	512	495

*DM = Dry matter; OM = Organic matter; CP = Crude protein; NDF= Neutral detergent fibre; ADF = Acid detergent fibre; *Concentrate DM offered to constitute 30% of the total DM intake; NPH = Natural Pasture hay; WB= Wheat Bran; VH=Vetch hay; NSC=Noug seedcake; CSC= Cotton seedcake; LSC= Linseed cake; T1= Natural pasture hay (NPH) ad libitum + Concentrate (16% WB and 84% VH); T2= NPH ad libitum + Concentrate (79% WB and 21% NSC); T3= NPH ad libitum + Concentrate (71% WB and 29% CSC); T4= NPH ad libitum + Concentrate (78% WB and 22% LSC)*

Feed intake and body measurements

The supplement DM intake of treatments ranged 26 to 30% of the entire diets, which was close to the 30% amount planned to be offered in the study (Table 2). Basal and supplement DM intakes were not significantly affected ($P > 0.05$) by treatment. Slight increase in basal and concentrate DM intake of T4 as compared to T1however, resulted to a significantly 1.65 kg higher ($P<0.05$) total DM intake of T4 than T1, while values for other treatments were similar among each other. The NDF content of vetch hay used in this study was almost two-fold as compared to the content in LSC, presumably contributing to the variations noticed in total DM intake between T1 and T4 (McDonald et al., 1995), as the NDF concentration of feeds promote gut fill (Forb, 2005) and is negatively correlated with DM intake (Saha et al., 2013). The lack of difference in total DM intake among the three oilseed cake supplemented treatments is in agreement with the result of Blackwelder et al. (1998) that noted cows consuming either soybean meal or CSM had similar DM intakes. Similarly, Wondwosen et al. (2010) reported that supplementing Sidama goats with NSC, CSC or LSC had no significant effect on intakes of the basal diet, the supplement and total DM intake. Intake of OM took a similar trend to that of total DM intake and differed only between T1 and T4. Crude protein intake was lower ($P < 0.05$) for T1 as compared to the other three treatments that had statistically similar values ($P >0.05$). This may presumably be due to the slight difference in CP content of vetch hay and the oil seed cakes coupled with small variation in intake between T1 and other treatments. The NDF and ADF intake did not differ (P > 0.05) among treatments in the current study.

Table 1. Feed and nutrient intake and body measurements of lactating Jersey cows fed a basal diet of natural pasture hay supplemented with vetch hay and different oil seed cakes as protein supplement

Parameter	T1	T2	T3	T4	SEM	P value
Intake (kg/day)						
Basal diet DM	6.98	7.71	8.02	8.56	0.03	0.0511
Concentrate DM*	2.98	3.04	3.03	3.05	0.00	0.2585
Total DM	9.96^{b}	10.75^{ab}	11.06^{ab}	11.61^{a}	0.03	0.0410
OM	9.09^{b}	9.85^{ab}	10.04^{ab}	10.73^{a}	0.03	0.0295
CP	0.95^{b}	1.15^{a}	1.13^{a}	1.16^{a}	0.00	0.0039
NDF	6.57	6.98	7.02	7.43	0.02	0.1106
ADF	4.24	4.12	4.64	4.34	0.01	0.0996
Body weight (BW)						
Initial BW (kg)	269.4	269.2	288.6	290.4	7.43	0.9345
Final BW (kg)	307.2	312.2	340.2	355.4	8.07	0.3371
BW Change (kg)	37.8^{b}	43.0^{ab}	51.6^{ab}	65.0^{a}	3.45	0.0224
ADG (kg/day)	0.12^{b}	0.14^{ab}	0.17^{ab}	0.21^{a}	0.01	0.0004
Body Condition Score	2.30	2.31	2.38	2.56	0.01	0.4772

*[a,b,c]Means with different superscripts within a row are significantly different (P<0.05); SEM = standard error of mean; DM= Dry matter; OM = Organic matter; CP= Crude protein; NDF= Neutral detergent fibre; ADF =Acid detergent fibre; BW = Body weight; ADG= Average daily gain; *Concentrate DM offered to constitute 30% of the total DM intake; WB= Wheat Bran; VH=Vetch hay; NSC=Noug seedcake; CSC= Cotton seedcake; LSC= Linseed cake; T1= Natural pasture hay (NPH) ad libitum + Concentrate (16% WB and 84% VH); T2= NPH ad libitum + Concentrate (79% WB and 21% NSC); T3= NPH ad libitum + Concentrate (71% WB and 29% CSC); T4= NPH ad libitum + Concentrate (78% WB and 22% LSC)*

Initial and final body weight did not statistically differ (P > 0.05) among treatments. However, there was significant difference in body weight change and ADG (P < 0.05) among treatments. Body weight change and ADG was higher for T4 as compared to T1, while values for other treatments were statistically similar among each other. This appears to be consistent with trends of differences in total DM and OM intakes observed in this study. The body condition score was not significantly affected by the type of protein supplement offered to the animals despite of significant body weight change difference among the dietary feeding regimes. On average, all animals were in within average to good body condition score.

Diet apparent digestibility

The apparent digestibility of DM, CP, ADF and NDF failed to differ significantly (P > 0.05) among treatments (Table 3). Digestibility in ruminants and consequently passage rate of digesta across the gut (Van Soest, 1982) varies greatly with the type of feedstuff (Saha *et al.*, 2013), and the ingredients dietary quality (Thomas *et al.*, 1976). Although, the CP content of the protein sources used in this study varies, both vetch hay and the oil seed cakes had more than 200 g/kg CP adequate to categorize them as protein supplements (Hendy *et al.*, 1995). This presumably might have resulted to a similar apparent digestibility values of the treatment rations indicating the comparable feeding values of the supplemental protein sources used in this study to dairy cows. In a companion experiment on *in vitro* and *in sacco* degradability parameters of dry matter of the treatment diets, similar observations to the current study were noted where *in vitro* values, *in sacco* degradability parameters such as potential degradability, effective degradability and DM degradability at different incubation hours were similar among treatment diets (Tekleab *et al*., unpublished). The percentage digestible DM of feeds of less than 55% is poor quality while feeds exceeding 65% digestibility are generally considered to be of high quality (Hinton, 2007). Thus, values in this study for percentage digestible DM of experimental treatment rations are within the range of 55 and 65%, indicating that, the feeding regime of the present study can satisfy the nutritional requirement of the animals.

Table 3. Apparent digestibility of dry matter and nutrients of of lactating Jersey cows fed a basal diet of natural pasture hay supplemented with vetch hay and different oil seed cakes as protein supplement

Apparent digestibility (%)	Treatments				SEM	P value
	T1	T2	T3	T4		
DM	55.87	59.10	63.02	64.41	0.642	0.0702
CP	61.64	64.80	70.09	70.09	0.678	0.0523
NDF	58.64	61.95	65.62	66.45	0.606	0.0762
ADF	54.74	52.29	56.92	58.08	0.724	0.4477

SEM = standard error of mean; DM = Dry matter; CP = Crude protein; NDF= Neutral detergent fibre; ADF = Acid detergent fibre; Concentrate DM offered to constitute 30% of the total DM intake; WB= Wheat Bran; VH=Vetch hay; NSC=Noug seedcake; CSC= Cotton seedcake; LSC= Linseed cake; T1= Natural pasture hay (NPH) ad libitum + Concentrate (16% WB and 84% VH); T2= NPH ad libitum + Concentrate (79% WB and 21% NSC); T3= NPH ad libitum + Concentrate (71% WB and 29% CSC); T4= NPH ad libitum + Concentrate (78% WB and 22% LSC)

Milk yield and composition

Milk yield of lactating Jersey cows was lower ($P < 0.05$) in vetch hay supplemented group as compared to those supplemented with oil seed cakes (Table 4). The milk yield values for oil seed cake supplemented groups were about 30% higher as compared to the vetch hay supplemented treatment. Difference in intakes of DM and CP between the vetch hay and oil seed cake supplemented treatments could happen due to the phosphorus content difference (Tekleab *et al*., unpublished) that might have contributed to such milk yield differences (NRC, 2001). Moreover, vetch hay being more rich in fiber as compared to the oil seed cakes, the volatile fatty acid proportion produced from ruminal fermentation may lean towards more acetate to propionate ratio for T1 than for the oil seed cake containing treatments (Beever, 1993). The possible more production of propionate from the oil seed cake containing treatments might promote gluconeogenesis as ruminal propionate up on absorption to portal blood is cleared by hepatic circulation and is one major precursor for glucose synthesis in ruminants' liver (Brockman, 1993). This will consequently increase the supply glucose to the mammary gland. A substantial part of the glucose taken up by the mammary gland is used for the synthesis of lactose (Bickerstaffee *et al.*, 1974). Lactose a major osmotic component of milk (Rook, 1979) has been shown to be the major determinant of milk yield (Davis and Collier, 1985), and its secretion draws water from the secretary cells osmotically. Danfaer (1994) showed that 0.4 mol of glucose is required per kg of milk synthesised by dairy cows. Considering a mean of 7 liter daily milk yield, the 305 days lactation performance of 2135 litter per cow of the current study is comparable with the 2154 liters of milk yield reported for the center herd for an average lactation length of 336 days (Direba *et al*., 2015).

Table 4. Milk yield and composition of lactating Jersey cows fed a basal diet of natural pasture hay supplemented with vetch hay and different oil seed cakes as protein supplement

Parameter	Treatments				SEM	P value
	T1	T2	T3	T4		
Milk yield (kg/day)	5.74[b]	7.42[a]	7.31[a]	7.55[a]	0.02	0.0196
Total solid (%)	14.41	14.73	14.55	14.77	0.07	0.5845
Fat (%)	5.27	5.56	5.44	5.41	0.03	0.5966
Protein (%)	3.73[b]	3.92[a]	3.89[a]	3.78[ab]	0.02	0.2569
Ash (%)	0.67	0.70	0.70	0.71	0.01	0.4006
Lactose (%)	4.76	4.58	4.53	4.88	0.07	0.4386

[a,b]Means with different superscripts within a row are significantly different (P<0.05); SEM = standard error of mean; Concentrate DM offered to constitute 30% of the total DM intake; WB= Wheat Bran; VH=Vetch hay; NSC=Noug seedcake; CSC= Cotton seedcake;LSC= Linseed cake; T1= Natural pasture hay (NPH) ad libitum + Concentrate (16% WB and 84% VH); T2= NPH ad libitum + Concentrate (79% WB and 21% NSC); T3= NPH ad libitum + Concentrate (71% WB and 29% CSC); T4= NPH ad libitum + Concentrate (78% WB and 22% LSC)

Milk protein content vary among treatments and was lower for T1 as compared to T2 and T3, while the value for T4 was similar with all other treatments. The content of milk fat, lactose, ash and total solids were similar among treatments (P > 0.05). Getu (2006) also reported similar findings and noted that lactose and total solid composition were not affected by supplementation of vetch versus other nutrients when supplemented to Holstein Frisian lactating cows. The lack of difference in daily milk yield and milk composition among the oil seed cake supplement treatments suggest that the three oil seed cakes used in this study can exchangeable be used depending on availability and cost by dairy producers.

Partial Budget Analysis

The overall cost of one lactation period (305 days) milk production per cow for T1 was ETB 10499 lower than T2, T3 and T4 by ETB 3101, 3999 and 5818, respectively. Hence, vetch hay can be used for relatively low cash farmers as compared to the oilseed cake supplemented feeding regimes. The average lactation yield per cow was 1751, 2263, 2230, and 2303 liters for T1, T2, T3 and T4, respectively. The lactation net return was in the order of T2 > T3 > T4 >T1. The benefit cost ratio (BCR) was greater than one indicating the profitability of the feeding regimes. BCR was higher for T1 and T2 than the other treatments indicating that cows in T1 and T2 were highly profitable over the ones T4 and T3. Result of the rate of return (ROR) implies that for every one Birr invested in milk production the farm gains ETB 1.39, 1.38, 1.20 and 1.02 for T1, T2, T3 and T4 respectively. Gross ratio (GR) result showed that T4 had the highest unit of expenditure per unit return followed by T3 and the value was lower for T1 and T2. Based on the current study findings even if vetch hay as a protein source was inferior in terms of gross feed intake and milk productivity, its supplementation to lactating Jersey cows was economically feasible at comparable level with NSC in buffering the increasing cost of production. The result is in agreement with Nega *et al*. (2001) who stated that even though supplementing LSC supported faster growth rate and higher body weight gain than NSC, supplementation with NSC was more economical.

Table 4. Economic analysis of lactating Jersey cows fed a basal diet of natural pasture hay supplemented with vetch hay and different oil seed cakes as protein supplement

Variable	Treatments			
	T1	T2	T3	T4
Days of experiment (days)	305	305	305	305
Feed cost /head/day (ETB)	34.42	44.59	47.54	53.50
Milk yield /cow/day (liter)	5.74	7.42	7.31	7.55
Feed cost kg milk/head/day	6.00	6.01	6.50	7.09
Gross income/day (GI) (ETB)	82.20	106.25	104.68	108.12
Total cost/cow (ETB)	10499	13601	14499	16317
Total Revenue (ETB)	25070	32408	31927	32975
Net Return (ETB)	14571	18807	17428	16658
Benefit Cost Ratio	2.39	2.38	2.20	2.02
Rate of Return	1.39	1.38	1.20	1.02
Gross Ratio	0.42	0.42	0.45	0.49

Concentrate DM offered to constitute 30% of the total DM intake; WB= Wheat Bran; VH=Vetch hay; NSC=Noug seedcake; CSC= Cotton seedcake; LSC= Linseed cake; T1= Natural pasture hay (NPH) ad libitum + Concentrate (16% WB and 84% VH); T2= NPH ad libitum + Concentrate (79% WB and 21% NSC); T3= NPH ad libitum + Concentrate (71% WB and 29% CSC); T4= NPH ad libitum + Concentrate (78% WB and 22% LSC)

Conclusion

The three oil seed cakes (NSC, CSC and LSC) used as supplement to a basal diet of NPH in lactating Jersey cows resulted in similar intake, digestibility, ADG and milk yield and composition. Conversely, crude protein intake, ADG and milk yield was relatively lower for the vetch hay supplemented treatment. Although, the oilseed cake supplemented treatments like T4 induced a higher biological performance, partial budget analysis showed that supplementation of vetch hay and noug seedcake (NSC) was found to be an economically feasible options. Vetch hay due to its effect of lowering production cost, can be used as an input in buffering the increasing cost of production on relatively lower capital owning farmers.

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Effects of Inclusion of Pigeon Pea Leaves in the Concentrate Mixture on Feed Intake, Digestibility, and Milk Yield of Crossbred Dairy Cows Fed Natural Pasture Hay

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Abstract

Pigeon pea is a multipurpose crop which can be used as human food and animal feed. It is rich in protein and it has been used to substitute oilseed cakes fully or partially in small ruminant ration. However, their feeding value in dairy cow rations is not well documented. An experiment was conducted to evaluate the effect of supplementation of pigeon pea leaves (PPL) and concentrate mixture (CM) to native pasture hay-based rations on feed intake, digestibility, and milk yield of crossbred dairy cows (Holstein × Zebu). A 4 × 4 Latin square design with three replications, balanced for carry-over effects, was used for this study. The treatments included native pasture hay provided ad libtum as a basal diet, supplemented with a CM alone (T1), or inclusion of 10% of PPL in the CM (T2), or 20% PPL in the CM (T3), or 30% PPL in the CM (T4). Supplements were iso-caloric and iso-nitrogenous. Except hay and supplement intake, dry matter and nutrient intake were similar (P > 0.05) among treatments. Greater (P = 0.05) hay intake was for T1 and T2 than T4. Supplement intake was the least for T1 (P < 0.05) while the pigeon pea supplemented groups (T2-T4) had similar (P > 0.05) supplement intake. Dry matter and nutrient digestibility, and milk were similar (P > 0.05) among treatments. Therefore, up to 30% of PPL could be included in a concentrate mix with out affecting the performance of crossbred dairy cows under the conditions of the current experiment.

Keywords: Cows, digestibility, feed intake, milk, pigeon pea leaves

Introduction

In most trp[ocal and sub-tropical countries, ruminants feeds are primarily native pasture and/or crop residues. These roughages are characterized by high fiber content and low concentrations of protein. When fed alone, these roughages results in low digestibility, feed intake and milk yield (Reynal and Broderick, 2003). Hence, it is required to supplement dairy cows with protein sources for better productivity and resource efficiency. Hence, before introducing non-conventional feed ingredients in dairy cow rations, effect on feed intake, digestibility, and milk yield needs to be evaluated.

Agro-industrial by-products such as oilseed cakes are common protein sources for dairy cattle; however, there is scarcity of such concentrates in rural areas of Ethiopia (Tolera et al., 2012) and other developing regions. Use of forage legumes, such as cowpea, in dairy cow rations can reduce the cost of feed without affecting milk yield and composition (Corea et al., 2017). It has been shown that supplementation of Calliandra/Sesbania to dairy cows was associated with an increase in milk produced of at least 1 L per kg fed (Makau et al., 2020). Hence, improved forage crop production could provide useful nutrients in areas where agro-industrial by-products are not available (Tolera et al., 2012).

Pigeon pea is a multipurpose leguminous plant that could be used as human food and livestock feed. It is widley adapted, drought tolerant (Bekele, 2007) and rich in protein (Nurfeta et al., 2013). The existence of a small amount of tannin (0.4 - 4.3 %) in pigeon pea (Alexander et al., 2007) could have beneficial effects through increasing rumen undegradable protein (Mezzomo et al., 2011), potentially improving feed intake, digestibility, and milk yield in cattle (Ali et al., 2009). Though information regarding the feeding value of pigeon pea leaves in dairy cow ration is limited, past research showed that pigeon pea leaves could completely replace Noug (*Guizota abyssinica*) seed cake in sheep rations (Nurfeta et al., 2013) and can comprise up to 50% of dry matter intake in goats (Tekle et al, 2018). Hence, pigeon pea leaves could serve as a protein supplement in dairy cow rations. However, due to its low energy density, pigeon pea leaves may not be ideal for completely replacing concentrate for dairy cows. Hence, the objective of this study was to evaluate the effect of pigeon pea leaves and a concentrate mixture as a supplement to native pasture hay-based rations on feed intake, digestibility, and milk yield of crossbred dairy cows.

Materials and methods

Study area description

The experiment was conducted at Hawassa University, Sidama region, Ethiopia (7°06' N and 38°51' E). Hawassa town is located at 1714 m above sea level, and the average minimum and maximum temperature is 13.1 and 27.5°C, respectively (NMAE, 2020). The study area is characterized by bimodal rainfall, where the short rainy season is between February and May, and the primary rainy season is between June and September and the average annual rainfall is 965 mm. The soil at Hawassa is loam with pH 6.8 (Mekonen et al., 2021).

Experimental animals, design, and treatments

Eight mid-lactating (four primiparous and four multiparous) and four early lactating multiparous Holstein-Friesian × Local zebu crossbred dairy cows, with an average daily milk yield of 9.16 $\pm$ 1.35 L (Mean $\pm$ SD) were selected from Hawassa University dairy farm. Cows were manually milked twice daily at 6:00 and 15:00 h throughout the experiment. The experimental design was 4 × 4 Latin square design with three replications. Treatments were arranged to balance for potential carryover effects. Dairy cows were assigned to three blocks (squares) according to parity and stage of lactation. Cows from each block were randomly assigned to treatment sequences such that every cow received all four treatments during the course of the experiment. Each period was a total of 22 days (15 days adaptation and 7 days for data collection and sampling). Native pasture hay was offered ad libitum (at 20% refusal), supplemented with a concentrate mixture (CM) alone (T_1), or inclusion of 10% pigeon pea leaves (PPL) in the CM (T_2), or 20% PPL in the CM (T_3), or 30% PPL in the CM (T_4). The treatments were iso-caloric and iso-nitrogenous and were formulated to satisfy the energy and crude protein requirements of dairy cow weighing 454 kg and producing 10 L/d of milk with 5% fat (NRC, 2001). Prior to inception of the experiment, to make sure that the nutrient composition of the experimental diet satisfy the nutrient requirment, the total dry mater intake was estimated (NRC, 2001) and the experimental diet was formulated fixing the supplement nearly at 50:50 of hay to supplement ratio. Due to the lower nutrient concentration of pigeon pea than the concentrate, the amount of supplements varied between 6.1 and 6.6 kg among the treatments to make the supplements isocaloric and isonitrogenous. The proportion of ingredients and the chemical composition of the feed ingredients and supplements are presented in Tables 1 and 2, respectively.

Table 1. Feed ingredient (% of supplement DM) and composition of experimental diets (DM%, unless specified)

Ingredients	T_1	T_2	T_3	T_4
Natural pasture hay	Ad libtum	Ad libtum	Ad libtum	Ad libtum
Pigeon pea	0	9.8	19.3	29.5
Wheat bran	58.7	56.4	54.9	54.1
Noug seed cake	30.3	23.0	15.4	5.3
Maize grain	8.0	7.7	7.2	7.3
Urea	0.0	0.2	0.3	0.7
Limestone	2	2	2	2
Common salt	1	1	1	1
Chemical composition of the supplements				
Crude protein	23.0	22.9	22.8	22.9
ME, MJ /kg DM	9.67	9.69	9.72	9.79
Neutral detergent fiber	34.7	34.9	35.2	35.3
Acid detergent fiber	15.2	15.9	16.5	16.9

ME: metabolizable energy; T_1: Native pasture hay (NPH) + concentrate mixture (CM), T_2: NPH + 90% CM + 10% pigeon pea (PPL), T_3: NPH + 80% CM + 20% PPL, T_4: NPH + 70% CM + 30% PPL.

Table 2. Chemical composition (% DM, unless specified of the experimental feed ingridients

	Native pasture hay	Pigeon pea leaves	Noug seed cake	Urea	Wheat bran	Maize grain
Dry matter	93.28	93.49	93.93	--	91.89	90.94
Ash	7.30	12.09	9.50	--	3.55	2.78
Crude protein	7.94	24.63	33.35	287.5	19.66	7.68
Neutral detergent fiber	66.98	36.25	33.18	--	37.36	21.30
Acid detergent fiber	42.90	28.65	24.99	--	11.64	3.69
ADL detergent lignin	6.08	13.04	13.51	--	2.03	0.70
ME MJ/kg DM	7.88	8.74	7.65	--	10.58	10.63
Total tannin	--	1.02	--	--	--	--
Condensed tannin	--	0.03	--	--	--	--

ME: Metabolizable energy

Animal management, feeds, and feeding

Prior to the commencement of the experiment, the experimental animals were treated against internal and external parasites using tetraclozan and ivermectin, respectively. The experimental animals were kept in individual pens and water was freely accessible.

Native pasture hay was purchased from the central highlands of Ethiopia. Wheat bran, noug seed cake, maize grain, urea, common salt, and limestone were purchased from the local market. Pigeon pea

(*Cajanus cajan*) was planted within Hawassa University's main campus during the primary rain season (June,2018), and harvested at 15% flowering. Pigeon pea branches with leaves were manually harvested and sundried. For proper drying of the leaves, it was continuously turned for 5-6 days until it get dried . After drying, pigeon pea leaves (PPL) were kept in sacks and stored under shed pending feeding. Hay was chopped (10-15cm) and offered at 08:30 h daily ad libitum. Concentrate mixtures and PPL were thoroughly mixed for each treatment and fed in two equal allocations at 07:00 and 15:00 h daily.

For each period, the feeding trial was conducted for 22 d including 15 d of adaptation. Feed offered and refusals were measured daily for the final 7 d of each period, and feed intake was determined as the difference between feed offered and refused. During the same 7 d, feed samples were collected daily and pooled by feed type. Similarly, samples of feed refusals were collected daily and pooled by cow. Representative samples from each feed type and refusal from each cow were taken for chemical analysis.

Digestibility analysis

As recommended by Kanani et al. (2014), acid detergent insoluble ash (ADIA) was used as an internal marker to determine digestibility. Fecal samples were taken directly from the rectum at the end of each period for 5 consecutive days. To avoid diurnal variation (Jancewicz et al., 2016) a special sampling plan was followed; fecal samples were collected daily at different times: d 1 from 06:30 to 8:30 h, d 2 from 11:00 to 13:00 h, d 3 from 14:30 to 16:30 h, d 4 from 17:00 to 18:30 h, d 5 from 3:30 to 5:30 h. The fecal samples were stored frozen at −20°C until the end of each sampling period. Then, the samples were thawed, manually mixed, and pooled by an animal, taking the same amount of feces from each daily sample. The apparent digestibility coefficient was computed by using the change in the ratio of each nutrient with reference to ADIA (indicator) in the feed and in the faeces.

$$\text{Apparent digestibility coefficient of dry matter} = 1 - \frac{\%\text{ indicator in feed DM}}{\%\text{ indicator in faecal DM}}$$

$$\text{Apparent nutrient digestibility coefficient} = 1 - \frac{\%\text{ indicator in feed} \times \%\text{ of nutrient in feces}}{\%\text{ indicator in feces} \times \%\text{ of nutrient in feed}}$$

Feed and feces analysis

Feed and feces samples were dried in a forced-air oven at 60°C for 48 h and ground to pass through a 1-mm sieve using a Wiley mill. The ground samples were kept in sealed plastic bags at room temperature pending analysis. Dry matter (DM) and ash were analyzed according to AOAC (2005). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to Van Soest et al. (1991) using an Ankom 220 fiber analyzer (Ankom Technology, Macedon, NY). Acid detergent lignin (ADL; offered feed samples only) was determined according to (Van Soest & Robertson, 1985). Nitrogen (N) content was measured by the Kjeldahl method (AOAC, 2005) and crude protein (CP) was calculated as N × 6.25. Total tannin and condensed tannin was determined according to Makkar (2003). Acid detergent insoluble ash was determined according to Kanani et al. (2014).

Milk yield was measured and samples collected twice daily at 6:00 and 15:00 h during the final 7 d of each period. The 4% fat-corrected milk yield (FCM) was calculated according to Gaines (1928): FCM (kg day^{-1}) = (0.4 × milk yield) + (15 × fat yield). Energy corrected milk (ECM) was calculated following the equation developed by Tyrrell and Reid (1965) as ECM = kg milk × (383 × fat % + 242 × protein % + 783.2)/3140. Feed conversion efficiencey was calculated by dividing ECM by total dry matter intake.

Statistical analysis

Data were analyzed following the MIXED procedure of SAS 9.4 (SAS Institute, 2016) for replicated 4 × 4 Latin square design. The restricted maximum likelihood method was used to estimate LS means. Means were separated using the PDIFF option in the LSMEANS statement.The linear and quadratic effect of inclusion of PPL was tested. Taking average values for the parameters that were repeatedly measured, the following model was used for this study:

$Y_{ijkl} = \mu + S_i + P_j + C_{k(i)} + T_l + ST_{il} + E_{ijkl}$

Where Y_{ijkl} is the dependent variable, μ is the overall mean, S_i is the effect of square i, P_j is the effect of period j, $C_{k(i)}$ is the effect of cow k (within square i), T_l is the effect of treatment l, ST_{il} is the interaction between square i and treatment l, and E_{ijkl} is the residual error. All terms were considered fixed except $C_{k(i)}$ and E_{ijkl} which were considered random. Significance was declared at $P \leq 0.05$. All reported values are least-square means.

Results

Feed intake and diet digestibility

Greater (P<0.05) hay intake was observed for T1 and T2 compared with T4 (Table 3). Supplement intake for T1 was the lowest ($P < 0.05$) while the pigeon pea supplemented groups (T2-T4) had similar ($P > 0.05$) supplement intake. Total dry matter, organic matter, crude protein intake,and dry matter and nutrient digestibility were similar (P>0.05) among treatments.

Table 3. Effect of supplementation of pigeon pea leaves and homemade concentrate mixture to native pasture hay-based diet on feed intake and apparent digestibility of crossbred dairy cows

Parameters	T1	T2	T3	T4	SEM	P value Linear	P-value Quadratic
Dry matter intake (kg/d)							
Native pature hay	5.28[a]	5.27[a]	4.99[ab]	4.66[b]	0.24	0.05	0.49
Supplement	6.14[b]	6.48[a]	6.65[a]	6.55[a]	0.14	0.04	0.15
Total intake	11.41	11.75	11.63	11.21	0.24	0.54	0.15
Organic matter	10.41	10.72	10.63	10.28	0.22	0.66	0.18
Crude protein	1.67	1.71	1.70	1.66	0.03	0.93	0.17
Neutral detergent fiber	4.60	4.67	4.57	4.31	0.12	0.14	0.26
Acid detergent fiber	2.26[a]	2.27[a]	2.22[a]	2.07[b]	0.07	0.05	0.25
Digestibilitycofficient :							
Dry matter	0.486	0.423	0.444	0.461	0.03	0.71	0.21
Crude protein	0.635	0.581	0.589	0.605	0.03	0.55	0.25
Organic matter	0.468	0.422	0.444	0.469	0.02	0.89	0.31
Neutral detergent fiber	0.316	0.256	0.276	0.263	0.03	0.50	0.83
Acid detergent fiber	0.227	0.169	0.180	0.164	0.04	0.42	0.63

T_1: Native pasture hay (NPH) + homemade concentrate mixture (CM), T_2: NPH + 90% CM + 10 pigeon pea (PPL), T_3: NPH + 80% CM + 20% PPL, T_4: NPH + 70% CM + 30% PPL; SEM: Standard error of the mean. Means in the same row with different superscript are significantly different ($P \leq 0.05$).

Milk yield and feed conversion efficiency

Milk yield (unadjusted and 4 % fat corrected), feed conversion efficiency and body condition score were similar ($P > 0.05$) among treatments (Table 5).

Table 4. Effect of supplementation of concentrate mixes and pigeon pea leaves on milk yield, composition, feed conversion efficiency and body condition of crossbred dairy cows fed native pasture hay as a basal diet

Parameters	T1	T2	T3	T4	SEM	P-Values Linear	P -vales Quadratic
Milk yield (L/d)	8.34	8.16	8.20	7.46	0.52	0.37	0.67
4% fat corrected milk yield (L/d)	8.65	8.44	8.52	7.94	0.65	0.55	0.81
Feed conversion efficiency	0.70	0.68	0.70	0.67	0.05	0.82	0.92
Body condition score (1-5)	2.69	2.69	2.65	2.60	0.18	0.72	0.91

T_1: Native pasture hay (NPH) + homemade concentrate mixture (CM), T_2: NPH + 90% CM + 10% pigeon pea leaves (PPL), T_3: NPH + 80% CM + 20% PPL, T_4: NPH + 70% CM + 30% PPL. SEM: standard error of mean. Means in the same row with different superscript are significantly different ($P < 0.05$).

Discussion

Chemical composition of feed ingredients

Assesment of the effect of replacing CM with PPL is relevant to dairy production in the tropics, where protein is a limiting nutrient and agro-industrial by-products are not readily accessible and are expensive. However, information regarding PPL in dairy cow feeding is limited making it challenging to formulate diets with this legume. The CP and ME content of native pasture hay was within the range reported for cooler tropical highlands (Feyissa et al., 2014). The condensed tannin concentration observed in the current study (0.024%) was within the range (0.01 - 1.24%) reported for pigeon pea by Tontini et al. (2019). Therefore, the relatively high CP, low NDF and low tannin concentration of PPL observed in the current study makes it appealing as an alternative protein supplement in dairy cow rations.

Dry matter intake and apparent digestibility

The average DM intake observed in the current study was greater than the value reported for crossbred dairy cows fed urea treated wheat straw as a basal diet and supplemented with concentrate and/or vetch hay (11.7 vs, 10.2 kg; Kitaw et al.,, 2010) and fed napier and bracharia grass with or with out desmodium supplementation (11.7 vs. 9.2; Mutimura et al. 2018). The variability might be attributed to breed difference (Stivanin et al., 2021) and/or the NDF concentration of the ration (NRC, 2001).

Because PPL had lower CP concentration than noug seed cake and PPL mainly replaced noug seed cake in the CM, as the inclusion level of PPL increased in the CM the amount of supplement offered increased. Therefore, as expected supplement intake was greater for T 2, 3, and 4 than T1. However, due to some refusals in PPL supplemented groups, the supplement intake was not varied among PPL supplemented groups. In Treatment 4, where 30 % of PPL was included in the concentrate mix, hay intake was the least, which might be due to the substitution of hay with PPL intake.

The relationship between the proportion of concentrate in the ration and DM intake has been reported, and the maximum DM intake is at 60% concentrate supplementation and increasing dietary roughage linearly decrease DMI in lactating dairy cows (Jiang et al., 2017). In contrast, in the present study the DM intake was similar among experimental diets and the total DM intake was not affected by the level of PPL supplementation, so that the proportion of concentrate in the ration was well below 50%. Similar to the current study, total dry matter intake was not affected as concentrate is substituted by alfalfa hay in ewes (Wang et al., 2019). Hence, the optimum concentrate to roughage proportion might varies with the quality of forage/roughage supplemented. Neutral detergent fiber intake is strongly related to DM intake (Sanh et al., 2002). In the current study, the similarity in DM intake among the experimental diet might be due to the similarity among experimental diet in NDF intake (Madsen et al.,1994). Dry matter intake is an important parameter to evaluate the quality of the diet (Coutinho et al., 2014), and the similarity in DM intake observed in the current experiment indicates that PPL up to 30% can be included in the dairy cow ration as far as total DM intake is considered.

The DM digestibility coefficient (0.47) observed in the present study is lower compared to the findings for cattle fed native pasture hay as a basal diet supplemted with 1 to 3 kg DM/d of concentrate (0.57-0.59; Nsahlai and Apaloo, 2007) and for lambs fed bahiagrass and supplemented at 50% of DM with pigeon pea hay or 4.25 % DM of soybean meal (0.56; Foster et al., 2009). The NDF, ADF, lignin, CP and energy concentration of the diet is known to affect DM digestibility (Mahyuddin 2008), and in the current study the high content of NDF and ADF in native pasture hay, which is nearly 50% of the total DM intake, might be responsible for reduced DM digestibility. Neutral detergent fiber digestibility known to affect DM digestibility (Krämer-Schmid, Lund, & Weisbjerg, 2016) and lack of variability in apparent DM digestibility among the experimental diets, might be due to similarity in NDF digestibility.

The apparent nutrient digestibility coefficient observed in the current study was low compared to the result reported for CP (70.2), OM (67.5), and NDF (50.2) in lactating dairy cows fed total mixed ration, which is composed of corn silage, grounded corn, soybean meal, wheat bran and mineral mixture, which have NDF concentration of 30 % (Coutinho et al., 2014). Even with higher dietary NDF concentration (40%), greater nutrient digestibility (CP = 75.5 – 77%; OM=71.34 – 72.8% and NDF=55.7 – 58.1%) was reported for different breeds of dairy heifers (Silvestre et al., 2021). Similarly, the apparent digestibility coefficient for organic matter (60 - 65%) reported for N'Dama and crossbred cattle breeds fed groundnut hay supplemented with concentrate mixture and moringa leaf (Nouala et al., 2009) is greater than the value observed in the present study (0.42 – 0.46). Forage source (Jiang et al. 2018; Nouala et al., 2009), forage particle size (Jiang et al., 2018), breed type and level of supplement (Nouala et al., 2009) are known to affect nutrient digestibility. The native pasture hay used in the currnt study is high in NDF and ADF which might have lowered the apparent nutrient digestibiliyty coefficient. The use of internal markers to determine digestibility is controversial. Though some of them are better in predicting digestibility, among ten internal markers tested, all of them fail to predict total tract digestibility accurately (Huhtanen et al., 1994). Similarly, dry matter digestibility coefficient predicted using four internal marker was different from in vivo dry matter digestibility with in tall fesue and prary hay (Cochran et al.,1986). As a result different authors suggest different internal markers to predict digestibility coefficient. Iinternal marker, such as acid detergent insoluble ash was initially evaluated to predict digestibility of a single roughage(Kanani et al., 2014), may under estimate digestibility coefficient of mixed ration.

Milk yield and body condition score

Milk yield is reduced as the proportion of concentrate is reduced in the diet, and 50% of concentrate is considered optimum for milk production of crossbred dairy cow (Holstein Fresian x local yellow) producing nearly 12 L/d milk (Sanh et al., 2002). In the present study formulating a ration nearly at 50:50 of concentrate to roughage ratio and inclusion of 10 to 30% pigeon pea leaves in the concentrate mixture have not resulted in reduction of milk yield. Coroborating the current result, similar milk yield was reported for Holstein dairy cows fed 80:20 and 20:80 roughage (Italian rye grass) to concentrate ratio and producing 25 L/d of milk (Eom et al., 2019). Similarly replacement of up to 50% concentrate with vetch hay have not reduced milk yield in crossbred dairy cow fed urea/molasses treated wheat straw as a basal diet (Kitaw et al., 2010). This indicate not only the proportion of roughage to concentrate ratio, but also the nutritional quality of roughages should be considered as well. Pigeon pea leaves has higher CP %, lower NDF and ADF %, and its inclusion at 10 to 30 % in the concentrate mixture has not affected nutrient intake and digestibility, and resulted in similar milk yiled among the treatments. Neutral detergent fiber is important energy source for ruminant and its digestibility positively related to dry matter digestibility and milk yield (Krämer-Schmid et al., 2016). The similarity in milk yield among the treatment might be related to similarity in NDF digestibility and DM digestibility across the treatments. Also, Existence of vitamins in forages might compensate the lost benefit of concentrates feeding (Johansson et al., 2014).

Feed conversion efficiency is a common measure of efficiency of dietary energy and important determinant that determines farm profitability. Inclusion of pigeon pea leaves in the concentrate mixture has not affected feed conversion efficiency,. However, in the present study, the observed FCE is lower than the value reported for lactating crossbred dairy cows (0.7 vs. 0.89; Hossain et al., 2017). The lower FCE observed in the current study might be attributed to lower nutrient digestibility. Also the reduced milk yield at mid lactation compared to early lactation might have lowered the FCE (Arndt et al., 2015).

Body condition score is a good indicator of body reserve mobilization and energy balance of lactating dairy cows. The body condition score found in the current study was comparable to the value reported for lactating dairy cows in mid lactation (Junior et al., 2010). In the current study, the body condition score was similar among treatments , indicating all experimental diets have satisfied the energy requirement.

Inclusion of different levels of pigeon pea leaves as a substitute to concentrate mix have resulted in similar effect on total dry matter intake, nutrient intake nutrient digestibility, milk yield, and body condition score. Thus, it can be concluded that pigeon pea leaves could be included up to 30% in the concentrate mix under the conditions of the current experiment.

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On-Farm Participatory Evaluation of Oat (*Avena Sativa*) and Vetch (*Vicia Villosa*) Mixtures in Farta District, Northwestern Ethiopia

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Abstract

A study was conducted in Farta district in Northwestern Ethiopia to assess the herbage dry matter yield, quality, farmers' preference of oat and vetch mixtures using NPSB soil fertilizer and to identify the best oat and vetch mixture for the study area. Four oat varieties CI-8237, CI-8251, Jassari and SRCPX80Ab2291 were evaluated each in mixture with vetch and the vetch species used for the study was Vicia villosa. The experimental design used was RCBD with ten replications of the treatments. Plot size was 5m x 5m. Forage samples and data were collected based on recommended methods. The mean dry matter yield of the oat and vetch mixtures tested was 10.2 ton per ha and the results of this study showed that there were significant differences in DM (dry matter) yield among the oat and vetch mixtures tested. The highest DM was recorded for the CI-8237, CI-8251 and SRCPX80Ab2291 grown with vetch whereas the lowest was from Jassari grown with vetch. The CP (crude protein) content of the mixtures ranged from 11.1 to 12.4%. There were also differences in farmers' preference. Based on the results of this study the oat varieties CI-8237and CI-8251 mixed with vetch species (V. villosa) had better performance using several evaluation criteria. These oat varieties are identified as promising for the production of oat and vetch mixtures for Farta district and other areas with similar agro-ecology in the highlands of Ethiopia.

Keywords: dry matter yield, farmers' preference, improved forages, nutritive value

Introduction

The Ethiopian highlands are characterized by mixed crop-livestock farming system and most of the human and livestock population of the country is found in these areas. About 88% of the human, 75% of the cattle, 75% of the sheep and 34% of the goat populations in Ethiopia are found in the highland areas (CSA, 2018). The human and livestock population density in the highland areas ranges between 37 – 120 people and 27 – 130 tropical livestock unit (TLU) per square kilometer. Livestock production is one of the main livelihood activities in the Ethiopian highlands. The human population in Ethiopia is increasing at an alarming rate that more and more food has to be produced to meet food security. Especially in the highland areas, more land is being devoted to produce more food and there is severe land degradation due to the traditional livestock and crop production system.

Ethiopia has the largest livestock population in Africa, but its productivity is low. Among several livestock production constraints feed shortage both in quantity and quality is the most important one. Currently, there is severe feed shortage both in quantity and quality for livestock production especially in the highland areas of the country. Research and development activities are needed to alleviate this constraint and improve livestock productivity in these areas.

Oat and vetch production either in pure stands or in mixtures is suitable for the highland areas. Oats and vetches withstand low soil fertility, soil acidity and low temperatures. In addition, Oat and vetch mixture production increases the DM yield and the CP content as compared with the pure stands

(Lemma and Alemu, 1991). The dry matter yield and quality of either the pure stand or the mixture is affected by several factors. According to Getnet and Ledin (2001), soil type, fertilizer application and variety used affects the dry matter yield and quality of oat and vetch mixtures produced in the highlands of Ethiopia. The CP content of the oat and vetch mixtures is also affected by the oat and vetch seed proportion used for the mixed forage (Negash *et al*., 2017). It is also reported that there is considerable variation in chemical composition and *IVOMD* of oat varieties (Fekede *et al*., 2007). According to the latter study, the CP content among the 20 oat varieties is significant and it ranges from 48 to 76 g per kg DM. In another study, the dry matter yield of pure oat varieties is affected by year, fertilizer application and variety used (Getnet *et al*., 2004). Under these varied circumstances the present study aimed to assess the DM yield and quality of the oat and vetch mixtures using NPSB fertilizer application and assess the farmers' preference for subsequent recommendation of promising oat and vetch mixtures.

Materials and Methods

Description of the study area - This study was conducted in Farta District, at Hiruy Aba Aregay and Awuzet kebeles in North Western Ethiopia. The total area of Farta District is 117,407.0 ha (ANRSPC, 2015). The altitude of the district ranges from 1920 to 4235 masl (FDOA, 2017). According to the same source, the agro-climatic zone of the district is Woina Dega (56%), Dega (42.5%) and Wurech (1.5%). The mean annual temperature ranges from 9 to 25°C and the mean annual rainfall of the district is 1599 mm. The dominant soil types of the district are brown (50%), red (30%) and black (20%) (FDOA, 2017).

Land preparation and time of sowing - The study was conducted on farmers' plots and at Farmers' Training Center (FTC) plots in Farta District. Farmers who were willing and who have the resources needed (land, livestock and labour) were selected to participate in the study. The land that was used for this study was ploughed 2 to 3 times before planting. Planting was conducted at the onset of the main rainy season in 2017.

Plot size and experimental design - The plot size used was 5m x 5m. The planting method was broadcasting. The experimental design used was RCBD considering farmers farm plots and farmers training center (FTC) plots as replications. Treatments were allocated to experimental units (farmers plots and FTC plots) randomly. There were 10 replications in the study.

Treatments, seed rate and fertilizer application - Four oat varieties (CI-8237, CI-8251, SRCPX80Ab2291 and Jassari) and one vetch species (*V. villosa*) were used for the trial. These varieties are among the numerous entries that Holetta Agricultural Research Center of EIAR (Ethiopian Institute of Agricultural Research) imported for screening purposes.

The treatments were:

Treatment 1. Oat variety (CI-8237) + *Vicia villosa*
Treatment 2. Oat variety (CI-8251) + *Vicia villosa*
Treatment 3. Oat variety (SRCPX80Ab2291) + *Vicia villosa*
Treatment 4. Oat variety (Jassari) + *Vicia villosa*

The seed rate used for oat and vetch mixture was 75 kg and 25 kg ha^{-1} for the oat and vetch seed, respectively. Chemical fertilizers NPSB 100 kg ha^{-1} and urea 50 kg ha^{-1} were applied uniformly to each plot at planting. At stand establishment 100 kg ha^{-1} urea was applied to each plot.

Data collection and sampling

Plant height - Five plants each of oat and vetch per plot were randomly selected from the stand and their height was measured from ground to the tip of the plant using graded stick in cms at harvesting.

Herbage yield - DM yield was determined by taking forage samples from the internal part of each plot using quadrats of 0.5m x 0.5m size. Two quadrat forage samples were taken from each plot. The first quadrat forage sample was taken as a whole (oat and vetch mixture) and the second quadrat forage sample was separated into two botanical sub-samples; sole oat and sole vetch samples. Fresh weight of the forage samples was measured at harvesting and then the air-dried weight was measured using sensitive balance.

Farmers' preference analysis - prior to harvesting and sampling, farmers were requested to compare the growth performance of the oat and vetch mixtures and the outcome of their judgment was noted based on recommended methods (CIAT, 2001). Farmers' preference analysis was conducted in Farta District at Hiruy Aba Aregay kebele.

Chemical analysis of forage samples - Chemical analysis was conducted for the samples taken the field experiment. The dried samples were pooled into treatment groups: oat & vetch mixtures, sole oats and sole vetch. Sub-samples were taken from each of these pooled samples, ground to 1mm size and chemical analysis of the sub-samples was conducted. The forage samples were analyzed for DM, ash and CP according to AOAC (1980). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed according to Van Soest and Robertson (1985).

Statistical analysis - The collected data were analyzed using IBM SPSS statistical software (Version 24). Analysis of variance was conducted using GLM and LSD was used for mean separation.

Results

Forage dry matter productivity

The mean dry matter yield of the different oat and vetch mixtures tested is given in table 1. There was a significant difference (P<0.01) in dry matter yield among the oat and vetch mixtures tested, as well as the oat varieties tested (Table 1).

Table 1. DM productivity of the different oat and vetch mixtures in Farta district

Treatment type	**Oats vetch mixture**	**Oats**	**Vetch**
Oat variety 1 (CI-8237) + *Vicia villosa*	11.7±3.32[a]	10.7±3.59[a]	1.0±1.36
Oat variety 2 (CI-8251) + *Vicia villosa*	11.4±2.52[a]	10.7±3.34[a]	1.0±1.07
Oat variety 3 (SRCPX80Ab2291) + *Vicia villosa*	10.0±2.29[a]	9.3±2.58[a]	1.8±1.15
Oat variety 4 (Jassari) + *Vicia villosa*	7.6±2.06[b]	6.8±2.13[b]	1.8±1.08
Average	10.2±2.97	9.4±3.27	1.4±1.19

Means within a column followed by different superscript letters are significantly different (P<0.01); *OAV = Oat and vetch mixture

Plant height - There was a significant difference (P<0.01) in height among the different oat varieties tested (Table 2). In addition, the height of the same vetch species used in the study was variable and significantly different (P<0.01) among the treatments (Table 2).

Table 2. Height of the different oat varieties and vetch in Farta District

Treatment type	Oat height (cm)	Vetch height (cm)
Oat (CI-8237) + *Vicia villosa*	151.1 ± 29.00^{a}	128.8 ± 37.37^{a}
Oat (CI-8251) + *Vicia villosa*	145.6 ± 32.01^{a}	122.0 ± 25.46^{ab}
Oat (SRCPX80Ab2291) + *Vicia villosa*	119.9 ± 32.21^{b}	112.8 ± 34.32^{bc}
Oat (Jassari) + *Vicia villosa*	91.5 ± 22.21^{c}	103.8 ± 33.73^{c}
Average	127.0±37.36	116.9±34.11

Means within a column with different superscript letters are significantly different (P<0.01)

Chemical composition

Chemical analysis result of the forage samples is given in table 3. The Crude protein (CP) content of the oat and vetch mixtures ranged from 11.13 to 12.35% and the CP content of the oat samples ranged from 9.85 to 11.96% (Table 3). The CP content of the vetch species (*V. villosa*) was 23.92%.

Table 3. Chemical analysis result of the oat and vetch mixtures, the sole oat varieties and the sole vetch species in Farta District

Treatment	DM	Ash	CP	NDF	ADF	ADL
Oat and vetch mixture						
Oat (CI-8237) and vetch	90	6.67	12.19	48.88	33.33	8.88
Oat (CI-8251) and vetch	90	7.78	11.13	64.44	46.67	11.11
Oat (SRCPX80Ab2291) and vetch	89	6.74	12.35	54.44	42.22	10.00
Oat (Jassari) and vetch	90	8.89	11.93	62.22	48.89	11.11
Pure stand oat						
Oat (CI-8237)	90	6.67	10.18	62.22	48.89	11.11
Oat (CI-8251)	90	6.67	11.96	60.00	44.44	10.00
Oat (SRCPX80Ab2291)	90	5.56	9.85	50.00	35.56	8.88
Oat (Jassari)	89	6.74	10.47	51.11	37.78	10.00
Pure stand vetch						
Vetch (*Vicia villosa*)	91	8.79	23.92	48.88	35.56	7.70

Farmers' preference analysis of oat and vetch mixtures

Farmers' preference analysis outcome is given in table 4. The oat variety CI-8237 mixed with vetch ranked first over the other three oat varieties (CI-8251, SRCPX80Ab2291 and Jassari) due to its high performance in the overall evaluation criteria (Table 4). The oat varieties CI-8251, Jassari and SRCPX80Ab2291 ranked second, third and last, respectively. The oat variety SRCPX80Ab2291 was observed to be affected by leaf and stem rust during the current study.

Table 4. Farmers' preference analysis of oat and vetch mixtures in Farta District

Evaluation criteria	Oat and vetch mixtures			
	CI-8237 + vetch	CI-8251 + vetch	2291* + vetch	Jassari + vetch
Height	1	2	4	3
More leaves	1	3	4	2
Thickness of stem	1	2	4	3
Effect on vetch growth	4	3	1	2
Disease tolerance (rust)	1	2	4	3
Early maturity	1	3	2	4
Total score	**9**	**15**	**19**	**17**
Rank	**1**	**2**	**4**	**3**

Note the smallest score indicates the highest preference and vice versa; *SRCPX80Ab2291

Discussion

Studies in Ethiopia show that the dry matter yield of the oat variety CI-8251 mixed with vetch is higher or comparable with the oat variety CI-8237 mixed with vetch production (Lemma and Alemu, 1991; Teshome *et al*., 2005). According to Lemma and Alemu (1991), the dry matter yield of CI-8251 with vetch mixture was higher than CI-8237 with vetch mixture production. Based on three years study result, the dry matter yield of CI-8237 and CI-8251 with *V. dasycarpa* was 9.86 and 10.76 ton DM per ha, respectively, and it was significantly different. In addition, the dry matter yield of CI-8237 and CI-8251 with another vetch species (*V. atropurpurea*) was 11.80 and 12.23 ton DM per ha, respectively, and it was also significantly different (Lemma and Alemu, 1991). Based on another study, the dry matter yield of the oat varieties CI-8237 and CI-8251 with *V. villosa* was 7.29 and 7.21 ton DM per ha, respectively (Teshome *et al*., 2005), which is lower than the present study. According to Getnet and Ledin (2001), the variety used affects the DM yield and quality of the oat and vetch mixture forage produced.

In the present study, the DM yield of the two oat varieties (CI-8237 & CI-8251) was also higher when compared with Jassari variety (Table 1). Based on several studies in Ethiopia, the dry matter yield of the oat variety CI-8251 was higher or comparable to CI-8237 oat variety. In the present study, the mean DM yield of the vetch species (*V. villosa)* grown with oats was on average 1.4 t DM per ha. According to a study in Ethiopia, there was a significant DM yield difference between *V. dasycarpa* and *V. villosa* and their DM yield was 3.1 and 3.6 t DM per ha, respectively (Kassahun and Wasihun, 2015). The high dry matter yielding oat varieties that were tested in the current study are late maturing oat varieties i.e. CI-8237 and CI-8251 (Fekede, 2009). So, growing these oat varieties with the late maturing vetch species, i.e. *V. villosa*, will be beneficial for better compatibility.

In the present study, the CP content of the oat and vetch mixtures ranged from 11.13 to 12.3%. The CP content of the oat and vetch mixtures in this study was more or less similar. According to Getnet (1999), the CP content of the different oat and vetch mixtures ranged from 8.3 to 8.8% and there was no significant difference in CP content among the oat and vetch mixtures tested in their study. Getnet and Ledin (2001) reported that the CP content of oats increases when grown in mixture with vetch. According to another study in Ethiopia, increasing the proportion of vetch in the oat and vetch mixture also increases the CP content of the oat and vetch mixtures and it ranges from 12.4 to 23.5% (Negash *et al*., 2017). Generally, growing oats with vetches increases the CP and *IVOMD* contents and intake of CP and DOM of oat and vetch mixtures compared to sole oats (Getnet and Ledin, 2001).

According to previous studies CI-8251 oat variety is better than CI-8237 oat variety in other characteristics studied. The oat variety CI-8251 is better in leaf and stem rust resistance, lodging and has better leaf to stem ratio. Based on another study in Ethiopia, CI-8251 was found to be less susceptible to disease and lodging (Usman *et al*., 2018). At soft dough stage, the proportion of leaf blade in CI-8251 was significantly higher than most other oat varieties studied (Fekede *et al*., 2008). On the other hand, CI-8251 had lower leaf blade at soft dough stage than most other oat varieties studied. In addition, based on the above study, CI-8251 had higher leaf to stem ratio than CI-8237.

Vetches have high CP content, and they improve the quality of the oats that are grown with them. In addition, they also improve soil fertility through nitrogen fixation. The CP content of *V. Villosa* in the present study was 23.92%. The CP content of *V. villosa* at Holetta was reported to be 21.4%, and the *IVDMD* 66.4% (Gezahagn, 2016). Generally, *V. villosa* is more adaptive and productive than other vetch species studied.

Farmers' preference analysis is another criteria used to assess the oat and vetch mixtures for their usefulness to farmers. Based on the farmers' preference analysis result, the oat varieties CI-8251 and CI-8237 mixed with vetch were more preferred by the smallholder farmers for growing and using for livestock feeding. The farmers' preference analysis result is in harmony with the oat and vetch mixtures DM yield result. Using their own evaluation criteria, farmers were able to prefer and identify the oat and vetch mixtures that had higher DM yields. These oat varieties (CI-8251 and CI-8237) were observed to be leaf and stem rust disease tolerant.

Conclusions

Based on the present study result, the oat varieties CI-8237 and CI-8251 mixed with the vetch species (*V. villosa)* are promising as annual mixed forage crops and can be recommended for farmers in Farta district and similar areas in the highlands of Ethiopia that have similar agro-ecologies. These mixtures were found to be high both in DM yield and CP content. They are also the preferred oat and vetch mixtures by farmers who judged them using different evaluation criteria. Generally, these selected oat varieties and the vetch species are late maturing forages and they have better compatibility for oat and vetch mixture production in the highlands of Ethiopia.

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Effect of *Desmodium intortum* hay and Brewery grain supplementation on Feed intake, Digestibility, Milk yield, Milk Composition, Milk Fatty Acid Profile, and Blood Biochemical response of Crossbred Dairy Cows Fed Basal Natural Pasture Hay

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Abstract

Feed scarcity in both quantitative and qualitative dimensions is the major constraints hampering the milk yield performance of livestock in Ethiopia. Dairy producers suffer from the skyrocketing prices of concentrate diets. Study was, therefore, conducted to evaluate the effect of desmodium intortum hay and brewery grain supplementation as partial replacement for concentrates on feed intake, digestibility, body weight change, milk yield and its composition, milk fatty acid profile, and blood biochemical response of crossbred dairy cows fed basal native grass hay. Twenty lactating cows were assigned randomly in a replicated 3 x 4 Youden square design to four treatments: T1 (Control diet): 100% Concentrate (Con); T2: 50% Con + 50% Brewery Grain (BG); T3: 50% Con +25% BG + 25% Desmodium hay (DH); and T4: 50% Con + 50% DH. Native grass hay was fed ad libitum to experimental animals. The experiment comprised of 3 periods: each with 21 days. Data was subjected to MIXED procedure of SAS (2001). Cows fed 100% Con had a higher CP intake than those fed 25% BG + 25% DH and 50% DH. The ME intake of cows fed distinct diets was similar, except for cows fed 50% DH diet. Cows fed 50% DH diet had the lowest ME intake. Cows fed T1 (100% Con) and T2 (50% BG) diets had the highest DM, OM and CP digestibility; while cow received T4 (50% DH) diets had the lowest. The milk yield (kg/d) and fat content (%) of milk was similar among cows fed different diets. The highest milk protein content was for cows fed T2 diet. The linoleic acid (C18:2) content in milk fat of cows received T1 and T2 diets was greater than cows fed T4 diet. Relatively cows fed T1 had a higher conjugated linoleic acid (C18:2, c9t11) content than those cows fed T3 and T4 diets. The higher blood urea level was for cows fed T1 and T2 diets, while the higher creatinin level was for cows fed T4 diet. The finding implied that either brewery grain or Desmodium hay can substitute concentrate up to 50% in a diet, without negatively affecting the milk yield. Combination 50% brewery grain and 50% concentrate were better in terms of crude protein intake, milk contents of protein, linoleic acid, and blood urea level. This indicates that brewery grain can replace concentrate up to 50% in a diet of crossbred dairy cows as save and efficient dry season alternative supplement. The result obtained from the study could contribute to address the feed related bottle neck of the majority of small holder dairy cow's in Ethiopia.

Keywords**:** Desmodium hay, Brewery grain, feed intake, milk yield, crossbred dairy cows

Introduction

Ethiopia holds large potential for dairy development due to its large livestock population, favorable climatic conditions, emerging market opportunity, and the relatively disease-free environment for livestock (Ulfina, *et al*, 2013). Despite the existing high potential for dairy development the performance of the dairy ruminant animals in Ethiopia is low. The major constraint for milk production of dairy cows in the tropics, particularly in Ethiopia is the consistent availability of quality feed in adequate amount, especially in the dry season (Aynalem *et al.*, 2011). The use of concentrates is fundamental to increase milk production. However, the ingredients that compose the concentrate are expensive, raising the feeding costs. Therefore, to attain the economic viability of supplementation, the use of alternative feed resource could support production of the same amount of milk with lower cost allowing a larger number of producers to adopt the supplement routinely in their farms (Oliveira, 2013).

In order to mitigate the problems associated with availability and high cost of conventional feedstuffs, nutritionists have advocated the use of nonconventional feed ingredients such legumes forages and agro-industrial by-products, which are not in competition with man’s dietary needs (Wanapat, 2009). Milk production by using cheaper nonconventional feed resources such as the use of *Desmodium intortum* hay and brewery grain will have great impact on the milk production performance of dairy cows and reduces costs of milk production (Khan and Uddin, 2012).

Milk from dairy cattle is widely recognized as a valuable natural food source containing beneficial amino acids and bioactive peptides with potential anti-hypertensive, antithrombotic and antimicrobial activities (Park *et al.* 2007). However, in recent years, a trend of decrease in fluid milk consumption is observed in certain countries (Paul *et al.,* 2020). This is because health-conscious consumers are demanding dairy products that are low in fat, especially saturated fat and some *trans* FA (Cicero *et al.,* 2012). As a result, milk fat has been a target of concern and a component with a decreasing value in many markets (Palmquist, 2005). In contrast, some milk FAs, such as polyunsaturated FA (PUFA) and conjugated linoleic acid (CLA) have been believed to have positive implications on human health (Pariza *et al.* 2001). Therefore, modifying the milk fat composition through dietary fat manipulation may be the most practical approach to enhance the healthiness of ruminant milk by increasing their PUFA composition (Coˆrtes *et al.* 2011).

In dairy cattle, both the concentration and composition of milk fat are influenced by the diet. Concentration is reduced by feeding diets that contain large proportions of readily fermentable carbohydrates (starch) and unsaturated fat. While fresh pasture feeding for dairy cows help to increase the amount of CLA in milk. For this reason, nutritional management targeting specific requirements of the cows should consider maximizing milk yield without compromising animal health and well-being (Palmquist, 2005).

Desmodium and brewery grains are among the most common alternative legumes feeds and agro industrial by products used for lactating dairy cows around Hawassa city in Ethiopia. However, information is lacking regarding the effect of desmodium hay and brewery grain supplementation on milk yield and milk fatty acid composition of dairy cows. Therefore, such study will help to highlight the nutritional strategies that might enhance the utilization specific dietary FA by ruminants, and thereby improve the nutritional value of milk for human being. The objective of this study was, therefore, to evaluate the effect of desmodium hay and brewery grains supplementation as a partial replacement of concentrates, on milk production, milk composition, milk fatty acid profile and blood parameters of lactating dairy cows fed basal native grass hay.

Materials and Methods

Description of study site - The trial was *conducted* at Hawassa University, Hawassa, Ethiopia. Hawassa city is located about 275 km south of Addis Ababa, the capital of Ethiopia. The area is situated at 7º04'N latitude and 38º29'E longitude with an altitude of 1694 meter above sea level (NMA-Hawassa branch directorates, 2017).

Experimental animals and management - Twenty lactating crossbred cows having similar body weights, milk yield levels and parity was selected for this experiment. All cows was housed on a concrete floor in separate pens; in a well-ventilated and properly built barn equipped with feeding and watering troughs. Before the start of the experiment, all cows were ear tagged for identification, de-wormed against internal parasites and also sprayed with acaricide against external parasite. The experiment was conducted for 63 days. Prior to the actual feeding trials, 2 weeks of adaptation was used to acclimatize lactating cows to the surrounding environment and to the experimental diets. During the data collection period, the feed intake and milk yield of each cow was recorded on daily basis. Cows was hand milked twice daily, at 06:00 and 14:00 h. Individual milk yield was recorded at each milking and summed for each day. Daily feed intake and milk production was averaged over a week, to see if there is a week x treatment interaction. Milk samples was collected from each cow for seven consecutive days at the end of each period and pooled for subsequent chemical analyses. Body weight changes and body condition score of cows was measured every 21 days.

Experimental Feed and Feeding - The experimental feed was a control diet, composed primarily of grass hay, and 2 diets (desmodium hay and brewery grain). The concentrate mix was formulated with wheat bran and nug-seed cake. The mineral salt was distributed in the same amount (g/day) for all cows in each treatment. Treatment diets were formulated to be iso-nitrogenous and energy using NRC (2001) standards. The desmodium was harvested from the agricultural farm of Hawassa University, and the hay was stored after drying the fresh forage in a shade properly. The nuge seed cake and wheat bran was purchased from a nearby enterprise. During the feeding trial, concentrate and supplementary diets was offered twice a day, at 7:00 and 15:00 h, just after milking, by dividing into two equal halves at each feeding time. Animals in each group were provided with chopped grass hay to ensure ad libitum intake (10% refusal). In addition, clean drinking water was freely always accessed. The amounts of feed offered and refused (orts) was weighed and recorded daily for nutrient intake estimation. Likewise, samples of feed offered and refused by each animal was collected and bulked once per week, and 10% of the collected samples was sub-sampled and stored properly for chemical analysis.

Experimental design and treatments - The feeding experiment was conducted for 63 days using 20 lactating cross-bred dairy cows and 4 treatments (T) in a replicated 4 x 3 Youden square design. Cows was grouped into 10 blocks (of 2 cows each) in accordance with pre-experimental milk yield (5.6 kg/d milk), lactation stage (135 days) and parity (2.6), and then assigned randomly to one of the four treatments. The feeding trial comprised of three experimental periods: each experimental period was 21 days, with 14 d for adaption and 7 d for actual data and sample collection. The amount of ingredients used in each treatment is presented in the table 1. The experimental feeds (treatments) were:

T1 (Control diet): Natural pasture hay *ad libitum* + 100% Concentrate.
T2: Natural pasture hay + 50% Concentrate + 50% Brewery Grain
T3: Natural pasture hay + 50% Concentrate +25% Brewery Grain + 25% Desmodium hay
T4: Natural pasture hay + 50% Concentrate + 50% Desmodium hay

Equal amount of mineral (1.3 % Ca + 0.7% Salt) was supplied to all cows in the experiment. Experimental diets were formulated based on the nutrient requirement of a 400 kg cow that produce 10L of milk daily (NRC 2001): 14 kg/d TDMI, 114 MJ/d ME and 1630 g/d CP.

Table 1. Amount of ingredients (kg DM) in each Treatment

Ingredient	T1	T2	T3	T4
Natural Pasture Hay (NPH)	*Ad libitum*	*Ad libitum*	*Ad libitum*	*Ad libitum*
Concentrate mix (Con)	8	4	4	4
Brewery Grain (BG)	-	4	2	-
Desmodium hay (DH)	-	-	3	6
Limes stone	0.18	0.18	0.18	0.18
Salt (NaCL)	0.1	0.1	0.1	0.1

NB: Composition of Concentrate mix (Con) = 2wheat bran: 1Nug seed cake ratio
T1= NPH+100%Con; T2 =NPH+50%Con+50%BG; T3=NPH+50%Con +25% BG +25% DH; T4 = NPH+50%Con +50%DH

Feed intake - The daily feed intake, individual animals was calculated, by subtracting the total refusal collected from the total feed offered and dividing the value for number of feeding days, as:

$$\text{Feed intake (g)} = \frac{\text{(Amount of feed offered (g) – Amount of feed refused (g))}}{\text{Number of feeding days}}$$

Live weight and feed conversion efficiency (FCE) - Cow's body weight changes and body condition score were measured and recorded at the end of each period. The average of two consecutive daily weights was measured using heart girth measure, soon after milking and before feeding the experimental diets in the morning and afternoon, to calculate the daily live weights gain of the cows. Feed conversion efficiency (FCE) was calculated by dividing FCM (kg /cow / day) by daily total DM intake.

Milk yield measurements and milk sample collection - Milk yield was individually recorded daily, at each milking, throughout the study period. Milk samples was collected at both milking, during the last seven days of each period and pooled. The yield of 4% fat corrected milk (FCM) was calculated using the equation (Walker *et al.*, 2001):

$$\text{FCM (kg /cow / day)} = \text{milk yield (kg / cow / day)} \times [0.4 + 0.015 \times \text{fat content (g/kg milk)}]$$

Sub-samples of composite milk samples taken from each cow during collection period was analyzed for fat, protein, lactose and solids-non-fat (SNF) content by a Milkoscan Tester (LactoStar® Item No.3510; Funke Gerber; Berlin, Germany), using the methods described by AOAC (1990). Milk fat separation was carried using the rapid method proposed by Feng *et al.* (2004). Thirty milliliters of refrigerated raw milk sample was tempered at 20°C for 20 min, and centrifuged at 12,000 × rpm for 30 min at 4°C. The fat layer was removed, transferred to microtubes, and left at room temperature for approximately 30 min before being micro-centrifuged at 13,000 × rpm for 20 min at room temperature. After the second centrifugation, separated lipids was stored in amber vials, and frozen at

−20°C until used for milk fatty acids (FA) analysis. Milk FA was identified by preparing FA methyl esters according to Pariza *et al.* (2001), and measured using a gas chromatograph (Varian CP 900, Varian Inc. Palo Alto, CA, USA) based on the procedure used by Martin *et al.* (2012). Fatty acids were identified based on the similarity of retention times with the GC reference standards (Nu-chek Prep, Inc., Elysian, MN). Accordingly, 40 esterified fat samples were analyzed for fatty acid profile at Chemistry Laboratory of Addis Ababa University, Ethiopia.

Digestibility - During the last week of the study, a digestibility trial was conducted using the acid insoluble ash as an indigestible internal marker. The digestibility trial period comprised of preliminary 7-days of adaptation dedicated to collection of faeces and a 5-days of actual faecal collection periods. Fecal grab samples was taken twice daily between morning and evening feedings of the faecal collection periods. Individual cows grab fecal samples was dried, composited over time for each animal and chemically analyzed for Ash, CP, ADF and NDF. The digestibility of a given nutrient will be determined by:

$$\text{Nutrient digestibility, \%} = 100 - 100 \times \left(\frac{\text{\% marker in feed} \times \text{\% nutrient in feces}}{\text{\% marker in feces} \times \text{\% nutrient in feed}}\right)$$

Blood sample collection and analysis - Blood samples was collected from the jugular veins in air-tight vacutoner tubes using dehydrated EDTA from individual calves prior to feeding and frozen for blood biochemical analysis. The hematological parameters were determined for: Total protein, Albumin (ALB), Creatinin, blood urea nitrogen (BUN), glucose, and Tri-acyl glycerol (TAG).

Chemical analysis of experimental feed ingredients - Sub-sample of feed offered, refusals and faeces samples that were taken during the course of study for chemical analysis was dried at 65°C for 48 h in a forced air oven in the Animal Nutrition Laboratory of Hawassa University. All the dried samples was ground to pass through a 1-mm screen using a cross-beater hammer mill (Thomas-Wiley, Philadelphia, PA, USA), and kept in screw-capped plastic bottles until analysis. Then the samples were analyzed for DM, OM, CP and ash content according to AOAC (1990) procedures. NDF was determined according to Van Soest et al. (1991) using an ANKOM^{200} fiber analyzer and ANKOM F57 filter bags (ANKOM Technology Corp., Fairport, NY, USA). ADF and ADL content of samples was analyzed sequentially according to the procedure of Van Soest and Robertson (1985).

Statistical analysis - Data were analyzed using the MIXED model procedure of SAS 6.12 (Proc Mixed) for a Youdin square design to test the effects of treatment, period and block. LSD (least significance difference) tests were used at 5% probability to compare least squares means. Data was considered to differ statistically at $P < 0.05$. The data was analyzed using the model:

$$Yijkl = \mu + Si + Pj + Vk(i) + Tl + PTjl + Eijkl,$$

Where Yijkl = dependent variable; μ = overall mean; S_i =effect of square i; P_j=effect of period j; Vk(i) = effect of cow k (within square i); T_l =effect of treatment l; PT_{jl} = interaction between period j and treatment l; and Eijkl = residual error. All terms were considered fixed except, Vk (i) and Eijkl, which were considered random.

Results

Chemical composition

The chemical composition of ingredients and treatment diets used in the experiment is presented in Table 2. All the experimental ingredients had comparable DM content, except brewery grain. Brewery grain had the lowest DM content (28.5 %). The nuge seed cake (NSC) had greater CP content (34.5%), followed by brewery grain (26.8%), while native grass hay had the lowest CP (5.8%) content. On other hand native grass hay had a higher NDF and ADF content, while wheat bran had the lowest. The nuge seed cake (NSC) and desmodium hay had relatively higher lignin content while wheat bran had the lowest lignin content.

Table 2. Chemical composition of ingredients and treatment diets used in the experiment

Ingredients	DM (%)	Chemical composition on DM basis (%)				
		OM (%)	CP (%)	NDF (%)	ADF (%)	Lignin (%)
Wheat Bran(WB)	87.4	95.2	18.0	38.1	16.0	3.08
Nuge seed Cake (NSC)	91.3	89.1	34.5	43.5	28.6	10.9
Concentrate mix (Con)	88.9	93.6	23.4	39.6	19.1	5.92
Desmodium hay (DH)	89.4	91.3	15.8	58.2	33.2	9.65
Brewery Grain (BG)	28.5	94.8	26.8	63.7	22.9	7.89
Native Grass Hay (NGH)	90.2	90.4	5.8	72.9	42.3	7.52
Treatments	Calculated chemical composition of the tested diets					
T1	89.4	92.4	16.8	52.1	27.8	6.52
T2	73.6	92.6	17.2	59.3	29.4	7.08
T3	81.9	92.1	15.8	58.6	30.9	7.45
T4	89.5	91.7	14.9	57.9	32.3	7.78

Concentrate mix =2:1 ratio of WB and NSC, T1= NPH+100%Con; T2 =NPH+50%Con+50%BG; T3=NPH+50%Con +25% BG +25% DH; T4 = NPH+50%Con +50%DH

The treatment (T) diets used in the experiment had comparable DM content, except for T2 (50%C+50%BG) diets. Treatment 2 had relatively lower DM content. Relatively, all treatment diets had approximate OM and lignin content. While the amount of CP, NDF and ADF was slightly differ among treatment diets.

Feed intake

The mean feed intake of dairy cows fed a basal diet of native grass hay supplemented with different levels of concentrates mix, desmodium hay and brewery grain is presented in Table 3. Cows fed 50% Con+25% BG+25% DH diet had a higher total DM and OM intake ($P<0.05$) than those cows fed 50% Con+50% BG diet. While cows fed 100% Con and 50% Con+50% DH diets had an intermediate DM and OM intake. Similarly, the greatest supplement DM intake was for cows fed 50% Con+25% BG+25% DH diet, while the lowest was for cows fed 50% Con+50% BG diet. However, there was no variation ($P>0.05$) in supplement DMI between cows fed 50% Con+25% BG+25%DH diet and 100% Con diet, and also between cows fed 100% Con and 50% Con +50%DH diet Conversely, there was no variation in basal DM intake as well as in total DM intake as percent of body weight (% BW) among cows fed different diets.

Table 3. DM and nutrient intake (DM base) of crossbred dairy cows fed basal native grass hay supplemented with different levels of concentrates mix, desmodium hay and brewery grain

Variables	T1	T2	T3	T4	SEM	P
Dry matter intake						
Basal feed	4.66	4.82	4.81	4.78	.083	NS
Supplement	7.22ab	6.68c	7.49a	7.12b	.118	***
Total	11.9ab	11.5b	12.2a	11.9ab	.164	**
Total (% BW)	2.14	2.04	2.19	2.17	.048	NS
Organic matter	11.0[ab]	10.7[b]	11.3[a]	10.9[ab]	0.15	**
Crude protein	1.97[a]	1.94[ab]	1.88[b]	1.57[c]	0.03	***
Neutral detergent fiber	6.29[c]	6.78[b]	7.17[a]	6.87[ab]	0.10	***
Acid detergent fiber	3.37[b]	3.40[b]	3.78[a]	3.76[a]	0.54	***
MEI (MJ / day)	116.9[a]	113.5[a]	114.1[a]	104.6[b]	0.20	**

[a - d] Means within rows with different superscript are different at *P<0.05; **P<0.01; ***P<0.001, NS: No Significance Difference SEM: Standard error of mean. Metabolizable energy (MJ/kg DM) = 0.0157 × DOMD (g/kg DM) (AFRC, 1993). T1= NPH+100%Con; T2 =NPH+50%Con+50%BG; T3=NPH+50%Con +25% BG +25% DH; T4 = NPH+50%Con +50%DH

Relatively, cows fed 100% Con diets had comparable (P>0.05) CP intake to cows fed 50% Con+50% BG diets but had higher CP intake than (P<0.05) those fed 50% Con+25% BG+25% DH diet and 50% Con+50% DH diet. While the CP intake of cows fed 50% Con + 50% BG diets was similar (P>0.05) to cows fed 50% Con+25% BG+25% DH diets, but higher than (P<0.05) those fed 50% Con+50% DH diets. In contrast, the NDF intake of cows fed 50% Con + 25% BG+25% DH diets was similar (P>0.05) to cows fed 50% Con+50% DH diets, but higher than (P<0.05) cows fed 100% Con and 50% Con+50% BG diets. Cows fed 50% Con+50% DH diets had higher NDF intake than (P<0.05) those fed 100% Con diets.

The ME (MJ/Kg DM) content of cows fed 100% Con diets and those fed 50% Con+50% BG was higher than (P<0.05) the ME content of cows fed 50% Con+ 25% BG+25% DH and 50% Con+50% DH diets. While cows fed 50% Con+50% DH had the least ME content. But there was no significant difference (P>0.05) in ME intake (ME/DMI) among cows fed distinct diets, except for cows fed 50% Con+50% DH diet. Cows fed 50% Con+50% DH had the lowest (P<0.05) ME intake.

Milk Yield and Milk Composition

The milk yield and its composition for cows fed different treatment diets presented in table 4. There was no variation (P>0.05) in daily milk yield (kg/d) and in 4% fat corrected milk (FCM) yield (kg/d) among cows fed different diets. However, except for milk fat (%), the percentage composition (%) of milk for cows received different treatment diets was different (P< 0.05). Cows fed 50% Con+50% BG diets had higher (P< 0.05) milk protein content than all cows fed other treatment diets. The milk lactose (%) and solid non-fat (SNF) content of cows fed 50% Con+50% BG diets was comparable to cows fed 50% Con+25% BG+25% DH diets, but higher than to cows fed 100% Con and 50% Con+50% DH diets. Cows fed 50% Con+25% BG+25% DH diets had greater milk lactose and SNF

(%) content than those cows received 50% Con+50% DH diets. But there was no difference in milk lactose and SNF (%) content between cows fed 50% Con+25% BG+25% DH diet and 50% Con+50% BG diet, and also between 100% Con diet and 50% Con+50% DH diet.

Table 4. Milk yield and milk composition of crossbred dairy cows fed basal native grass hay supplemented with different levels of concentrates, desmodium hay and brewery grain.

Variables	T1	T2	T3	T4	SEM	P
Milk yield (Kg/day)	7.91	8.12	7.73	7.15	0.56	NS
4% Fat corrected milk	8.53	9.03	8.35	7.83	.611	NS
Milk composition (%)						
Milk fat	4.51	4.66	4.49	4.64	0.12	NS
Milk protein	2.77^{b}	2.91^{a}	2.81^{b}	2.75^{b}	0.03	*
Milk lactose	4.18^{b}	4.28^{a}	4.22^{ab}	4.13^{b}	0.03	**
Milk SNF	7.56^{bc}	7.75^{a}	7.64^{ab}	7.46^{c}	0.05	**

$^{a-d}$ Means within rows with different superscript are significantly different (P<0.05)
*SEM: Standard error of mean, *P<0.05; **P<0.01; ***P<0.001, NS: No Significance Difference*
NPH+100% Con; T2 =NPH+50% Con+50% BG; T3=NPH+50% Con +25% BG +25% DH; T4 = NPH+50% Con +50% DH

Body weight, Body Condition Score and Feed Conversion Efficiency

The body weight (BW) changes, body condition score (BCS) and feed conversion efficiency (FCE) of experimental cows is presented in table 5. There was no significant variation (P> 0.05) in BW changes (initial BW, final BW, and BW gain), BCS and FCE among experimental cows.

Table 5. Body weight changes, BCS and FCE of crossbred dairy cows fed basal native grass hay supplemented with different levels of concentrates mix, desmodium hay and brewery grain

Variables	Treatments (n=5)				SEM	*P*
	T1	T2	T3	T4		
Initial BW (kg)	558	565	561	546	9.29	NS
Final BW (kg)	560	567	563	548	9.35	NS
Weight gain (kg)	2.28	2.09	2.65	2.30	0.32	NS
BCS	3.57	3.48	3.57	3.47	0.11	NS
FCM /DMI	0.78	0.85	0.74	0.72	0.06	NS

$^{a-d}$ Means within rows with different superscript are significantly different (P<0.05)
SEM: Standard error of mean, NS: No Significance Difference, BCS: Body condition score based on a five-point scale (1 = very thin, 5 = obese).

Digestibility

The DM and nutrient digestibility of crossbred dairy is presented in table 6. The DM, OM and CP digestibility of cows fed 100% Con and 50% Con +50%BG diets was comparable (P> 0.05), but higher (P< 0.05) than to those cows fed 50% Con +25%BG+25%DH and 50% Con +50%DH diets. While cow received 50% Con +50%DH diets had the lowest (P< 0.05) DM, OM and CP digestibility. The highest (P< 0.05) NDF digestibility was for cows fed 50% Con +50%BG diet, and the lowest was for cows fed 50% Con +50%DH diet. Cows fed 100% Con and 50% Con +25%BG+25%DH diets had an intermediate NDF digestibility.

Table 6. The nutrient digestibility (%) of crossbred dairy cows fed basal native grass hay supplemented with different levels of concentrates, Desmodium hay and brewery grain

Digestibility	Treatments (n=5)				SEM	*P*
	T1	T2	T3	T4		
Dry matter	64.5^{a}	64.3^{a}	60.8^{b}	57.7^{c}	.760	***
Organic matter	67.7^{a}	67.6^{a}	64.3^{b}	61.1^{c}	.687	***
Crude protein	79.1^{a}	81.2^{a}	76.0^{b}	64.0^{c}	1.01	***
Neutral detergent fiber	56.9^{b}	61.2^{a}	57.5^{b}	53.2^{c}	1.13	***
Acid detergent fiber	41.5^{b}	45.0^{a}	37.0^{c}	31.0^{d}	1.19	***

*$^{a-d}$ Means within rows with different superscript are significantly different (P<0.05) , ***P<0.001*
SEM: Standard error of mean, NS: No Significance Difference, T1= NGH+100%Con; T2 =NGH+50%Con+50%BG; T3=NGH+50%Con+25%BG+25%DH; T4=NGH+50%Con+50%DH

Milk Fatty Acid Profile

The milk fatty acid (MFA) FA profile of the experimental cows is presented in Table 7. The result has shown that there was no variation (P>0.05) among different treatment groups in palmitic (C16:0), palmitoleic (C16:1), C17:1, stearic (C18:0) and Oleic (C18:1) concentrations. But difference in milk FA concentration was observed for capric (C10:0), lauric (C12:0), tridecanoic (C13:0), myristic (C14:0), pentadecamic (C15:0), heptadecanoic (C17:0), linoleic (C18:2) and conjugated linoleic acid (C18:2, cis9t11) content among cows fed unlike diets.

Cows fed T1 (100% Con) and T4 (50% Con+50% DH) diets had a higher (P<0.05) capric acid content than cows fed T2 (50% Con+50% BG) diet. While cow fed T3 (50% Con+25% BG+25% DH) diets had an intermediate C10:0 content. Similarly, the milk fat from cows fed 100% Con had greater (P<0.05) lauric acid content than cows fed 50% Con+50% BG diet.

Relatively cows fed 100% Con had a higher conjugated linoleic acid (C18:2, c9t11) content than those cows fed 50% Con+25% BG+25% DH and 50% Con+50% DH diet, while cows fed 50% Con+50% BG dies had an intermediate C18:2, c9t11 content. The FA types that account the larger portion of milk fat for cows in the study were oliec (27.7g/100g FA), palmitic (24.0g/100g FA) and stearic acid (19.5g/100g FA) respectively.

Table 7. Milk fatty acid (FA) profile (g/100g fat) of crossbred dairy cows fed basal diets supplemented with different levels of concentrates, desmodium hay and brewery grain

Type of FAs	Treatments (n=5)				SEM	P
	T1	T2	T3	T4		
C10:0	1.09[a]	.790[b]	.927[ab]	1.05[a]	.066	**
C12:0	1.21[a]	.960[b]	.998[ab]	1.14[ab]	.079	*
C13:0	.107[b]	.128[b]	.109[b]	.161[a]	.007	**
C14:0	7.35[a]	6.25[b]	6.15[b]	7.69[a]	.450	*
C16:0	23.8	25.9	23.6	25.5	1.25	NS
C18:0	21.4	20.8	18.0	17.9	1.32	NS
C18:1	28.6	28.6	24.7	28.8	1.54	NS
C18:2	6.87[a]	6.52[ab]	6.08[bc]	5.48[c]	0.35	*
C18:2, cis9t11	.639[a]	.476[ab]	.431[b]	.376[b]	.062	*

*[a - d] Means within rows with different superscript are significantly different (P<0.05), SEM: Standard error of mean, *P<0.05; **P<0.01; NS: No Significance Difference; SFA= Saturated fatty acids: Sum of C10:0, C12:0, C14:0, C15:0, C16:0, C17:0, and C18:0; USFA = Unsaturated fatty acids: Sum of C17:1, C16:1 C18:1, C18:2, and CLA; MUFA= monounsaturated; PUFA= polyunsaturated fatty acids; tFA= Trans fatty acids; T1= NGH+100% Con; T2 =NGH+50% Con+50% BG; T3=NGH+50% Con + 25% BG +25% DH; T4 = NGH + 50% Con+50% DH*

Blood Biochemical Composition

Blood biochemical analysis result is presented in Table 8. There was no significant variation (P>0.05) in blood biochemical's except for blood urea and creatinin level. The blood urea level of cows supplemented with 100% Con and 50% Con +50% BG was higher (P<0.05) than the blood urea level of cows supplemented with 50% DH hay. In contrast the creatinin level for cows received 100% DH hay was higher (P<0.05) than the creatinin level of those received 100% Con and 50% Con +25% BG +25% DH hay.

Table 8. The Blood biochemical composition of crossbred dairy cows fed basal native grass hay supplemented with different levels of concentrates mix, brewery grain and desmodium hay

Variable	Treatment (n=5)				SEM	*P*
	T1	T2	T3	T4		
Albumin (g/dl)	1.19	1.21	1.14	1.23	.036	NS
Glucose (mg/dl)	46.2	47.5	46.5	46.2	1.29	NS
Urea(mg/dl)	44.3[a]	43.5[a]	41.3[ab]	38.5[b]	1.60	*
Creatinin (mg/dl)	0.98[b]	1.05[ab]	1.00[b]	1.12[a]	.041	*
Total Protein(g/dl)	8.49	8.70	8.98	8.33	.302	NS
Tri acyl-glycerol (mg/dl)	23.3	25.4	25.6	24.8	1.09	NS
Cholesterol (mg/dl)	135.6	144.7	138.2	143.8	8.15	NS

[a - d] Means within rows with different superscript are significantly different (P<0.05)
*SEM: Standard error of mean, *P<0.05; NS: No Significance Difference, T1= NGH+100% Con; T2 =NGH+50% Con+50% BG; T3=NGH+50% Con + 25% BG +25% DH; T4 = NGH + 50% Con+50% DH*

Discussion

Chemical composition

The chemical composition of different ingredients used in the experiment (Table 2) has shown the higher NDF (72.9 %) and ADF (42.3 %) contents of the native grass hay could have negative effect on intake and digestibility because feeds with high NDF content reduce intake due to bulkiness and hence rumen fill effect (Van Soest, 1994), while ADF content could reduce the availability of nutrients since there is a negative relationship between ADF and digestibility of feeds (McDonald *et al*., 2002). Moreover, the grass hay used in this experiment had low CP (58 g/kg DM) content (Table 2), which is below the minimum microbial requirement (70 g CP/ kg DM) in feeds assumed to support acceptable ruminal microbial activity and the maintenance requirement of the host animal (McDonald *et al.,* 2010). This indicates that supplementation is required in order to improve the nutritive values of such poor quality feed (Adugna and Sundstøl, 2000; Ajebu *et al.*, 2013).

Among treatment diets, T2 (50% Con +50%BG) and T1 (100% Con) had the lowest DM (73.6) and NDF (52.1) content respectively. The lower DM content observed in T2 diets was due to the lower DM content of brewery grain that was included as supplement. The lower DM (28.5 %) content of the brewery grain hay could have negative impact on intake due to the rumen fills effect. As a result cow fed T2 diets had relatively lower DM intake. While, the lower NDF contents for T1 diets was due to the lower NDF content of wheat bran that accounts the larger supplement portion in treatment one. Hence, cows fed T1 diets had relatively lower NDF intake. Rumen fermentation studies have shown that the differences in cell wall content and structure result in lower rumen fill and higher rumen passage rate, thereby explaining higher intake capacity (Dewhurst *et al.* 2003).

Nutrient intake

Results of the study (Table 3) implied that the higher ($P<0.05$) total DM and OM intake for cows fed 50% Con+25% BG+25% DH diet as compared with cows fed 50% Con+50% BG diets could be due to the higher DM content and the need the cows to satisfy their energy requirement. Because the ME content of cows fed 50% Con+25% BG+25% DH diets was lower. Conversely, the lower total DM intake observed in cows fed 50% Con+50% BG diet could be attributed to the lower DM content of brewery grain that was offered as supplement. This was evidenced by the lower supplement DM intake of cows fed 50% Con +50%BG diets. It was reported that feeding large amounts of wet brewer's grains could depress dry matter intake, because of the high moisture (70 to 75%) content of BSG (Tang *et al.,* 2009). Studies have also evidenced that a significant depression in dry matter intake when cows fed with wet BG replacing 30% and above DM content of ration, because of the combined filling effects of BG (Miyazawa *et al*., 2007).

In contrast, the lower NDF intake observed for cows fed 100% Con diets could be associated with the low NDF content of wheat bran that accounts the larger supplement portion in treatment one. The lower NDF content in 100% Con diets could be responsible for the increased total DM and OM intake observed for cows fed 100% Con diets. It is known that the fiber fraction represents the main physical parameter in the regulation of feed intake because less fibrous diets occupy less space in the reticulo-rumen, promoting less filling and a shorter intake time (José and da Silva, 2017). The higher ($P<0.05$) NDF intake observed for cows fed 50% Con +25%BG+25%DH diet and 50% Con +50%DH diet could be attribute partly to higher NDF content of the BG and DH hay and partly to the lower energy

(ME content) available in T3 (50% Con+25%BG+25%DH) and T4 (50%Con+50%DH) diets. Hence to satisfy their energy requirement cows allocated in T3 and T4 should have consumed more DM or OM.

The result of this study has shown that cows received either desmodium hay or brewery grain had similar basal diet intake (P>0.05) as those cows received control diets (100% concentrate supplement). This indicated that inclusion of desmodium hay or brewery grain as supplement had no negative effect on basal diet intake. Therefore, the variation in total DM and OM intake occurred because of the increased intake of supplement. However, the literature reports on feed intake are inconsistent with respect to the effects of forage and browse legume supplementation to poor quality roughages (Adugna and Sundstøl, 2000).

In agreement with this study, Bird *et al.* (1994) and Bonsi *et al.,* (1994) showed that forage legume supplementation increased total DM intake without any significant effect on intake of the basal, cereal straw, diet. Other studies showed a significant decrease in basal DM intake with increasing level of desmodium supplementation (Adugna and Sundstøl, 2000). Mosi and Butterworth (1985) and Kaitho *et al.* (1998) observed an increase in total DM intake and a decrease in basal tef straw intake with increasing level of forage legume supplementation. The variation could partly be attributed to the quality of the forage supplements and the quality of the basal roughages. Therefore, the effect of forage legume supplements on basal roughage intake is a function of their solubility, rate of degradation and rate of passage from the rumen (Adugna and Sundstøl, 2000).

The higher total CP intake observed (Table 2) for cows fed 100% Con and 50% Con+50% BG diets as compared to those cows fed 50% Con+25% BG+25% DH diet and 50% Con+50% DH diets could be due to the higher CP content and better CP digestibility of the supplemented feeds. It was indicated that the supply of rumen N increase the digestibility of the fiber, by increasing the supply of both degradable and un-degradable protein to the rumen microbes (Osuji *et al*., 1995).

Milk yield and milk composition

Analysis of data has shown that even if the intake and digestibility of feed was varied among treatment group; the daily milk yield and 4% FCM yield (kg/d) did not differ among treatments (Table 4) in the study. In accordance with the result, different studies indicated that the supply and digestion of nutrients in dairy cows may be improved through an increase in the CP concentration of the supplement or the amount of supplement offered; however, the effects on the yield of milk and milk components may be small (Jones-Endsley, *et al.,* 1997).

Despite the DM intake was reduced for cows fed 50% con +50% BG diets in the study (Table 4), the milk yield of cows fed 50% BG diets was similar with cows fed other treatment diets; indicating a higher nutrient utilization (digestibility) and a higher metabolic energy value of 50% BG diets. Report implied that a higher feed digestibility and a higher metabolic energy value of a diet contributes for better milk yield despite lower DMI (Steinshamn, 2010). Several studies reported that there was no significant difference in milk production of dairy cows fed with diets containing up to 30% wet brewer's grain of total DM fed (Dhiman *et al*., 2003 and Miyazawa *et al.*, 2007). Chioua *et al.* (1998) observed significant reduction in milk production of dairy cows fed with diets containing wet brewer's grain.

Results reveal that the milk composition for cows received unlike treatment diets was different (P<

0.05), except for milk fat (Table 4). Milk fat percentage was not altered by dietary treatment, and the percentages were within normal ranges. The variation in milk protein, lactose and SNF percentages observed among cows fed different treatment diets could be attributed partly to the nature of supplemental diets. Replacing 30% of DM ration with wet BG in the study showed significant ($P<$ 0.05) changes in milk composition, except for milk fat (%).

The higher percentage ($P<$ 0.05) milk protein for cows fed 50% BG diets (50% con +50% BG) as compared to cows fed other diets could be associated with the higher N utilization (CP digestibility) of 50% BG diets. Likewise the greater percentage of milk lactose and SNF observed for cows fed 50% Con+50% BG diet as compared to those fed 100% Con and 50% Con+50% DH diets, or for cows fed 50% Con+25% BG+25% DH diet as compared to cows fed 50% Con+50% DH diet could be due to the higher metabolic energy (ME) value of BG in 50% Con+50% BG and 50% Con+25% BG+25% DH diets. Miyazawa, *et al*. (2007) suggested that the increase in percentage of milk lactose and SNF might be partly due to the slightly higher ruminal acetic acid in cows fed a BG diet. While the similarity in milk lactose and SNF content between cows fed 50% Con+25% BG+25% DH and 100% Con diets could be attributed to comparable ME intake of these diets. It is noticeable from results shown in table (4) that a higher milk protein observed in cows that consumed diets containing 50% brewer's grains as compared to cows received 50% DH, and this was possibly due to increasing levels of undegradable protein (UDP) for diets contained brewers grains. It was reported that brewer's grains have a larger un-degradable fraction of protein, and thus 50 to 60 % of the crude protein is by-passes the rumen without degradation (Tang *et al.,* 2009). Because, milk yield and its protein affected by the amount of CP flow into the small intestine (Hof *et al.*, 1994).

In addition, BG is high in digestible fiber, which provides a positive opportunity by reducing the digestion speed of starch (Tang *et al.,* 2009). Perhaps the synchronization between ruminal degradability of non structural carbohydrates (NSC) and rumen degradable protein (RDP), in cows received brewer's grains (50% Con+50% BG diets) could maximize microbial protein synthesis which supports milk production (El-Shabrawy, *et al.,* 2010).

Body weight change and feed conversion efficiency

The similarity in body weight gain and gross feed efficiencies (4 % FCM yield per kg DMI) among cows fed different treatments (Table 5) reflects that the supplements had comparable potential in effectively supplying the required nutrients for the cows to maintain body weight, without affecting milk yield. In this study inclusion of either BG or desmodium up to 350 g/kg DM in a diet did not affect both MY and BW gain of dairy cows. Compatibly, Corriher, *et al* (2014) suggests that use of legumes at modest level may be a suitable supplement for supplying adequate protein and digestible grain source that supports gains**.**

A meta-analysis compared diets without legumes with diets with medium (101–400 g/kg DM) and high (401–800 g/kg DM) legume inclusion shown that there were no differences in DMI, MY and ADG between the medium inclusion and without legumes, but all these parameters and FCE decreased with high inclusion of legumes (Castro-Montoya and Dickhoefer, 2017). In other study, Aliyu, *et al.,* (2011) reported that milk production can be increased when dairy cows are fed about 4.5 to 5.5 kg of BG blended with other protein supplements that contain more lysine**.**

The absence of BW loss (the positive BW gain) in the present study indicated that the level of N in all treatments diets suffices the minimum requirement for the daily gain obtained. The results are in accordance with the observation of Van Soest (1994) who reported that weight gain in ruminants is not compromised if the N content of the diet is more than 12.8 g/kg DM. On other hand, the uniform milk yield observed among cows fed different treatment diets indicated that the metabolizable energy (ME) intake was sufficient to produce reasonable levels of milk. Milk synthesis in dairy cows was more limited by the supply of ME than by CP (Jones-Endsley, *et al.*, 1997). The efficiencies of milk yield (milk yield/DMI) in the study were not significantly ($P > 0.05$) varied among cows received different treatment diets, indicating that either BG or desmodium had the potential to replace concentrate mix as high as 50% for production of optimum milk yield without affecting productivity (BW gain) of cows.

Nutrient digestibility

The result of the current study (Table 6) showed a significant difference in DM, OM, CP and NDF digestibility among cows fed different treatments. The higher ($P<0.05$) DM and OM digestibility of T1 (100% Con) and T2 (50% Con +50% BG) diets as compared to T4 (50% Con +50% DH) diets could be attributed to the higher CP intake of cows fed T1 and T2 diets. Because feed with higher CP content could promote higher microbial populations and growth, thereby facilitate rumen fermentation and better digestibility (McDonald *et al.*, 2010). According to Khan *et al.*, (2003) high CP intake usually increases the rate of cell-wall carbohydrates digestion of forages containing less than 80 g/kg DM CP (Van Soest, 1994).

The higher NDF digestibility observed for cows supplemented with 50% BG (T2) as compared to those cows supplemented with 50% DH (T4) could be attributed to a higher content of easily rumen degradable NDF in brewery grain (BG). The highly digestible fiber in BG allows it to serve as a partial replacement for forages and concentrates in diets for dairy and beef cattle (Levic *et al.*, 2006). Several explanations exist for the observed difference in fiber digestibility between the two treatments (T2 and T4) in the current study. These include inherent differences in the rate and potential degradability of the different fiber sources used in the two diets and feed associative effects, particularly the impact of changes in rumen pH and microbial populations with changes in concentrate to forage ratios (Klinger, *et al.*, 2007).

Even though the DM intake was decreased, the comparable digestibility and milk yield value observed for cows fed T2 diet (50% Con +50% BG) as compared to those cows fed only concentrate mix supplement (100% Con) demonstrates a quality, not only of proteins, but also a higher digestibility of their carbohydrates, indicating the capacity of reducing the amount of concentrated in diets with substitution of BG up to 50% levels. On other hand, there has been a decrease in the digestibility with increase of desmodium hay (Table 6). The lower digestibility observed in cows supplemented with T4 (50% DH) diet could be due to the lower available nutrients (such as CP and ME) and the greater total ADF intake of cows supplemented with 50% desmodium hay, which negatively correlated with digestibility of nutrients (McDonald *et al.*, 2010). Though the digestibility value decreased with increase of desmodium hay, milk yield of cows fed both T3 diets (25% BG+25% DH) and T4 (50% DH) was still comparable to cows fed either T1 (100% Con) and T2 (50% Con +50% BG) diets. This indicates the capacity of replacing the amount of concentrates in feed with desmodium hay up to 50% levels. However, the choice among the diets could depend on the availability and economic feasibility of the feed.

Milk Fatty Acid Profile

The milk fatty acid (FA) profile analysis result (Table 7) revealed that similarity in concentration of C16:0, C16:1, C17:1, C18:0 and C18:1 among cows received different diets was probably because of the comparable dietary supply and subsequent de novo synthesis of these FA in the mammary gland. On other hand, the higher C10:0 content observed in milk fat of cows fed T1 (100% Con) and T4 (50% Con+50% DH) diets as compared with cows fed T2 (50% Con + 50% BG) diet could be attributed to the higher nutrient supplied by 100% Con and 50% Con+50% DH diets, which could favored the de novo production of more short chain (C10:0) FA. The higher C12:0 content observed in milk fat of cows fed 100% Con diet as compared to cows fed 50% Con + 50% BG diet could be similarly attributed to the nutrient supplied by 100% Con that could favored the de novo production of more C12:0 fatty acid.

The higher C14:0 concentrations observed in milk fat of cows fed 100% Con (control diet) and 50% DH diets as compared to those fed 50% BG and 25% BG+25% DH diets could be similarly associated with the nutrient supplied by 100% Con and 50% DH diets, which could favored the rumen production of more substrates (acetic, propionic, and butyric acids) for endogenous mammary synthesis of medium-chain (C14:0) FA.

Result (Table 7) indicated that the proportion of saturated FA increased ($P<0.05$) when cows were given diets consist of desmodium hay than those given diets consist of brewery grain. In consistent with the finding it has been reported that cows fed with hay-based diets can increase some FA (10:0, 12:0, 14:0 and 16:0) of milk fat (Roy *et al.,* 2006). On the other hand, the proportion of unsaturated FA were decreased for cows received diets based on desmodium hay than those received diets based on brewery grain, except oleic fatty acid (C18:1) which showed a uniform ($P>0.05$) increase with both brewery grain and desmodium hay supplementation. Jenkins and McGuire (2006) documented that grain feeding reduces the proportions of milk fatty acids having 6 to 16 carbons, and increases the proportion of 18-carbon unsaturated fatty acids.

The higher linoleic acid (C18:2) and rumenic acid (C18:2 *c*9t11) concentrations observed in milk fat of cows fed 100% Con as compared to those fed 50% Con+25% BG+25% DH and 50% Con+50% DH diets could be attributed to the higher linoleic acid present in 100% Con diets and as a consequence a higher rumenic acid produced. Study showed that cereal grains (i.e. corn, barley, wheat, other) and oilseeds (i.e. soybean, sunflower, canola, other) contain a high proportion of C18:2 (Schroeder *et al.,* 2004). It has been reported that the proportion of CLA increased with high linoleic acid diets (AbuGhazaleh *et al*., 2004). Conversely, the lower C18:2 and C18:2, c9t11 content observed in milk fat of cows fed 25% BG+25% DH and 50% DH diets as compared to cows fed 100% Con diets could be associated with the low linoliec (C18:2) acid present in these diets and as a consequence lower production of C18:2, c9t11 isomer in the mammary gland.

The lower C18:2 FA in milk fat of cows fed 50% Con+50% DH reported in our study could be attributed to the loss of precursor FA during the hay–making process. In agreement with findings report indicated that forage preservation, either by drying or ensiling, reduce the concentration of total and polyunsaturated FA in forage DM (Dewhurst *et al.,* 2003). Similar report has shown that hay making reduces the total FA by over 50%, with a greater loss of linolenic acid (Doreau and Poncet, 2000). The greater polyunsaturated FA profile of milk from cows fed grain based concentrates (100% Con diets) has been linked to the distinct nature of FA profiles reaching the rumen (Schroeder *et al.,* 2004). Study has shown that feeding diets rich in fermentable carbohydrates (high-concentrate, low-fiber diets) or linoleic acid can increase the vaccenic acid (18:1 *trans*-11) content of milk fat (Shingfield and Griinari, 2007), which is the main precursor of (Griinari *et al*. 2000). Thus an increase in milk conjugated linoleic acid (CLA) is associated with an increase in vaccenic acid (Lock and Shingfield, 2004). In the current study, the higher (P < 0.05) concentration of CLA (18:2 *t*9*c*11) observed in milk fat of cows fed 100% Con diets as compared with those fed 50% Con+25% BG+25% DH and 50% Con+50% DH diets could be due to the greater DMI and isomerization of the oleic acid supplied by 100% Con diets.

Relatively, the higher (P<0.05) proportion of C18:2 milk fatty acid found in cow fed 50% BG than 50% DH, suggest that the presence of a higher linoleic acid content in the BG diet than in the desmodium hay. Concurrently, the proportion (g/100g fat) of CLA (18:2 *t*9*c*11) in the milk fat of cows fed 50% DH and those of 50% BG were 0.38 and 0.48, respectively (Table 4), showing a tendency for them to be increased by the BG diet. Therefore, the higher linoleic acid in 50% BG diet as compared with 50% DH diet may partly contribute to increase CLA (18:2 *t*9*c*11) in the milk fat of the cows fed a BG diet**.** In agreement with the findings, Miyazawa, *et al*. (2007) reported that when compared with cows fed 50% forage and 50% grain, the proportions of C18:1 and C18:2 was significantly increased, while those of C16:0 and C16:1 tended to decrease in cows fed the BG diet. Though, the proportion of C18:1 was not significantly differed in the study, the value 17.9 and 20.8 observed for cows fed 50% DH and 50% BG respectively (Table 7), indicates a tendency for C18:1 to be increased by the BG diet feeding. The same study has also shown that the CLA in the milk fat was higher in cows fed BG than in those fed typical dairy diets containing 50% forage and 50% grain (Miyazawa, *et al*., 2007).

The higher CLA in milk of cows fed a BG diet might be due to an increased supply of digestible fiber from BG (Dhiman *et al*. 2003). While Miyazawa, *et al*. (2007) suggested that the increased proportion of CLA indicated that delta-9 desaturase activity in the mammary gland may be increased by feeding diets containing BG. However, further studies are needed to clarify the mechanisms by which BG feeding influences these changes. The variation in CLA concentration among cows consuming different treatment diets in the study, in general, could be attributed to the positive linear relationship established between CLA and Vaccenic (VA), to the differences in rumen biohydrogenation, and to the mammary Δ9–desaturase activity (Peterson *et al.,* 2002).

Different studies have suggested that consumption of milk containing CLA has been shown to promote various beneficial health-related effects such as: potential anti-carcinogenic and anti-atherogenic effects, anti-obesity, and anti-diabetic effects, and also to reduces risk factors for ischemic heart disease and stroke (Cicero *et al.,* 2012; Imamura *et al.,* 2012). The increase of CLA, as observed in 100% Con and 50% Con+50% BG diets in the current study, therefore, would raise the nutritive and therapeutic value of milk products.

Blood Biochemical Composition

Blood chemistry analysis (Table 8) revealed that only the blood urea and creatinine level was varied among treatment groups. The uniform biochemical blood level observed indicted that the experimental dairy cows did not have mobilize the main form of body energy storage: triacylglycerol, nor were changes in cholesterol levels, which maintains a direct relation with triacylglycerols because they are transported together by lipoproteins (José and Silva 2017). The variation in intake of dairy cows observed in the study has not been difference in blood glucose (Table 8) level. This may have been a result of an increased availability of the substrate due to the consumption of all treatment diets (Ragni *et al.,* 2018).

The data for blood biochemical composition has shown that feeding desmodium leaf hay as a sole supplement (100% DH) lowered (P <0.05) the blood urea concentration as compared with 100% Con and 50% Conon+50% BG diets feeding. The higher (P<0.05) blood urea level in cows fed 100% Con and 50% Conon+50% BG as compared to those fed 100% DH reflect changes in protein metabolism. Study have noted that blood urea concentration depends on factors such as the amount of ingested proteins in the diet, their degradation in the rumen, the dietary composition of ingested amino acids and carbohydrate degradation in the rumen (Thrall *et al.,* 2004). Masoero *et al.* (2005) reported that those more degradable protein fractions cause an increase in blood urea level as a consequence of protein degradation. The higher creatinin level of cows received 100% DH hay as compared to cows received 100% Con and 25% BG +25% DH hay could be attributed to lower CP intake and digestibility of cows fed 100% DH hay which resulted a in host protein degradation, because creatinin is a metabolite that has a proportional relation with body muscle degradation (Chizzotti *et al.,* 2008).

Conclusions

The results of the study have shown that even though the nutrient intake and digestibility was varied, the milk yield was similar among treatment groups, indicating that either brewery grain or desmodium hay can substitute concentrate up to 50% in a diet, without negatively affecting the milk yield, as dry season alternative feed for crossbred dairy cows. Typically, combination 50% brewery grain and 50% concentrate were better in terms of crude protein intake, milk contents of protein, lactose and solids not fat, and linoleic acid (C18:2) content, and thus could be used as dry season alternative feed for crossbred dairy cows. One of the major problems observed with the use of wet BG is without proper storage and addition of preservatives the shelf life of wet BG is considerably questionable.

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Herbage Dry Matter Intake of Fogera-Friesian Crossbred Dairy Cows Using a Wireless Bite Counter Compared with Other Methods: A Case Study

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Abstract

Measurement of intake of individual grazing animals remains one of the fundamental challenges to improving efficiency of livestock production. Information about the individual herbage dry mater intake (HDMI) of grazing dairy cow is important for an efficient use of pasture herbage and to ensure the release of adequate nutrients for maintenance and production. However, practical and reliable methods are not available to measure intake of pasture by individual dairy cow particularly for grazing based production system for developing countries. Thus, this research was initiated to estimating HDMI using the wireless bite counter system for individual dairy cow. A simple, compact bite counter was used to record dairy cow jaw movements to estimate feed intake. For the calibration of the bite counter, the correlation between the number of bites measured by personal observation and the values reported by the bite counter was linear with an R^2 value of 0.74. The utility of the bite counter recordings and other methods (cage system, net energy maintenance equation (Nem), body weight and plate meter biomass) were used for estimating intake from 16 dairy cows of which nine Fogera and seven Holstein Friesian crossbred. For cage system, sixteen individual paddocks were established in the grazing land of Andasa livestock research enter. The experiment was conducted for two consecutive years (2018 and 2019) during the main rainy seasons (June to October) of Ethiopia. The grazing herbage in the paddocks were dominantly comprised of Cynodon plectostachyus, Hyparrhenia rufa, Paspalum notatum, Setaria viridis and Trifolium species. The average HDMI using the bite counter was 4.2 kg DM/day and 7.7 Kg DM/d, for Fogera and Holstein Friesian crossbred dairy cows, respectively. The HDMI could be estimated by applying linear regression to the number of bite counts with R^2 values >0.68. In comparison with the bite counter, the HDMI was higher for other methods (plate meter biomass > body weight > Nem Clipping Biomass > bite counter). In conclusion, the wireless bite counter offer new opportunities for rapid estimation of HDMI followed by the prediction equations of net energy maintenance. Moreover, the bite counter was easy to attach to the cows using the collar and could be used effectively by farmers in the grazing based dairy production system.

Key words: *bite counter, dairy cow, grazing, herbage intake, jaw movement, paddock.*

Introduction

Livestock production is the most widespread agricultural livelihood strategy in Africa along the Blue Nile Basin especially in Ethiopia. Grazing is the main way of feeding ruminants in the tropics (Steinfeld et al., 2006). Most of the livestock production is based on free grazing; however, the intake from free grazing is not known. Feed intake is regulated by three different factors: bite size, bite rate (bites per minute) and total grazing time. Present methods for estimating intake by grazing livestock, lack precision and are often tedious, expensive, and time consuming. So, accurate measurement of feed intake is important to meet nutritional requirements of the animal and optimize production (Greenwood et al., 2017). To estimate dry matter intake (DMI) is very important factor to ensuring the release of adequate nutrients for maintenance and production. Because feed intake is difficult to measure, farmers are often concerned that their stocks are not being appropriately fed (Holmes and Wilson, 1984). Rapid, practical and reliable methods are not available to measure intake of pasture by individual livestock in meaningful numbers over adequate lengths of time for genetic improvement, livestock and pasture management, and/or data generation for prediction and simulation modeling (Greenwood et al. 2014).

Due to their complexity, few studies are carried on to the estimation of voluntary intake of grazing ruminants and actually, it is very difficult to estimate this parameter easily and with a sufficient precision. When it is done, intake is usually measured for one ruminant’s species on one type of pasture. Indeed, even if, according to the definition of Baumont et al. (2000) “intake is the maximum quantity of feed that can be eaten by an animal when this is supplied ad libitum as the sole feed” and, so, seems easy to quantify, its study is more complex. In reality, according to Illius et al. (1996) intake can be considered as a “psychological” phenomenon, involving the integration of many signals, and reflects the flexibility of a biological system evolved to cope with variability in food supply, composition and animal states.

But it is difficult to estimate the pasture intake for the free ranging cattle. For this, wireless sensor networks offer new opportunities for rapid estimation of pasture intake (Umemura et al., 2009 and Smith et al. 2015). The device is composed of a pendulum, a microcontroller, and a transmitter attached to a collar. Sensors and wireless sensor networks offer new opportunities for rapid estimation of pasture intake by larger numbers of livestock under commercial grazing conditions. Technologies exist or are evolving that can generate sensor data aligned with specific behaviours (González et al. 2015 and Smith et al. 2015) that relate to intake of pasture. No universally accepted strategy for estimating animal DMI in grazing systems. (Undi et al. 2008).

The aims of this paper were to measure DMI of grazing dairy cows using the bite counter and other different methods and compare their estimates. Furthermore, the estimates of the herbage dry matter was compared with a calculated DMI based on the energy requirements for lactation and maintenance (NEL, required) of the cows and the net energy content (NEL) of the herbage

Therefore, this study initiated to estimate the grazing pasture intake for individual animal using a wireless bite counter system and compare with other methods. Therefore, this study was initiated with the following objectives:

- To evaluate the herbage quality, nutritive value and biomass of the grazing pasture
- To estimation dry matter intake for individual animal grazing on free grazing pastureland
- To compare the different methods for pasture intake estimation in relation to the bite counter

Material and Method

Study site - The study area is found about 22 km south of Bahir Dar city on the way to Tis Abay (Figure 1); located at 11°29’N latitude and 37°29’E longitude with an elevation of 1730 m above sea level in Amhara Region, Ethiopia (Kebede et al., 2013). The area has dark clay soil, which is seasonally waterlogged and cracked when dry (Sewalem and Banjaw, 1992). The area receives about 1434 mm of rainfall annually. The mean annual temperature varies from a maximum of 29.5oC in March to a minimum of 8.8oC in the wet season. The center has huge grazing land (360 ha) that used for grazing through the years (Figure. 2).

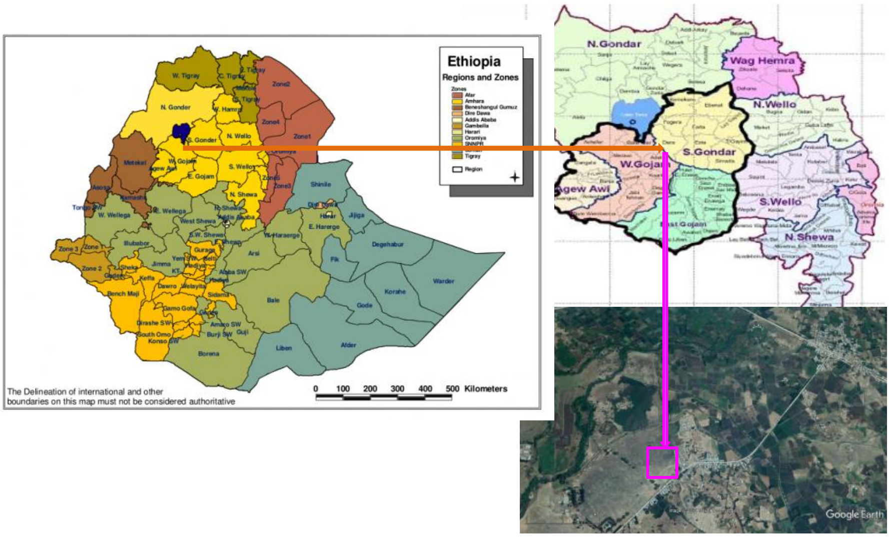


Figure 1. Map of the Study area (Source: Google Earth)

Figure 2. The partial view of the grazing land of the center

Experimental design and protocols for estimation of herbage dry matter intake

a) Method 1 - Estimation of pasture intake using bite counter

A simple, compact bite counter was used to record dairy cow jaw movements (Figure 3a). The device is composed of a pendulum, a microcontroller, and a transmitter attached to a collar. Jaw movements were recorded using a system developed by Panasonic Electric Works Co. Ltd. (Kadoma, Osaka, Japan) and consisting of an 8-bit microcontroller (PIC16LF873), a 64-kB nonvolatile memory, and a transmitter with an internal antenna (Figure 4).

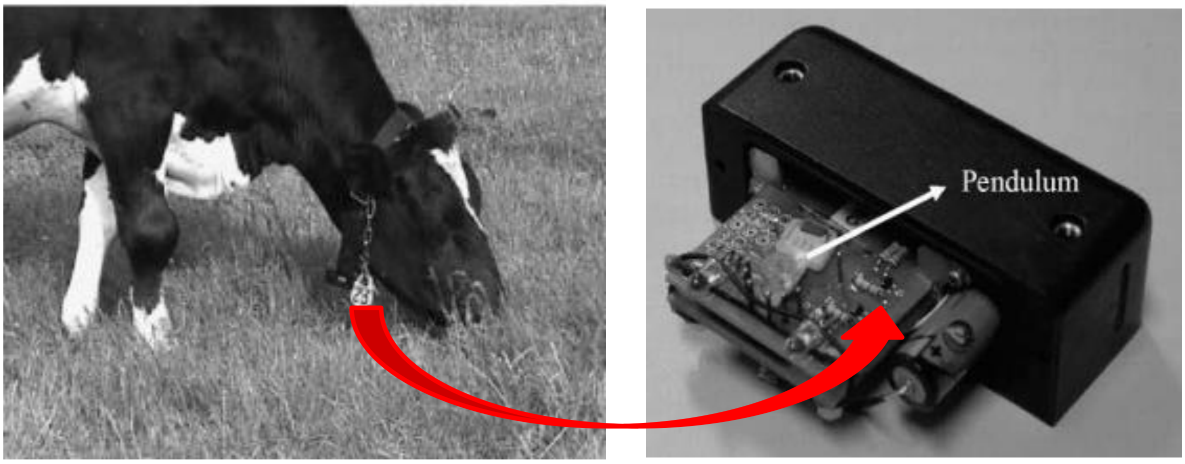


Figure 3a. The bite counter pendulum and the data access process (Umemura et al., 2009).

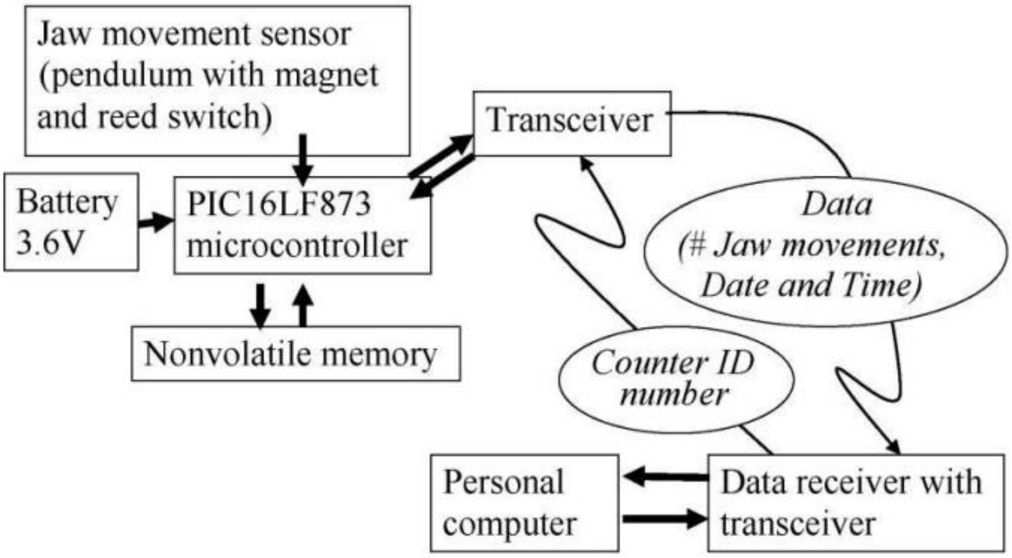


Figure 3b. Diagrammatic illustration of the bite counter data access process (Umemura et al., 2009).

Experimental design and animals for the bite counter

The grazing experiment was conducted from 2018 to 2019 in mainly rainy grazing season of Ethiopia (specifically from July – October in each year). In general, each experimental trail consisted of 2 wk of adaptation to adjust pasture-accustomed cows to the various feeding treatments and measuring devices followed by the data collection. All experimental procedures were in accordance with guidelines for animal welfare and were approved by the Animal Care Committee of the Andassa Livestock Research Center. Before selection of the experimental cows, all cows passed a medical check. Dairy cows were selected based on their parity, lactation stage and milk yield. Two breeds; Local (Fogera) and Crossbred dairy cows (Fogera crossbred with Holstein Friesian) were used the grazing experiment (Figure 4). A total of seventeen bite counters were used for the experiment in which seven in 2018 and ten in 2019. For this the trial 16 lactating dairy cows were delivered from Andasa Livestock Research center. The cows were graze for 8 hours per day in the natural grazing pasture. The utility of the bite counter recordings for estimating feed intake. During the experiment period, all experimental cows grazed as an individual in the paddocks and the also permitted to graze with the herds in non-restricted/free grazing system. The stocking periods lasted 1 to 3 d for one month and repeated for the remains three months. In the meantime, the crossbred lactating cows were supplemented concentrate in the barn before milking in the evening time intended to produce more milk yield. All cows had free access to drinking water during experiment period.

Figure 4. Local (Left) and HF crossbred (Right) cows grazing with the bite counter as neck tie

The grazing layout of the dairy cows with a bite counter

One cattle with a bite counter in each grazing paddock

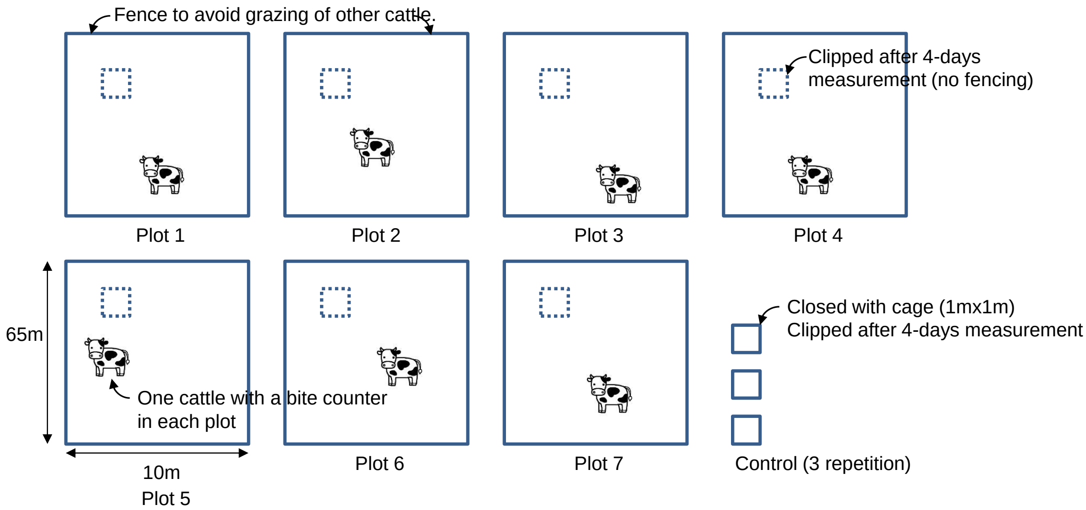


Figure 5. Individual dairy cows wear bite counter graze in the paddock.

All the experimental cows with bite counters in free ranging with the group in free grazing land

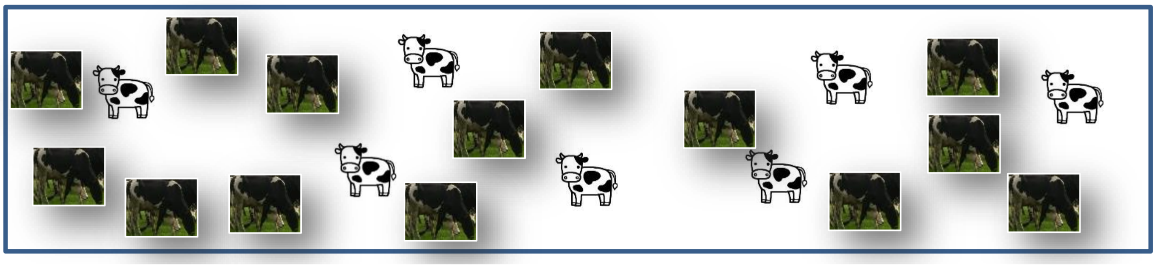


Figure 5. All the experimental cows wear bite counters in free ranging with the herds

b) **Method 2 - Estimation of pasture intake using Cages system in the paddock**

A total of 16 (7 in 2018 and 9 in 2019) grazing paddocks were used for clipping after 3-4 days grazing. The cage, approximately 1m^2 and constructed with wood fence and mesh wire in each paddock with the area shown in Figure 6. Forage inside and outside the cages was clipped from 0.5 m x 0.5m quadrants after grazing. Grazing cages were used to measure forage disappearance before and after grazing. Clipping of forage was done above a 5-cm stubble height of the ground level. The difference between forage inside and outside the grazing cage represented the amount of pasture forage consumed by grazing animals. Experimental paddocks were constructed using locally available wood (Figure 7).

Paddock and cage layout of the experiment

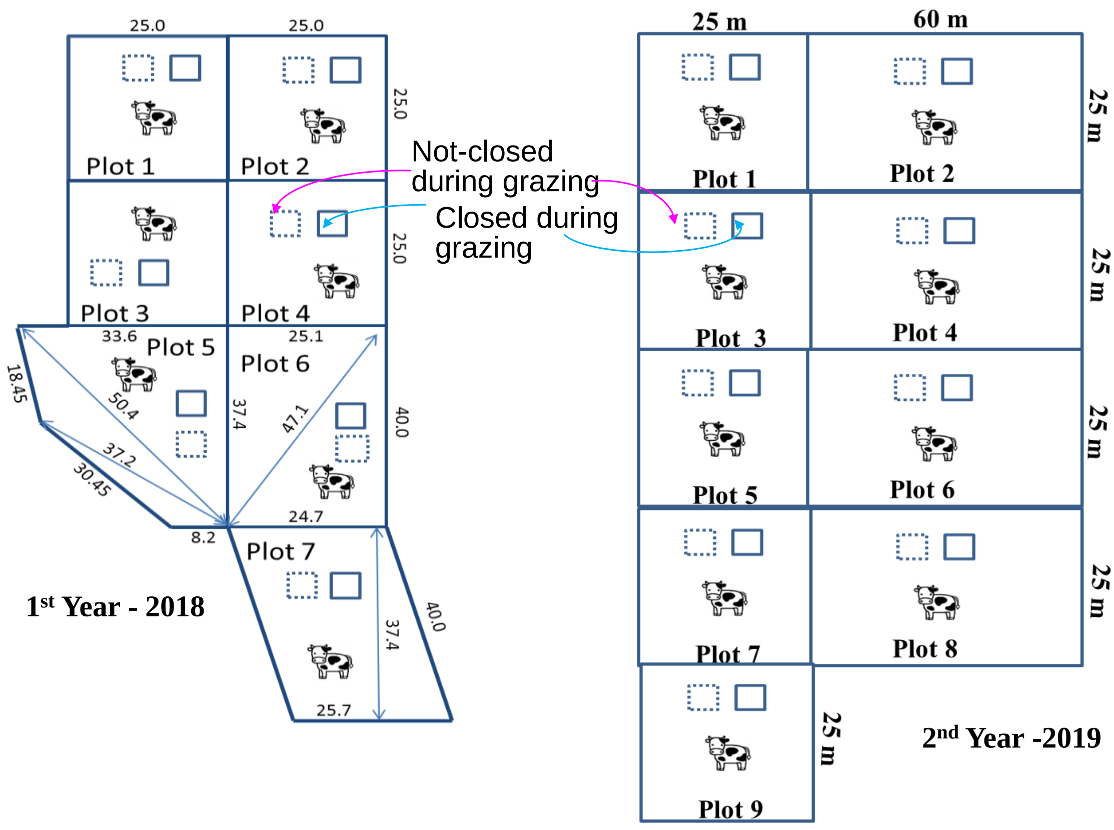


Figure 6. Paddock and cage layout of the experiment

These 16 paddock observations were conducted at 1 time. The RPM was calibrated to measure the available DM above a 5-cm stubble height, using seventeen 1 meter square quadrants (Figure 8). The equations for estimation of DM (g of DM/m^2) was developed using reading of RPM as follow;
Dry matter intake was calculated as follows:

$$\mathrm{DMI(kg\ d^{-1})} = \frac{[\mathrm{DM\ inside\ cage\ (kg\ ha^{-1})} - \mathrm{DM\ outside\ cage\ (kg\ ha^{-1})}] \times \mathrm{area(ha)}}{\mathrm{Number\ of\ grazing\ days}}$$

Figure 7. Dairy cow wear bite counter graze in individual paddock

Hand Clipping of grass   Rising Plate Meter Measurement

Figure 8. Clipping of the grass and rising meter measurement

C) Method 3 - Estimation of pasture intake using prediction equations

i) Estimation of Forage DMI from BW and ADG

Sixteen lactating dairy cows were used in graze pasture, BW measurement was taken using ground balance and heart girth. Average daily weight gain (ADG) was calculated from weight over the grazing period. Pasture Forage DMI Estimated from BW and ADG using the Equation (Minson and McDonald 1987):

a) DMI (kg day^{-1}) = $(1.185+0.00454\times BW-0.0000026\times BW^2+0.315ADG)^2$
Where BW=body weight (kg) and ADG= average daily gain (kg/day).
b) DMI = 3 % of the body weight (Undi, eta al., 2008).

ii) Pasture DMI estimation using forage Net Energy

Animal DMI was estimated using a prediction equation based on individual animal BW and standing forage NEm concentration (NRC 1996). The net energy concentration of the grazing pasture was analyzed using the In vitro digestibility and NDF content analyzed in Animal Nutrition laboratory at Shimane University Japan. Thus, the pasture DMI was estimated using Net Energy Equation:

DMI (kg day^{-1}) = $SBW^{0.75}\times (0.1493\times NEm-0.046\times NEm^2-0.0196)$ (NRC 1996)
Where $SBW^{0.75}$: shrunk metabolic body weight (kg)
NEm = (2.0180 + 0.38 x ADF) x 0.7 (Undi, eta al., 2008)

Data recording and Laboratory Analysis

The herbage biomass, species composition and the nutritive value data were recorded. Milk yields were recorded at every milking during the milking time. Concurrently with pasture disappearance assessment, herbage samples from the pastures were collected immediately before grazing and after grazing for chemical analysis. All pasture samples were analysed for ash, NDF, acid detergent fibre (ADF), CP, and lipid concentrations, along with organic matter digestibility (OMD) and metabolizable energy (ME) concentration.

The herbage sampling started 24 h before the feces sampling and ended 24 h earlier. These samples were chopped and stored at −20°C for further analysis. The N and C content of herbage and supplement samples was analyzed using the CN coder. The contents of ADF (AOAC International, 1995; method 973.18) and NDF (AOAC International, 1995; method 2002.4) for the herbage and supplement samples were analyzed with Gerhardt Fibertherm (Gerhardt GmbH & Co. KG, Königswinter, Germany). The NDF and ADF contents were separately determined (parallel). A correction for the residual ash obtained after 2 h of incineration at 550°C was made for ADF corrected for residual ash and NDF corrected for residual ash.(Rombach et al., 2019). The NEL content of herbage was calculated from chemical composition according to Agroscope (2015).

Statistical analyses

Mean pasture DMI per day was determined from the slope of linear regression equations for each plot for each pasture measurement meter. Bite counts were converted to true (observed) bites because the counter values is 1. 9 times the number observed. Individual animal DMI estimates from three different techniques was compared using the PROC MIXED procedure of SAS software (version 9.1, SAS). For comparison of all techniques, the PROC MIXED procedure was carried out on data pooled by period and paddock. Correlation and Regression analysis were conducted for intake and Jaw movement as well as biomass and height.

Result and discussion

Biomass and species composition of the grazing pasture

The average biomass yield of the grazing land harvested in the main rainy season was 1.17 ton/ha. The biomass yield was influenced by season where high production was recorded in October followed by September (Figure 8). The pastures comprised different species of grasses mainly *Pennisetum pedicellatum, Clinacanthus nutans* and *Parthenium hysterophorus*; 26.25% of the fresh herbage biomass); legumes (*Trifolium quartinianum and Trifolium angustifolium*; 70.75% of the fresh herbage biomass), and forbs 3% of the fresh herbage biomass. In line with this study, Yihalem (2004) also reported that the dominant grass of the area includes *Cynodon spp., Hyparrhenia spp., Paspalum spp., Pennisetum spp., Setaria spp., Eleusine spp., Eragrostis spp., Sporobolus spp., and Andropogon spp. and Trifolium species*. It is, therefore, concluded that the biomass yield from the grazing land in the study area is poor with poor combination of legumes and grass composition.

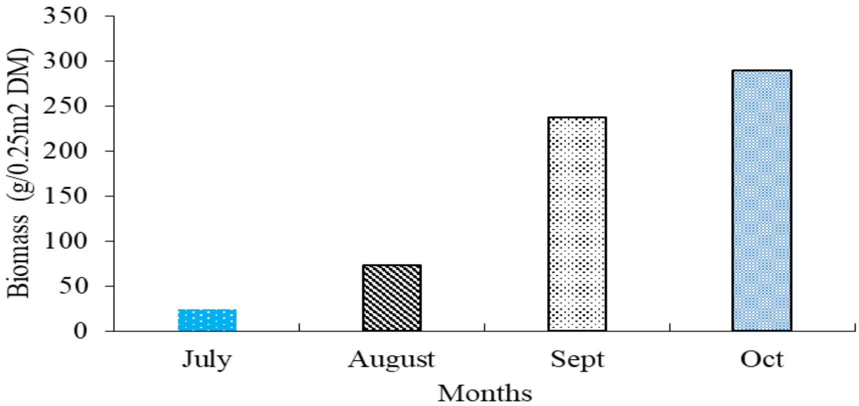


Figure 8 - Biomass prodution in across different months

Herbage nutritive value of the grazing pasture

The chemical composition of the herbage and the supplements fed during the experimental periods are shown in Table 1. The NDF concentration in the Napier grass used was lower than that in the natural-grassland hay and that of the grazing grasses (Table 3). In contrast, the higher crude-protein concentration in the Napier grass than in the natural-grassland hay and the grazing grasses resulted in the cows feed the highest crude-protein. The variations in chemical composition reported in the present experiment are also in agreement with those reported by Delagarde *et al*. (2000) for samples of perennial ryegrass.

Table 1. Chemical compositions (% on DM basis) of the grazing pasture and feed ingredients

Feed Types	CP	EE	NDF	ADF	ADL	CA
Grazed pasture	2.5	1.7	77.8	46.5	5.9	7.0
Napier grass	8.2	1.8	68.3	42.9	6.7	11.9
Natural-grassland hay	4.1	1.5	72.1	48.2	8.3	11.1
Concentrate	19.4	5.9	29.9	18.6	3.5	10.3

ADF, acid detergent fiber; ADL, acid detergent lignin; CA, crude ash; CP, crude protein; DM, dry matter; EE, ether-extracted fat; NDF, neutral detergent fiber (Nobuyuki et al., 2021).

3.3 The relation ship between grazing pasture biomass and height

The grazing pasture height has strong apositive relation (r^2 = 0.89) with the biomass (Fig. 9). This indicates shows clipping height is a good indicate to estimate the biomass with out destruction or cutting the pasture in grazing land.

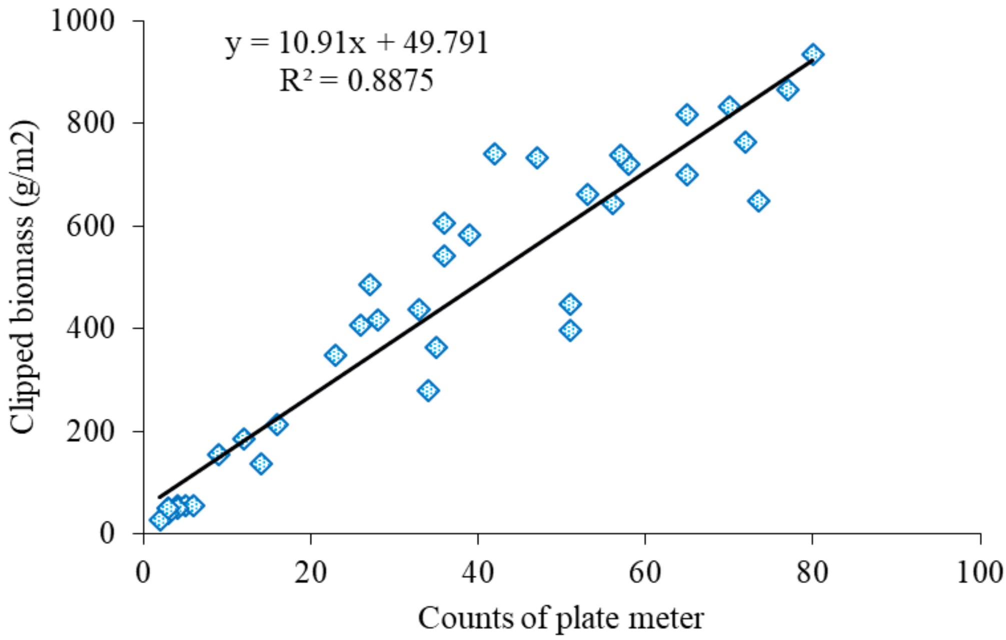
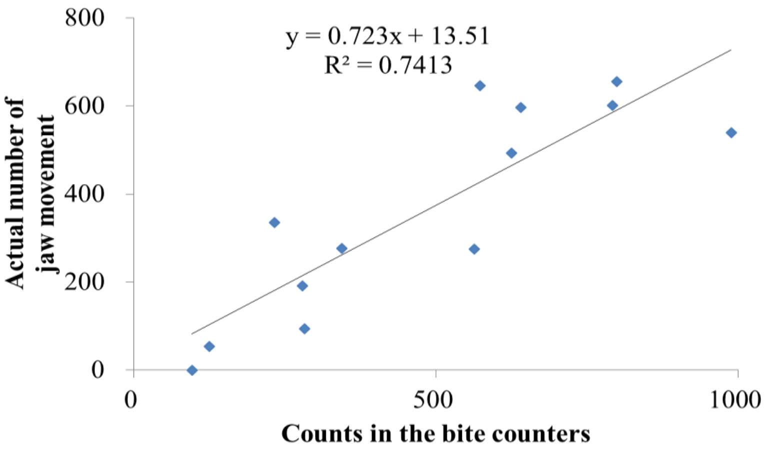


Figure 9. The relation ship between clipping and plate meter for estimation of biomass.

Estimation of herbage dry matter intake using bite counter

The herbage dry matter intake estimated using bite counter was presented in Table 2. The dry matter intake was 4.2 and 6.7 Kg DM per day for local and HF crossbred, respectively. This agreed with the previous studies on red deer (Clutton-Brock et al. 1982; Heydon et al. 1993). This pattern could be related to either higher energy requirements during peak lactation (which decrease towards weaning), or greater herbage availability in early summer, followed by a slight decrease when plants reach maturity. Heydon et al. (1993) found that both reproductive and non-reproductive red deer hinds exhibited the same DMI declines from July to October, with lactating hinds having significantly higher intakes, and the difference decreased as weaning approached. Most estimates of intake for cattle and sheep grazing ranges in Western United States fall within the range of 40 to 90 g DM/Wkg'" or from 1 to 2.8% of body weight. This observation shows that it is possible to use the bite counter since the dairy cows can graze wearing it even though they struggled at the beginning of tying the equipment (Fig.10). Information about individual herbage DMI (HDMI) allows estimating the nutrient supply from pastures and determining an adapted optional supplementation in the barn that may improve efficiency and lead to higher acceptance in practice. Furthermore, information about intake compared with production can be used to assess the nutrient and energy efficiency of individual grazing dairy cows and may enable selection for this trait (Rombach et al., 2019). To improve the predictability of daily herbage intake and, hence, develop more efficient grazing management systems, it is necessary to understand how the cow grazes or adapts its grazing behaviour throughout the day and to changes in sward condition(Barrett et al., 2001). In conditions that were similar to those in our study, Kaufmann et al. (2011) found a mean deviation between estimated and weighed DMI of 0.2 kg for cows fed in the barn with fresh herbage.



Jaw movement of cow with bite counter

Figure 10. Correlation between jaw movement and bite counter

Table 2 - Herbage dry matter intake of the grazing cows wear a bite counter

Breed	x-actual jaw movement	Jaw movement For grazing (10^4 times/cow)	Feed intake/hr	Feed intake (Kg DM)/day
Local breed	422.03	0.04	0.18	4.2
HF crossbred	3105.07	0.31	0.27	6.7
Overall	1763.55	0.18	0.22	5.5

The relation between manual jaw count and counts made by jaw movement counter; y=0.723x + 13.51 (y is value of bite counter, x is actual jaw movement and R^2=0.74). The relationship between bite for grazing and feed intake; y=6.82x+ 2.45 (y is Feed intake, x is Jaw movement for grazing and R^2=0.77) (Umemura et al., 2009).

Comparison different methods for pasture dry matter intake

The herbage dry matter intake estimated using the different techniques was presented in Table 3. In a grazing situation, the clipping cutting method and the n-alkanes method have not been compared with our knowledge. Reeves et al. (1996) concluded that herbage intake estimates from the pre- and postgrazing mass, estimated with the rising plate meter, were not acceptable because of large errors in estimating tropical grass intake. In the present study, a large difference in herbage intake estimated with the clipping method was found between 16.2 vs. 18.6 kg of DM. The cows did increase in BW; the estimation by the sward cutting technique seemed to underestimate DMI. The sward cutting method gave fast results; 24 h after the postgrazing cut, herbage intake could be calculated. The n-alkanes method was more time consuming, and it took more than 1 mo before the data for herbage intake were available. In addition, the nalkanes method needs expensive equipment for measuring and analyzing materials, whereas the sward cutting method is much less expensive. Pasture disappearance techniques: high variability in estimating pasture biomass. Pasture intake estimates by the plate meter: higher than for the other techniques. Intake estimates obtained using pasture-disappearance and chemical-marker methods were not correlated (Margaret et al., 2014). Precision of estimating individual feed intake of grazing animals offered low, declining pasture availability.

Table 3. Pasture intake using different methods

Intake estimation techniques	Local	HF Crossbred	Average
Bite counter	4.2	6.7	5.5
Clipping Biomass	5.4	7.7	6.6
Plate meter Biomass	7.7	9.1	8.4
Body weight (3%)	7.5	9	8.3
Nem	6.4	7.3	6.8

Pasture Intake and milk yield

Estimates of pasture intake of the local dairy cow of 4 kg/d produce 0.71 L/day while the HF crossbred procedure 1.72 which consumed 6.7 kg/d grazing pasture, 2.03 kg/d concentrate diet and 2.85 kg/d improved forage (Table 4). This result showed that the lactating dairy cows can produce milk depending on the good grazing pasture but the recent problem in our country is the alarmingly decline of grazing land for subsistence small holder dairy production. In line with this study, Peyraud et al. 2001 reported that although pasture herbage has widely been identified as the cheapest source of nutrients for dairy cows, the decline in grazing may be the result of larger herds, fragmentation or lack of land, development of automatic milking systems, and farmer expectations regarding productivity in a pasture-based system (Kristensen et al., 2010). The feeding of protein and concentrate supplements was associated with a decrease of HDMI in the GA model. O'Neill et al. (2013) observed a substitution rate of 0.58 to 0.71 kg of HDMI/kg of concentrate compared with our results (0.63 kg of HDMI/kg of concentrate).

Table 4. Pasture intake, supplementary diet and milk yield

Breed	Pasture intake (kg/d)	Supplement feed		Milk yield (L/d)
		Concentrate(kg/d)	Improved Forage(kg/d)	
Local	4.0	0	0	0.71
HF crossbred	6.7	2.03	2.85	1.72
Average	5.35	1.01	1.43	1.215

Conclusion and recommendations

The average biomass yield of the grazing land harvested in the main rainy season was 1.17 ton/ha. The pastures comprised different species of grasses. The average herbage dry matter intake using the bite counter was 4.2 kg DM/day and 7.7 Kg DM/d for local and crossbred individual dairy cow, respectively. The herbage dry matter intake could be estimated by applying linear regression to the number of bite counts with R^2 values of 0.68. In conclusion, the wireless bite counter offer new opportunities for rapid estimation of herbage dry matter intake for free gazing system. Moreover, the bite counter was easy to attach to the cows using the collar and could be used effectively by farmers in the grazing based dairy production system in Ethiopia.

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Participatory Evaluation and Demonstration of Different Grazing Land Improvement Techniques: Case Study in Mecha District of West Gojjam

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Abstract

In Ethiopia, grazing land as a source of dairy feed is diminishing because of natural and human induced factors, such as increased conversion of grazing lands to other uses, very limited improvement practices and little attention given to grazing lands by extension system. Thus, participatory action research was undertaken in Mecha district, West Gojam to evaluate and demonstrate effects of grazing land improvement techniques on biomass production and carrying capacities. Each treatment was replicated three times and the herbage harvested was sorted into different vegetation components and oven-dried at 65^{0}C for 72 hours. Analysis of variance to verify significant differences among treatments and partial budget analysis was undertaken. Seventy-three people, comprising livestock office staff, administrators, model farmers, farmers, researchers and SNV-WUR staff attended the event. Compared to the control treatment (enclosing only), application of lime; lime + urea+ DAP-; wood ash; Lime + urea; lime + DAP and cattle manure resulted in yield advantages of 61.14%, 144.80%, 118.48%, 106.64%, 83.18% and 77.73%, respectively. Across the treatments, the herbaceous yield ranged from 4.22 (control) to 10.33 tons/ha (Lime+ Urea+ DAP). The carrying capacities (TLU/ha) increased because of increased biomass production due to the interventions. The net benefit was also in favour of the interventions. Participants of the event evaluated the treatments visually and expressed their appreciation of the results and lessons learnt, and their willingness to implement the results. Future research should investigate the possibility of two to three harvests in a season and long-term study taking into account socio-economic, ecological and climatic changes.

Introduction

Grasslands represent around 26% of the world land area, spreading over 3.5 billion hectares and more than two-thirds of the world agricultural area, and contain about one-fifth of the world's soil carbon stocks (Ghosh *et al*., 2015). Grasslands are used as one of the foundations of human activities and civilizations for centuries by supporting production from grazing livestock. The situation still exists, particularly for developing countries where 68% of the total grasslands are located (Ghosh *et al*., 2015). Ethiopia is among the 28 smaller countries (25 in Africa) where grasslands account for about 60% of the total land area (White *et al*., 2000; ADB, 2014). A recent estimate by CSA (2021) revealed green fodder/grazing is to be the largest source of livestock feed (54.54%), while crop residues, improved feed, hay, by-products, and others comprise 31.13, 0.57, 7.35, 2.03 and 4.37%, respectively though most of the grazing areas are located in the lowlands. In addition, Ethiopia has the largest livestock population in Africa, 70.3 million heads of cattle, 43 million sheep, 52.5 million goats, 8.2 million camels, 10.8 million donkeys, 2.15 million horses, 382, 784 mules, 57 million chicken and 7 million beehives (CSA, 2021). Nevertheless, the production and productivity of livestock in Ethiopia is low primarily attributed to feed shortage both in quantity and quality (Getinet *et al*., 2017).

In Ethiopia, the natural pasture production is limited to the periods of the rainy season and the pasture that provides the bulk of ruminant feed in Ethiopia are diminishing/depleted from time to time because of natural and human induced factors, such as increased conversion of grazing lands to other uses, very limited improvement practices (such as stocking rate adjustment, soil and grazing management), and little attention given to grazing lands by extension system (Abule *et al*., 2016). This problem is also aggravated by the lack of awareness and proper training regarding grazing land management and the lack of appropriate improvement methods. Thus, this study examined the effect of applying different grazing land improvement techniques on biomass production and carrying capacity of the grazing lands in North Mecha district of West Gojam. The specific objective were 1) to increase hay/grass production through availing alternative technological options for farmers; 2) to determine the biomass production and carrying capacities of the natural pasture; 3) to evaluate/demonstrate the effects of different grazing land improvement techniques with farmers and development partners and; 4) to evaluate the interventions using partial budget analysis

Materials and Methods

Brief description of the study area: The study was undertaken in north Mecha district, west Gojam zone, Amhara Region, Ethiopia (Figure 1). The reasons for the choice of the study district are its high potential for dairy production, representativeness for midlands, accessibility, it is one of the 11 BRIDGE (Building Rural Income through Inclusive business growth) intervention district and advice from knowledgeable people. It is located at 30 kms from Bahir Dar city, the regional capital. The district falls within Woina-Dega's (mid highland) agro-ecological zone. A major part of the soils is Nitisols which are mainly acidic with a pH range of 4.7 to 5.4 (Mekonnen, 2015) where a pH below 5 will severely limit plant growth (Lathwell, 1986). The altitude varies from 1, 800 m to 2, 500 m above sea level. The area receives an annual rainfall ranging from 820 to 1,250 mm and it is an area described as high rainfall area (Astemel and Yihenew, 2018)**.** The mean annual temperature ranges from 17^0C to 30^0C. The farming system is characterised by mixed crop livestock production system. The dominant crops grown in the study area are wheat, barley, finger millet, teff, and maize. The livestock population in the district in 2020 were: cattle = 351, 844; Crossbred = 2, 377; ovine = 110,834; caprine= 61, 883; equine = 39, 214 and poultry= 230, 286 (Mecha district livestock office, 2020). The largest area is used for cultivation, it covers 72,178 ha. This is followed by forest land mainly Eucalyptus (18,547 ha). Grazing land has an area of 15,591 ha (Astemel and Yihenew, 2018)**.** With regard to grazing land ownership, there are two types, communal and private grazing lands.

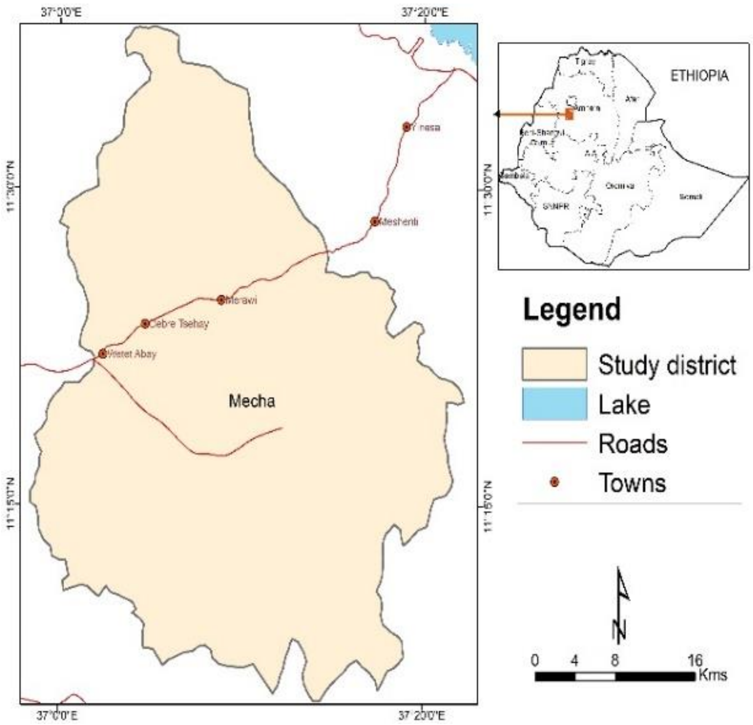

Figure 1. Location of the study area - Mecha, West Gojjam

Study procedures

Engagement with farmers and development partners: Before embarking on the study, different assessment reports of the BRIDGE project and other studies were reviewed. Discussions were also undertaken with the staff of the cluster and Mecha district livestock office regarding the overall feed related problems and collaboration in action research undertaking. Participatory discussions were undertaken with the community members, development agents, and experts about the problems of the grazing land.

Site selection and field layout: In site selection, which was undertaken together with farmers, livestock experts, and development agents, the representativeness of the site for grazing land in the mid altitude and poor herbaceous production condition of the site as witnessed by the farmers and livestock experts/development agents by considering runoff to reduce leaching of nutrient was taken into consideration. At the end, a representative communal flat grazing land was identified for the study and permission was obtained for using the land for research.

Soil sampling and analyses: To characterize the study area, soil samples were taken in a zigzag fashion from at least 10 spots from the grazing site before the application of the treatments to the depth of 0-20 cm. The soil samples were analysed for pH, organic matter/organic carbon, total nitrogen, available phosphorous, available potassium, and cation exchange capacity at the Amhara Regional soil laboratory, Bahir Dar, Ethiopia. pH was determined using a pH-meter in 1:5 soils: water ratio (w/v) and soil organic carbon by the walkey-black method (Walkley and Black, 1934). The percent soil organic matter (SOM) was calculated by multiplying the percent organic carbon by a factor of 1.724 (Brady, 1990). Total nitrogen was determined by the Kjeldahl method. Availability of K and P were analyzed using ammonium acetate method and Olsen method (Olsen and Dean, 1965), respectively. Cation exchange capacity was analysed by titrating ammonia, which occupy all the exchangeable cation sites after extraction with 1N ammonium acetate at pH 7 (ammonium acetate method). Based on the laboratory results, the soil of the grazing land at Mecha is characterized by pH = 4.25; sand (%) = 14; silt =25.33 %; clay = 60.67%; OC = 2.05%; TN (%) = 0.21%; Available K (PPM) = 85.70; Available P (PPM)= 6.67. The soil of the study area is clay soil and it is acidic which agrees with previous soil studies in the area (Mekonnen, 2015).

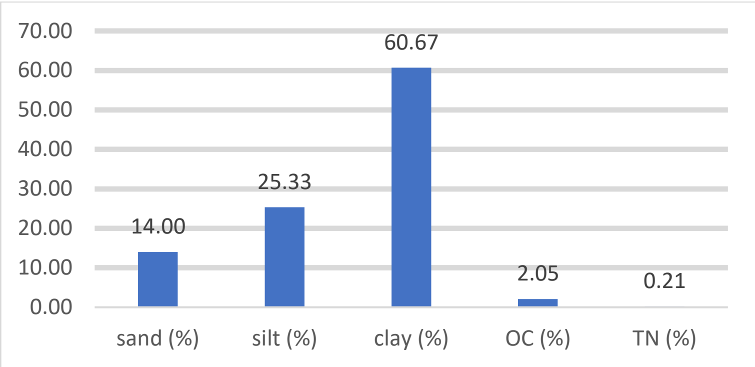

Figure 2. Soil physical and chemical characteristics of the study site

Application of treatments

The treatments described in this study are mainly based on locally available resources (manure, wood ash, enclosing, lime) except Urea and DAP. The latter two are imported products but can be purchased in the village from service cooperative level in the villages. Twenty-one plots of 3 x 5 meters were laid out to apply the seven treatments shown in table 1. The residual grass biomass was harvested before applying the treatments. The experimental plots were fenced during the main growing season (June to October 2019). The distance between plots and replications/blocks were 1m and 2m, respectively. The distance of experimental plots from border was 2m to reduce boarder effects. The proportion or amount applied was 100 (DAP) &150 kg (Urea), 7.5, 3, and 2 tones/ ha^{-1} for chemical fertilizer, cattle manure, wood ash and lime, respectively (Anderson *et al.*, 2013; Asmare *et al.*, 2015 and Ritchey *et al.*, 2015). After the plot layout, the quantity of the different treatments to be applied was calculated for each plot and weighed using sensitive balance and applied. The design of the experiment was a completely randomized design with three replications.

Table 1. Experimental treatments and applied quantity

Treatments	Applied quantity
Lime	2 tons/ha
Lime + Urea	2 tons lime/ha + 150 kg urea/ha
Lime+ DAP	2 tons lime/ha + 100 kg DAP/ha
Lime + Urea +DAP	2 tons lime/ha + 150 kg urea/ha+ 100 kg DAP/ha
Application of wood ash	3 tons/ha
Application of cattle manure	7.5 tons/ha
Control	No treatment applied, enclosing only

The chemical fertilizer and lime (calcium carbonate) were acquired by purchasing while cattle manure and wood ash were collected from farmers in the study area. The plots were ripped to incorporate the treatment materials into the soil except for the control plot. Urea and DAP were over-sown by broadcasting and lime and ash were scattered over the plots. Cattle manure was dissolved into water and applied in the form of slurry.

Herbaceous vegetation sampling and biomass determination: Towards the end of the growing season (beginning of October 2019), herbaceous vegetation was harvested from each of the sub-plots using quadrant of 0.5 x 0.5 m, and three quadrants were harvested at each sub-plot (3 x 21= 63 quadrants). The samples were weighed immediately after harvest and kept in plastic bag under a shade until sampling for the day is completed. On the same day, the samples were sorted into grass, legume and other forbs (meaning non-grass and non-legume), weighed and transferred to paper bags. At the end, the samples were oven dried at 65^{0}C for 72 hours to determine dry matter and dry matter was calculated in tons/ha.

Organization of grassland day and field assessment: A total of 73 people drawn from Amhara Region Livestock Agency, BRIDGE implementing districts and city Administration livestock offices, north Mecha district livestock office, North Mecha administrator, model farmers, research participating farmers, development agents, staff gfrom Andassa RC, and SNV-WUR staff attended the grassland day.

Statistical analysis: The formula proposed by Moore *et al*. (1985), modified by Moore and Odendaal (1987) and Moore (1989) was used for carrying capacity estimation by taking in account the total biomass yield. The equation is as follows: Y= d ÷ (DM x f) /r where Y is the carrying capacity (ha TLU^{-1}), d = Number of days in a year (365), total biomass DM yield (tons ha^{-1}), f is the utilization factor, r the daily grass DM required. The carrying capacity was calculated using tropical livestock unit (TLU) which is an animal weighing 250 kg and consuming 2.5% of its body weight. Thus, each TLU consumed 6.25 kg of forage dry matter daily and utilization factor of 0.5 (ILCA. 1990). Partial budget analysis was undertaken using Upton (1979) and CIMMYT (1988) to compare the treatments economically. All costs considered in the analysis were for 2019.

Results and Discussion

2.1. Biomass production and carrying capacity

The herbaceous biomass production and carrying capacities are shown in Table 2. Application of Lime+ Urea + DAP and lime + urea outperformed the other treatments in terms of their effect on grass production while there was no significant difference (P>0.05) among the control, wood ash, DAP + Lime and application of manure in terms of their effect on grass production. The significant improvement in grass production in response to chemical fertilizers in single or combination is documented in the literatures (e.g., Cameroon *et al*., 2002; Gagnon *et al*., 2005) and this is mainly attributed to the source of nitrogen. Nitrogen is also known as the most limiting nutrient for pasture production (Cameron *et al*., 2005). The application of wood ash (6.92 ton/ha) significantly increased legume/clover production which was followed by the application of Urea+ Lime+ DAP, DAP+ Lime and manure applications. The higher biomass production in response to these treatments is possibly associated with mineral composition of the treatments though not investigated in this study (Lickaez, 2002) and is documented in different literatures (e.g., University of Georgia, 2013). The total biomass was the highest in response to the application of Urea+ DAP+ Lime (10.33 tons/ha) which was followed by the application of wood ash (9.22 tons/ha) and lime+ urea application (8.72 tons/ha) which agrees with the findings of Fekadu (2016).

The carrying capacities of the land based on the number of TLU supported per hectare is shown in table 1. The number of TLU supported per hectare was the highest in Lime + DAP + Urea application as the biomass production was also the highest and there was no significant difference ($P>0.05$) in the number of TLU supported per hectare among lime, DAP+ Lime, and cattle manure applications. The increase in the number of TLU supported per hectare or the decrease in the land size required to support a given TLU is mainly attributed to the improvement in the production of the grazing land owing to the application of the treatments which corresponds with the findings of Cameroon et al. (2005); and Fekadu *et al*. (2018). The lowest number of TLU is supported in the control plot and at the same time the land required per TLU was the highest ($P<0.001$) for the control treatment which is a direct reflection of the relatively lower production of the grazing land compared to the plots where treatments are applied.

Table 2. Herbaceous biomass production and carrying capacity in Mecha district, West Amhara

Treat	Description	Biomass production (tons/ha)				Carrying capacity (ha TLU^{-1})	Carrying capacity (TLU ha^{-1})
		Grasses	Legumes /clover	Other forbs (non-grass and non-legumes)	Total biomass		
1	Control	2.52a	1.70a	0.00	4.22^{a}	1.12^{a}	0.92^{a}
2	Lime – 2t/ha	4.00b	2.50a	0.29	6.80^{b}	0.70^{b}	1.49^{b}
3	Lime + Urea + DAP	5.67c	4.66b	0.00	10.33^{e}	0.44^{c}	2.27^{e}
4	WA	1.90^{a}	6.92c	0.21	9.22^{d}	0.50^{cd}	2.02^{d}
5	Lime + Urea	6.58c	2.14^{a}	0.00	8.72^{cd}	0.53^{cd}	1.91^{bd}
6	Lime + DAP	2.54^{a}	4.90b	0.20	7.73^{bc}	0.61^{bd}	1.70^{bc}
7	Cattle manure	3.06ab	4.39b	0.00	7.50^{b}	0.63^{bd}	1.63^{b}
	SEM	0.25	0.27		0.27	0.03	0.06
	Level of significance	***	***		***	***	***

1) Control = No any treatment, only enclosure, 2) Lime = 2 tons/ha, **3)** Lime + Urea + DAP = 2 tons lime/ha + 150 kg urea/ha+ 100 kg DAP/ha, 4) WA= 3 tons/ha, 5) Lime + Urea = 2 tons lime/ha + 150 kg urea/ha, 6) Lime + DAP = 2 tons lime/ha + 100 kg DAP/ha 7) Cattle manure = 7.5 tons/ha

Assessment and perceptions of the community

Based on the assessment of the participants of the field day, the improvement of the land in terms of production and emergence of the species is highly appreciated. It was discussed that there are many grazing lands that are poor in their production in the district which can be improved through such a technique. The surrounding farmers discussed the point that if the researchers brought such a positive change in a very short time, what should we do. While the action research is undertaken, the farmers were also doing their experiment using compost and urea application.

2.2. **Economic analysis**

The simple economic analysis of the different interventions is shown in table 3. The different treatments had a positive net benefit at harvest and during the dry season. The application of wood ash during the harvest season and lime+ DAP +Urea applications during the dry season seem to have better net benefit.

Table 3. Partial budget analysis for the different interventions (Ethiopian Birr)

Treatment	Total variable cost	Biomss yield (tons/ha)	Gross Benefit-Harvest season (birr/ton)	Gross benefi-dry season (birr/ton)	Net benefit-harvest season	Net benefit-dry season
Control	2390.0	4.22	21100	31650	18710.0	29260.0
Cattle manure	4219.6	7.45	37250	55875	33030.4	51655.4
Wood ash	4537.2	9.22	46100	69150	41562.8	64612.8
Lime	6708.5	6.80	34000	51000	27291.5	44291.5
Lime + DAP	7745.6	7.73	38650	57975	30904.4	50229.4
Lime + Urea	9454.4	8.72	43600	65400	34145.6	55945.6
Lime + Urea + DAP	11569.7	10.33	51650	77475	40080.3	65905.3

Conclusion, recommendations, and lessons learnt

The study revealed that compared to the control, the application of different treatments improved biomass production and improved the carrying capacity of the land. Furthermore, farmers can make use of locally available materials to improve their grazing land. As there are only very limited grazing land studies in the country, future research should investigate the possibility of two to three harvests in a season and long- term studies on the effects of the different treatments on productivity of the grazing land, livestock productivity, soil, plant nutrients, considering socio-economic and climatic condition.

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Milk Yield, Milk Composition, Nitrogen Utilization Efficiency, and Methane Emission of Lactating Fogera Dairy Cows Fed Improved Pasture Hay and Treated *Eragrostis Tef* Straw

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Abstract

Nutritionally imbalanced poor-quality diet feeding is a major constraint for dairy production in tropical regions. Hence, alternative high-quality roughage-based diets are required to improve milk yield and reduce methane emission (CH_4). We tested the effects of feeding natural pasture hay, improved forage grass hays (Napier and Brachiaria hybrid) and treated crop residues (Eragrostis tef straw) on nutrient digestibility, milk yield, nitrogen balance, and methane emission. Eight lactating Fogera cows were selected for the experiment and assigned randomly to a 4 × 4 Latin square design. Cows were housed in well-ventilated individual pens and fed a total mixed ration (TMR) comprising 70% roughage and 30% concentrate. The four treatments: control (natural pasture hay (NPH)); treated teff straw silage (TTS); Napier grass hay (NGH); and Brachiaria hybrid grass hay (BhH). Compared with the control diet, the daily milk yield increased ($p < 0.01$) by 31.9%, 52.9%, and 71.6% with TTS, NGH, and BhH diets, respectively. Cows fed BhH had the highest dry matter intake (8.84 kg/d), followed by NGH (8.10 kg/d), TTS (7.71 kg/d) and NPH (6.21 kg/d). Nitrogen digestibility increased ($p < 0.01$) from the NPH diet to TTS (by 27.7%), NGH (21.7%), and BhH (39.5%). The concentration of ruminal ammonia nitrogen was higher for cows fed NGH than other diets ($p = 0.01$) and positively correlated with plasma urea nitrogen concentration ($R^2 = 0.45$). Feeding TTS, NGH, and BhH hay as a basal diet changed the nitrogen excretion pathway from urine to feces, which can help protect against environmental pollution. Estimated methane yields per dry matter intake and milk yield were decreased in dairy cows fed BhH, NGH, and TTS diets when compared to cows fed an NPH diet ($p < 0.05$). In conclusion, feeding of TTS, NGH, and BhH roughages as a basal diet to lactating dairy cows in tropical regions improved nutrient intake and digestibility, milk yield, nitrogen utilization efficiency, and reduced enteric methane emission.

***Key words**: Brachiaria Hybrid; digestibility; methane emission; milk yield, milk composition and nitrogen efficiency.*

Introduction

The poor quality and inadequacy of feed supply is the major stumbling block affecting livestock production in tropical region (Mediksa, 2017). Ethiopia has huge livestock population (CSA, 2017), however dairy production very limited due to poor feeding management, among others (Mesfin and Kebede, 2011). This is further aggravated by the fact that yield and nutritive value of tropical grasses decline sharply as the dry season approaches leading to reduced feed intake, greater body weight loss, and poor milk production in conventional grazing systems (Phelan et al., 2015; Ali et al., 2019). Moreover, due to rising human population, grazing lands for natural hay production for dry season are widely being converted to croplands and forest planation (Berihun et al., 2019), forcing cattle to graze on marginal and overgrazed lands with poor quality forage (Kitaba and Tamir, 2007; Mekasha et al., 2017). Besides, dairy animals in developing countries produce more methane (CH_4) and excretion of nitrogen primarily feeding low quality roughage which in imbalanced in nutrients (Garg et al., 2018).

Use of improved forages and quality enhancement of crop residues through treatment needs to be considered to overcome supply and quality challenges (Shapiro et al., 2017). To this end, supplementing traditional feed resources with planted forages appears to be an alternative and plausible solution (Berhanu et al., 2019). In this respect, Napier grass (Pennesitum purpureum) (Tessema and Baars, 2004; Mutimura et al., 2018) and Brachiaria grass accessions including the hybrid (CIAT 36087) Mulato II grass have good potentials (Adnew et al., 2018) in order to full fill the nutrients requirement of dairy cows for milk production using cut and carry feeding system (Nyambati et al., 2003). Napier grass is a fast-growing perennial grass widely grown across the tropical and subtropical regions for smallholder dairy production (Tessema and Baars, 2004; Teressa et al., 2017). Whereas Brachiaria hybrid grass is the newest alternative to improve productivity in semi-intensive systems; and some of these new varieties are high-yielding, nutritious and climate smart grass (Creemers and Aranguiz, 2019). Due to these benefits, recently, there has been considerable interest in Brachiaria hybrid grasses in tropical region and several initiatives are ongoing to promote to support the emerging livestock industry focusing in dry season (Ghimire et al., 2015; Wassie et al., 2018). Despite the potential of these new released varieties of the improved forages in different tropical regions including Ethiopia (Adinew et al., 2019), there is scarce information on performance of lactating dairy cows.

On the other hand, crop residues represent a large feed resource as basal diet for ruminant animals especially during the dry season in tropical dryland environment (Valbuena et al., 2012) but most smallholder farmers feed them without any treatment which consequently impacts animal production performance (Kashongwe et al., 2014).

Thus, we hypothesized that using improved forage and treated tef straw as a basal diet would increase milk yield, dietary N utilization efficiency and reduce methane emission. Therefore, the objective of this research was to evaluate the effect of feeding improved grasses hay and treated tef straw on milk production, nitrogen utilization efficiency and methane emission of lactating Fogera dairy cows.

Materials and Methods

Experimental location, cows, and design: The current study was conducted at Andasa Livestock research center of Amhara Region Agricultural Research Institute which is located an elevation of 1730 m above sea level in Bahir Dar Zuria (11°42′–11°92′N, 37°07′–37°65′E) district of the Amhara Region. It receives an average annual rainfall of 1150 mm with temperature ranging from 6.5ºC to 30ºC (Bitew et al., 2010). A total of eight lactating Fogera breed dairy cows at their mid stage of lactation were used from Andasa livestock research center dairy farm. The cows were placed in an individual pen in a well-ventilated barn with concrete floor and appropriate drainage slope. All cows were weighed and drenched with broad-spectrum anti-helminthics prior to the commencement of the feeding experiment. The experimental design was replicated 4 x 4 Latin square design (LSD) (Kuehl, 2000). The experiment consisting of 4 treatments and 4 periods; the treatments were assigned randomly for dairy cows within each period. The periods have 2l days in which 14 days of dietary feed adaptation and 7 days of data collection. The experiment was conducted for the total of 12 weeks.

Experimental dietary treatments and feed management: Cows were fed a total mixed ration (TMR) consisting of the various treatment ingredients as shown in Table 1, apportioned into three: morning (8:00 h), noon (12:00 h) and after noon (16:00 h). The four dietary treatments were: Control (Natural pasture hay + formulated concentrate (NatuPH)) (T1, control); Effective microbe–urea molasses treated tef straw + formulated concentrate (EMUTTS) (T2); Napier grass hay + formulated concentrate (NapGH) (T3) and Bracheria hybrid grass hay + formulated concentrate (BraHGH) (T4). Each dietary treatments have a 70:30 forage to concentrate ratio and formulated as an isonitrogenous and isocalorious diets (Table 1) in order to fulfil the nutrient requirement of lactating dairy cows (NRC, 2001). For feed allowance, it was assumed that total dry matter intake (kg DM/day) of a mature cow is equivalent to 3% of its body weight (NRC, 2001). The formulated concentrate comprised maize grain, noug seed cake, wheat bran, iodized salt and ruminant premix (Table 1). It was mixed, ground and processed in a private animal feed factory. The natural pasture hay was purchased from private dairy farm and dominantly composed of grass species (*Andropogon, Cynodon, Digitaria*, *Hyparrhenia* and *Panicum)* and legumes (*Trifolium quartinianum, T. polystachyum and Indigofera atriceps)* (Denekew et al., 2015). The improved forages were planted using the recommended agronomics practice for Napier grass (Accession number ILRI-1574) (Tessema and Baars, 2004) and for Bracheria grass (Adnew et al., 2018) at Anadasa Livestock Research Center in 2.65 ha of irrigated land.

Table 1. Ingredients and chemical composition of the experimental diets

Feed ingredient	DM[1]	OM[2]	CP[3]	NDF[4]	ADF[5]	ADL[6]	ME[7]	NEm[8]	NEL[9]
Natural pasture hay	878.6	869.9	41.75	741.8	512.1	76.5	8.04	5.01	5.31
Treated Tef Straw	764.8	748.3	115.50	644.2	454.3	49.8	7.03	4.12	4.31
Napier grass hay	856.9	837.7	92.50	626.5	450.6	83.1	7.26	4.23	3.42
Bracheria grass hay	822.7	817.9	135.90	564.2	362.6	44.6	8.03	5.55	4.14
Formulated Concentrate10	910.4	904.9	201.60	340.6	153.8	60.3	9.15	6.15	5.12
Treatment Diet (g/kg)									
NatuPH11	901.2	892.4	122.9	541.2	332.95	68.4	8.595	5.08	5.15
EMUTTS12	840.1	804.35	126.1	492.4	304.05	55.05	8.09	5.135	4.715
NapGH13	863.6	839.3	120.8	483.55	302.2	71.7	8.205	5.19	4.27
BraHGH14	866.5	827.9	129.9	452.4	258.2	52.45	8.59	5.85	4.63

[1]DM, dry matter (g/kg); [2]OM, organic matter; [3]CP, crude protein (g/kg); [4]NDF, neutral detergent factor (g/kg); [5]ADF, acid detergent factor (g/kg); [6]ADL, acid detergent lignin; [7]ME, metabolizable energy (Mcal /kg); [8]NEm, net energy for maintenance (Mcal /kg); [9]NEL, net energy for lactation (Mcal /kg); [10]Formulated concentrate, composed of maize grain (40%); noug seed cake (NSC, 49%); wheat Bran (8 %); iodized salt (1 %) and ruminant premix (2%); The ruminant premix was produced by INTRACO LTD, JORDAENSKAAI 24; 2000 ANTWERPEN, BELGIUM (https://intraco.be/en) having the additives per kg (Ca, 1310.5g; Na, 192.2g; Mg, 520.8g; Fe, 5000 mg; Co, 1500 mg; Mn, 5000 mg; Zn, 10000 mg; I, 150 mg; Se, 40 mg; Co, 150 mg; Vitamin A, 999750 IU; Vitamin D3, 199950 IU; Vitamin E, 800 mg; BHT, 50 mg; Ethoxyquin, 55 mg); [11]NatuPH, natural pasture hay; [12]EMUTTS, Effective microbe – urea molasses treated tef straw based TMR; [13]NapGH, Napier grass hay; [14]BraHGH, bracheria hybrid grass hay.

The planted forages were irrigated to allow continuous growth to harvest sufficient amount of forage hay. The cut forage was allowed to sun cure from 2-3 days in the field before storage for the feeding trial. The forage hay was bright green, fine stemmed, and mold free. The hay was chopped in to 2-5 cm to mix with the formulated concentrate in the TMR. Samples of each forage were oven-dried to a constant dry weight, ground to pass a 2-mm screen for chemical analysis.

Tef straw treated silage was prepared in plastic bag as describe by (Dejene et al., 2019). To prepare the solution: one liter of effective microbes (EM) solution, one kg of molasses, 2.5 kg of urea and 18 liters of chlorine free water in the ratio of 1:1:2.5:18 were mixed to treat 50 kg of tef straw. The treated tef straw was put in plastic bag and pressed by hand layer by layer to avoid air space and kept at room temperature that could facilitate the anaerobic fermentation for 21 days which is commonly recommended in Ethiopian condition (Alemu et al., 2020). Cows had individual and free access to drinking water throughout the entire experiment.

***Measurements and sample collection*:** Feed offered, and orts were recorded daily at each feeding time over the whole experimental period; TMR samples were collected and stored for laboratory analysis. Daily milk yield for all 8 cows were recorded at each milking time. Cows were hand milked twice daily (at 08:00 am and at 4:00 pm) throughout the experiment. Milk samples were collected in each period and transported in an ice box for milk composition analysis. Another pooled milk sample for each period was stored immediately at -20°C for determination of milk urea nitrogen (MUN) contents.

Spot urine samples were collected from all cows in a plastic container between days 15 and 21 of each experimental period and immediately stored at -20 °C for N and creatinine concentration determination. A sample of 100 ml was collected for every cow and 8 ml of an aqueous solution of sulphuric acid 10% (v/v) through which outflowing air was led to trap aerial ammonia and reduce urine pH (Castro-Montoya et al., 2019). Feces were collected from each cow from 15 to 21 days of each experimental period. Plasma samples were collected from the jugular veins of individual animals into 10-mL sodium heparin and potassium EDTA Vacutainers according to (Nichols et al., 2018) in 21 days of each experimental period. After each sampling point, collection tubes were immediately stored at 4°C. Rumen fluid samples were collected from each cow 4 h post feeding every morning using a rumen-fluid collector through esophageal gavage with manual sucker (syringe) (Steiner et al., 2014) on 21 day of each period of the Experiment. The samples were temporarily placed on ice and then processed for ammonia nitrogen (NH3-N). Body weight (BW) of dairy cows was measured by ground weight balance at the beginning, middle and end of each experimental period. The weight of cows was obtained by averaging two successive weighing's taken before supply of feed and after milking for two days.

Laboratory analyses and procedures: All feed and feces samples were dried in oven at 60°C for 48 h. The dried samples were ground to pass a 2-mm screen and stored in plastic bags for subsequent determination of chemical components. Dry matter (DM) and organic matter (OM) of the diets and feces were determined according to (AOAC, 2000). Nitrogen (N) concentrations were determined by the Kjeldahl method (AOAC, 2000) and the CP concentration was estimated by multiplying the N concentrations by 6.25. Neutral detergent fiber, acid detergent fiber and acid detergent lignin of feed and feces were determined according to the procedures of (Goering and Van Soest, 1970). Metabolizable energy (ME, MJ/kg DM) was estimated on the basis of 24-h gas production (ml) and CP content (g/kg DM) (Menke et al., 1979); $ME = 2.20 + 0.136 \times GP + 0{:}057 \times CP + 0.0029CP^2$ where GP is the 24-h gas volume (ml/0.2 g DM), CP in % and XA is ash as % DM of the feed. The estimated Net energy maintenance (NEm) and Net energy lactation (NEl) was calculated as per the following equation (NRC, 2001): NEm = ME (0.554 + 0.287ME/GE) and NEl = ME (0.4632 + 0.24ME/GE) where Metabolizable Energy (ME) was calculated from in vitro gas fermentation as the procedure describe in detail while Gross Energy (GE) of feed was determined using Bomb calorimetric. For the TMR, these were calculated from ration composition of roughage and concentrate ingredients. The in vitro gas production for the feed samples analysis was conducted at Shimane University Japan, in which the detail procedure was explained by (Mekuriaw et al., 2019).

Feed intake was determined between days 16 to 21 of each period by weighing feeds offered to animals and refusals as described in (Nichols et al., 2019). For the calculation of daily nutrient intakes (kg/d) = ([DM offered (kg/d) × % of nutrient in TMR] – [DM refused (kg/d) × % of nutrient in orts]) whereas as for nutrient digestibility = ([nutrient intake (kg/d) – fecal nutrient output (kg/d)]/nutrient intake) × 100 (De Seram et al., 2019). For milk composition analysis, pooled milk sample was prepared from the morning and afternoon milking to determine milk fat, protein and lactose using a Lacto scan milk analyzer (Milkotronic Ltd, Nova Zagora Bulgaria). The fat and protein-corrected milk production was calculated as (0.337 + 0.116 × milk fat % + 0.06 × milk protein %) × kg (De Koster et al., 2019). MUN concentrations (mmol/L) was performed by spectrophotometric enzymatic colorimetric methodology using commercially available kits from Fujifilm Wako in Japan (Urease-GIDH method, product code 410-55391 _ 418-55191, λ= 525nm).

Urinary creatinine concentrations (mg/dL) were determined using enzymatic colorimetric assays using UV-VIS spectrophotometer (HACH DR6000, DR 6000, Germany) using with commercial kit (Sarcosine Oxidase Method, product code 439-90901, λ= 515 nm). Total daily urine volume was estimated by dividing daily urinary creatinine excretions by the observed values of creatinine concentration of spot urine samples assuming a daily creatinine excretion of 0.197 ± 0.047 mmol/kg BW for lactating dairy cows (Jardstedt et al., 2017). Urine N was analyzed by Kjeldahl method (AOAC., 2000) using the same equipment for feed, feces and milk samples; hence, urinary N excretion was calculated by multiplying urine N by urine volume. Nitrogen excreted in milk was calculated using the equation: milk N (g/d) = milk CP concentration (g/kg) X milk yield (kg/d)/6.38 whereas nitrogen excreted in feces was as: fecal N (g/d) = CP in feces (g/kg) X DM fecal excretion (kg/d)/6.25 (Silva et al., 2018). Fecal output was estimated using chromium oxide as an external indicator according to (Kimura et al., 1957) and analyzed at the Laboratory of shimane university, Japan. Nitrogen balance was obtained by subtracting the values obtained for nitrogen in urine, feces and milk from the total nitrogen intake (Castro-Montoya et al., 2019).

Blood samples were pooled over sampling time points by cow & period and prepared after centrifugation of the plasma at 1000×*g* for 5 min at 23°C and the supernatant was transferred to identified plastic tubes and stored at -20 ºC until laboratory analysis. The plasma was analyzed for glucose, non-esterified fatty acid (NEFA), β-hydroxybutyrate (BHBA) and plasma urea nitrogen (PUN) analysis. These parameters were measured by enzymatic colorimetric assays using UV-VIS spectrophotometer with commercially available kits from Fujifilm Wako in Japan: for plasma glucose (Mutarotase-GOD method, product code 439-90901, λ= 455nm); NEFA (ACS-ACOD method, product code 279-75401, λ= 550nm); BHBA (Cyclic Enzyme method, product code 279-75401, λ= 405nm; PUN (Urease-GIDH method, product code 410-55391 _ 418-55191, λ= 340nm).

Rumen fluid samples was tested for pH immediately after collection using a portable pH meter and stored at −20°C for analysis of ruminal ammonia N. For ruminal fluid samples that were preserved with 1% H_2SO_4, the rumen fluid collected was centrifuged at 2000 x g for 15 minute and the resulting supernatant was analyzed for NH3-N concentration as described by (Smith and Murphy, 1993).

Enteric methane emission measurement: The enteric methane emissions of lactating dairy cows were calculated according to the intercontinental equations recommended by (Mutian et al., 2018): CH_4 production (g/day per cow) = 124 + 13.3 X Dry matter intake (DMI, kg/day). This equation was selected because it has a low root mean square prediction error (RMSPE) compared to other equations evaluated by the same authors [RMSPE= 17.5; Observations standard deviation ratio = 0.64; mean bias as a percentage of MSPE= 1.09; slope bias as a percentage of MSPE = 0.27; Concordance Correlation Coefficient= 0.73]. In addition, (Appuhamy et al., 2016) also evaluate performance of more than 40 empirical models in predicting enteric CH4 emissions and suggested that DM intake alone may be sufficient to achieve satisfactory prediction.

Statistical Analysis

For data on feed intake, digestibility, N balance, plasma metabolites, milk yield and milk composition were analyzed using the MIXED procedure of SAS (version 9.4; SAS Institute Inc., Cary, NC). The model is:

$$Y_{ijk} = \mu + T_i + P_j + C_k + (T_i \times P_j) + e_{ijk}$$

Where Y_{ijk} represents the observation on cow k given treatment i at period j;
T_i represents the fixed effect of the i^{th} diet treatment, i = 1, 2. . . nt;
P_j represents the fixed effect of the j^{th} period, j = 1, 2. . . np;
C_k represents the random effect of the k^{th} cow, k = 1, 2. . . nc,
TP_{ij} the interaction between the i^{th} treatment and j^{th} period and
ε_{ijk} is the random residual error.

The model contained treatment and period as fixed effects and cow as a random effect. Differences among the means were considered significant at the $P \leq 0.05$ level on the basis of the Tukey's test. In order to study the relationship between urea concentration in plasma, milk and rumen ammonia N; as well the methane emission with dry matter intake and milk yield, regressions were fitted using the pooled data of all dietary treatments.

Results

Feed intake and nutrient digestibility

Nutrient composition of feed ingredients and experimental treatment diets are listed in Table 1. There was a large variation particularly in dietary CP concentration (from 41.75 to 201.6 g/kg) and NDF (340.6 to 741.8 g/kg) which include a wide range of feed ingredients to formulate isonitrogenous diets to achieve the lactating dairy cow requirement. The nutrient intake and digestibility of lactating Fogera dairy cows fed different roughage based basal diets are presented in Table 2. Compared with control diet (NatuPH), cows consuming EMUTTS, NapGH and BraHGH diets had higher ($P = 0.012$) DMI by 1.50, 1.89 and 2.63 kg/day, respectively. Cows fed BraHGH diet has the highest DM, OM and CP intake and digestibility followed by NapGH and EMUTTS ($P < 0.05$; Table 2). The digestibility of CP tended to increase by 10.89%, 16.75% and 22.78% from NatuPH to EMUTTS, NapGH and BraHGH diets, respectively. This variation of digestibility may be related to dietary CP content of the feed ingredients. On the other hand, cows fed NatuPH diet had higher ($P = 0.031$) NDF intake but lower ($P = 0.027$) digestibility of NDF than other treatment diets.

Table 2. Feed intake and nutrient digestibility treatment diets feed to local Fogera dairy cows

Item	Dietary Treatments[1]				SEM[2]	P value
	NatuPH	EMUTTS	NapGH	BraHGH		
Intake (kg /day)						
DM[3]	6.21[c]	7.71[b]	8.1[b]	8.84[a]	0.56	0.012
OM4	5.59 c	6.63b	7.20 ab	8.02a	0.46	0.001
CP[5]	0.76[c]	0.97[b]	1.03[b]	1.14[a]	0.15	0.022
NDF[6]	4.30[a]	3.87[b]	2.62[c]	2.77[c]	0.29	0.031
ADF[7]	2.47	2.45	2.01	1.26	0.08	0.074
Intake8, g/kg BW0.75	0.10	0.12	0.14	0.15	0.01	0.082
Nutrient Digestibility (%)						
DM	64.2c	79.6 b	80.6b	87.7a	4.95	0.031
OM	58.9c	71.4 b	74.12ab	79.4a	4.35	<0.01
N	59.7c	76.2b	72.7b	83.3a	4.94	<0.01
NDF	48.1c	52.9b	54.2a	56.5a	1.77	0.027
ADF	47.7	49.1	50.5	53.4	1.22	0.612

[a–c] Means within a row with no common superscripts differ (P < 0.05).
[1]NatuPH , natural pasture hay; EMUTTS, Effective microbe – urea molasses treated tef straw; NapGH, Napier grass hay; BraHGH, bracheria hybrid grass hay; [2]SEM, standard error of means; [3]DM, dry matter (g/kg); [4]OM, organic matter; [5]CP, crude protein (g/kg); [6]NDF, neutral detergent factor (g/kg); [7]ADF, acid detergent factor (g/kg); [8] $BW^{0.75}$, metabolic body weight.

Nitrogen balance and utilization efficiency

The nitrogen intake increased by 61.78 %, 57.63% and 97.42% for EMUTTS, NapGH and BraHGH diets compared to the NatuPH diet, respectively (P<0.01; Table 3). Likewise, the same trend also observed for nitrogen retention that increased for cows fed EMUTTS, NapGH and BraHGH by 56.72%, 54.72% and 67.64% than NatuPH as basal diet nitrogen source (P<0.01). The milk nitrogen of the cows fed EMUTTS, NapGH and BraHGH increased (P = 0.023) by 6.76, 9.88 and 15.10 g/day over NatuPH diets, respectively. The urine N to fecal N ratios showed a tendency to decrease by 10.45%, 34.59% and 38.38% from NatuPH to EMUTTS, NapGH and BraHGH, respectively (P=0.015). Similar trend also observes for as urine N to intake N ratios by decreased 29.45%, 44.04% and 53.0% from NatuPH to EMUTTS, NapGH and BraHGH diets, respectively (P=0.045). This might be related to the high-quality protein sources of the dietary feed ingredients that contain the treated tef straw and improved forages. What is more, the milk nitrogen efficiency (MNE) increased for cows fed BraHGH by 9.1% as compared to NatuPH diet (P = 0.034).

Plasma metabolites and ruminal fermentation characteristics

The cows fed EMUTTS has highest plasma urea nitrogen concentration among the dietary treatments (P<0.01; Table 4). This might be related to the presence of urea in the treated tef straw. In contrast, lowest plasma glucose was recorded for EMUTTS treatment (P=0.014). This might be due to addition of urea and molasses to tef straw that lead to slows down of the absorption of glucose in the blood. Remarkably, cows fed NatuPH has higher (P ≤ 0.05) NEFA and BHB than other diets. The ruminal ammonia N was higher for cows feed NapGH than other diets (*P* = 0.013). Rumen pH was not affected by dietary treatments (P≥ 0.05). Ruminal ammonia N was positively correlated with plasma urea nitrogen (R^2 = 0.45) (Fig. 1b).

Table 3. Effect of dietary treatment on nitrogen balance and utilization of local Fogera dairy cows

Item	Dietary treatments[1]				SEM[2]	P value
	NatuPH	EMUTTS	NapGH	BraHGH		
Nitrogen balance, g/day						
N Intake, g/day	120.98[c]	195.59[b]	190.58[b]	238.68[a]	24.11	<0.01
N Fecal	42.81a	29.96c	33.06b	35.13b	4.52	0.012
N Urine	25.70b	29.33a	22.67c	23.83c	1.93	0.041
N Retention 3	39.68d	92.27b	87.64c	125.09a	17.48	0.025
Nitrogen utilization efficiency (NUE), g/g						
Retention N/ N Intake	0.33c	0.47b	0.46b	0.51a	0.05	<0.01
4MNE (%)	10b	10b	11b	13a	0.02	0.034

[a–d] Means within a row with no common superscripts differ (P < 0.05).
[1]NatuPH, natural pasture hay; EMUTTS, Effective microbe – urea molasses treated tef straw; NapGH, Napier grass hay; BraHGH, bracheria hybrid grass hay; [2]SEM, standard error of means; [3]N retention = N intake − N fecal − N urine − N milk; [4]MNE, milk N efficiency = (N milk/N intake) × 100 (Nichols et al., 2019).

Table 4. Plasma concentrations of metabolites and ruminal fermentation characteristics

Item (mmol/L)	Dietary treatments[1]				SEM[2]	P value
	NatuPH	EMUTTS	NapGH	BraHGH		
PUN[3]	2.96[b]	3.56[a]	2.76[b]	2.64[b]	0.23	<0.01
Plasma glucose	2.94b	2.55c	2.72b	3.77a	0.40	0.014
NEFA4	0.51a	0.36b	0.32b	0.30b	0.39	0.017
BHBA5	0.22a	0.05b	0.05b	0.04b	0.06	0.045
Ruminal ammonia N	2.29c	2.70b	3.25a	2.9b	0.21	0.013
Rumen pH	6.6	6.5	6.9	6.7	0.33	0.364

[a–d] Means within a row with no common superscripts differ (P < 0.05).
[1]NatuPH, natural pasture hay; EMUTTS, Effective microbe – urea molasses treated tef straw; NapGH, Napier grass hay; BraHGH, bracheria hybrid grass hay; [2]SEM, standard error of means; [3]PUN, Plasma urea nitrogen’ [4]NEFA, non-esterified fatty acids; [5]BHBA –beta hydroxybutyra.

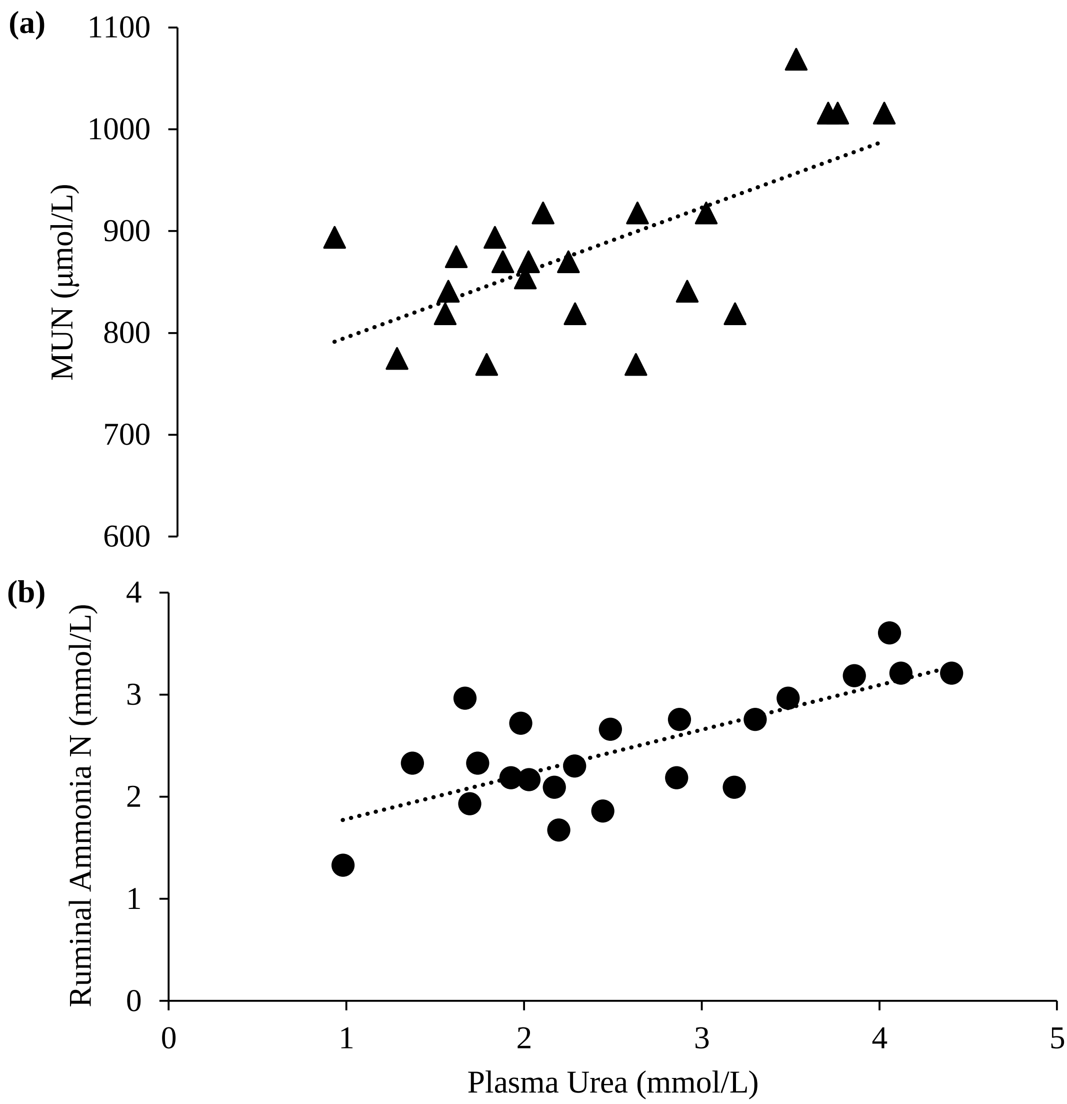


Figure 1. (a) Plasma urea nitrogen in relation to ruminal ammonia nitrogen (MUN = 57.507x Plasma urea nitrogen+ 734.86; R^2 = 0.45); (b) Plasma urea nitrogen in relation to ruminal ammonia N (Ruminal ammonia N = 0.438x Plasma urea nitrogen+ 1.3416; R^2 = 0.53)

Milk yield and composition

Compared to NatuPH diet, the cows fed EMUTTS, NapGH and BraHGH diets increased (P<0.01; Table 5) the daily milk yield 31.98%, 52.97% and 71.60%, respectively. Similar increasing trend also observed for FPCM among the dietary treatments (P<0.01). The concentration of milk fat (P = 0.158) and protein (P = 0.063) were not affected by dietary treatments. However, cows fed EMUTTS and NapGH diet increased milk lactose over other diets (P = 0.039). The concentration of MUN was increase in cows fed EMUTTS, compared with other diets (P=0.041). This could be related to the inclusion of urea in treated tef straw, which can contribute for MUN. Moreover, MUN was positively correlated with plasma urea N (R^2 = 0.53) (Fig. 1b). Compared with NatuPH, the efficiency of milk production increased for EMUTTS, NapGH and BraHGH diets (P = 0.032) by 6.13%, 25.94 and 23.55%, respectively.

Table 5. Milk yield, composition, and urea content of mid-lactation Fogera dairy cows

Item	Dietary treatments[1]				SEM[2]	P value
	NatuPH	EMUTTS	NapGH	BraHGH		
Yield						
Milk, kg/d	1.77[c]	2.34[b]	2.83[b]	3.3[a]	0.33	<0.01
FPCM[3], kg/d	1.98[c]	2.69[b]	2.91[b]	3.40[a]	0.38	<0.01
Composition (%)						
Fat	5.49	6.38	5.68	5.40	0.13	0.158
Protein	2.77	2.76	2.88	2.78	0.16	0.063
Lactose	4.18[c]	4.79[a]	4.59[ab]	4.21[b]	0.23	0.039
MUN (μmol/L)[4]	858.6[b]	975.6[a]	837.2[b]	879.5[b]	37.8	0.041
Efficiency[5]	0.28[b]	0.29[b]	0.35[a]	0.34[a]	0.02	0.032

[a–c] Means within a row with no common superscripts differ (P < 0.05).
[1]NatuPH, natural pasture hay; EMUTTS, Effective microbe – urea molasses treated tef straw; NapGH, Napier grass hay; BraHGH, bracheria hybrid grass hay; [2]SEM, standard error of means; [3]FPCM, fat and protein corrected milk = (0.337 + 0.116 × fat % + 0.06 × protein %) × milk yield (kg/d); [4]MUN = milk urea nitrogen; [5]Efficiency = milk yield (kg/d)/DMI (kg/d) (Nichols et al., 2019).

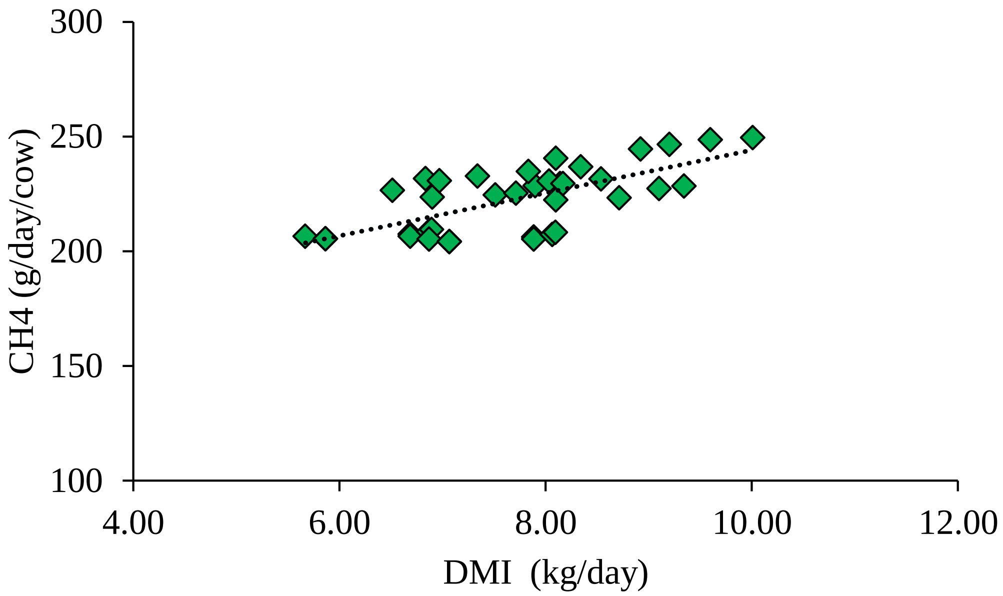
Enteric Methane emission

The CH_4 production increase (P<0.01; Table 6) with increasing the DMI for EMUTTS, NapGH and BraHGH over NatuPH by 19.95, 25.14 and 34.98 g/day/cow, respectively. Moreover, the DMI positively correlated (R^2 = 0.53) with CH_4 emitted from lactating dairy cows in pooled analysis data (Figure 2). In comparison with NatuPH diet, the CH_4/DM intake decreased (P=0.014) linearly with diets of EMUTTS, NapGH and BraHGH by 11.67%, 14.0% and 17.85%, respectively. This might be resulted due to the high totally digested nutrient variation among the dietary treatments. Similarly, the cows fed EMUTTS, NapGH and BraHGH diets produce less CH_4 per kg of total OM intake than NatuPH diet (P=0.032). Methane emission per unit of milk yield and FPCM (kg) was also lower for EMUTTS, NapGH and BraHGH than NatuPH diet (p<0.05). The CH_4 emitted per unit of DMI has negative linear correlations (R^2 = 0.76) with milk yield production across the dietary treatments (Figure 3). This also showed that the low methane production with higher milk yield from cows fed BraHGH than other diets.

Table 6. Effects of different treatment diets on methane emission by local Fogera dairy cows

Item	Dietary treatments[1]				SEM2	P value
	NatuPH	EMUTTS	NapGH	BraHGH		
CH4 (g/day) 3	206.6d	226.5c	231.73b	241.57a	7.66	<0.01
CH4/BW0.75, g/kg4	3.04	3.25	3.28	3.38	0.08	0.214
CH4/feed intake or milk yield (g/kg)						
CH4/DM Intake	33.30a	29.38b	28.61b	27.33b	1.44	0.014
CH4/OM Intake	36.90a	32.55b	32.17b	30.7b	1.28	0.032
CH4/Milk yield	116.5a	96.89b	79.5c	71.07c	9.09	<0.01
CH4/FPCM5	84.09a	69.60b	65.22b	38.07c	8.85	0.021

[1]NatuPH, natural pasture hay; EMUTTS, Effective microbe – urea molasses treated tef straw; NapGH, Napier grass hay; BraHGH, bracheria hybrid grass hay; [2]SEM, standard error of means; [3]CH_4, methane; [4]$BW^{0.75}$, metabolic body weight; [5]FPCM, fat protein corrected milk.



Figures 2. Relationship between daily dry matter intake (DMI) and CH_4 emissions (CH_4 = 9.3343xDMI + 150.66; R^2 = 0.53)

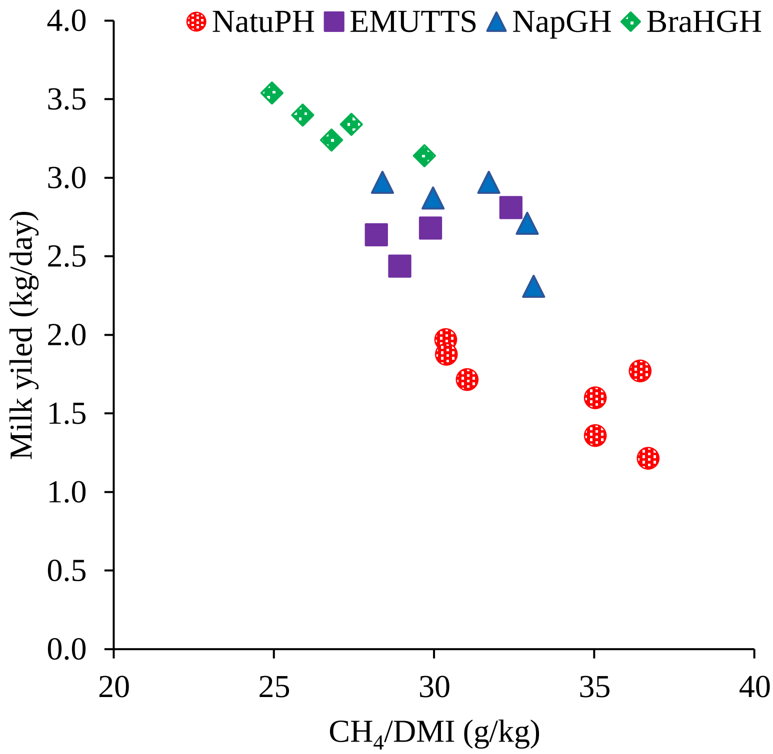


Figure 3. CH_4 emissions per dry matter intake (DMI) corresponding to daily milk yield; NatuPH, natural pasture hay; EMUTTS, Effective microbe – urea molasses treated tef straw; NapGH, Napier grass hay; BraHGH, bracheria hybrid grass hay.

Discussion

Feed intake and nutrient digestibility

In the present study, the natural pasture hay has the lowest CP value (41.75 g/kg) which is even below the recommendation for maintenance of lactating dairy cow (NRC, 2001). In contrast, the other feed ingredients can fulfill the maintenance and the lactation requirement exclusively Bracheria hybrid grass hay (135.9 g/Kg) and formulated concentrate (201.6 g/Kg) as the main nitrogen source (NRC, 2001). The CP content of the feed ingredients was in the range with the previous study for natural pasture hay (Mekuriaw and Asmare, 2018), Napier grass hay (Adnew et al., 2003) and Bracheria hybrid grass hay (Adnew et al., 2019). However, the CP contents of Bracheria hybrid grass has lower than Brachiaria brizantha cultivar (157.9 g/kg) reported by (Mutimura et al., 2015). This might be due to the variation in chemical composition of diverse brachiaria cultivars (Wassie et al., 2018).

The findings in this study provided insights supporting the use of improved forage (BraHGH and NapGH) and EMUTTS to increase feed intake and digestibility of nutrients as compare to the control diet (NatuPH). In this study, the DMI increased as CP content increased in the diet due to inclusion of EMUTTS, NapGH and BraHGH as a basal diet of the feed ingredients for nitrogen source. Similarly, (Mutimura et al., 2015) reported that the differences in DMI of Napier grass and Bracheria brizantha as sole diets is related to the effect of grasses. In this study, the improved grasses has the highest potential of nutrient digestibility; and yet BraHGH is supper than NapGH. In line with this, (Mutimura et al., 2015) reported that animals and farmers preferred Brachiaria to Napier grass for palatability and response of animal. Furthermore, NDF digestibility increased from NatuPH (48.1%) to BraHGH (56.5%). These differences in digestibility of forages probably altered diet retention time in the rumen, and are related to differences in lignin concentration of the forages (Christensen et al., 2015). (Sánchez et al., 2006) also reported that inclusion of improved forage in the diets affects the DMI through its influence on nutrient digestibility. Moreover, the higher intake of the EMUTTS than NatuPH could be the increased palatability due to urea molasses added to diet (Alemu et al., 2020).

Nitrogen excretion and utilization

In this study, the dietary treatments have effect on N intake and excretion in feces and urine, N balance, and the efficiency of N utilization for milk production (milk N g/g N intake). The remarkable finding of this study in feeding EMUTTS, NapGH and BraHGH hay resulted in changing the N excretion pathway from urine to feces, which can benefit the environment. Because urinary N is more volatile and harmful to the environment compared with fecal N as the urinary N is inorganic N and microbial ureases react easily and hydrolyzed rapidly to ammonium and then converted to ammonia which lead to N lose from the farm to the environment (Koenig and Beauchemin, 2018). In agreement with this result, the previous studies shown that dairy cows fed with fresh forage or hay shifted excretion of N from urine to feces towards sustainable dairy production (Koenig and Beauchemin, 2018).

In the present study, there is linearly decreasing urine N to fecal N ratio from NatuPH to EMUTTS, NapGH and BraHGH diets (Table 3), which indicated that using treated tef straw and improved forages as a basal diet reduce urine N excretion and indirectly mitigate ammonia emissions. In supporting this, (Ghelichkhan, et al., 2018) also reported that inclusion of quality forages in the diet reduce urinary N excretion in dairy cows. Furthermore, N balance was also vary among dietary treatments in which retained N in the body of the cows fed EMUTTS, NapGH and BraHGH was higher compared with NatuPH in increasing order. This indicates N utilization improvements in diets related with the high N intake and digestibility in these diets. Thus, the improved forages and treated tef straw used in this study as a basal diet increase protein utilization efficiency and reducing excreted N to the environment per kg of milk production.

Plasma metabolites and rumen fermentation

The plasma urea nitrogen (PUN) concentrations in this study (2.64 - 3.56 mmol/L) were found within the acceptable values between 2.6 and 7.0 mmol/L for lactating dairy cow (Morales et al., 2016). The lower PUN concentrations recorded in BraHGH and NapGH diets than NatuPH and EMUTTS which attributed to a better utilization of nitrogen in the rumen. Because PUN is corresponds to an end product of protein metabolism and used as a sensitive indicator of crude protein intake and ruminal protein synchrony (Kan and Meijer, 2007). The plasma glucose values in this study (2.55-3.77 mmol/L) is under the range of 2.5 - 4.2 mmol/L for lactation dairy cows and above the level (2.29 mmol/L) that cause hypoglycemia in early lactation cows (NRC, 2001). Besides, the highest plasma glucose concentration in cows fed BraHGH diet can be associated with increasing the DMI which in turn increases the availability of nutrients for ruminal fermentation, resulting in higher concentrations of propionic acid, which can be converted to glucose in the liver during gluconeogenesis (NRC, 2001). The plasma concentrations of NEFA and BHBA were found within the range for mid lactation daily cows proposed by (NRC, 2001; Ospina et al., 2013) except the higher value for cows fed NatuPH diet. The higher concentrations of NEFA (0.51 mmol/L) in NatuPH likely due to the lower DMI. In supporting this result, (Djoković et al., 2013) also reported that DMI was negatively correlated with NEFA and BHBA. The levels of NEFA above the thresholds (NEFA ≥0.5 mmol/L) association with negative energy balance and milk loss (NRC, 2001), this might be one of the reason for the low milk production of cows fed NatuPH in this study. Even though, the mid-lactating Fogera cows fed NatuPH have higher BHBA (0.22 mmol/L) in this study, it is below the threshold level for BHBA ≥1.2 mmol/L (Gruber and Mansfeld, 2019). Furthermore, (Djoković et al., 2013) also observed high concentrations of NEFA and BHBA in mid-lactation stage of dairy cows.

In the present study, the increase in ruminal ammonia nitrogen concentration is directly associated with the plasma concentration of urea observed (Figure 1b). In agreement with this, (Migliano et al., 2016) also reported the strong positive correlation between ruminal ammonia N and blood urea nitrogen. The use improved forages and treated tef straw as basal diet decreased ruminal ammonia N concentration (average 2.79 mmol/L in the current study) which suggests adequate for microbial growth (Prakash et al., 2013). In this study, the ruminal pH (6.32) is normal for lactating dairy cows fed roughage based diets. This might be due to the sufficient amount of dietary NDF concentration for all dietary treatments to maintain the optimal ruminal pH for cows fed high forage diets (Ghelichkhan, et al., 2018).

Milk yield and methane emission

In this study, the lowest milk yield recorded for cows fed NatuPH (1.77 kg/day) among the dietary treatments which might be due to the low dietary CP and DMI that probably cause reduction of milk yield. Even below this result, (Hussien et al., 2013) also reported 1.44 kg/day of milk yield for Fogera dairy cows fed natural hay as basal diet. On the other hand, the cows fed BraHGH increase the milk – yield almost in double as comparable to NatuPH diet. This indicates the promising of improved forages such as the new cultivar of Bracheria hybrid to increase the milk production of indigenous dairy cows. The concentration of MUN, which reflects inefficiency of N utilization (Doska et al., 2012) was higher in EMUTTS over other diets. This might be related to the addition of urea for the treatment that can increased MUN and associated with increased total N excretion.

In the present study the methane production per day per kilogram of DMI differed between diets. As enteric CH_4 emission represents the final production of ruminal fermentation via methanogenesis, it can be significantly affected by a range of factors including dietary components (Dong et al., 2019). The positive relationship between DMI (kg/d) and methane emission (g/d) is documented in the literature (Hammond et al., 2016) and observed in this study (Fig. 2) ($R^2 = 0.53$). The CH_4 emission result of this study is compared with earlier studies where cows usually produced less than 30 g/day of DMI (Brask et al., 2013) except for NatuPH diet. This may be related to variations of dietary components such high NDF content in NatuPH diet that can change the rumen fermentation environment and methanogenesis functions which subsequently affect the CH_4 emissions (Berhanu et al., 2019). F+ermentation of fibrous materials would favour the formation of acetate and butyrate, which would have positive impact on CH_4 emissions (Dong et al., 2019). In this study, the methane emission per kg of OM intake was lower for EMUTTS, NapGH and BraHGH diets over NatuPH, in which highly digestible roughages can be as promising for reducing CH_4 emission. Likewise, in this study, cows fed NapGH and BraHGH followed by EMUTTS, have significantly lower methane output per unit of daily milk yield compared with NatuPH diet. This indicates that improved forage species abs treated tef straw with high CP contents have a great potential to mitigate methane emission (Berhanu et al., 2019).

Conclusion

Among the dietary treatments, NatuPH diet has the lowest nutrient intake and digestibility. The cows fed EMUTTS, NapGH and BraHGH have higher milk yield compared to NatuPH diet. The cows feeding EMUTTS, NapGH and BraHGH hay resulted in changing the N excretion pathway from urine to feces, which can benefit the environment. The linearly decreasing urine N to fecal N ratio for EMUTTS, NapGH and BraHGH compared with NatuPH as a basal diet reduce urine N excretion and indirectly mitigate ammonia emissions that benefit the environment. Furthermore, N balance also vary among dietary treatments in which retained N in the body of the cows fed EMUTTS, NapGH and BraHGH was higher compared with NatuPH diet. Diet has also significant effect on methane emission in which cows fed EMUTTS, NapGH and BraHGH over NatuPH has less methane production per daily milk yield. In summary, feeding the improved forages and treated tef straw as a basal diet for lactating cows increase nutrient digestibility, milk yield and nitrogen utilization efficiency as well as reducing excreted N and methane emission to the environment which can improve the dairy production in tropical regions.

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On farm Evaluation of Ensiling Wet Brewery Spent Grain with Crop Residues: Silage Characteristics, Nutrient Composition, and Perceptions of Users

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Abstract

Wet brewery spent grain (WBSGs) is a by-product with huge potential as dairy feed. However, owing to its high moisture content, it deteriorates rapidly and preservation techniques, such as its with crop residues are needed. A study was undertaken in Hawassa-Shashmene cluster to (i) evaluate and demonstrate effect of ensiling WBSGs with teff straw or wheat straw on silage physical characteristics (PC) and nutrient composition, and (ii) assess perceptions of stakeholders on ensiled feed. The project involved different approaches like training of actors, ensiling WBSGs with either teff straw or wheat straw, and organization of field days. Silage was prepared in PICS sacks and plastic drums in the ratio of 80% WSBGs and 20% straw. The silage PC was evaluated; pH and temperatures recorded. Composite silage samples per each site were analyzed at BLESS laboratory for nutrient composition. Silage color was yellowish, and the smell was mild acidic. The average pH of the silage was close to 4 while the temperatures 20.6^{0}C (Hawassa) and 18.21^{0}C (Shashmene). Silage PC were not affected by type of container used to ensile them. Nutritive contents of WBSGs ensiled with teff straw were DM = 30.07±0.13%; CP = 22.23±5.52%, ash = 6.1±1.2%, CF= 27.49±5.52%, energy = 288.95±27. 73 kcal/100gm while that with wheat straw (DM=32.06±0.94%; CP=18.99±5.10%, ash = 12.83±1.09%, CF = 27.77±6.01%, energy = 261.05± 29.12kcal/100gm). The study revealed that it is possible to prolong shelf-life of WBSGs by ensiling with crop residues. Farmers and extension staff reported the technology to benefit them, and participants suggested improvement in distribution of WBSGs.

Key words: Silage temperature, Silage pH, crude protein, energy, prolong

Introduction

Ethiopia has diverse agro-ecologies suitable for production of different crops that can be used in brewery industries. There are 12 beer factories producing wet brewery spent grain (WBSG) and brewery spent yeast (BSY) which are the main by-products from breweries that can be used as animal feed (Amare, 2016). It was reported by Alvarez Aranguiz *et al*. (2019) that the breweries in Ethiopia can produce between 160,000 to 320,000 tons of WBSG residual and 20,000 to 28,000 tons of BSY. The WBSG produced can be enough to feed 60,000 cows with 10 kg per day throughout the year. With the desire of Ethiopia to plant more brewery factories soon and some on pipeline, the production of WBSG and BSY will undoubtedly increase making it the fastest growing commodity feed for livestock.

Wet brewery spent grain has been extensively studied for its use as an alternative animal feed ingredient globally. As indicated by Alvarez Aranguiz *et al*. (2019), the nutritional content of WSBG makes it an interesting ingredient for feed of dairy cows from global perspective. It is characterized by high protein content (averages 25% on DM), 50 to 60% of the CP by-passes the rumen without degradation, low content of lysine, and energy content of 8.8 to 10 MjME. Furthermore, a recent review by Emanuel (2021) revealed the brewers' spent grain being a chief by-product from barely beer brewing has been acknowledged as a high- quality source of animal feed because of its richness in nutritional composition, being generated in bulk, low cost and being environmentally friendly. Inclusion of 25 - 30 % (DM basis) of BSG in dairy cattle feed rations can improve palatability, digestibility and dry matter intake (DMI) which in turn influence the dairy performances such as milk yield, milk composition and body weight. Nevertheless, there are different challenges in using the WBSG as an animal feed. Because of its high moisture and high nutrient content, it can deteriorate rapidly (short shelf life) with risk of mycotoxins contamination.

Transporting WBSG will also be expensive because of its low bulk density (Mussatto *et al*., 2006; Getu *et al*., 2019). There is also a weak regulations and standards. The study by Alvarez Aranguiz *et al*. (2019) in Ethiopia revealed together with farm storage, the lack of knowledge in the WBSG and how to properly feed was recognized as major problem for 100% of the farmers in Ethiopia. In addition, the difficulties for good conservation and heating up of the product during storage and feeding out management are their major concerns of dairy farmers in Ethiopia. For instance, some farmers in the study cluster, Hawassa-Shashmene, abandoned purchasing of WBSG for their dairy cows because of rapid spoilage of the product and lack of technique on how to preserve it.

In addition to the above, hay and straws, which are the common feeds for dairy cattle in Ethiopia, are low quality and have low digestibility that clearly limits the total dry matter intake and productivity of the animals. These crop residues are widely and abundantly used in the feeding of dairy cattle in the Hawassa-Shashmene cluster, as it is without any treatment. To tackle some of the problems, ensiling WBSG alone or in combination with other feeds was suggested (Kindbom, 2012; Chanie and Fievez, 2017; Alvarez Aranguiz *et al*., 2019). Wet brewery spent grain can significantly help improve the nutrient balance of hay, straw diets and may have many other added advantages (Garcia and Kalscheur, 2004; Alvarez *et al*., 2019). However, there are no studies in Ethiopia in general and the Hawassa-Shashmene cluster in particular to evaluate/demonstrate the effect of ensiling WBSG with crop residues on physical characteristics, nutrient composition, and perceptions of dairy farmers and development partners regarding the ensiled wheat straw with WBSG and teff straw with WBSG.

The BRIDGE project (Building Rural Income through Inclusive Dairy Business Growth in Ethiopia) together with partners (Livestock offices, Adami Tulu agricultural research center, and Southern agricultural research institute) undertook action research to tackle the indicated problem. Thus, the objectives of the study were 1) to study the physical characteristics and nutrient composition of teff straw and wheat straw based WBSG silage; 2) to introduce the techniques of ensiling WBSGs with crop residues to farmers, development agents and other dairy stakeholders and; 3) to assess perceptions of dairy farmers, and extension staff regarding teff straw and wheat straw based WBSGs silages.

Materials and Methods

Area description

The study was undertaken in Hawassa area, and Shashmene district, Ethiopia (Figure 1). The choice of the two districts was based on their dairy potential in urban/peri-urban settings, their closeness to the Hawassa brewery industry (BGI) and the diverse crop residues used for feeding their dairy cows.

Hawassa is on the shores of Lake Hawassa in the great rift valley and has an area of about 15,720 hectares comprising more than 422,752 people. It is located 270 kms south of Addis Ababa, the capital of Ethiopia and at an altitude of 1,708 meters above sea level (masl). The average temperature ranges from 17^0C (July) to 23^0C (March) at Hawassa in 2020, the minimum temperature 11^0C (July and October) to 15^0C (February and March) and the maximum, 27^0C (February and March, December) to 21^0C (July and August). The annual rainfall in 2020 at Hawassa was 1017.69 mm. The farming system is characterized by crop livestock system. The crops grown surrounding Hawassa are maize, teff, haricot bean, wheat and barley (small extent). Cash crops like enset, coffee, ch'at (khat, *Catha edulis Forssk*. ex Endl.) are widely cultivated around the areas.

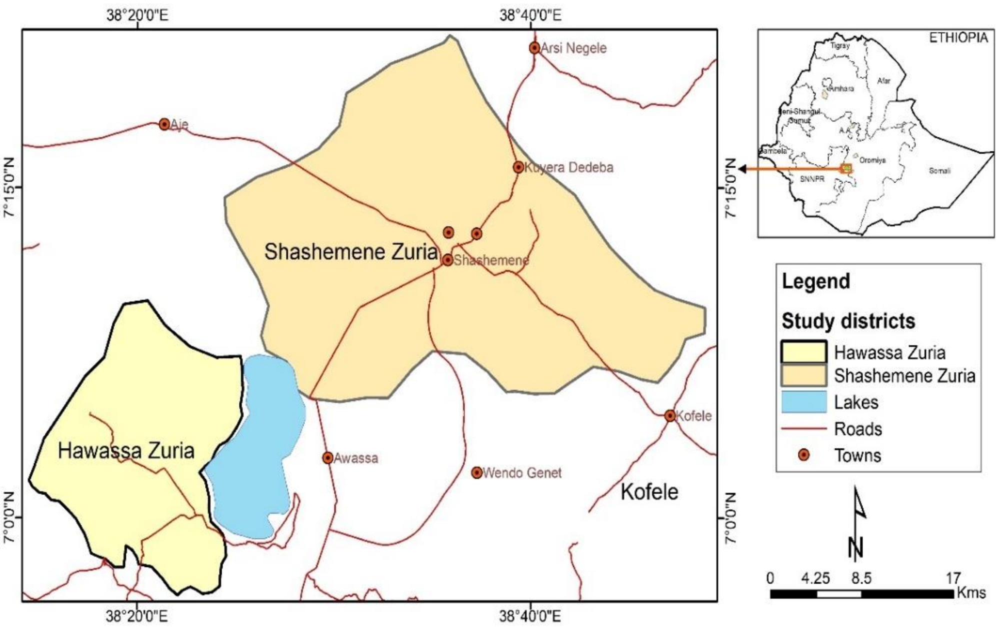

Figure 1: Location of the study areas

Shashmene, capital of west Arsi zone, Oromia Region, Ethiopia lies along the same route with that of Hawassa, about 253 kms, south-east of Addis Ababa. It has an area of 779 km^2 and lies within an altitude range of 500 to 1,700 masl and practice mixed crop-livestock production system where the main crops grown are potato, teff, maize, barley, millet, sorghum, wheat, and beans, while coffee is produced for cash (ShLDO, 2020). The district has a cattle population of 93,100 (79,786 indigenous; 13,314 crossbred); 25,974 sheep; 46,757 goats; 5,706 horses; 39 mules; 21,968 donkeys; 77,703 poultry, and 25,371 honeybee hives (ShLDO, 2020). The average temperature ranges from 17^0C (July) to 22^0C (March) during the study period of 2020, the minimum temperature 12^0C (August, October, November) to 16^0C (March) and the maximum, 25^0C (February and march) to 19^0C (July) (Table 1). The annual rainfall in 2020 for Shashmene was 1047.47 mm.

Table 1. Temperatures of Hawassa and Shashmene in 2020 (source = World weather online)

Month	Hawassa			Shashmene		
	Temperature (°C)					
	Maximum	Average	Minimum	Maximum	Average	Minimum
January	26	22	14	24	20	14
February	27	22	15	25	21	15
March	27	23	15	25	22	16
April	26	22	14	24	21	15
May	24	20	13	24	21	15
June	22	18	12	21	18	13
July	21	17	11	19	16	13
August	21	18	12	20	17	12
Septembe	22	19	12	21	18	13
October	24	20	11	22	18	12
November	26	21	12	23	19	12
December	27	21	12	24	20	13

Study procedures

Selection of Kebeles and farmers - The study kebeles and farmers in both districts were selected within the BRIDGE project implementing areas and they were selected by a team comprising district livestock experts, BRIDGE district officers, and researchers. The kebeles (lowest administrative unit within the government structure) selected for the study in both districts were urban and peri-urban areas which were close to the suppliers/distributors of WBSG. Accordingly, three kebeles from Hawassa areas (Dato = 4 farmers, Fara = 5 farmers, and Tula = 5 farmers) and two kebeles from Shashmene district (Bute Filicha= 7 farmers, and Karara Filicha = 7 farmers) were identified for the study. Farmers were selected using criteria among others which included farmers' disposition to participate in the action research, accessibility for transportation, and willingness to involve in the action research. Finally, twenty-eight farmers, fourteen in each district, were identified for the silage making study. The farmers at Hawassa area used teff straw to ensile the WBSG while those at Shashmene used what straw to ensile the WBSG. The farmers in both locations used plastic drum and PICS sacks for ensiling.

Training of farmers and other development partners - Following the selection of the farmers, discussions were undertaken regarding the research, and trainings were given to farmers and other value chain actors in both districts (35 in Shashmene, and 36 in Hawassa area). The training focused on feed resources treatment, utilization with reference to the proper preservation, and utilization of WBSGs and the ensiled feed.

Quick assessment - A quick assessment of the dairy feed resources, management, and conservation practices with focus on WBSGs was undertaken with the 28 farmers involved in the research using simple questionnaire and it was administered by the research team. The farmers were interviewed individually. Similarly, farmers were interviewed individually to get their response regarding the ensiling technology and the ensiled feed. Key informant interviews were also undertaken with six retailers and the wholesaler who have a contract with the company for purchasing and distributing the WBSG. The KII also involved development agents and experts (5 in Shashmene and 5 in Hawassa).

Feeds used in the study and the ensiling technique - The crop residues, teff straw, and wheat straw were from own source or purchased by farmers. Fresh WBSG was purchased from the Hawassa BGI brewery factory by the project. The WBSG was transported using Isuzu vehicle and shared to each farmer in PICS sacks (Purdue improved crop storage; double layered plastic sheet inside the sack). The WBSGs on arrival was hot, so it was allowed to cool for 24 hours before ensiling. For ensiling with crop residues, plastic drums owned by the farmers and PICS sacks purchased by the project were used.

The ensiling of WBSG with either teff straw or wheat straw was undertaken using the layer-by-layer ensiling technique (Alvarez Aranguiz *et al*., 2019) and the silage was prepared based on the ratio of 20% (crop residue): 80% (WBSG) on weight basis. In addition to the crop residues and WBSG, molasses (2 to 3 kg per 100 kg of the ensiled feed) diluted in water, and salt were the ingredients used in the silage making. Salt was sprayed on the top layer (3 kg of salt per m^3) to decrease aerobic activity and silage spoilage. Initially, the amount of feed materials that can be contained in each type of the ensiling container was determined followed by the calculation of the amount of each feed (crop residues and WBSG) based on the ratio indicated above on weight basis. Each feed type was weighed using a weighing scale and divided into ten parts with some more addition of the straw at the beginning of the bottom layer than in the other nine layers to absorb the moisture to be accumulated at the bottom layer (for instance 2 kg in the case of the pic sacks and 3.5 kg in the case of the plastic drums was put at the first bottom layer). The first bottom layer was filled with teff straw (Hawassa area) and wheat straw (Shashmene areas) while spraying/sprinkling molasses on the straw and properly compacting the straw to exclude air as the silage must be prepared under anaerobic conditions. On the second layer, WBSG was added while compacting to avoid the entrance of air. Again, straw was filled while spraying molasses, compacting, addition of WBSG, compacting, straw while sprinkling molasses and continued until all layers were properly filled. At the top of the layer, which basically was the WBSG, 1 to 2 cm salt was added. Before ensiling, the size of the straw was reduced to smaller sizes using hand chopper/bone chopper or otherwise trashed in usual way.

In the case of the plastic drum, plastic sheet was put on the top and tied properly with nylon rope and the top was covered with the lead properly. In the case of the pics sack, following the addition of salt, it was properly tied with nylon rope while excluding air from the sack. All containers were properly labeled (date of ensiling, the names of the ingredients used for ensiling and their ratio, name of the owner) and kept inside the house or under a shade to avoid direct contact with the sun and water with an ambient temperature. The containers were kept on raised materials from the floor like cemented floor, wood, or other suitable material to avoid the entrance of water and other materials from piercing the containers.

Physical characteristics and chemical composition of the ensiled feed

Physical characteristics of the silage - To assess the physical characteristics of the ensiled feed, different measurements were taken. For the measurement of pH values, pocket-sized pH meter with ATC wholesales (pH meter Hanna instruments; with Electrode, Range 0-14 pH±1 pH); made in China) was used. The pH meter was tested before use by using distilled water purchased from medical equipment and reagent suppliers as distilled water has a neutral pH of 7. It was also tested using drinking water, acid and alkali test powders prepared by the manufacturer. To make a pH measurement, the electrode is immersed into the sample solution until a steady reading was reached. The electrode is then rinsed using distilled water after each sample and kept in the bag designed for the purpose. Graduated thermometer was used to measure the temperature of the ensiled WSBG by inserting deep inside the ensiled material by waiting for 2 to 5 minutes until the reading be stable. The pH was measured 3 times/container/farmer while the temperature was also read 3 times/container type/farmer.

The silage color, smell/aroma, taste, and texture were inspected and subjectively evaluated under field condition by a team of researchers, extension staff, and farmers after training on the evaluation techniques. The measurement were recorded for each of the farmer per container type. Furthermore, the physical characteristics were also assessed by the participants of the field days at the two sites. The color was assessed visually. Regarding the smell, acidic or sweet-sour pleasant smell indicates good quality. On the other hand, if there is manure or putrid smell and it is so repugnant that one cannot put the silage near one's nose, the quality is poor. In addition, the smell/aroma of the silage was evaluated based on a scale of 0 to 4; where 0= very offensive; 1= offensive; 2= almost pleasant; 3= pleasant; 4= very pleasant. If the silage tastes sour and there is no problem in putting it in one's mouth, the quality is good. On the other hand, if the silage tastes bitter and one cannot put it in one's mouth, the quality is poor (Kumari, 2017). The. texture of the silage was assessed using a scale of 0 to 4 where 0 = slimy, 1= very soft; 2 = soft 3= fairly firm and 4= firm. (Ososanya and Olorunnisomo, 2015).

Nutritional composition of the silage - Samples of WBSG ensiled with teff straw or wheat straw were taken for determination of the nutrient composition immediately after opening and kept in plastic bags designed for sample taking. The samples were taken from at least 5 spots per container per farmer to avoid local variations interfering in the results and mixed to make representative sample.. Furthermore, the samples were taken 10 to 15 cm below the surface to ensure that the silages are not exposed to air. The samples were kept in a field refrigerator with an icebox until sampling for the day is completed. The fourteen farmers at each site were grouped in four (3, 3, 4 and 4). From each group, 1 composite sample was taken which made it four per site and in total eight samples were prepared for laboratory submission from both sites. The silage samples and the WBSGs were analyzed for DM, crude protein, crude fibre, energy and ash contents at Bless Agri-Food laboratory services PLC, Addis Ababa, Ethiopia using standard procedures.

Organization of action research field visit: As the technology of ensiling is new to the area and with the objectives of sharing the experience acquired regarding the ensiling processes and get feedback on the technology, an action research field days were organized at Hawassa and Shashmene. The participants were from west Arsi zone and Sidama Region livestock offices, livestock office heads from town agricultural offices, Shashmene, Arsi-Negale, Kofle, Hawassa, Tula, Wondogenet and Malga districts livestock offices. In addition, development agents and non-research farmers from the mentioned districts, research center directors from Hawassa and ATARC, livestock research director from SARI, extension researchers, livestock research program coordinator from Hawassa RC, a staff from Hawassa University, BRIDGE national extension advisor, BRIDGE staff from the cluster attended the field visit. Generally, about 78 (38 in Hawassa; 40 in Shashmene) people attended the AR field visits.

Data analyses - Perceptions of the farmers involved in the action research before the intervention and thereafter and their perceptions regarding the ensiled feeds (WBSG ensiled with teff straw or WBSG ensiled with wheat straw) was analyzed and the results presented using descriptive statistics (SPSS, version 20). The perceptions of the suppliers and extension staff was described qualitatively. Mean and standard deviations were calculated for temperature, pH and chemical composition of the ensiled feeds. The effect of container type on pH and temperature of the ensiled feeds at each site was analyzed using T-test (SPSS, version 20). Qualitative information regarding the study obtanined from farmers, extension staff and participants of the field days were summarised and interpretated while the video documentations were transcribed.

Results and Discussion

3.1. Types of dairy feeds, their sources, and prices

The types of dairy feeds used by the research farmers to feed their dairy cows in Hawassa and Shashmene districts and their sources are shown in Table 2. The major feeds at Hawsssa were teff straw, cereal and pulse residues, desho grass, concentrate mixture/formulated ration, wheat bran, oil seed cake, molasses, enset leaves and salt while at Shashmene teff straw, barely straw, wheat straw, wheat bran, linseed cake and salt were the major feeds used by the study households to feed their dairy cows. These feed resources are the common feeds fed to dairy animals in urban and peri-urban areas of Ethiopia (e.g., Yitaye *et al*., 2011; Belay and Geert, 2016; Kiros *et al*., 2018) except feeds which are specific to a given area (for instance enset/*Ensete ventricosum* in the Sidama area). Some of the variations in feed resources between the two areas is attributed to the resource endowment and availability in the areas. Generally, in both districts, the study households purchase commercial feeds. Regarding the roughage feeds, study farmers at Shashmene used their own and purchased sources while the study households at Hawassa mainly relay on purchased items, Desho grass (100%) owned and enset which was about 20% from their own farm. Depending on the resource basis, availability and accessibility, the use of own and purchased roughage sources is widely practices in urban and peri-urban areas of Ethiopia though the proportion varies from locality to locality (Admasu *et al*., 2019).

Table 2. Types of feed resources used for feeding dairy cattle in Hawassa and Shashmane areas by the study households

Feed type	Percent users (Yes response)		Source of feed (Hawassa) Percent			Source of feed (Shashmene) Percent		
	Hawassa	Shashmene	Own	Purchased	Both	Own	Purchased	Both
Grass hay	31.6	-	50	50				
Teff straw	100	100		100			6.3	93.8
Barely straw	0	100					12.5	87.5
Wheat straw		100					6.3	93.8
Grazing	5							
Cereal and pulse residues	100			100				
Desho grass	75		100					
Alfalfa	0							
Silage	0							
Concentrate mixture / formulated ration	100	18.8		100			100	
Wheat bran	100	100		100			100	
Linseed cake/noug cake	100	100		100			100	
Molasses	100			100				
Brewery spent grain	63	43		100			100	
Atella (local brewery)	0	12.5					50	50
Salt	100	100		100			100	
Other (enset leaves)	90		20	80				

Ration formulation

At Shashmene and Hawassa, none of the study farmers practiced proper ration formulation for feeding their animals. As indicated by the dairy farmers, they do not know how to formulate a ration. To a question asked if you do not formulate ration, then how do you feed you animals? The respondents indicated I feed by guess mixing available feed resources (93.75%) and I feed based on milk yield (6.25%). This lack of adequate practical knowledge in ration formulation forced the farmers either to overfeed or to under-feed their dairy cows which has implication on the performance of the animals and income of the farmers (Belay and Geert, 2016).

Use of WBSG, management, utilization and conservation practices

Of the study households in Shashmene, 43% used brewery spent grain as feed to dairy cows while at Hawassa 63.18% of the study farmers feed WBSGs to their dairy cows. Those who did not feed WBSG to their dairy animals reported the lack of awareness to be the main reason for not feeding this by-product. At Hawassa, the study households that did not feed WBSG as dairy feed indicated their main reason to be lack of access to the product (85.71%), and the lack of awareness and finance (14.29%). In both areas, the farmers who feed their dairy cows WBSG feed their animals in fresh and wet form. All the farmers at both sites reported that they had problems in the management and use of WBSG. The main challenges as indicated by the study farmers were perishability/stay short duration, supply problem, and storage facility problems which are also reported by Alvarez Aranguiz *et al*., 2019; Getu *et al*., (2019). The short shelf life of WBSG is a common problem (e.g., Kindbom, 2012; Alvarez Aranguiz *et al*., 2019). As witnessed by the study households, contacted retailers and the whole seller, because of the growing demand for the by-product from time to time, there is shortage of supply. To prolong the shelf life of the WBSG, farmers in the area commonly practice simply storing in plastic drums/metal barrels, draining the liquid part by turning upside down the sacks they use for storing. The farmers indicated that with these techniques, the feed can stay up to 10 to 15 days without spoilage. As indicated by all study farmers who use WBSG as dairy feed, the main challenge is the lack of knowhow on how to preserve the feed. The farmers also indicated that there are variations in the quality of the WBSG in relation to the time of year, it is better preserved during the rainy season compared to the dry season, which is attributed to the lower temperature in the wet season. For all most all farmers, the main factor responsible for deterioration in quality of brewery's grain is storage condition (temperature, moisture, and humidity). Hygienic conditions in the storage facilities is also indicated by few farmers as responsible for deterioration in the quality of the WBSG. In both locations, farmers use plastic/metal drums as storage facilities for WBSG in their farm. Different storage facilities including these ones were reported in different studies undertaken in Ethiopia (e.g., pits, plastic containers, etc., Alvarez Aranguiz *et al*., 2019). All farmers who used WBSG as a dairy feed encountered feed quality deteriorations regardless of the storage facilities and conservation practices. Smell, change in color, mold creation and sticky texture when handled were the major symptoms in WBSG quality deteriorations associated to storage conditions and/or facilities. The main hygiene and safety procedures that farmers follow is to avoid feeding beer grains in poor condition (selective feeding), avoiding the part of the grain in poor condition (moldy). Furthermore, maintaining hygienic conditions in the storage and feeding facilities and use conserved grain are some of the techniques used. For all the farmers that feed WBSG as a source of dairy feed, the local retailers are the suppliers of the WBSGs. The study farmers who feed WBSG to their dairy animals at Hawassa get the feed once every 15 days, while those at Shashmene once every 15 days (66.7%), and ones every week (33.3%) as they are the regular customers of the retailers. The price/quintal of BSGs in 2020 was 250 ETB (66.7%) and 300 ETB (33.3%) at Shashmene while it was 100 ETB per quintal at Hawassa (average price of 1 USD in 2020 = 34.9505 Ethiopian birr). As witnessed by the farmers, retailers and the whole sellers, the price of WBSGs fluctuates with season and increases steadily from time to time. For instance, the price of 100 kg WBSG increased by 63.9% as compared to the price in 2020 at Shashmene. The main factor affecting the price trend of WBSG is the availability and prices of other ingredients.

Views of the suppliers

The six key informant interviews (retailers; 3 from each of the site) started distributing WBSGs to farmers by working as brokers for large suppliers in the town. Currently, these retailers get the WBSGs from the wholesaler that contracted the by-product from the factory (e.g., Hawassa BGI, Hawassa and Shashmene retailers), from cooperatives organized around factory area (e.g., Mojo national brewery, retailers from Shashmene) or directly supply from factory when they bring the by-product from Addis Ababa (retailers in Shashmene). Depending on the quantity of brewery spent grain they get, they transport the WBSG using Sino or ISUZU truck, which depends on amount they supply. They transported from Hawassa, Mojo and Addis Ababa. Initially, they used to supply the WBSG directly by moving house to house/at each farm gate. Because of the increased demand for the by-product, they built a distributing station where the producers come and purchase. The WSBG is transported from its source to the distributing stations where it is filled into sacks and the producers purchase and transport to their home/farm. The frequency of their supply ranged from once in a week to twice in a week. As witnessed by the wholesalers at Hawassa, the demand for the by-product is increasing from time to time whereas the production in the factories is not increasing, In one trip, depending on the availability of the by-product, the retailers load 55 quintals in ISUZU and 180-200 quintals in Sino-truck. As they have agreement with the wholesaler/cooperatives/factories, they indicated that they can get supply consistently according to their schedule. The retailers indicated that there is a seasonal variation in the demand, supply and cost of the byproduct. The main reason for the variations depends on the availability and price of other feed options for the producers. Generally, the price was high during the dry season where the demand was high. Regarding any precaution retailers took while transporting and distributing, they indicated that they take precautions such as vehicle showering to avoid foreign materials, avoiding contamination with soil and other derbies during filling into the sacks and distributing for users immediately as soon as possible. Regarding the major problems they observe in the utilization and management of the WBGSs, the retailers and the wholesaler indicated three major problems which also partly consider the major problems of the end users. These are:

- Shortage of the product from the factory
- Working space and shade problem for storing until distribution
- Perishability of the product and lack of knowledge how to prolong the shelf life

As the business has different and complex market supply systems, a detailed distribution system study taking into consideration the different actors need to be undertaken.

Physical characteristics of the silage at opening

The initial plan to open the silage at both sites was at day 28 to 35 days of ensiling. Nevertheless, because of external challenge, it was opened on average days of 41 (37 to 45 days) at Hawassa and on average days of 48 (44 to 52 days) at Shashmene. The assessment of the physical characteristics of the silage is described below:

Color- The color of the ensiled feed was described as yellowish or that resembling the color of the brewery spent grain.

Smell/Aroma - The smell/Aroma of the ensiled WBSG with either teff straw or wheat straw was described as alcoholic/mild acidic or sweet-sour pleasant smell which revealed the good quality of the silage. The smell/aroma was rated as pleasant (Shashmene = 20%,' Hawassa = 25%) and very pleasant (Shahmene = 80% and Hawassa = 75%).

Taste: The ensiled feeds tasted sour and there was no problem in putting it in one's mouth at both sites.

Texture: At both sites, 85% of the accessors described the texture of the silage as firm while 15% rated as fairly firm.

pH and Temperature: At Hawassa, the mean pH value of the silage was 3.99 while it ranged from 3.8 to 4.3 for WBSG ensiled with teff straw. Similarly, the pH values at Shashmene ranged from 3.6 to 4.3 with a mean value of 4.02 for WBSG ensiled with wheat straw. According to recommendations, a pH reduced to approximately 4.0 to 4.5 is optimum for a good preservation (Kung and Shavers, 2001). Furthermore, according to Sahoo (2018), a good silage is friable, non-sticky and free from mold/ fungal growth and should have an acceptable and pleasant aroma (fruity odor) and mild acidic taste. It should have a pH < 4.5. Since none of the samples taken from each farmer rose above the critical value of 4.5, the silage was aerobically stable and acceptable to be used as dairy feeds.

The type of container used for ensiling (plastic drums and PICS sacks) the feeds did not have significant effect ($P>0.05$) on the pH of the ensiled feed (Shashmene, PICS sack = 3.93±0.05; plastic drum = 3.86 ± 0.21; Hawassa, PICS sack = 3.96 ± 0.17; plastic drum = 4.07 ± 0.10). This implies that the farmers can use either of the two containers for ensiling the feeds.

Regarding the temperatures of the silage, the mean value at Hawassa was 20.57±1.60^{0}C ranging from 18 to 22^{0}C while the mean value at Shashmene was 18.21±1.25 ^{0}C ranging from 16 to 20^{0}C. Looking at the temperature of the study areas, it can be said that the silage temperatures are reasonable enough to describe a good silage. It is known that high temperatures enhance mould and yeast activities, the stability of the temperature is of considerable importance (Dongxia *et al*., 2019). The silage temperatures reported in this study may not enhance mould and yeast activities. At both sites, no significant difference ($p>0.05$) was observed in silage temperature whether it was made in plastic drum (Hawassa = 20.14±1.86^{0}C; Shashmene = 18.00 ± 0.62^{0}C) or sacks (Hawassa = 21.00 ±1.29^{0}C; Shashmene = 18.43±0.79^{0}C). This might imply that the farmers have the possibility of using either of the two container types.

Chemical composition of the experimental feeds (WBSG, ensile SBG with crop residues and other feeds)

The chemical composition of WBSG ensiled with teff straw or wheat straw is shown in table 3. The average dry matter of WBSG and WBSG ensiled with teff straw or wheat straw is about 27.06, 30.07 and 32.06%, respectively. The average protein content (%) WBSG ensiled with teff or wheat straw and their energy values (11 to 13 MJ/kg) can make them suitable to be used as dairy feed. These chemical composition values are within the acceptable range suggested by Alvarez Aranguiz *et al*. (2019) for WBSG ensiled with crop residues. Generally, the ensiled feeds have good nutritional composition to be used as dairy feed.

Table 3. Chemical composition of WBSG ensiled with teff straw or wheat straw, WBSG and crop residues used

Type of feed	Dry matter (%)	Crude protein (%)	Ash (%)	Fibre (%)	Energy (kcal/100 gm)
Wet brewery spent grain (WBSG)	27.60±0.03	29.70±0.10	10.20±0.10	19.10±0.10	306.7 kcal/100 gm
Ensile WBSG with teff straw	30.07±0.13	22.34±5.52	6.10±1.16	27.49±5.52	288.95 ±27.73/ 100 gm
Ensiled WBSG with wheat straw	32.06±0.95	18.99±5.10	15.82±1.09	27.77±6.02	261.05 ±29.13/100 gm

- 1 kcal= 0.0041868; 1 MJ= 238.9 kcal, the proportion were 80 % WBSG and the 20 straw (either teff or wheat)

Perceptions of farmers, extension staff and participants of the action research field days regarding WBSG ensiled with teff straw or wheat straw

The study households were also interviewed about their perceptions of WBSG ensiled with teff straw or wheat straw. Farmers at both districts indicated they did not face any major problem in using the ensiled WSBG for their animals. All farmers at Hawassa rated the quality of the silage as excellent while at Shashmene 91% rated it as very good and 9% rated it as excellent. Farmers at Hawassa expressed the sign of quality deterioration of WBSG (before ensiling) by comparing with the quality of the ensiled WBSG with teff straw as the former (before ensiling) has a bad smell, color and moldy appearance. In the current ensiling process, they reported that as it has brown color, smell of kocho (Kocho is one of the food products generated from enset by spontaneous fermentation of decorticated and pulverized pseudo stem and corm sections) and mold free appearance while opening and during the whole period of feeding the animals. Regarding the silage making process, all farmers at both locations indicated that it will require labor (somehow challenging particularly the layer by layer doing the silage). The major issues raised were the silage making process requires experience and needs labor during preparation. Regarding the benefits they obtained from the intervention, the study households indicated as:

- We get knowledge and skill on WSBG silage making and its preservation techniques
- Acquired knowledge and skill on how to properly feed the available WBSG for their animals
- Improved utilization of the crop residues
- Increased milk yield and quality whereby increased family income from sale of milk

The overall suggestion of the farmers regarding the intervention was that it is a good approach where they obtained knowledge on the utilization and conservation of WBSG and such a technology has to be demonstrated to other dairy cattle producers. However, the supply and distribution system need further interventions. These views of the farmers were also supported by the participants of the field days and the extension staff.

Conclusion and recommendations

Conclusions

- The physical characteristics, nutrient contents, pH and temperature ranges showed the ensiled feeds to be suitable as dairy/livestock feed
- It is possible to prolong the shelf life of WBSG by ensiling with crop residues which can also improve the utilization of the crop residue as witnessed by the study farmers and other development partners
- Farmers and development partners are introduced with the ensiling techniques and the process involved to avoid the deterioration of WBSG
- It is possible to use plastic drum or PICS sacks for ensiling WBSG with crop residues

Recommendations:

- The dairy performance can be maintained or even improved when the spent grain is utilized within nutritional and feeding management guidelines which needs to be developed.

- Studying the current supply and distribution system of WBSG in the study areas
- Determination of volatile fatty acids and ammonia concentration of the ensiled feeds
- More research studies and surveys need to be done to generate data on epidemiology, exposure and health impacts on both animals and human beings
- The use of chopping facilities for the crop residues to speed up the ensiling process.

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