FEEDING AND MANAGEMENT STRATEGIES FOR RURAL POULTRY PRODUCTION IN CENTRAL TANZANIA

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DEDICATION

To the memory of my father AYUBU HAMISI KIKOBA and my mother ELIZABETH TUMBU

Feeding and Management Strategies for Rural Poultry Production in Central Tanzania

Abstract

The main objective of the present study was to develop feeding and management strategies that would help to increase the overall productivity of rural poultry production in Tanzania. The first study which aimed at analyzing the existing poultry production systems in developing countries with special reference to the village poultry production showed that the productivity of village chickens is generally low. The second study showed that scavengeable feed resources (SFR) play a critical role in the village poultry production systems. SFR such as cereal grains and their by-products, oil seeds and oil seed cakes were the most important scavengeable feed resources (SFR) during the dry season; whereas forage leaves, flowers, seeds, garden vegetables, insects and worms were the most important SFR during the wet season. Nevertheless, the availability of the SFR varied with seasonal conditions, farming activities, land size available for scavenging and the flock size. The third study showed that the amount and physical composition of the crop/gizzard contents varied between the seasons and farming systems. The chemical compositions of the crop contents showed a higher crude protein (10.1%) and ash (24.9%) in the rainy season and higher metabolizable energy (12.2 $MJ/kgDM^{-1}$) in the dry season. The study also showed that quantity and nutrient contents did not meet the birds' requirements. Studies four and five were carried out on-farm with growing chicks and their mother hens to evaluate the effect of protein and energy supplementation and management practices (i.e. weaning and laying) on growth and carcass yield of chicks and the performance of broody hens. Chicks and hens supplemented with either high protein or low energy diets showed a higher body weight gain and high egg output respectively, than non-supplemented chicks and hens. Chicks weaned at 4 and 8 weeks of age had shorter length of reproduction cycles which increased the laying performances of scavenging hens without compromising chicks' survival or growth rate. Similarly, hens supplemented with either high protein or low energy diets showed a higher body weight gain and high egg output than non-supplemented hens. Hens in Lay-hatch-rear group produced only about 30 eggs on average compared to the 53 eggs from the Lay-hat group and 73 eggs from the Lay group. It is concluded that the commonly observed low production performance of indigenous chickens is mainly due to inappropriate management conditions under which the birds are raised. Thus the productivity of indigenous hens under traditional management systems can be increased by supplementary feeding and relieving the hens from some aspects of the reproductive burden such as from brooding and rearing.

Keywords: Central Tanzania, rural poultry, scavengeable feed resources, nutrient composition, crop contents, season, farming system, chemical composition, supplementary feeding, weaning, egg production, growth rate, survival rate, laying management, indigenous chickens.

CONTENTS

Chapter 1

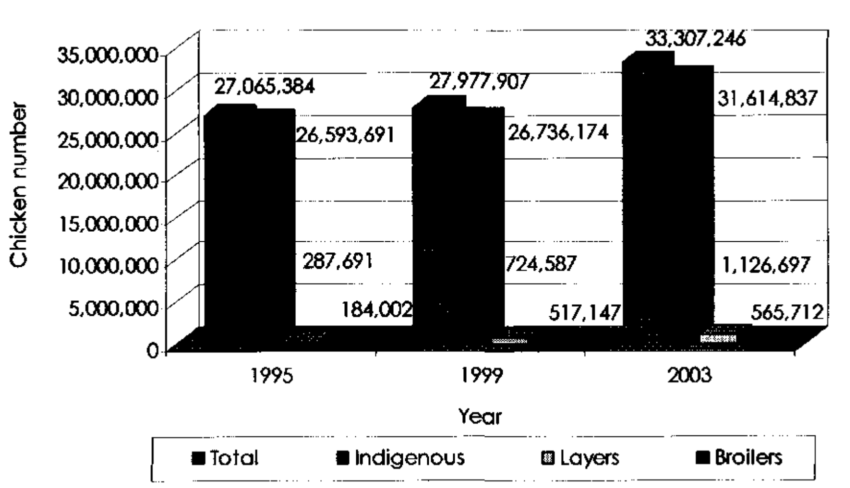
GENERAL INTRODUCTION

GENERAL INTRODUCTION

Poultry production in Tanzania

The poultry production industry in Tanzania like in other African countries can be divided into a traditional and commercial sector. The traditional sector is part of traditional small-scale farming where the majority of the so-called village poultry - in particular chickens - are raised under extensive management conditions. The commercial sector consists of small-scale to large-scale poultry enterprises under intensive management conditions. The layers and broilers are kept for egg and meat production, respectively. According to the Agriculture Sample Census (2003), the total poultry population in Tanzania is estimated at 33.3 million, where 31.6 million are indigenous poultry, 1.27 million are exotic layers and 0.57 million are broilers. From these statistics, the traditional poultry production system appears to be the largest sub-sector compared to the commercial poultry production system. Traditional poultry production is dominated by indigenous poultry species and plays an important contribution to household food security and income in Tanzania compared to commercial chickens. Chicken population trend in Mainland Tanzania indicate that numbers have increased at a moderate rate of 2.6% per year over the period of 1995 to 2003 (Figure 1). This increase in poultry population is generally low compared to the increase in local demand for poultry meat and eggs in the country.

Figure 1. Chicken population trend in mainland Tanzania



Commercial poultry production

Commercial poultry production in Tanzania dates back to 1937 when exotic breeds like Rhode Island Red, Light Sussex, White Leghorns, Brown Leghorns, and Black Australorps were introduced in the country. These pure-breeds were used in up-grading breeding programmes to increase protein supply to the local population by improving egg and meat potential of local chickens. From the 1960s onwards, poultry production on a commercial scale in Tanzania started with the import of hybrid chicks for egg and meat production (Boki, 2000). Initially, the government ran most of the production, processing and marketing of poultry under centralized economy. However, in early 1980s many private companies started keeping poultry as a commercial business. This was followed by liberalization of the commercial sector where production of day old chicks, parent stock, processing and marketing are being done by private sector while the government provide support in terms of policy formulation, research and extension, and regulatory services (Njombe, 2005). Thus nowadays this sector consists of small to medium scale and large scale intensive poultry production units with exotic breeds for both the broiler and layer sector.

Often, in small-scale intensive systems, flock sizes are between 50 and 1000 birds per household. This small-scale intensive system is particularly practiced by families living in peri-urban and urban areas because there are markets for both eggs and meat. Producers use the recommended standard practices such as appropriate housing, feeding, and health and disease control as recommended by the manufacturers. Poultry productivity at these farms is very similar to the large-scale commercial poultry units with production levels of 250-300 eggs hen^{-1} year^{-1} and growth rate of broilers of up to 50-55g day^{-1}. The intensive poultry production system in total is, however, much smaller than the traditional poultry production system. The intensive system is not well developed. The small size of the commercial sector is related to a poor quality of commercial feeds, diseases, veterinary expenses, unreliable supply of day-old chicks, and limited credit facilities (Boki, 2000; Minga *et al.*, 2000). As a result, commercial chicken meat and eggs are available only in the peri-urban and urban areas.

Traditional small-scale poultry production

Traditional small-scale poultry production in Tanzania is by far the largest poultry sub-sector and it supplies all poultry meat and eggs consumed in the rural areas (Boki, 2000). Poultry in this sector consists of various indigenous ecotypes of poultry species such as chickens, ducks, turkeys, geese, and guinea fowls. These poultry species account for about 95% of the total poultry population in Tanzania (Agriculture Sample Census, 2003). Indigenous chickens commonly known as rural chickens or village chickens are the most numerous poultry species, and are widely distributed over all agro-ecological zones in the country (Figure 2). It accounts for about 95% of total poultry in the traditional poultry sector (National Sample Census of Agriculture, 1995). Indigenous chickens vary widely in body size, conformation, plumage colour and other phenotypic characteristics (Msoffe *et al.*, 2001). Indigenous chickens are classified as dual purpose chickens, which produce low to moderate levels of both meat and eggs (Pedersen, 2002). In general, indigenous chickens are kept by small scale-holders under the free-range system or traditional village system and in the backyard system or semi-scavenging. Free-range system or traditional village system is the main type of poultry husbandry system practiced by the majority of the Tanzanians living in the rural areas. The village poultry production system in Tanzania is based on subsistence production using indigenous bird breeds. There is no recorded information about the time when indigenous birds were introduced in the country. However, it is believed that this low-input/low-output system has been a major component in smallholder farming communities for many centuries (Boki, 2000). The free-range system is considered as the only system of poultry production that can be afforded almost by all households, particularly by those living in rural areas of Tanzania. Village poultry plays a very important role in almost every rural household and in the livelihoods of rural farming communities. In addition to the provision of rural families with a high quality animal protein consumed at home in the form of eggs and meat, village poultry are kept for various purposes. These include income to meet family needs, gifts, manure, decoration and sports. Additionally, indigenous chickens play an important role in traditional medicine and can be bartered with food products to meet family needs. However, in spite of the social and economical importance of the free range system, few developments have been undertaken in Tanzania to improve the overall productivity of scavenging chickens. As an example, in the past, breeding programmes had been introduced to the villages to improve productivity of indigenous chickens by introducing exotic cocks (Kyomo and Kifaro, 2005). A majority of these programmes failed because the management skills that were needed for these crossbreds were not adopted by the rural people (Goromela, 2000).

Feeding system of village poultry

The scavenging system is the most dominant poultry production system under traditional management in the rural areas of Tanzania. This system has been characterized by inappropriate bird management practices with little or no inputs for housing. In addition, in this system there is only marginal feeding or health care. The chickens are left to search for their own food around the homesteads and in surrounding crop-fields during daytime. At night, they are kept in shelters or in the houses together with the household members for security reasons (Goromela *et al.*, 1999).

Sometimes the birds can roost in kitchens or in tree branches (Kitalyi, 1998). Scavenging chickens usually obtain their diets from scavengeable feed resources (SFR). SFR is thus the major nutritional input in a free range system and comprises an array of household materials and environmental feed materials. However, the amount and availability of SFR is not constant throughout the year (Cummings, 1992; Tadelle, 1996). The proportion of the SFR that comes from household materials varies with cropping patterns and consumption habits of the village households (Roberts, 1999). Other part of the SFR that comes from the environment varies with seasons, farming activities, life cycle of insects and other invertebrates (Roberts, 1995; Tadelle, 1996; Sonaiya, 2004).

At village level the SFR are estimated to provide more than 60% of the feed needed by chickens (Kitalyi, 1998). Seasonal fluctuations in the availability of SFR are a constraint to production of the village poultry. For example, in central Tanzania, grain supplements are usually available to the chickens during the dry season when farmers are harvesting sorghum, pearl millet, maize and groundnuts, and their availability decreases progressively towards the end of the dry season. It has been reported furthermore that, the absence of such local supplements in the diets of rural chickens resulted in a dramatic decline of egg production and growth rate of chicks (Goromela *et al.*, 1999). Besides seasonal fluctuations in feed supply, scavengeable feed resources in general have a low crude protein (8-10%) and energy (10-12 MJ AME/kg) content and low mineral levels (in particular calcium (0.5-1.2%) and phosphorus (0.5-0.7%)) (Goromela *et al.*, 2006). As a result, the supply of these nutrients from available SFR is limited and is below the requirements of the scavenging birds for optimal production (Tadelle, 1996; Mwalusanya *et al.*, 2002; Sonaiya, 2002). Studies in Ethiopia have indicated that energy is deficient in the diet of scavenging birds for most periods (dry, short rainy and long rainy) of the year and protein becomes inadequate in the dry season (Tadelle, 1996). Sonaiya (2002) after analysing feed resources for smallholder farmers concluded that for Nigeria, feed supply on the free-range and backyard system is not optimal. This means the scavenging birds can not get all the nutrients they need for production throughout the year. Under the present feeding system, which is based entirely on scavenging, the productivity of village chickens has remained very low. The system can only provide feeds that can meet maintenance requirements of the birds and marginal productivity as presented in Table 1. Limitations in terms of nutrient supply (protein, energy and minerals) from scavengeable feed resources are one of the major factors causing low productivity in scavenging chickens.

Improved feeding systems for scavenging birds have been suggested by various authors (Sonaiya, 1995; Tadelle, 1996; Huque and Mwalusanya *et al.*, 2001) as a way of achieving optimum production. Supplementation of village chickens with protein and energy supplements increase egg production, egg sizes, feed efficiency and reduce mortality rate (Huchzermeyer, 1973; Tadelle, 1996). Roberts (1992), after analysing SFR of local birds in different production systems in Sri Lanka and Indonesia, concluded that supplementation of birds according to age and production status can result in considerable improvement of egg production performance of local hens.

Table 1. Productivity of local chickens under scavenging conditions in Tanzania

Production parameter	Value
Mean carcass weight (kg)	0.6 -1.2
Mean egg output (hen^{-1} $year^{-1}$)	40 -60
Mean flock size per household	16
Mean eggs per clutch	12
Mean egg weight (g)	44
Hatchability (%)	84
Chick survival rate at 10 weeks of age (%)	60
Mean body weights for cocks (g)	1948
Mean live body weights for hens (g)	1348
Mean growth rates up to 10 weeks of age for male birds (g/day)	5.4
Mean growth rates up to 10 weeks of age for female birds (g/day)	4.6
The age at first lay (months)	6 -8
Mean laying cycles per year	3
Mean egg output per hen per year	36
Laying interval (months)	3-4

Source: Minga, 1998; Boki, 2000; Chiligati *et al.*, 1997; Mwalusanya *et al.*, 2001

Management of chicks and broody hens under village conditions

Under traditional or village management, chicks are usually hatched by means of natural incubation with broody hens sitting on clutches of eggs. The hatched chicks are then fed, protected from enemies, and raised by their mother hens until they are naturally weaned when they can look after themselves (Sazzad, 1993; Sarkar and Bell, 2006). This means that weaning of chicks i.e. separation of chicks from the broody hens at an early stage is not practiced under the traditional management system. It has been reported for Tanzania that a mother hen can take approximately three to four months to incubate, brood and rear her batch of chicks until they are naturally weaned (Chiligati *et al.*, 1995; Goromela *et al.*, 1999). The major reasons for not weaning chicks under the traditional management system are: (1) lack of alternative chick brooding management practices; (2) lack of appropriate infrastructure to care for the weaned chicks at an early stage of their life and (3) the high costs of special feeds for young chicks when weaned. As a result farmers have continued relying on broody hens to perform brooding and taking care of baby chicks which has consequently resulted into long reproductive cycles. Long reproductive cycles are a result of long brooding and rearing period of which a hen undertake until it naturally wean her baby chicks. The effect of long reproductive cycles on egg production has been studied in Indonesia (Prasetyo et al., 1985) and Bangladesh (Sazzad *et al.*, 1990). The results indicated that egg production of indigenous hens under the traditional village systems were 52 eggs per hen per year in Indonesia and 42 eggs per hen during 240 days in Bangladesh. After the hens were relieved from brooding and rearing young baby chicks by separating the chicks from their mother hens at an early stage; egg output increased from 52 eggs to 115 eggs per hen per year in Indonesia and from 42 eggs to 60 eggs per hen during 240 days in Bangladesh. These results clearly show that long reproductive cycles can potentially limit the laying performance of a hen and thus is one of the factors that cause low productivity in village poultry.

In addition to natural brooding and rearing of chicks (long reproductive cycles), lack of proper management of baby chicks after hatching is a problem. Under the traditional system it is often that after hatching, chicks walk together with their mother hens when scavenging. As a result these newly hatched chicks are therefore exposed to predators and diseases including harsh environmental conditions (cold, rain or hot). The consequence of this has been a high mortality rate of these chicks in early life (i.e. between hatching and end of brooding) which ranges between 40 to 80% at an age of 6 or 8 weeks (Minga *et al.*, 1989; Cumming, 1992; Wilson, *et al.*, 1987; Mwalusanya *et al.*, 2001) and a total mortality of 80% at the age of one year (Wilson *et al*, 1987). In such situations, chicks tend to compete for feeds with aggressive older chickens. Because of this competition they usually get malnourished and sometimes starve to death. Starvation due to nutrient deficiencies and insufficient feed resources has been reported to be the primary cause of high mortality in young chicks (Prawirokusomo, 1988; Ologhoho, 1992; Roberts and Senaratne, 1992). Moreover, when feed contains insufficient quantities of energy, protein, minerals and vitamins, growth in young chicks is impaired and in hens a drop in egg production occurs (Sonaiya and Swan, 2004). In Ethiopia, feed deficiency and malnutrition weakened the birds and made them more vulnerable to predators and to diseases (Tadelle and Ogle, 2000). Improving the nutrition and husbandry conditions of the baby chicks is essential in minimizing the reproductive losses (Cumming, 1992).

Constraints to village poultry production

The major constraints under village poultry production in developing countries are high mortalities, low egg production and a slow rate of growth. In recent years efforts have been placed on how these constraints can be minimized and also how the overall productivity of indigenous chickens can be improved (Pedersen, 2002). High chicken mortality rates of 40 to 80% have been recorded in local chickens in Tanzania and in other African countries (Smith, 1990; Tadelle, 1996; Kitalyi, 1998; Mwalusanya *et al.*, 2001). Diseases and predation are the major causes of the high losses of chickens (Goromela *et al*, 1999; Mwalusanya *et al.*, 2001). The major loss (40 to 50%) among the free ranging chickens occurs in chickens up to an age of 8 and 10 weeks mainly due to predators (Minga *et al.*, 1989; Mwalusanya *et al.*, 2001). They suggested that protection of chickens up to an age of 8 weeks can reduce losses due to predators but only when there is improvement in chicken housing and in feeding system. The other losses of growers and adult chickens are due to chicken diseases and theft. Chicken losses during adult-hood is mainly due to diseases especially Newcastle disease. Losses due to disease outbreaks can be substantial as the free ranging chickens are rarely if at all vaccinated against the disease (Minga *et al.*, 2000). In Tanzania, Newcastle disease has been singled out as the most devastating, whereby whole village flocks may be devastated. In central Tanzania, Newcastle Disease was reported to be the main constraint to chickens production in rural areas causing mortalities of 50% to 100% (Goromela *et al.*, 1999). According to Minga *et al.* (2000) the greatest loss due to Newcastle disease occurs during the hot and dry season starting from July up to the start of short rains in October to November. The other important infectious diseases which have been reported to affect free ranging birds in Tanzania include *Collibacillosis*, fowl pox, infectious coryza, fowl typhoid, and Gumboro disease (Minga *et al.*, 1986). Some other common diseases among free range poultry include fowl cholera (*Avian Pasteurellosis*), Pullorum (Bacillary white Diarrhoea) and *Salmonelosis* (Sonaiya and Swan, 2000). Apart from diseases, worms and ecto-parasites like fleas and mites have been reported to cause losses in free ranging poultry by Permin and Bisgaard (1999).

THE SCOPE OF THE STUDY

From this general introduction it is clear that village poultry production plays a critical role in the rural livelihoods of farming communities in Tanzania and in other developing countries. Despite its contribution to the rural economy, the development of traditional village poultry production in the country has been hampered. Major characteristics are a slow rate of growth and a low number in egg production of the indigenous birds. In addition there is a high mortality, especially in growers. Seasonal fluctuations in quantity and quality of SFR and deficient dietary circumstances of energy and protein supply in a free range system are the most important factors for the low growth and egg production. Long reproductive cycles due to incubation and brooding and rearing behaviour in the local chickens is another factor associated with low egg production under traditional poultry production system. Poor nutrition due to inadequate supply of nutrients (protein, energy and calcium and phosphorus) from scavengeable feed resources together with high prevalence of diseases and predators are the major cause of the low survival rates of indigenous chickens in Tanzania.

In order to maximize the potential of village chickens to meet the current high demand of poultry meat and eggs in the country, the present traditional poultry management systems must be improved. Various strategies to improve the productivity of scavenging chicken systems have been suggested by many authors (a. o., Smith, 1990; Roberts, 1999; Copland and Alders, 2005). These include improvement of the scavenged diets, the use of more productive birds, better management, disease control and the use of unconventional feeds. Improved feeding systems for scavenging birds have been suggested as a way forward for achieving optimum production in scavenging chickens (Huque and Hossain, 1991; Tadelle, 1996; Sonaiya, 1995). Supplementation of the rural chickens with protein and energy supplements has been reported to increase egg production, egg sizes, feed efficiency and reduced mortality rate (Huchzermeyer, 1973, Tadelle and Ogle, 1996). Roberts (1992) concluded after analysing SFR of local birds in different production systems in Sri Lanka and Indonesia that supplementation of birds according to age and production status could result in considerable improvement of egg production performance of local hens. However, improving the overall diet of scavenging chickens appears to be a problem (Smith, 2001). Firstly, it is not known exactly what feeds they are scavenging and what the birds are actually eating in the field. Secondly, it is also not known what nutrients should be provided as supplements to meet their requirements. Gunaratne (1999) suggested that knowing the capacity of the scavenging feed resource base and the seasonal variations are essential before efficient strategies for production of scavenging chickens can be developed. Therefore a proper estimation of the feed resource available, feed intake and nutrient utilization by the scavenging chickens is an important pre-requisite for improving feeding and management strategies in a free range system (Ajuyah, 1999).

Thus such information on scavengeable feed resources available for the village poultry in Tanzania are still scarce, and any improvement of these scavengeable feed resources could make an important contribution to the improvement of rural poultry productivity. The present thesis seeks to improve feeding system and management practices under traditional poultry management systems in the agro-pastoral farming systems of Central Tanzania.

The specific objectives of the study were:

1. To identify, characterise and quantify different and potential scavenging feed resources and study the constraints to the availability of these feed resources for rural poultry in the free-range system;
2. To determine the quantity and nutritional quality of scavengeable feed resources (SFR) by investigating the effect of SFR in interaction with management practices on the nutritional status and productivity (performance and carcass yield) of scavenging chickens;
3. To study the effects of supplementation of protein and energy resources and management strategies (weaning and laying management practices) on growth and carcass yield of growing chickens and egg production in the free-range system.

The overall objective of the present study was to develop feeding and management strategies that would help to increase the overall productivity of rural poultry production in Tanzania.

Each of these specific objectives had research questions as outlined below:

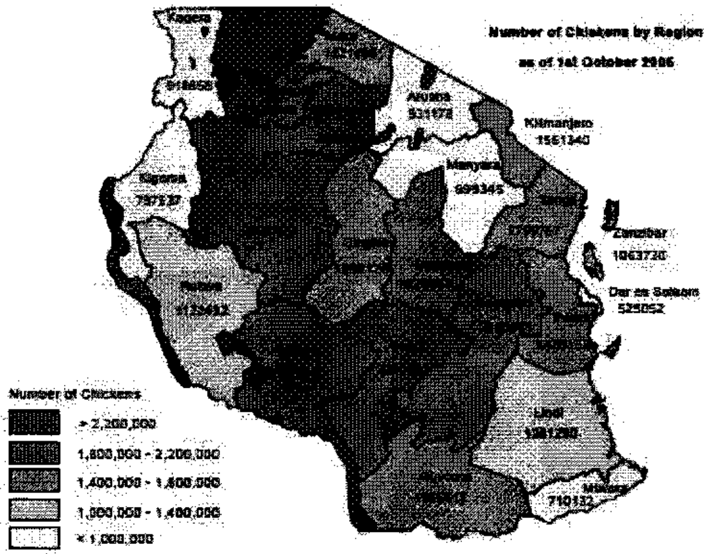
- Objective 1 (a) what feed resources and nutrients do rural poultry eat in various households and farming systems at different times (seasons) of the year? (b) What factors affect the quantity and quality of scavenging feed resources (SFR)? (c) How do these factors affect the availability of SFR? (d) Which interventions/strategies could be used to improve SFR availability and quality?
- Objective 2 (a) what are the requirements (energy, protein, mineral, etc.) of rural poultry? (b) How does a certain nutrient intake and quality from distinguishable SFRB, as well as management practices, affect growth, egg production and carcass yields of rural poultry at different times (seasons) of the year? (c) In which season of the year and in which farming system is a certain feed resource limiting?
- Objective 3 (a) which local feed resources can be used as protein and energy supplements to complement SFRB for scavenging chickens? (b) Are these feed resources (supplements) metabolizable? (c) To what extent does supplementation of protein and energy from locally available feed resources and improved management/strategies improve growth, egg production and carcass yields of scavenging chickens in a free-ranging system? (d) Is there any bias in the effect of a nutritional strategy (i.e., SFR and/or supplementation) on performance of rural chickens if a farmer prepares a certain management intervention (i.e., vaccination, housing, brooding and chick rearing period)?

Presentation of the study area

The field work for this thesis was carried out in Tanzania in East Africa. The country is located between latitudes 1° - 12° South and longitude 30° - 40° East (Figure 2). The country has a tropical savannah climate with two distinct seasons: the rainy and the dry season. Temperatures and rainfall are modified by altitude, with high elevations receiving more precipitation up to 2000mm per annum. About 90 percent of the country's landscapes are covered by savannah vegetation, mainly grasses, bushes, shrubs and widely scattered trees. The country is divided into seven agro-ecological zones namely: Central, Lake, Western, Eastern, Northern, Southern and Southern highlands zones. Human population has grown from 12.3 million in 1967 to 36.6 million in 2004 and projections show that by 2015 the population will be 49.3 million (FAOSTAT, 2003). Over 80 percent of the country's poor people live in the rural areas and rely on agriculture as their main source of income and livelihoods (MKUKUTA, 2005). Agriculture is the main contributor to the country's economy whereby the agriculture sector accounts for an average of 45 percent of the national Gross Domestic Product (GDP) with an average growth rate 4.8%; and constitutes for about 60 percent of the export earnings and employs about 80 percent of the workforce (MKUKUTA, 2005). The livestock industry contributes about 18 percent of the national GDP and about 30 percent of the agricultural GDP, and provides food which is consumed in the form of meat, milk and eggs (World Bank, 1994).

The study was largely conducted on-farm involving farmers with the aim to familiarize them with the feeding and management strategies to allow for future scaling up of the results. The study was conducted in Mpwapwa and Kongwa districts located in the Dodoma region in two farming systems that are representative for the agro-pastoral farming system zone of central Tanzania (Figure 2).

Figure 2. Map of Tanzania showing distribution of chickens by region and the research sites



OUTLINE OF THE THESIS

Despite the efforts that were undertaken in the past to improve the productivity of indigenous poultry in most developing countries, hitherto the real improvements of these indigenous breed have not realized under typical village conditions. The single-discipline approach used in the past to address the diverse and complex problems in the traditional poultry production seems to be the major impediment to the improvement of poultry productivity. The current thesis uses various approaches in attempt to improve the overall production efficiency of the traditional system in order to improve the livelihoods of rural faming communities in Central Tanzania. The results of a series of studies to form this thesis are reported in seven chapters as summarized below.

Chapter 1 gives background information which is basically a review of the poultry production systems, management of village poultry and constraints to the development of the traditional sector. It also presents the scope of the study which is the way forward of this review. Furthermore, it explains the overall objective and the specific objectives of the present study and research questions, study sites and the outline of this thesis. Chapter 2 describes various poultry production systems in developing countries in particular African countries. It explains the role, management system, productivity and the underlying constraints of the village production system. It presents an overview of the scavengeable feed resources (SFR) in this traditional poultry system and the role it plays as a major nutritional input in terms of quantity and nutritional quality, factors affecting its availability and highlighted strategies to optimize the use of SFR by small-scale farmers in the traditional poultry production. Chapter 3 explains participatory methods and local key informants in a study to identify existing and potential SFR for rural poultry in Central Tanzania. The study explores various SFR available at farm level and factors affecting availability of SFR in the study villages and possible interventions to their availability. Proximate analysis was used to analyze samples of selected SFR and the crop and gizzard contents of sacrificed scavenging chickens to quantify their feeding value. Moreover the "crop analysis method" was used to determine the intake of SFR whereas visual separation of crop and gizzard was used to give an overview of the physical composition of the diet consumed and proportions of each feed item in the total diets. Chapter 4 describes the effect of season and farming system on the quantity and quality of SFR and the performance of village chicken in Central Tanzania. The study aims to determine the actual feed intake of chickens in real scavenging conditions, food habits and preferences of chickens as indicated by their proportions in the total diet consumed and their chemical composition. This was done in order to provide an indication of the amount of supplementary feeds and nutrients required to meet the bird's requirements. The study was carried out in four villages and two farming systems in the rainy and dry season. The results of these previous studies formed the basis of Chapters 5 and 6. These chapters give the results of two *in vivo* experiments carried on-farm in the study villages. In these experiments supplementation with either protein or low energy diets in combination with weaning or laying management practices were studied to know their effect on growth, carcass yield in growing chickens and egg output in scavenging hens under village conditions in Central Tanzania. Chapter 7 presents the general discussions of the major findings drawn from the preceding chapters and it gives conclusion and recommendations of these results.

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CHAPTER 2

STRATEGIES TO OPTIMIZE THE USE OF SCAVENGEABLE FEED RESOURCE BASE BY SMALLHOLDERS IN TRADITIONAL POULTRY PRODUCTION SYSTEMS IN AFRICA: A REVIEW

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STRATEGIES TO OPTIMIZE THE USE OF SCAVENGEABLE FEED RESOURCE BASE BY SMALLHOLDERS IN TRADITIONAL POULTRY PRODUCTION SYSTEMS IN AFRICA: A REVIEW

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ABSTRACT

Traditional poultry production accounts for about 80% of the poultry population in Africa. Such poultry species are kept by smallholders, mostly in free-range and in backyard systems for food security, income and socio-cultural purposes. Flock productivity is low compared to high input systems due to sub-optimal management, lack of supplementary feeds, low genetic potential and diseases. The scavenging system provides most of the scavengeable feed resource base (SFRB) for rural poultry. However, the quantity and quality of SFRB for scavenging poultry varies with season, altitude, climatic conditions, farming activities as well as social, management and village flock biomass. In the present review, diets consumed by scavenging poultry indicates to contain on average low nutrient concentration of protein (100 g kg DM^{-1}), energy (11.2 MJ kg DM^{-1}) and minerals such as Ca (11.7 g kg DM^{-1}) and P (5 g kg DM^{-1}). This low concentration indicates that the amount of nutrients from SFR alone cannot support optimal growth and egg production of scavenging poultry. Thus such nutrients should be provided as supplementary feeds. Quantitative assessment of SFRB and nutrient concentrations could provide the best strategy to optimize the available SFRB for improving rural poultry productivity.

Key words: Traditional, rural poultry, free-range, backyard, scavenging, scavengeable feed resource, nutrient, composition

INTRODUCTION

In many developing countries, particularly Africa, poultry production in rural and peri-urban areas is based on traditional scavenging systems. It is estimated that about 80% of Africa's poultry population is found in traditional production systems (Guèye, 1998; Branckaert *et al*, 2000). These husbandry systems are characterized by a low input/low output production system and contribute significantly to household food security in developing countries (Branckaert *et al*, 2000). Traditionally, the scavenging system plays an important role in supplying local populations with additional income and high-quality food in the form of meat and eggs. Moreover, the production system is closely linked to the religious and socio-cultural lives of many farmers in developing countries (Kitalyi, 1998; Branckaert *et al.*, 2000). In traditional poultry production systems, different poultry species are kept and the most important being chickens, guinea fowls, ducks, pigeons, geese and turkeys. Productivity of these poultry species depends on the management systems adopted (Guèye, 2003) and increases with the level of improved feeding and management (Sonaiya *et al.*, 1999). In general under the scavenging systems whereby the low input/low output is the dominant husbandry system, several authors have acknowledged low productivity (Smith, 1990; Gunaratne *et al.*, 1993; Guèye, 1998; Kitalyi, 1998; Guèye, 2003); compared to high-input systems. The low productivity is caused by a number of factors, the most important being sub-optimal management, lack of supplementary feed, low genetic potential and diseases (Permin and Bisgaard, 1999). However, much of the low performance of poultry under scavenging systems has been attributed to poor SFRB (Roberts and Gunaratne, 1992; Tadelle and Ogle, 1996). Thus if SFRB is improved in the traditional poultry production systems, productivity of local birds can be increased. However SFRB are dependent on extrinsic factors such as seasonal variables, and levels of predation, health, scavenging behaviour, age, and physiological status of the scavenging birds (Gunaratne, 1999). This paper gives a review of the existing poultry production systems in particular African countries, the role of SFRB as a major nutritional input and the factors influencing its quantity and quality. The paper concludes by suggesting strategies that can be used to optimize the use of SFRB in traditional poultry production systems to maximize flock productivity.

Poultry Production Systems in Developing Countries

Generally four poultry production systems in developing countries can be distinguished (Bessei, 1987, Sonaiya *et al*, 1999, Branckaert and Guèye, 2000; Guèye, 2000a). These include the free-range system or traditional village system; the backyard or subsistence system; the semi-intensive system and the small-scale intensive system. These poultry management systems are also found in smallholder poultry sector in Africa (Kitalyi, 1998). Some important characteristics of these poultry production systems in Africa are summarized in Table 1. However; according to Guèye (1998), free-range system and the backyard system are the main types of poultry husbandry system practiced in the traditional poultry production in Africa. The free-range system is commonly practiced by the majority of the rural families. Flock sizes may vary from an average of 1-10 indigenous poultry per rural household. The birds are owned mostly by women and children for home consumption, small cash income, social and cultural activities. They are left to scavenge around the homesteads during daytime, feeding on household leftovers, waste products and environmental materials such as insects, worms, seeds and green forages. In addition, the birds are not regularly provided with water and other inputs such as supplementary feeds, houses, vaccination and medication. As a consequence, many birds die during pre-weaning periods due to starvation, diseases and predators. The level of productivity in terms of number of eggs produced (30-50 eggs hen^{-1} $year^{-1}$) and growth rate (5-10g day^{-1}) is very low compared to improved free-range or backyard systems. The backyard or semi-scavenging system is practiced by a moderate number of rural families. They keep about 5-50 birds, which mostly are owned by women and family members. In the backyard system, birds are semi-confined either within an enclosure made from local materials, overnight shelters or within a fenced yard (Sonaiya, 1999). Thus in this system, there is a regular provision of water, grains and household wastes, improved night shelters, vaccination and little medication to control diseases and parasites and to some extent exchange of cockerels between the farms. Because of better management, mortality is less and there is an increased egg production (50-150 eggs hen^{-1} $year^{-1}$) and growth rate (10-20g day^{-1}). Moreover, profitability is high and products are used for home consumption, family cash income and as a source of micro-credit. The semi-intensive system is a sub-system of the intensive system. In this system, poultry are kept in complete confinement, fed with formulated diets either bought commercially or produced from feed mills (Sonaiya, 1995; Aini, 1999). Sometimes they are fed with home-made rations by mixing various ingredients such as oyster shells, fishmeal, bone meal, blood meal, oil seed cakes, cereal grains, cereal by-products and kitchen wastes (Sonaiya, 1995; Kitalyi, 1998). In this system, flock size varies between 50 and 200 birds (Sonaiya, 1990, Kitalyi, 1998) and a domestic fowl hen produces between 80 and 160 eggs $year^{-1}$ (Sonaiya, 1990; Guèye, 2003). However, genetically improved breeds or dual-purpose breeds have been recommended as they are more efficient both in utilizing high-quality feeds provided by small-scale producers as well as economically than the indigenous breed (Roberts, 1999). The small-scale intensive or "small-scale confined" system is another sub-system of the intensive system. The system is based on specialized breeds of broiler and layer with a flock size ranging between 50 and 500 birds (Sonaiya *et al*, 1999). This husbandry system is practiced by few rural families particularly those living in peri-urban and urban areas where there are markets for eggs and meat and is owned mainly by business men. Producers use the recommended standard practices such as appropriate housing, feeding, health and disease control programmes. Poultry productivity is as high as that of large-scale commercial poultry with production of 250-300 eggs hen^{-1} $year^{-1}$ and growth rate of 50-55g day^{-1}(Sonaiya *et al*, 1999). However, according to Guèye (2000a) the choice of any of these production systems depends on the availability of resources and inputs needed for a particular production system. In poultry farming, feed is the most important input accounting for 60-70% of the total production costs (Smith, 1990; Gunaratne, 1999).

Table 1. Characteristics of major types of husbandry systems practiced in traditional poultry production systems in Africa

	Types of husbandry systems practiced			
Characteristics	Traditional free range	Backyard or subsistence	Semi-intensive	Small-scale intensive
Flock size	1-10 birds	10-50 birds	50-200 birds	50-500 birds
Key rearers	Majority of rural families	Moderate number of rural families	Few rural families	Urban families
Ownership	Mostly women & children	Mostly women and family	Middlemen	Business men
Type of breeds	Indigenous breeds	Indigenous and few crossbreds	Local/improved	Layers or broilers
Feed resources	Scavenging	Scavenging and supplementation	Commercial/local	Balanced diets
Health status	No vaccination/medication	Vaccination and little medication	Vaccination	Full vaccination
Housing system	No specific housing	Simple and small houses	Medium/improved	Big and improved
Egg production	30-50 eggs hen^{-1} $year^{-1}$	50-150 eggs hen^{-1} $year^{-1}$	80-160 eggs hen^{-1} $year^{-1}$	250-300 eggs hen^{-1} $year^{-1}$
Growth rate	5-10g day^{-1}	10-20g day^{-1}	10-20g day^{-1}	50-55g day^{-1}
Mortality rate	High mortality	Moderate mortality	Low mortality	Low mortality
Use of products	Home consumption	Home consumption and sale	Family income	Business income
Profit	Small cash income	Family income	Family income	Business income
Socio-economic	Social and cultural	Social and micro-credit	Credit based assets	little social

Source: Kitalyi (1998); Sonaiya *et al.* (1999); Guèye (2003) and Riise *et al.* (2004)

SFRB as a Major Nutritional Input in Traditional Poultry Production Systems

SFRB can simply be defined as those feed resources available at farm level that consists of household refuse and all the materials available in the immediate environment that the scavenging birds can use as feed. In Table 2, a range of SFRB and their physical components as given in various literature sources can be distinguished. More broadly, Sonaiya (2004) has defined SFRB as scavengeable feed resources which are the total sum of (1) household materials i.e. food left over, kitchen wastes, gardens, crop grains, orchards, and harvest residues (2) environment materials such as plant leaves and seeds, worms, insects, snails, slugs, stone grits and sand. Under normal conditions, the proportion of the SFRB supplied by household materials as determined by the crop contents of scavenging birds usually forms a greater part of the total SFRB consumed per day (Roberts, 1999). In Sri Lanka, Gunaratne *et al* (1993) found that 72% of the crop contents of the 15 hens slaughtered consisted of household materials and the remaining of the crop contents came from the environment. Similar observations have been reported by Sonaiya (2004) in Nigeria where the household refuse made up 64% of the crop content. This trend can also be seen in Table 3, where several authors (Tadelle, 1996; Mwalusanya *et al*, 2002; Rashid *et al*, 2004) have indicated the greater proportions of SFRB being supplied by household refuse. However, the size of the household materials in scavenging systems always varies depending on factors such as population density (Roberts 1999), food crops grown, their processing methods and decomposition due to climatic conditions (Kitalyi, 1998) and the number of scavenging animals which all may compete with rural poultry (Sonaiya, 2004). As a result, the supply of SFRB in scavenging systems in developing countries is not always constant (Cumming, 1992; Tadelle and Ogle, 1996).

Table 2. Types and physical components of scavengeable feed resources (SFRB) found in the crop and gizzard contents of eviscerated scavenging birds

Types of SFRB	Physical components	References
Household materials		
Grains	Paddy, rice, broken rice	Huque (1999); Mwalusanya *et al.* (2002)
	Maize and Wheat	Gunaratne *et al.* (1993); Rashid *et al.* (2004)
Bran and polishings	Rice bran, wheat bran and rice polishings	Huque (1999); Mwalusanya *et al.* (2002); Rashid *et al.* (2004, 2005)
Kitchen wastes	Cooked rice, cooked pulses,	Huque (1999); Mwalusanya *et al.* (2002
	egg shells, dried fish scraps, intestine and scales of fish, pulses, pieces of bread, vegetable trimmings, coconut residues	Gunaratne *et al.* (1993)
Environmental materials		
Seeds	Grasses and fruits	Tadelle (1996); Rashid *et al.* (2004, 2005)
Green forages	Green leaves of vegetables	Mwalusanya *et al.* (2002); Rashid *et al.* (2004, 2005)
	Grasses, plant materials	Gunaratne *et al.* (1992); Tadelle (1996)
Insects and worms	Small snails, earthworms	Huque (1999); Mwalusanya *et al.* (2002)
	Cockroaches, ants, flies	Rashid et al. (2004) Gunaratne et al. (1992)
Sand and grits	Sand and insoluble grits	Gunaratne *et al.* (1993); Rashid *et al.* (2004)
Miscellaneous materials		
	Feathers, hair, polythene, Piece of glass and paper- products and button	Rashid *et al.* (2004, 2005)
Unidentified materials		
	Various feed particles	Huque (1999); Rashid *et al.* (2004)

Factors Influencing the Quantity and Quality of SFRB

Season, altitude and climatic conditions

As it can be noted in Table 2, SFRB in the traditional scavenging systems consists of household refuse and environmental feed materials. During the rainy season there is an abundant supply of insects, worms and green forage materials while in the dry or harvesting season there is a high supply of cereal grains, cereal by-products and a low supply of green forage and insects/worms (Table 3). The amount of kitchen wastes as indicated in Table 3 appears to be small in the rainy season indicating that in this period there is less food available in most rural households compared with the dry period. In Tanzania, Mwalusanya *et al.* (2002) reported that during the wet season there are less amounts of grains and kitchen wastes with high amount of insects/worms and green forages. In Ethiopia, type of altitudes seems to have no difference on the availability of insects and worms but in high and medium altitudes there is a high amount of grains and forages with low amounts of kitchen wastes compared with low altitude (Tadelle, 1996). Moreover, observations show that not all materials that are part of the SFRB are available in each environment. This is apparently seen in some countries such as Ethiopia, Indonesia, Sri Lanka and Tanzania, where studies have shown that the amount of the available SFRB varies greatly with season, climate and location (Table 3). In addition, the SFRB could vary also with the type of birds due to their foraging behaviour and stage of growth. The proportion of the grains in the layers' crop contents was lower compared to that in growers' crop contents (Table 3). The higher proportion of green forages, insects/worms and kitchen wastes in the layer crop contents could be due to their selective feeding behaviour which depends upon nutritional requirements of a particular age group of chickens and production stage. Since laying hens have higher requirement of CP and Ca, they are more likely to pick up feedstuffs rich in protein and calcium compared to growers to support egg production (Rashid *et al.*, 2005). According to Sonaiya *et al.* (1999) most of the materials available for scavenging are not concentrated enough in terms of energy because they contain a lot of crude fibre. Thus a bird kept on free-range and backyard systems can certainly not find all the nutrients it needs for optimal production all the year round. These findings are in line with those of other authors (Huque *et al* 1994; Tadelle, 1996; Huque, 1999; Mwalusanya *et al.*, 2002; Rashid *et al.*, 2005) who observed that in different seasons, SFRB is critically deficient or unbalanced in nutrients. The chemical composition, as indicated in Table 4, of crop and gizzard contents of scavenging indigenous chickens and ducks in various countries contains on average low amounts of protein (100 g kg DM^{-1}), energy (11.2 MJ kg DM^{-1}) and minerals such as Ca (11.7 g kg DM^{-1}) and P (5 g kg DM^{-1}). The difference in chemical composition could be due to differences in climate which determine the type and availability of SFRB consumed by scavenging birds. The protein content of SFRB tends to fall considerably during the short rainy season and dry season which could be due to the comparatively lower population of insects and worms (Tadelle and Ogle, 1996; Mwalusanya *et al.*, 2002) which were of minor proportion in the diets of scavenging birds. Insects, snails, maggot larvae and earthworms are potential feedstuffs which have reasonably high protein content (Smith, 1990, Sonaiya *et al.*, 1999). Studies in Ethiopia have indicated that energy supply is deficient in the diet of scavenging birds for most of the periods throughout the year (Tadelle and Ogle ,1996) and the supply of energy is even more critically low in the dry periods (Tadelle (1996). The contents of minerals such as calcium and phosphorus in the crop and gizzard contents of SFRB are also very low in the dry season. This might have been contributed by a minor proportion of succulent green forages in the diet consumed by scavenging birds (Table 3).

Table 3. Physical composition of crop contents of chickens as summarised in relation to the season, climatic zone, altitude and type of bird

Factors	Physical components of crop contents (% fresh basis					References
	Bran	Grains	Green forages	Insects and worms	Kitchen wastes	
Wet season						
Short rains	-	37.5	22.5	17.4	22.6*	Tadelle (1996)
Short rains	11.5	13.5	33.7	17.9	23.4	Mwalusanya *et al.* (2002)
Long rains	-	25.9	31.8	18.9	23.4*	Tadelle (1996)
Long rains	19.3	37.4	22.6	7.6	13.1	Mwalusanya *et al.* (2002)
Dry season						
Dry period	-	29.5	27.7	17.2	25.6*	Tadelle (1996)
No harvesting	-	33.5	15.4	10.8	40.3	Rashid *et al.* (2004)
Harvesting	-	54.5	14.7	12.4	18.4	Rashid *et al.* (2004)
Climatic zone						
Warm wet	13.7	38.8	25.1	5.5	16.9	Mwalusanya *et al.* (2002)
Warm dry	13.1	41.5	20.6	4.7	20.1	Mwalusanya *et al.* (2002)
Cool wet	30.0	20.1	23.6	7.1	19.2	Mwalusanya *et al.* (2002)
Altitude						
High	-	33.2	28.2	17.8	20.8	
Medium	-	32.0	27.9	17.4	22.7*	Tadelle (1996)
Low	-	27.7	25.8	18.2	28.3*	Tadelle (1996)
Bird type						
Layers	19.3	38.2	23.1	5.8	13.6	Mwalusanya *et al.* (2002)
Layers	-	42.2	16.1	11.9	29.8	Rashid *et al.* (2004)
Growers	19.2	38.4	22.6	5.6	14.2	Mwalusanya *et al.* (2002
Growers	-	46.0	14.2	11.2	28.6	Rashid *et al.* (2004)

*Unidentified feed materials

Table 4. Chemical composition of crop and gizzard contents of scavenging indigenous chickens and ducks as influenced by season

Season	Chemical composition (g Kg DM^{-1})									References
	DM (g/kg)	CP	EE	CF	ASH	NFE	Ca	P	ME ($MJkgDM^{-1}$	
Short rains	541.0	87.0	23.0	103.0	55.0	732.0	7.0	5.0	13.1	Tadelle (1996)
Short rains	397.0	123.0	68.2	58.8	137.0	613.0	6.7	4.8	-	Mwalusanya *et al.* (2002)
Long rains	397.0	102.0	17.0	99.0	108.0	674.0	11.0	9.0	11.4	Tadelle (1996)
Long rains	437.0	85.7	54.1	57.7	114.0	688.0	6.5	2.4	-	Mwalusanya *et al.* (2002)
Rainy	-	79.0	14.9	90.9	113.0	581.0	38.7	4.1	-	Huque (1999)
Dry period	610.0	76.0	12.0	105.0	81.0	726.0	8.0	7.0	11.5	Tadelle (1996)
Harvesting	514.0	109.0	26.6	81.3	113.0	674.0	9.4	3.5	11.2	Rashid *et al.* (2005)
No harvest	443.0	102.0	14.9	47.1	137.0	700.0	9.7	3.9	11.8	Rashid *et al.* (2005)
Winter	-	87.4	14.3	99.0	99.0	571.0	28.5	4.7	-	Haque *et al.* (1994)
Winter	-	79.9	14.6	94.4	113.0	574.0	37.3	4.2	-	Huque (1999)
Summer	-	87.7	15.2	91.2	104.0	582.0	36.8	4.1	-	Huque (1999)

Flock biomass and managemental factors

Flock biomass is defined as the total liveweight or the number in the flock times the mean liveweight. Like other feed resources, the availability of SFRB can be determined by the total biomass of scavenging poultry that can be optimally supported by the available feed resources. Roberts (1995) has described this relationship between the availability of SFRB and village flock biomass using a model of the scavenging village chicken production system. The model of Roberts describes the village community in terms of families which discard household refuse and which then becomes available to the village chicken flock as SFRB. The remainder of the SFRB usually comes from the environment. In the absence of disease outbreaks or festival activities which diminish the flock, the biomass of the village flock which is the sum of the flocks of those families in the village which keep chickens, will remain at a level which can be supported by the available SFRB (Roberts, 1995). However, if the village flock biomass exceeds the carrying capacity of the SFRB, then there will be a strong competition pressure among chickens of different sexes and ages on the available household refuse and environmental feed. Under this competition, chicks and growers - because they are the weakest members of the village flock - can not compete with adult chickens for SFRB. In Nigeria, Sonaiya *et al* (2002b) found that the quantity of SFRB available for a chick was 0.996 kg year^{-1} whereas a hen had 11.04kg year^{-1} under a communal disposal of SFRB in six villages of south-western Nigeria. This small quantity of SFRB that was available to the chicks demonstrates that there is likelihood that both chicks and growers consume less amount of SFRB with low quality. As can be noted in Table 5, chicks and growers at this stage of development require more nutrients, in terms of energy, protein and minerals, than other members of the poultry flock. This low concentration of energy, protein and minerals in the SFRB is inadequate to support growth of chicks and growers. As the result, chicks and growers grow slowly and the weaker birds may die due to starvation when there is strong competition for SFRB (Roberts, 1999). Thus, growth and survival of chicks and growers can be greatly improved if they are given preferential access to household refuse supplemented with energy, protein and mineral sources by smallholders.

Table 5. Recommended nutrient levels per bird type for commercial and village chickens in comparison with the nutrients supplied by SFRB in various villages of developing countries

Flock class and bird type	ME ($MJ\ kg\ DM^{-1}$)	Nutrient levels ($g\ kg\ DM^{-1}$)			References
		CP	Ca	P	
White egg layers (6-12 weeks)	11.9	160	8.0	3.5	NRC (1994)
Brown egg layer (6-12 weeks)	11.7	150	8.0	3.5	NRC (1994)
Broilers (3-6 weeks)	13.4	200	9.0	3.5	NRC (1994)
White egg layers	12.1	150	32.5	2.5	NRC (1994)
Brown egg layers	12.1	165	36.0	2.7	NRC (1994)
Nutrient from SFRB of a village	9.6	94	-	-	Roberts (1999)
Nutrient from SFRB of a village	12.0	88	9.0	6.0	Tadelle (1996)
Nutrient from SFRB of a village	10.7	82	33.8	5.7	Ukil (1992)
Nutrient from SFRB of a village	9.5	94	8.0	9.0	Gunaratne *et al.* (1993
Nutrient from SFRB of a village	-	104	6.5	3.6	Mwalusanya *et al.* (2002)

Social and bird behavioural factors

The availability of SFRB provided by household refuse is directly related to the density of housing (Roberts, 1999). This means that in areas where the density of housing is high there is an abundant supply of house refuse provided that most of the village families do not keep large numbers of poultry. However, if the village families keep large number of poultry, this would lead to a competition pressure for the household refusal and the poultry will have a limited land area for scavenging. The land area available for scavenging and distance a flock can travel to scavenge will depend on many factors such as flock size, feed availability, population density, agricultural activities and predators (Gunaratne, 1999). In some areas, social factors such as rapid urbanisation, development projects and environmental changes are causing restrictions on the availability and accessibility of the SFRB (Roberts, 1999). In Tanzania, the last few decades most post harvesting activities such as threshing; winnowing, pounding and milling were carried out at the homesteads. This situation allowed for more access of scavenging feed resource base to the rural poultry. However due to villagization programme, some farmers are living in the villages or towns far away from the crop fields and most of post-harvest activities are carried out there or some processes such as milling of cereal grains are carried out by machines where some of the cereal by-products go to other livestock production systems. In addition, bird behaviour also determines the availability of SFRB. A participatory study in central Tanzania shows that some indigenous chickens have better scavenging ability compared to their counterpart crossbreds (Goromela *et al.*, 1999). Similar findings have been reported by Gunaratne (1999) in behavioural studies in Sri Lanka where crossbred chickens released for scavenging environment tended to restrict their scavenging area close to the household compounds.

Strategies to Optimize Available SFRB in Traditional Poultry Production Systems

Determination of SFRB available for scavenging birds

The first attempt to determine quantity of SFRB in the free-range system was done in south-east Asia by Roberts (1992) and Roberts and Gunaratne (1993). This method requires weighing the amount of household refuse from each family per day for a specific period of time and the proportion of the household leftovers determined from the crop content of a bird slaughtered after scavenging. However for precise estimates of SFRB, each family should have access to the household refuse and environmental feed. This approach helps to determine the quantity of SFRB required by each family flock per unit time. The contribution of household refuse and environmental feed to the total SFRB can easily be determined by examining the feed components in the chickens' crops at different times of the day. This estimate however, does not show the proportion of the SFRB available to each individual bird category in the family flock (Sonaiya 2002a). Because of the variations within the family flocks due to age-group and sex; and because of competition for the SFRB in a communal scavenging condition, estimation of the SFRB on the basis of bird category such as cocks, hens, growers and chicks is more appropriate (Sonaiya *et al.*, 2002a). In this case, any differential access to the SFRB by chicks, growers, hens and cocks in the family flock can be easily assessed. Thus Sonaiya *et al.* (2002a) have proposed the concept of using "bird unit" by modifying the formula developed by Roberts (1992) and Roberts and Gunaratne (1993). According to Sonaiya *et al.* (2002a), the advantage of the "bird unit" method is that it shows the difference in the quantity of SFRB available for each bird category in a family flock. Using this method, Sonaiya (2002b) found that the quantity of SFRB that was available to a cock was 43.7g day^{-1} while a hen and the chick had access to 34.98 and 2.19g day^{-1}, respectively. This estimate shows that the quantity of SFRB available to a chick was very low and the results suggest that the chicks should be given supplementary feeds over a certain period of time in order to reduce losses that may occur due to starvation. Under scavenging conditions, starvation has been reported as one of the main causes of mortality rates in village chicks and growers in Africa and south-east Asia (Ologhoho, 1992; Roberts and Senaratne, 1992; Wickramaratne *et al.*, 1993). In South-east Asia, chicks and growers which died had lower growth rates than the average chick in their groups had (Wickramaratne *et al.*, 1993). This could be due to the fact that the amounts of nutrients supplied by the SFRB are generally too low for optimal growth of chicks and growers. Thus the low survival rates of chicks and growers reported in Africa and south-east Asia during a pre-weaning period could be greatly improved by providing them with small amounts of supplements.

Determination of nutritional value of SFRB

Determination of nutritional values of SFRB might help to develop appropriate feeding and management strategies for optimal performance of scavenging poultry. The nutritional values of SFRB as shown by the chemical composition of the crop and gizzard contents from scavenging birds in Table 6 demonstrate the presence of some variations. These variations in chemical composition might have a direct relationship with the differences in physical quantities and nutritional quality of SFRB consumed by scavenging birds from various environments (Table 3). The proximate analysis of the crop and gizzard contents of the sacrificed scavenging chickens indicates protein contents of the feed consumed ranged between 82 and 117 g kg DM^{-1} (Table 6). This indicates that the availability of protein was a constraint on poultry production in these countries. According to NRC (1994), the recommended levels of protein in growing chicken ranges from 150-200 g kg DM^{-1} and in mature chicken from 100-160 g kg DM^{-1} for commercial birds (Table 5). Protein rich materials such as earthworms, snails, insects and young plant shoots can be used to correct the protein imbalance observed in these countries (Table 6). The crude fibre content in the scavenged feed was very high in almost all countries ranging between 54 and 102 g kg DM^{-1}. Fibre fraction is known to have cellulose, lignin and hemicelluloses that can not be digested efficiently by monogastric endogenous enzymes. The higher fibre content observed in the crop and gizzard feed might have a significant effect on the feed digestibility and nutrient intake in scavenging chickens. Moreover, the energy contents from the SFRB were generally low ranging between 9.5 and 12.0 ME (MJ kg DM^{-1}) than the recommended levels of between 11.7 and 13.4 ME (MJ kg DM^{-1}) for optimum growth of growers and 12.1 ME (MJ kg DM^{-1}) for high egg production in layers (Table 5). The mineral contents such as calcium and phosphorus in the scavengeable feed resources were also low compared to the recommended levels of these minerals for growers and laying hens (Table 5). These results indicate that there is a high chance of an imbalance of calcium: phosphorus ratio in the diets consumed by scavenging birds. The recommended optimal ratio of these two mineral elements in poultry is within the range of 1:1 to 2:1. Nevertheless, in laying hens the proportion of calcium in the diets is much higher since they require a large amount of this element for egg shell formation (McDonald *et al.*, 2002).

Table 6. Chemical composition of crop and /or gizzard contents of scavenging indigenous chickens and ducks in developing countries

	DM (g/kg)	Chemical composition (g Kg DM^{-1})							ME (MJkgDM^{-1})	References
		CP	EE	CF	ASH	NFE	Ca	P		
Chicken crop[1]	432.0	97.3	60.4	55.2	132.0	655.0	7.5	3.7	-	Mwalusanya *et al.* (2002)
Chicken crop[2]	429.0	111.0	61.9	61.3	119.0	647.0	5.8	3.5	-	Mwalusanya *et al.* (2002)
Chicken crop[3]	431.0	104.0	61.0	58.0	125.0	652.0	6.3	3.6	-	Mwalusanya *et al.* (2002)
Hen crop	523.0	88.0	19.0	102.0	-	-	9.0	6.0	12.0	Tadelle and Ogle (1996)
Crop/gizzard	-	96.2	-	-	-	-	-	-	11.7*	Ali (2002)
Crop/gizzard	-	81.8	16.1	94.4	97.8	579.0	33.8	5.7	10.7	Ukil (1992)
Layer crop	455.0	117.0	20.7	60.4	124.0	683.0	13.2	4.6	11.6	Rashid *et al.* (2004)
Grower crop	489.0	98.9	21.1	64.0	123.0	693.0	7.6	3.4	11.5	Rashid *et al.* (2004)
Crop /gizzard	-	113.0	81.3	97.4	-	-	13.8	5.3	-	Prawirokusumo (1988)
Crop /gizzard	344.0	94.0	92.0	54.0	160.0	600.0	8.0	9.0	9.5	Gunaratne *et al.* (1993)

*Gross energy; Chicken crop[1] = Adult female chickens; Chicken crop[2] = Growers (2-4 months) of mixed sex; Chicken crop[3] = Mean of adult female chickens and growers

CONCLUSION

The present review shows that most of the poultry in developing countries in particular Africa is found in the traditional sector. These poultry play an important role in supplying the local people with additional income and high-quality protein food. Under traditional sector, four poultry management systems can be distinguished where free-range and backyard systems are mostly practiced by rural households. Flock productivity is generally low due to sub-optimal management, lack of supplementary feeds, low genetic potential and diseases. Scavenging is a dominant husbandry system and provides most of the SFRB consumed by scavenging poultry. However, the availability of SFRB varies with seasons, altitude, climatic conditions, farming activities, social, management, flock biomass and bird behaviour. Moreover it is indicated that SFRB contain on average low amounts of protein (100 g kg DM^{-1}), energy (11.2 MJ kg DM^{-1}) and minerals such as Ca (11.7 g kg DM^{-1}) and P (5 g kg DM^{-1}). The low concentration of these nutrients can only support maintenance, a low growth rate and low egg output for scavenging poultry. The low concentration can be corrected by providing scavenging poultry with supplementary feeds rich in these nutrients. A quantitative assessment of SFRB and its nutritional value could help in developing appropriate supplementation strategies using locally scavengeable feed resources. In order to achieve this, further studies are needed to identify and characterize potential scavengeable resources in different farming systems at different periods of the year.

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CHAPTER 3

IDENTIFICATION, CHARACTERIZATION AND COMPOSITION OF SCAVENGEABLE FEED RESOURCES FOR RURAL POULTRY PRODUCTION IN CENTRAL TANZANIA

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IDENTIFICATION, CHARACTERIZATION AND COMPOSITION OF SCAVENGEABLE FEED RESOURCES FOR RURAL POULTRY PRODUCTION IN CENTRAL TANZANIA

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ABSTRACT

A participatory study was carried out in four villages of central Tanzania to appraise existing and potential scavengeable feed resources available for rural poultry. In addition, proximate analysis of selected scavengeable feed resources, including chicken crop and gizzard contents, was carried out to quantify their feeding value. Results indicate that the most important scavengeable feed resources in the dry season were cereal grains and their by-products, oil seeds and oil seed cakes and in the wet season these were forage leaves, flowers, seeds, garden vegetables, insects and worms. Changes in seasonal conditions, farming activities, land size available for scavenging and flock size had a major influence on feed availability. The mean dry matter (DM) of the feed resource was 888 ± 1.8 g per kg. Gross energy ranged from 17.1 to 29.3 MJ kgDM^{-1} and crude protein (CP) from 64.5 to 418 g kg DM^{-1}. Crude fibre (CF) ranged from 33.3 to 230 g kg DM^{-1} and ether extract (EE) ranged from 16.0 to 488 g kg DM^{-1}. The mineral composition ranged from 1.5 to 18.4 g kg DM^{-1} for calcium (Ca); 3.6 to 17.3 g kg DM^{-1} for phosphorus (P); 9.5 to 34.5 g kg DM^{-1} for potassium (K) and 0.2 to 8.5 g kg DM^{-1} for magnesium (Mg). Physical analysis of crop and gizzard contents indicated that the diets consumed by scavenging chickens consisted of cereals and cereal by-products (29.0%), vegetables and forage materials (1.8%), seeds and seed by-products (3.4%), insects and worms (0.2%), egg shells, feathers and bones (0.3%), unidentified feeds (41.5%), inert materials (0.8%) and sand/grit (23.0%). The diet consumed as determined from the crop/gizzard contents had a DM of 479 ± 9.6 g per kg and metabolizable energy (ME) of 10.1 ± 0.5 MJ kg DM^{-1}. Nutrient composition in kg DM^{-1} of the crop and gizzard contents was: 80.4 g CP; 70.7g EE; 45.7 g CF; 234 g Ash; 6.6 g Ca; 6.5 g P; 12.1g K and 2.6 g Mg. The study showed that the nutrient concentrations of scavengeable feed resources consumed by rural poultry were below the recommended levels for optimum growth and egg production.

Key words: Central Tanzania, rural poultry, scavengeable feed resources, nutrient composition, crop and gizzard.

INTRODUCTION

The livestock industry in Tanzania contributes about 18% of the national GDP and about 30 % of the agricultural GDP, and provides food which is consumed in the form of meat, milk and eggs (URT, 2005). The livestock industry is divided into a traditional and commercial sector. Cattle and poultry are the major livestock species. The poultry sub-sector consists of traditional small-scale poultry production in the rural areas and commercial small to large-scale poultry production in peri-urban and urban areas. The traditional small-scale poultry production is the largest sub-sector and comprises various poultry species such as chickens, ducks, turkeys, geese, pigeons and guinea fowls. Most of these species are local ecotypes and account for about 90% of the total poultry population in Tanzania (MOAC, 1995). Due to their high degree of adaptation to a wide range of environments, rural poultry or village poultry are widely distributed throughout the country. Chickens are the most common poultry species in the country, and account for about 95% of total poultry in the traditional sector (MOAC, 1995). These rural poultry are owned by individual smallholder farmers that practise a wide range of management strategies, mainly characterized by hardly any or no inputs for housing, feeding and health care. Free-ranging is the dominant poultry production system practiced by most of the households in the rural areas. In this system, poultry usually are allowed to scavenge their own food around homesteads and from the surrounding environments during daytime. This low-input/low-output system has been a major component of smallholder farming in the country for centuries. In spite of the social and economical importance of this free-range system, few developments have been undertaken in Tanzania to improve the overall productivity of rural poultry. For example, in the past, breeding programmes were introduced to the villages to improve the productivity of local birds by crossing with exotic cockerels (Goromela, 2000). Such programmes have also been reported in many other African countries (Tadelle and Ogle, 1996; Kitalyi, 1998). However, these programmes placed more emphasis on a rapid genetic improvement with the justification that improvement in feeding would be inefficient when animals of low genetic potential are raised (Sonaiya *et al.*, 1999). As a result, the majority of these programmes failed due to lack of management skills that were needed for the crossbreds and the management changes that should be adopted by the rural people.

In recent years, there has been a growing awareness of the need to balance the rate of genetic improvement with improvements in feeding and management (Kitalyi, 1998; Sonaiya *et al.*, 1999; Minga *et al.*, 2000). Moreover, there has been a renewed interest in rural poultry production and in the potential of rural poultry as efficient converters of locally available scavengeable feed resource base (SFRB) into eggs and meat (Kitalyi, 1998; Sonaiya *et al.*, 1999; Minga et al., 2000). In the free-range system, rural poultry obtain their diets mainly from SFRB. However, the amounts and availability of SFRB are not constant throughout the year (Cummings, 1992). Such feed resources tend to vary with factors such as seasonal conditions, farming activities, life cycle of insects and other invertebrates (Roberts, 1995; Tadelle, 1996; Sonaiya, 2004). If the supply of SFRB and the seasonal variations are known, efficient strategies for production of scavenging poultry can be developed (Gunaratne, 1999). Thus the objectives of this study were to appraise existing and potential scavengeable feed resources available for rural poultry and quantify their feeding value. The second aim was to determine the constraints with regard to the availability of these feed resources for rural poultry in free-range systems in Central Tanzania.

MATERIALS AND METHODS

The study area

This study was carried out in four villages of Bumila, Chitemo and Kisokwe in Mpwapwa district and Chamkoroma in Kongwa district in Dodoma region. Administratively, Central Tanzania comprises Dodoma and Singida regions with a total human population of 2.7 million. About 80% of this population depends on crop and livestock production as the major basis of their livelihoods. Central Tanzania is categorised as a semi-arid zone with a savannah climate characterized by a short rainy period of four months between December and May. The average annual rainfall is 450 mm. The average maximum temperature is 28°C and the minimum temperature is 17°C with an average relative humidity of 70%. The villages were selected essentially based on the farming systems being practiced. Bumila and Chamkoroma villages are located in the maize-beans-sunflower based farming system while Kisokwe and Chitemo villages are located in the sorghum-pearl millet-groundnut based farming system.

Identification of available scavengeable feed resources

A reconnaissance survey was carried out in November, 2005 to obtain background information of the above mentioned four villages. A group of 20 - 30 key informants in each village was interviewed. Using this background information, the questionnaire for a formal survey was developed and pre-tested for consistency of questions. Then a formal survey was carried out in December, 2005 in the above mentioned villages and the questionnaire addressed feed resources and nutrients eaten by rural poultry in the villages at different times of the year; factors affecting quantity and quality of SFRB and interventions/strategies that should be used to improve feed resource availability. A total of 318 households from the four villages were interviewed with a sample size of 70 - 80 households per village. Most of the respondents were adult women who had responsibilities for the daily management of local birds as their main domain. In addition, a balanced sub-sample of 40 farmers involved in the formal survey from each village was used in group interviews to obtain qualitative information on seasonal availability of SFRB and constraints with regard to the availability of these feed resources. PRA tools such as pair-wise ranking; matrix scoring and direct observations were used. Samples of existing and potential feed resources were collected from interviewed farmers during the household survey. These samples were sorted out in the laboratory and pooled together based on types and varieties of the feed resources. The final feed samples were sub-sampled for the determination of chemical composition.

Characterization of scavengeable feed resource base

Characterization of scavengeable feed resources for rural poultry was carried out to assess the relative availability of each feedstuff separately during the wet and dry season. A relative qualitative scale was developed by farmers and ranged from abundantly available to scarcely available. In addition, a pairwise ranking method was used to rank the most important feedstuffs which had significant impact on the rural poultry production. Feed resources which had the highest scores and ranked from 1 to 6 were considered as the most important feedstuffs in each feed category.

Moreover, the factors affecting quantity and quality of SFRB with respect to the variation of energy and protein sources were investigated using matrix scoring method. Using a total of 120 groundnut seeds, farmers assigned these seeds to each month of the year drawn on a flip-chart where 10 seeds per a particular month indicated maximum availability of the feed resources. The number of seeds assigned on each month was counted as scores or percentage of the feed resources that were more likely to be available and the underlying factors were discussed.

Quantitative assessment of SFRB from chickens' crop and gizzard contents

A quantitative assessment of SFRB in the chickens' crop, proventriculus and gizzard contents was carried out between December 2005 and January 2006. A total of 141 scavenging chickens of both sexes with an average live weight of 1.2 kg ± 0.3 were randomly purchased from farmers in the four villages for the analysis of crop and gizzard contents. The crop and gizzard contents were used to determine the amount and composition of the diets consumed by scavenging chickens. The chickens were collected directly from the farmers between 11.00 and at 16.00 h. Chickens were weighed before slaughtering using an electronic balance. The chickens were slaughtered according to normal practice on farms and the feathers were removed after dipping the body into hot water. The carcasses were eviscerated and the whole gastro-intestinal tracts were removed and packed in the cool boxes containing ice-packs. Samples of the gastro-intestinal tracts were taken to the laboratory where they were frozen at -30° C. Later the frozen gastro-intestinal tracts were opened up after thawing in the air for a few hours and the crop, proventriculus and gizzard were eviscerated. The ingested feed materials from crop, proventriculus and gizzard were identified visually using magnifying lenses. Chyme of crop, proventriculus and gizzard was physically separated into different individual feed components. These individual feed components were weighed using an electronic balance. In order to determine their proportions on a dry weight basis the samples were partially dried at 60°C in the laboratory using an oven.

Chemical analyses of scavengeable feed resources and chickens' crop/gizzard contents

Samples of scavengeable feed resources and samples of chickens' crop and gizzard contents were sub-sampled according to the villages from which they had been collected. All the samples were ground using laboratory mills to pass through a 2 mm screen in order to produce homogenous samples for the analysis of chemical composition. The homogenous samples of feed resources and crop/gizzard contents were analysed for dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF), Ash, calcium (Ca), phosphorus (P), potassium (K), and magnesium (Mg) according to the procedures of AOAC (1985). NFE was estimated from organic matter (OM) minus the sum of amounts of CP, EE and CF (g/kg DM). Gross energy (GE) was determined using a regression equation of the chemical composition of the feed resources as described by Wiseman (1987): GE (kcal/kg DM) = 57.2 CP% + 95.0 EE% + 47.9 CF% + 41.7 NFE%. The Metabolizable energy (ME) of the crop/gizzard contents was determined by calculating the True Metabolizable energy (TME) with the assumption that TME was 8% higher than the ME (Wiseman (1987).

Data analysis

All the data collected were coded and analysed for descriptive statistics for each variable investigated using SPSS programme version 11.0 for Windows 2003.

RESULTS

Scavengeable feed resources available for rural poultry in the villages

The scavengeable feed resources available for rural poultry in the 4 villages of Mpwapwa and Kongwa districts are presented in Tables 1 - 4. The results show that feed resources consisted of energy, protein and mineral/vitamin-rich feedstuffs. About 52.9% of the respondents in Kisokwe, 64.8% in Bumila, 61.6% in Chamkoroma and 46.7% in Chitemo reported that energy-rich feedstuffs were slightly available during the wet season while 80.79% of the respondents in Kisokwe, 82.28% in Bumila, 68.66% in Chamkoroma and 72.6% in Chitemo reported that these feedstuffs were abundantly available in the dry season. Regarding the availability of protein and mineral/vitamin-rich feedstuffs, 64.8% of the respondents in Kisokwe, 70.0% in Bumila, 68.1% in Chamkoroma and 55.7% in Chitemo reported that such feedstuffs were highly available in the wet season while 56.8% of the respondents in Kisokwe, 60.0% in Bumila, 50.7% in Chamkoroma, and 53.9% in Chitemo reported that these feedstuffs were slightly available in the dry season. The study revealed that both conventional and unconventional feedstuffs in all the four-villages were generally similar and abundantly available in certain periods despite the differences in farming systems and climatic conditions.

Characterization of scavengeable feed resources available for rural poultry

The relative availability of scavengeable feed resources during different seasons is shown in Tables 1 - 4. The results indicate that the availability of various SFRB between dry and wet seasons varied widely. Much of this variation is in amounts and in flora and fauna and origin of species available as food for the rural poultry. Most of the energy-rich feedstuffs and some protein-rich feedstuffs - particularly sunflower seed cakes and groundnut seeds - were abundantly available during the dry season. However, at the end of the dry season and during the wet season (January - April) the availability of these feed resources was relatively low. Protein-rich feedstuffs (insects and earthworms) and mineral/vitamin-rich feedstuffs were abundantly available during the wet season while in the dry season the availability of these feedstuffs was relatively low. Among the energy-rich feedstuffs: maize bran, maize brew wastes, maize thick porridge (ugali), maize grains and sorghum grains ranked highest in Bumila village and Chamkoroma village while in Kisokwe village and Chitemo village sorghum ugali, maize ugali, pearl-millet ugali, pearl millet brew wastes, sorghum brew wastes and maize brew wastes ranked highest. In Bumila village and Chamkoroma village the protein/mineral feedstuffs: forage leaves, forage flowers, garden vegetables, tree seeds, sunflower seed cakes and groundnuts ranked highest while in Kisokwe village and Chitemo village garden vegetables, termites, grasshopper, cutworms, earthworms and maggot larvae ranked highest.

Factors affecting availability of scavengeable feed resource base for rural poultry

Factors affecting availability of SFRB are presented in Table 5. Results indicate that season, harvesting of crops, poultry flock size and land size for scavenging had significant association ($P<0.05$) with the availability of SFRB while land preparation and management of feed resources at household level had no significant association ($P>0.05$). Further analysis of the data revealed that there were highly significant interaction effects ($P<0.001$) among the factors affecting availability of scavengeable feed resources. The effect of season and farming activities on the availability SFRB could evidently perceived by farmers as shown in Figures 1 - 4.

Table 1. Relative availability of scavengeable feed resources for rural poultry during wet and dry season as assessed by farmers at Bumila village in Mpwapwa district

Categories of scavengeable feeds	Relative feed availability during rainy season[1]						Relative feed availability during dry season[1]						Pair-wise ranking by farmers	
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Total scores	Rank
Cereal grains														
Maize	xx	xx	x	x	xx	xxx	xxx	xxx	xxx	xxx	xxx	xx	5	4
Sorghum	xx	xx	x	x	xx	xxx	xxx	xxx	xxx	xxx	xxx	xx	4	5
Cereal by-products														
Maize bran	xx	xx	x	x	xx	xxx	xxx	xxx	xxx	xxx	xxx	xx	8	1
Maize brew-waste	xx	x	x	x	xx	xxx	xxx	xxx	xxx	xxx	xxx	xx	7	2
Sorghum bran	xx	xx	x	x	xx	xxx	xxx	xxx	xxx	xxx	xxx	xx	2	7
Sorghum brew-waste	xx	x	x	x	xx	xxx	xxx	xxx	xxx	xxx	xxx	xx	0	9
Other cereal and tuber products														
Maize Ugali	xx	xx	xx	xx	xx	xxx	xxx	xxx	xxx	xxx	xxx	xx	6	3
Sorghum Ugali	xx	xx	xx	xx	xx	xxx	xxx	xxx	xxx	xxx	xxx	xx	1	8
Cassava	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	3	6
Crop and animal protein feeds														
Sunflower seed cake	x	x	⇩	⇩	⇩	⇩	x	xx	xxx	xxx	xxx	xx	9	5
Groundnuts seeds	x	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	8	6
Sesame seeds	⇩	⇩	⇩	⇩	⇩	⇩	x	x	⇩	⇩	⇩	⇩	0	14
Fish meal	x	xx	x	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	3	11
Meat meal	⇩	⇩	⇩	⇩	⇩	⇩	x	x	⇩	⇩	⇩	⇩	1	13
Insects and worms														
Earth worms	xxx	xx	xx	xxx	xxx	xx	x	⇩	⇩	⇩	⇩	⇩	4	10
Maggot larvae	xx	xxx	xx	xxx	xxx	xx	x	⇩	⇩	⇩	⇩	⇩	2	12
Termites	xx	xx	xxx	xxx	xxx	xx	xx	xx	xx	x	x	xx	7	7
Grasshopper	xx	xxx	xxx	xxx	xxx	xx	xx	xx	xx	xx	xx	xx	6	8
Cut worms	xxx	xxx	xxx	xxx	xxx	xx	x	⇩	⇩	⇩	⇩	⇩	5	9
Minerals and Vitamins feeds														
Garden vegetables	xx	xxx	xxx	xxx	xxx	xxx	xx	xx	⇩	⇩	⇩	⇩	11	3
MTPs/forage leaves	xx	xxx	xxx	xxx	xxx	xxx	xx	xx	x	⇩	⇩	⇩	13	1
Forage flowers	**x**	**xx**	**xxx**	**xxx**	**xxx**	**xxx**	**xx**	**⇩**	**⇩**	**⇩**	**⇩**	**⇩**	**12**	**2**
Tree seeds	⇩	⇩	⇩	x	xx	xx	xxx	xxx	xxx	xx	x	⇩	10	4

[1]Relative scale: xxx= abundant, xx = average, x= low, and ⇩ = very low/none

Table 2. Relative availability of scavengeable feed resources for the rural poultry during wet and dry season as assessed by farmers at Chamkoroma village **in Kongwa district**

Categories of scavengeable feeds	Relative feed availability during wet season[1]						Relative feed availability during dry season[1]						Pair-wise ranking by farmers	
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Total scores	Rank
Cereal grains														
Maize	xxx	xx	x	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xxx	7	3
Sorghum	⇩	⇩	⇩	⇩	⇩	xx	xx	xxx	x	⇩	⇩	⇩	6	4
Rice	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xx	xx	3	7
Cereal by-products														
Maize bran	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	8	2
Maize brew-waste	xx	x	⇩	⇩	xx	xx	xxx	xxx	xxx	xxx	xxx	xx	5	5
Sorghum bran	⇩	⇩	⇩	⇩	⇩	xx	xx	xxx	xx	⇩	⇩	⇩	2	8
Sorghum brew-waste	⇩	⇩	⇩	⇩	⇩	xx	xx	xxx	x	⇩	⇩	⇩	1	9
Rice bran/polishings	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xx	xx	0	10
Other cereal and tuber products														
Maize Ugali	xxx	xx	x	x	xx	xx	xxx	xxx	xxx	xxx	xxx	xx	9	1
Sorghum Ugali	xx	xx	xx	xx	xx	xxx	xxx	xxx	xxx	xxx	xxx	xx	4	6
Crop and animal protein feeds														
Sunflower seed cake	xx	x	⇩	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xx	8	4
Groundnuts seeds	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xxx	xx	6	6
Fish meal	x	⇩	⇩	⇩	x	xx	xx	xx	xx	xx	xx	xx	2	10
Insects and worms														
Earth worms	xx	xxx	xx	xxx	xxx	xx	x	⇩	⇩	⇩	⇩	⇩	4	8
Maggot larvae	xx	xxx	xxx	xxx	xxx	xx	x	⇩	⇩	⇩	⇩	⇩	1	11
Termites	xx	xxx	xx	xxx	xxx	xxx	xxx	xx	x	x	x	x	7	5
Grasshopper	xx	xxx	xxx	xxx	xx	xx	x	x	x	x	x	x	3	9
Cut worms	xx	xxx	xxx	xxx	xxx	xx	xx	x	⇩	⇩	⇩	⇩	5	7
Minerals and Vitamins														
Garden vegetables	xx	xxx	xxx	xxx	xxx	xxx	xx	xx	x	⇩	⇩	⇩	11	1
MTPs/forage leaves	xx	xxx	xxx	xxx	xxx	xxx	xx	xx	x	x	⇩	⇩	10	2
Forage flowers	x	xx	xxx	xxx	xxx	xx	x	x	⇩	⇩	⇩	⇩	9	3
Tree seeds	x	⇩	⇩	x	x	x	xx	xxx	xxx	xxx	xxx	xx	0	12

[1] Relative scale: xxx= abundant, xx = average, x= low, and ⇩ = very low/none

Table 3. Relative availability of scavengeable feed resources for the rural poultry during wet and dry season as assessed by farmers at Kisokwe village in Mpwapwa district.

Categories of scavengeable feeds	Relative feed availability during wet season[1]						Relative feed availability during dry season[1]						Pair-wise ranking by farmers	
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Total scores	Rank
Cereal grains														
Maize	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xx	xx	0	12
Sorghum	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xx	xxx	3	9
Pearl-millet	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	1	11
Cereal by-products														
Maize bran	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	4	8
Maize brew-waste	x	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	6	6
Sorghum bran	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	5	7
Sorghum brew-waste	x	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	7	5
Pearl millet bran	x	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	2	10
Pearl-millet brew waste	x	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	8	4
Other cereal and tuber products														
Maize Ugali	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	10	2
Sorghum Ugali	xx	x				xx	xxx	xxx	xxx	xxx	xxx	xx	11	1
Pearl-millet Ugali	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	9	3
Crop and animal protein feeds														
Sunflower seed cake	x	⇩	⇩	⇩	⇩	⇩	x	xx	xxx	xxx	xx	xx	0	12
Groundnuts seeds	x	⇩	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xx	xx	5	7
Fish meal	xx	x	x	x	⇩	⇩	⇩	x	xx	xx	xx	xx	1	11
Insects and worms														
Earth worms	xx	xxx	xx	xxx	xx	x	⇩	⇩	⇩	⇩	⇩	⇩	4	8
Maggot larvae	xxx	xxx	xxx	xxx	xx	xx	x	⇩	⇩	⇩	⇩	⇩	2	10
Termites	xxx	xxx	xxx	xxx	xxx	xx	x	x	x	x	x	x	7	5
Grasshopper	xx	xx	xxx	xxx	xxx	xx	xx	xx	x	x	x	x	6	6
Cut worms	xx	xxx	xxx	xxx	xxx	xx	x	x	⇩	⇩	⇩	⇩	3	9
Minerals and Vitamins														
Garden vegetables	xx	xxx	xxx	xxx	xxx	xx	xx	x	⇩	⇩	⇩	⇩	8	4
MTPs/forage leaves	xx	xxx	xxx	xxx	xxx	xx	xx	x	⇩	⇩	⇩	⇩	9	3
Forage flowers	xx	xx	xxx	xxx	xxx	xx	xx	x	⇩	⇩	⇩	⇩	11	1
Tree seeds	xx	⇩	⇩	⇩	⇩	⇩	x	xx	xx	xxx	xxx	xxx	10	2

[1]Relative scale: xxx= abundant, xx = average, x= low, and ⇩ = very low/none

Table 4. Relative availability of scavengeable feed resources for the rural poultry during wet and dry season as assessed by farmers at Chitemo village in Mpwapwa district

Categories of scavengeable feeds	Relative feed availability during wet season[1]						Relative feed availability during dry season[1]						Pair-wise ranking by farmers	
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Total scores	Rank
Cereal grains														
Maize	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	1	12
Sorghum	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	2	11
Rice	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	0	13
Pearl-millet	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	4	9
Cereal by-products														
Maize bran	x	x	⇩	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xx	5	8
Maize brew-waste	x	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	7	6
Sorghum bran	xx	x	⇩	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xx	6	7
Sorghum brew-waste	x	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	8	5
Pearl millet bran	x	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	3	10
Pearl-millet brew waste	x	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	9	4
Other cereal and tuber products														
Maize Ugali	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	11	2
Sorghum Ugali	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	12	1
Pearl-millet Ugali	xx	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	10	3
Crop and animal protein feeds														
Groundnuts seeds	x	x	⇩	⇩	x	xx	xxx	xxx	xxx	xxx	xxx	xx	2	9
Fish-meal	x	x	x	x	x	x	x	x	x	x	x	x	4	7
Meat- meal	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	0	11
Insects and worms														
Earth worms	xx	xxx	xxx	xxx	xxx	x	⇩	⇩	⇩	⇩	⇩	⇩	7	4
Maggot larvae	xxx	xxx	xxx	xxx	xxx	xx	x	⇩	⇩	⇩	⇩	⇩	5	6
Termites	xxx	xxx	xxx	xxx	xxx	xx	x	⇩	⇩	⇩	⇩	⇩	10	1
Grasshopper	x	xx	xxx	xxx	xxx	xxx	xxx	xx	x	x	x	x	9	2
Cut worms	xx	xxx	xxx	xxx	xxx	xxx	xx	x	⇩	⇩	⇩	⇩	8	3
Minerals and Vitamins														
Garden vegetables	xxx	xxx	xxx	xxx	xxx	xx	x	x	⇩	⇩	⇩	⇩	6	5
MTPs/forage leaves	xxx	xxx	xxx	xxx	xxx	xx	xx	x	⇩	⇩	⇩	⇩	1	10
Forage flowers	xx	xxx	xxx	xxx	xxx	xx	xx	x	⇩	⇩	⇩	⇩	3	8

[1]Relative scale: xxx= abundant, xx = average, x= low, and ⇩ = very low/none

Table 5. Factors affecting availability of scavengeable feed resource base for rural poultry in the four villages of Mpwapwa and Kongwa districts

Factors	% frequency of the factors affecting availability of SFRB				
	Kisokwe	Bumila	Chamkoroma	Chitemo	Pearson Chi Square ((χ^2)
Season	24.5	26.1	25.2	24.2	(χ^2) (4) = 12.87, $P<0.05$
Land preparation	25.8	24.2	25.2	24.8	(χ^2) (4) = 6.66, $P>0.05$
Harvesting	25.6	25.6	25.2	23.6	(χ^2) (4) =14.59, $P<0.05$
Flock size	24.6	26.5	26.1	22.8	(χ^2) (4) = 9.75, $P<0.05$
Feed management	20.6	28.1	28.1	23.1	(χ^2) (4) = 7.49, $P>0.05$
Land size for scavenging	22.4	27.0	28.2	22.4	(χ^2) (4) = 34.76, $P<0.001$

Figure 1: Effect of seasonal changes and farming activities on the availability of scavengeable feed resource base at Kisokwe village

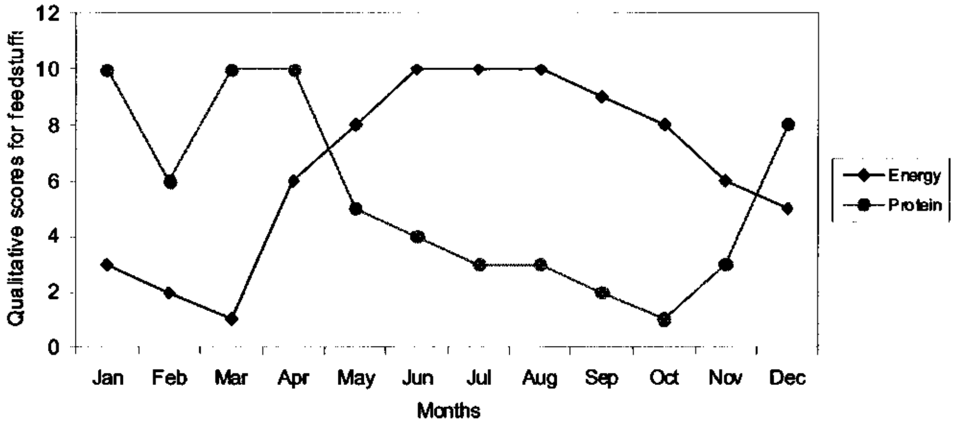
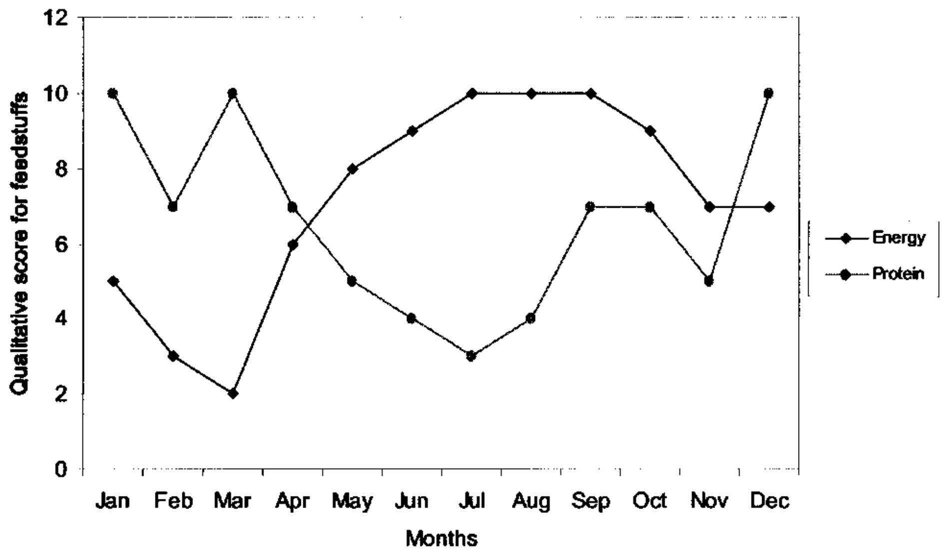


Figure 2: Effect of seasonal changes and farming activities on the availability of scavengeable feed resource base at Chitemo village



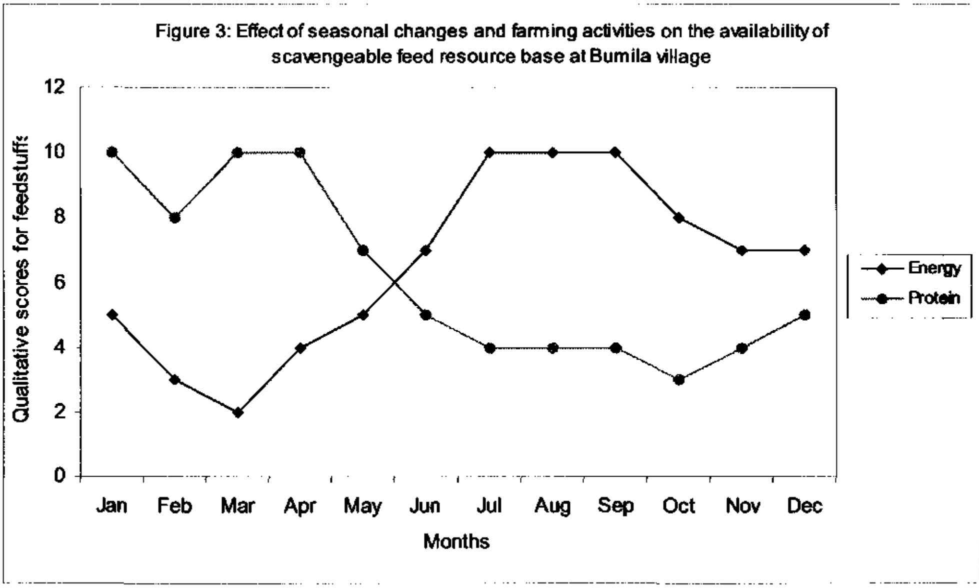


Figure 3: Effect of seasonal changes and farming activities on the availability of scavengeable feed resource base at Bumila village
Qualitative scores for feedstuffs
12
10
8
6
4
2
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Months
Energy
Protein

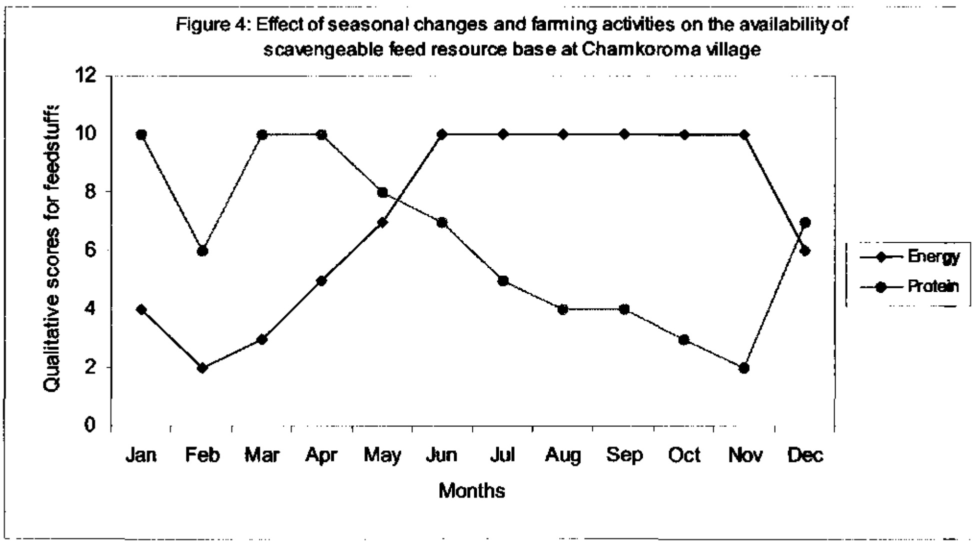


Figure 4: Effect of seasonal changes and farming activities on the availability of scavengeable feed resource base at Chamkoroma village
Qualitative scores for feedstuffs
12
10
8
6
4
2
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Months
Energy
Protein

Chemical composition of scavengeable feed resources available for rural poultry

Results on the chemical composition of scavengeable feed resources are presented in Table 6. The results show that the chemical composition of scavengeable feed resources varied considerably. The DM contents of cereals, oil seeds and their by-products and fish-meal were higher than those of dried cassava chips. Gross energy (GE) ranged from 17.1 to 29.3 MJ kg DM^{-1}. Cereal grains and their by-products had low energy content compared to oil seeds and their by-products. Maize bran and pearl millet brewers' wastes had high crude fibre contents. Also sesame seeds, sunflower seeds and sunflower seed cakes had high crude fibre content owing to the presence of husks. Crude protein contents of cereal grains and cereal bran were similar. They ranged between 113.3 and 145 g CP kg DM^{-1} but cereal bran had higher values than grains. Rice grains and rice bran/polishings had the lowest protein values of 108 and 89 g CP kg DM^{-1} respectively. The oil seeds, their by-products and fish meal had higher protein contents than cereal grains and their by-products. Cereal grains and their by-products had low crude fat contents (EE) compared to the oils seeds and their by-products. The Ash contents of scavengeable feed resources were fairly high except for grains of maize, red sorghum (improved variety) and rice polishings. The Nitrogen-free extract (NFE) content was high in all energy-rich feedstuffs than protein feedstuffs. The mineral contents of potential feed resources were generally low.

Table 6. Chemical composition of feed resources for rural poultry obtained from interviewed farmers in the four villages of Mpwapwa and Kongwa districts

Categories of Scavengeable feeds		Chemical composition (g kg DM^{-1})									
	DM (g/kg)	CP	CF	EE	ASH	NFE	Ca	P	K	Mg	GE (MJ/kg)
Cereal grains											
Maize	877	113	52.1	41.8	14.5	779	1.5	5.0	11.0	1.0	19.0
Sorghum[1]	874	136	157	77.7	25.0	604	3.9	5.2	10.1	2.1	20.0
Sorghum[2]	875	121	136	48.1	33.3	662	3.2	5.4	11.7	1.3	19.1
Sorghum[3]	865	111	33.3	15.6	17.2	823	3.6	3.5	9.5	0.8	18.3
Pearl-millet[4]	875	123	37.0	51.3	69.0	720	3.4	5.8	11.4	1.4	18.3
Pear-millet[5]	869	130	63.8	140	76.6	590	3.8	6.5	15.4	2.2	20.2
Finger-millet	865	122	106	16.0	73.4	683	6.0	3.6	11.4	0.8	17.5
Rice grains	875	108	62.6	16.2	90.1	723	6.2	4.8	12.0	1.0	17.1
Cereal bran											
Maize[6]	897	145	229	92.8	53.4	480	2.6	7.7	17.1	3.6	20.1
Maize[7]	874	142	186	105	62.7	504	2.1	8.1	16.2	3.7	20.1
Sorghum[8]	871	137	62.3	51.5	53.6	696	3.9	6.7	16.2	2.4	18.8
Pearl-millet	875	122	72.8	52.2	84.1	669	2.6	5.8	11.4	1.6	17.7
Rice polishings	879	89.2	48.9	35.6	15.3	811	6.1	6.4	20.1	2.8	18.7
Cereal brewers waste											
Maize & P/millet	890	275	97.7	27.6	36.4	563	12.7	7.9	22.1	3.5	19.5
Sorghum[9]	875	287	70.7	140	53.6	449	12.6	9.4	21.8	4.5	19.8
Pearl millet	906	294	184	62.9	84.1	375	11.4	9.2	20.1	4.2	19.8
Other energy feeds											
Cassava chips[10]	856	64.5	74.7	68.1	64.0	729	3.5	2.6	9.9	0.2	19.5
Oil seeds & by-products											
Sunflower cakes	915	303	202	145	38.1	312	15.4	13.0	25.9	6.1	22.5
Sunflower seeds	912	284	230	399	35.4	51.6	8.8	17.1	26.0	8.3	28.1
Sesame seeds	900	328	146	279	67.2	180	10.3	17.3	30.0	8.5	24.9
Groundnut seeds	922	322	17.8	488	64.7	108	8.5	15.0	25.6	7.7	29.3
Animal protein feeds											
Fish meal	910	418	109	105	37.8	330	18.4	16.5	34.5	7.5	22.1

Note: [1]Red sorghum (local variety); [2]White sorghum (Pato variety); [3] Red sorghum (improved variety); [4]Pearl-millet local variety; [5]Pearl-millet improved variety; [6]Maize (hand processed); [7]Maize (machine processed); [8]Sorghum bran, [9]White sorghum local variety (Lugugu) and [10]Dried cassava chips, GE = Gross energy (MJ/kg DM).

Physical composition of scavengeable feed resources found in chickens' crop and gizzard

Results on physical composition of the individual feed components found in the crop, proventriculus and gizzard (Table 7) show that there was diversity in the composition of the diets consumed by scavenging chickens. The aggregate analysis of individual feed materials in the crop and gizzard consisted of: cereals and cereal by-products (29.0%), vegetables and forage materials (1.8%), seeds and seed by-products (3.4%), insects and worms (0.2%), egg shells and bones (0.3%), unidentified feeds (41.5%), inert materials (0.8%) and sand/grit (23.0%). Generally, the proportion of energy feedstuffs was higher than protein and mineral/vitamin-rich feedstuffs. Average dry weight of both crop and gizzard contents (g) did not vary very much between villages where in Bumila village was 22.1 ± 7.9, Chamkoroma village was 20.6 ± 11.0, Chitemo village was 24.8 ± 16.0 and Kisokwe village was 20.0 ± 13.4.

Chemical composition of scavengeable feed resources found in chickens' crop and gizzard

The results on chemical composition of scavengeable feed resources found in crop, proventriculus and gizzard of scavenging chickens are given in Table 8. The DM concentration of the crop and gizzard contents ranged from 472.3 to 493.7 g DM per kg and the mean DM was 478.7 ± 9.6 g per kg. The crude protein content of the crop and gizzard contents was generally low with an overall mean of 80.4 ± 2.3 CP g kg DM^{-1}. The crude fibre content varied among the villages and the overall mean was 70.7 ± 15.7 CF g kg DM^{-1}. Ether extract content was relatively low with an overall mean of 45.7 ± 21.3 EE g $kgDM^{-1}$. Kisokwe had the lowest value of 19.9 g kg DM^{-1}. The Ash content ranged from 210.2 to 258.0 g kg $DM^{-1}2$ and the overall mean was 234.2 ± 20.5 g kg DM^{-1}. The NFE content had high values and the overall mean was 555.0 ± 32.5 NFE g kg DM^{-1}. The mineral content was generally low but had constant values.

Table 7. Physical composition of SFRB in the dry season expressed as percentage of total dry weight of the chickens' crop and gizzard contents in the four villages of Mpwapwa and Kongwa districts

Category of feedstuffs	Physical components of crop and gizzard contents (% dry basis)				
	Bumila (n = 35)	Chamkoroma(n = 30)	Chitemo (n = 41)	Kisokwe (n = 35)	Overall (n= 141)
Energy feedstuffs					
Maize grains	8.0	7.0	4.1	6.3	6.3
Maize bran	4.0	6.0	0.8	2.3	3.3
Sorghum grains	0.3	0.0	3.5	0.8	1.2
Sorghum bran	0.2	4.4	13.7	11.4	7.4
Pearl-millet grains	0.0	0.0	1.4	0.0	0.4
Pearl-millet bran	0.0	0.0	0.1	0.0	0.0
Local brew wastes	3.0	0.0	1.2	2.8	1.8
Cassava chips	0.0	0.1	0.0	0.9	0.2
Kitchen wastes	11.0	9.3	7.8	5.5	8.4
Protein feedstuffs					
Insects	0.1	0.3	0.4	0.1	0.2
Earthworms	0.0	0.0	0.0	0.1	0.0
Feathers	0.1	0.1	0.1	0.0	0.1
Sunflower cake	0.5	4.3	0.1	5.5	2.5
Watermelon seeds	0.0	0.0	0.0	0.2	0.1
Tree seeds	0.0	0.2	0.1	0.0	0.1
Ground nuts	0.1	2.2	0.3	0.7	0.7
Mineral/vitamin feedstuffs					
Grass leaves/stems	0.0	0.3	0.0	0.0	0.1
Fruits	0.0	0.7	0.0	0.4	0.4
Forage leaves	0.2	0.8	0.1	0.4	0.4
Onions	0.0	0.1	0.0	0.0	0.3
Egg shells	0.0	0.0	0.2	0.0	0.1
Tree flowers	0.0	0.6	0.0	0.2	0.2
Fibrous materials	0.7	0.9	0.2	0.1	0.5
Bones	0.1	0.2	0.2	0.0	0.1
Inert materials					
Metal materials	0.2	0.3	0.4	0.9	0.4
Trouser/shirt button	0.1	0.0	0.0	0.2	0.1
Shoes materials	0.1	0.0	0.0	0.0	0.0
Plastic materials	0.5	0.4	0.2	0.2	0.3
Other feed materials					
Sand/grits	24.1	28.7	17.3	22.2	23.0
Unidentified feeds	46.7	32.2	47.8	39.4	41.5

Table 8. Average chemical composition of crop and gizzard contents of scavenging chickens in the four villages of Mpwapwa and Kongwa districts

Village		Chemical composition (g Kg DM^{-1})									
	DM (g/kg)	CP	CF	EE	ASH	NFE	Ca	P	K	Mg	ME (MJ/kg
Bumila	472	80.3	83.1	52.2	258	517	7.1	7.3	13.6	2.9	9.4
Chitemo	474	82.1	51.5	39.9	242	563	7.2	7.2	14.3	2.9	10.5
Kisokwe	494	77.3	64.2	19.9	227	594	7.2	6.8	13.2	2.4	9.9
Chamkoroma	479	82.1	83.8	70.7	210	545	7.8	8.0	13.3	3.3	10.5
Overall mean	479	80.4	70.7	45.7	234	555	7.3	7.3	13.6	2.9	10.1
	±9.6	±2.3	±15.7	±21.3	±20.5	±32.5	±0.3	±0.5	±0.5	±0.4	±0.5

DISCUSSION

Scavengeable feed resources for rural poultry and the factors affecting their availability

Energy-rich feedstuffs such as grains of maize, sorghum, pearl-millet and their by-products appeared the most important scavengeable feed resources in all villages. The cereals are the most important crops grown for human consumption in the semi-arid areas of central Tanzania. Their availability is high during the dry season when they are harvested. These energy-rich feedstuffs are used mostly as basal feeds or as supplements to the diets scavenged by rural poultry in most of rural households in the villages. Supplementation with available feedstuffs is sometimes done by giving cereal grains and their by-products and household wastes generally in the morning or evening depending on their availability in the households. However, supplementation of these feedstuffs decreases and sometimes disappears during the wet season in most of the households due to their scarcity. Protein-rich feedstuffs such as sunflower seeds, groundnut seeds, sesame seeds, sunflower seed cakes are also the most important poultry feeds in the villages. Again, these are important oil seed crops found in the farming systems of semi-arid areas of central Tanzania. Like the energy feedstuffs, these feedstuffs are given to the birds as supplements. In some households, ground sunflower meals from screw pressed cakes are given to the poultry in combination with cereal by-products. Other protein-rich feedstuffs such as fish-meal and meat-meal are not commonly available in the villages. However, in recent years, fish-meal has been gradually taking an important place in poultry feeding in Chamkoroma, Bumila, and Kisokwe and Chitemo villages.

Unconventional feedstuffs such as earthworms, maggot larvae, termites, and grasshopper and cut worms are another potential scavengeable feed resource in the study area. Availability of these feedstuffs is season dependent. Higher quantities are available during the wet season and they are always obtained from the surrounding environments. Similar findings have been reported by Tadelle (1996) in Ethiopia and Mwalusanya *et al.* (2002) in Tanzania. The study revealed that heaps of cattle dung in the kraal or bomas is used as media for earthworms, maggot larvae and cutworm production and they provide an excellent source of protein rich-diets for the rural poultry. In Africa: insects, maggot larvae and earthworms are the most important protein sources for scavenging chickens (Smith, 1990; Sonaiya, 1995). In Ghana, maggot larvae are produced by farmers from fermented mixture of blood, rumen contents and cattle dung (Smith, 1990). In Colombia, a 100 kg of cattle manure could yield between 0.9 and 2.6 kg of earthworms (Beteta, 1996).

The study also showed that mineral and vitamin-rich feedstuffs particularly garden vegetables, forage leaves, flowers and forage seeds are also important feed resources for the rural poultry. Leaves, flowers and seeds from trees species such as *Leucaena leucocepahala*, *Caliandra colothyrus*, *Acacia tortilis* and *Citrus vulgaris* are collected by some farmers for their poultry. However their availability is limited by the seasonal nature as most of them are available during the wet season. This indicates that during the dry season, rural poultry can develop mineral and vitamin deficiencies because of the scarcity of the succulent forage materials on the range.

Apart from season, the study also revealed that availability of scavengeable feed resources for rural poultry was significantly associated wit farming activities. In the study area, land preparation involves clearing and burning of crop-residues and natural weeds in the fields. These are the ecological niches for termites, grasshopper, reptiles and other invertebrates. Such invertebrates are usually destroyed by fire during land preparation and in some cases they migrate to bushy areas where they cannot be scavenged by poultry. In addition, during ploughing and planting, farmers use hand-hoes and animal drawn implements such as ox-drawn ploughs. As a result, some surface vegetation and crop-residues are incorporated into the soil and the soil bome insects are exposed to the surface where they become available to the rural poultry. Moreover, during planting some grains and oil seeds sown in the fields become available for scavenging poultry. As previously stated, crop harvesting and post harvest activities had also significant effect on the availability of SFRB. The study noted that there are substantial amounts of cereal grains, oil seeds and their by-products spilled on the ground during harvesting and threshing of these crops which are picked up by the rural poultry. Moreover, availability of SFRB is associated with the land size available for scavenging and the size of the flock biomass in the village. The study revealed that land size available for scavenging is directly related to the density of village houses. In all the four villages, housing density was relatively high and most of the family flocks had to mix with flocks from their neighbours when scavenging. Such situation in most cases could result into high competition for SFRB among the poultry and the chicks are more likely to suffer from this competition. Management of the feed resources at farm level is another factor reported to contribute to the availability of SFRB. It was noted that most of the household wastes discarded out by the family members could be available for other livestock species such as pigs, goats, pets and wild birds.

Nutritional composition of scavengeable feed resources for rural poultry in the villages

The high gross energy values in the cereal grains and their by-products indicate that these feedstuffs are good sources of digestible energy and metabolizable energy for poultry (McDonald *et al.*, 2002). Despite the high energy content, most of the grains and their by-products had relatively low protein contents ranging from 8 - 12 CP g kg DM^{-1}. The low protein values in cereal grains and their by-products could have been associated with the high fibre content in these feedstuffs. High fibre content has been reported to have diluent effect on the grains as a whole and reduces the energy and protein value proportionally (McDonald *et al.*, 2002). As a result of this, most of the cereal grains and their- by-products have moderately to low content of lysine, tryptophan and threonine for monogastric animals and methionine for poultry (McDonald *et al.*, 2002). Regarding the mineral contents, the results showed that scavengeable feed resources in the villages had very low mineral contents particularly calcium (Ca) and magnesium (Mg). Phosphorus (P) and potassium (K) contents seem to be comparatively high, although much of it was present in oil seeds and their by-products and fish meal than in cereal grains and their by-products. The low mineral contents in cereal grains could have been associated with the marginal soil fertility in the study area coupled with very low fertilization inputs and erratic rainfall pattern.

The high content of ether extract and crude protein in the oil seeds and their by-products shows that these feedstuffs can have a significant contribution to the energy and protein diets for rural poultry. However, in general oil seed proteins are deficient in essential amino acids in particular cystine, methionine and lysine and the feed materials have high fibre content (McDonald *et al.*, 2002). Thus the high fibre content and the relative low levels of essential amino acids in these feed materials is a constraint to their inclusion in poultry feeds because they cannot provide adequate supplementation of the cereal bran. Therefore they should be used in combination with other protein sources such as soya bean and fish meal.

Physical and chemical composition of chickens' crop and gizzard contents

Visual observations of the crop and gizzard contents revealed that the scavenged feed had a diversity of feed ingredients. The diversity in the composition of the diets consumed by scavenging birds showed that they can select from various feed ingredients available and compose their own diets. Thus a free-range system is of particular importance to small-scale poultry producers in developing countries such as Tanzania because it reduces substantially the costs of commercial feeds which most of the farmers can not afford to buy. Also the system offers an effective way to make use of locally available grains such as maize, sorghum and pearl millet, oilseeds and their by-products. However, as indicated in Table 8, most of the SFRB available for scavenging are not concentrated enough particularly in terms of protein. The crop and gizzard contents in the present study contain on average 80.4 g of CP per kg DM. The low crude protein in the scavenged feeds could be explained by the lower percentage of protein feedstuffs in the diets consumed by birds in the dry season. Similar results were obtained by Tadelle (1996) and Rashid *et al.* (2005) who reported low CP content of 76 and 102 g per kg DM respectively, in the crop contents of scavenging hens in the dry season. However, Pousga et al. (2005) in Burkina Faso reported that the CP in the crop contents was higher in the dry season (115 g kg DM^{-1}) compared to the wet season (105 g kg DM^{-1}) for both local and crossbred birds, resulting from higher consumption of green grass/leaves, larvae, insects and worms due to occasional showers occurred at the end of dry season. The metabolizable energy (ME) concentration of 10.1 MJ kg DM^{-1} in the crop and gizzard contents was approximately similar to the energy content of around 11.4 MJ kg DM^{-1} reported by Pousga et al. (2005) in Burkina Faso, Rashid *et al.* (2005) in Bangladesh and Tadelle (1996) in Ethiopia in the dry season. However, these energy values were lower than the energy content of around 12.4 MJ kg DM^{-1} reported by the same authors during the rainy season. These results confirm the earlier findings that birds kept in the free-range system can certainly not find all the nutrients they need for optimum growth and egg production all the year round (Goromela *et al.*, 2006). Supplementation with the energy and protein sources can complement what birds need for optimum growth and egg production in central Tanzania.

CONCLUSION

From the present study, it can be concluded that in Central Tanzania cereal grains and their by-products, and oil seeds and their by-products are the most important scavengeable feed resources available for rural poultry. Unconventional scavengeable feed resources such as forage leaves and flowers, forage seeds, garden vegetables, insects and worms are also the most important protein and mineral-rich feedstuffs for rural poultry. However, their availability is seasonal in nature. Considerable amounts of cereal grains and some of their by-products were available during the dry season while large amounts of protein and mineral/vitamin feedstuffs were available during the wet season. Thus any attempt to improve the diet of scavenging birds should take into consideration what the birds are essentially consuming depending on season and farming activities. The chemical composition of SFRB indicates that cereal grains and their by-products had high energy contents and low contents of crude protein and minerals particularly calcium and magnesium. The low protein and mineral/vitamins contents in these energy-rich feedstuffs require supplementation with locally available protein and minerals/vitamins sources. The high crude fibre levels of above 20% and the low content of amino acids in oil seeds and their by-products can potentially limit the inclusion of this feed material in poultry diets where the recommended maximum fibre level of inclusion rate is 10% of the diet for adult poultry. Thus they should be combined with other protein sources such as soya-bean and fish-meals when given to poultry. The low concentrations of energy, protein and minerals in the crop and gizzard contents indicates that diets consumed by birds could not meet optimum requirements of scavenging birds for growth and egg production. Supplementation of these nutrients would be necessary to attain reasonable growth and egg performance for rural poultry. However, the major part of the present study has evaluated the available SFRB and the nutrient contents which may not represent the actual diets and nutrients scavenged by rural poultry. Thus further studies should be undertaken to determine the physical and chemical composition of the crop and gizzard contents and thus feed consumed by scavenging birds in different seasons and farming systems of central Tanzania and investigate their interaction effects with poultry management practices on the productivity of rural poultry.

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CHAPTER 4

EFFECT OF SEASON AND FARMING SYSTEM ON THE QUANTITY AND NUTRITIONAL QUALITY OF SCAVENGEABLE FEED RESOURCES AND PERFORMANCE OF VILLAGE POULTRY IN CENTRAL TANZANIA

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Effect of Season and Farming system on the Quantity and Nutritional quality of Scavengeable Feed Resources and Performance of Village poultry in Central Tanzania

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ABSTRACT

A 2x2 factorial study was conducted to assess the effect of season and farming system on the quantity and nutritional quality of scavengeable feed resources and the performance of village poultry in central Tanzania. A total of 648 scavenging chickens purchased from farmers were slaughtered and the crop contents were subjected to physical and chemical analysis. The mean fresh weights of the crop contents were higher ($P<0.05$) in the dry season (34.5 g) than in the rainy season (28.4 g) and there were no significant differences between the farming systems. Visual observations of the crop contents revealed that kitchen/brew wastes, sand and grit, oil seeds and cakes, cereal bran, cereal grains, and other feed materials were the main physical components and varied ($P<0.05$) with seasons and farming systems. The overall chemical compositions (% dry matter (DM)) of the crop contents showed that crude protein (9.24), ash (21.6), magnesium (0.22), nitrogen free extract (58.8) and metabolizable (11.5 $MJkgDM^{-1}$) contents varied ($P<0.05$) with seasons and farming systems. The mean live body weights at slaughter of chickens were higher ($P<0.05$) in the dry season (1238 g) than in the rainy season (890 g). The study showed that quantity and nutritional quality of scavengeable feed resources varied considerably between the seasons and farming systems; and the nutrient contents were below the birds' requirements for high productivity.

Key words: Season, farming system, scavengeable feed resources, village poultry, crop contents, chemical composition, Central Tanzania

INTRODUCTION

The village poultry production system, commonly known as traditional free-range system, is the most important poultry production system in rural communities of Tanzania and those of other African and Asian countries. This system is entirely practised by smallholders using indigenous stocks with low input levels that make the best use of locally available resources. In addition, village poultry constitutes an important component of the agricultural and household economy in these countries. This contribution is thus more than direct food production for the fast-growing human population (Guèye, 2003). A major characteristic of the village poultry production system is that part of the diet consumed by poultry is obtained through scavenging on available feed resources. These include those at household level such as food leftovers or kitchen wastes, garden vegetables, crop grains, orchards, harvest residues, and environmental materials such as insects, worms, snails, slugs, forage leaves/flowers, forage seeds, sand and grits (Sonaiya, 2004; Goromela et al., 2007).

Under scavenging conditions, village poultry usually obtain their own diet during daytime mainly through scratching and foraging activities. Studies have indicated that the amount of scavengeable feed resources consumed by scavenging chickens depend on several factors. The most important are season, grain availability in the household, time of grain sowing and harvesting (Cummings, 1992; Roberts, 1995; Tadelle, 1996; Sonaiya, 2004). Goromela *et al.* (2007) reported that changes in seasonal conditions, farming activities, land size available for scavenging and village flock size have significant influences on availability of scavengeable feed resources for village poultry in Central Tanzania. Based on seasonal feed fluctuations, it was concluded that it is uncertain whether the available scavengeable feed resources at the household level and those available on the range-environment are sufficient in quantity and quality to sustain village poultry production throughout the year. A general consensus is that by estimation of the feed intake from scavenging and its relation to nutrient requirements of the birds can improve feeding and management system of village poultry (Huchzermeyer, 1973; Ajuyah, 1999). Wood *et al.* (1963) indicated that analysis of crop contents of free-ranging birds can help determine the food habits and preferences of chickens and provide an indication of the amount of supplementary feed required. The objective of the present study was to determine the quantity and nutritional quality of the feed consumed by scavenging birds in different seasons and farming systems by assessing physical and chemical composition of the crop contents and carcass characteristics of village poultry in Central Tanzania.

MATERIALS AND METHODS

Description of the study area

The study was carried out in two farming systems in Central Tanzania: a sorghum-pearl millet and groundnut farming system located in Chitemo and Kisokwe villages (Mpwapwa district) and a maize-bean and sunflower farming system located in Bumila village (Mpwapwa district) and Chamkoroma village (Kongwa district). All villages are located in the semi-arid zone of Central Tanzania which lies between longitude 34°50' E to 35°15'E and latitude 5°32'S to 6°15'S. This zone covers an area of 140,000 km^2 and it lies between 750 and 1750 m above sea level. The zone has a savannah type of climate, characterized by a long dry season from July to December. The area has one growing season due to uni-modal type of rainfall which varies across the zone. The average rainfall ranges between 450 and 700 mm per annum and the day temperature ranges between 19°C and 29°C with a diurnal range of 12°C.

Selection of villages and contact farmers

The above four villages were selected during a reconnaissance survey based on the representativeness of the area in terms of physical, biological and socio-economic characteristics and the farming systems practised. Chitemo and Kisokwe villages have drier climate with sunny days and low soil fertility and the major crops grown are sorghum, pearl millet and groundnuts. Bumila and Chamkoroma villages have relatively cool climate, slope, flood plains and high soil fertility and the major crops grown are maize, beans and sunflower. The villages were also chosen based on accessibility, institutional support and co-operation of local farmers. In each village, twenty seven farmers were chosen and selected based on their interest and willingness to participate in the research activities and owning at least 6 to 10 mature chickens. The farmers were randomly picked from three sub-villages, stratified systematically to cover the entire population in the village who owned chickens. In each sub-village, nine contact farmers were selected and were located at least 1000 metres from each other in order to ensure that there was no mixing of family flocks when scavenging.

Experimental period and management of birds

The study consisted of two experimental periods (seasons) which were the rainy season from January to June and the dry season from July to December. In each season three sampling periods of each two month intervals were set up. In the rainy season these sampling periods were: January-February; March-April, and May-June while in the dry season these were: July-August; September-October, and November-December (Table 1). In each period, sampling of crop contents was done once where a total of 27 scavenging chickens per village was slaughtered. Sampling of the crop contents mostly took one day to cover all the 27 contact farmers in a village. However, in rare cases, sampling could take two days in a village especially when some of the contact farmers could not be available or when it was raining. The experimental birds were purchased from the contact farmers after they had spent 4 hours scavenging, assuming that birds fill their crops in four-hour cycles of eating (Feltwell and Fox, 1978). Thus three sampling times per day were set up as: at 10.0h in the morning, at 14.0h in the afternoon and at 18.0h in the evening. These samplings assisted to assess the amount and types of feeds scavenged by birds at different times of the day. The birds were allowed to scavenge at 6.00h early in the morning. In each sampling time, a total of 9 scavenging chickens were slaughtered according to normal practice on farms.

Table 1. On farm experimental design for data collection in each period, village and sampling time of the day during the rainy and dry seasons in two farming systems

Seasons	Periods[1]	Farming systems		Sampling time of the day	No. of birds slaughtered per village
		Sorghum-pearl millet-groundnut	Maize-bean-sunflower		
Rainy	Jan-Feb	Chitemo+ Kisokwe	Bumila + Chamkoroma	10.0h+14.0h+16.0h	27
	Mar-Apr	Chitemo+ Kisokwe	Bumila + Chamkoroma	10.0h+14.0h+16.0h	27
	May-Jun	Chitemo+ Kisokwe	Bumila + Chamkoroma	10.0h+14.0h+16.0h	27
Dry	Jul-Aug	Chitemo+ Kisokwe	Bumila + Chamkoroma	10.0h+14.0h+16.0h	27
	Sept-Oct	Chitemo+ Kisokwe	Bumila + Chamkoroma	10.0h+14.0h+16.0h	27
	Nov-Dec	Chitemo+ Kisokwe	Bumila + Chamkoroma	10.0h+14.0h+16.0h	27

[1]Jan = January, Feb = February, Mar = March, Apr = April, May = May, Jun = June, Jul = July, Aug = August, Sept = September, Oct = October, Nov = November and Dec = December

Determination of physical composition of crop contents

A total of 648 scavenging chickens of both sexes with an average live weight of 1.1±0.3 kg and with an age of seven to eight months, were randomly purchased from contact farmers in the above four villages to assess both physical and chemical composition of crop contents and carcass characteristics (weights and body parts). The crop contents were used to determine the amount or intake and types of feeds consumed by scavenging chickens in different seasons and farming systems. Chickens were weighed before slaughtering using an electronic balance (Salter max 5000g with dimension of 2g). The chickens were slaughtered in different seasons and farming systems at different times of the day according to the 2x2 factorial design (Table 1). Feathers were removed in 2-3 minutes after dipping the body into hot water. The carcasses were dissected and the chicken crops were removed and packed in 2 coolmate boxes each with 6 ice-blocks. Samples of the crop contents were taken to the laboratory where they were frozen in a deep freezer at -30° C. Later the crop contents were thawed for 2-3 hours in the laboratory. The crop contents of each bird slaughtered at 10.0h, 14.0h and 18.0h were physically separated differently into different individual feed components using forceps. These individual feed components were weighed using laboratory electronic balance and were then dried at 60°C until constant weight in the oven for determination of air dry matter.

Determination of carcass yields

The carcass of each bird was taken after feathers, intestinal tract, shanks, liver, heart, lungs, ovary, testis or oviduct, spleen, kidneys, gizzard, crop, proventriculus, pancreas, and head had been removed. The weight of each of the body parts or organs was recorded. A measuring tape was used to measure the length of the gastro-intestinal tracts (GIT) and caeca and the circumference of thigh. The carcass dressing percentage was calculated by dividing carcass weight over live bodyweight at slaughter multiplied by 100%.

Chemical analysis of crop contents

Samples of the crop contents collected during the experimental period were sub-sampled according to the seasons and farming systems they had been collected. All the samples were ground using laboratory mills with a 2 mm screen and were analysed for dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF) and ash, calcium (Ca), phosphorus (P), potassium (K) and magnesium (Mg) according to the procedures of AOAC (1990). Nitrogen free extract (NFE) was calculated by difference: 100%DM - (CP + EE + CF + Ash). The Metabolizable energy (ME) of the crop contents was calculated using a regression equation: TME (MJ kg DM^{-1}) = (3951 + 54.4 EE% - 88.7 CF% - 40.8 ash %) multiplied by 0.004184, where TME refers to the True Metabolizable energy content (Wiseman (1987).

Statistical analysis

The 2x2 factorial design was analysed using the General Linear Model (GLM) of the SPSS software version 11.0 for windows (2001). The statistical model used was:

$Y_{ijklm} = \mu + S_i + F_j + V_{jk} + P_{il} + (SF)_{ij} + E_{ijklm}$, where

Y_{ijklm} is an observation from the m^{th} time of the day in the l^{th} period of recording and k^{th} village within the j^{th} farming system and i^{th} season; μ is the general mean common to all observations in the study; S_i is the effect of the i^{th} season of the year (i = 1, 2); F_j is the effect of the j^{th} farming system (j = 1, 2); V_{jk} is the effect of the k^{th} village within the j^{th} farming system; P_{il} is the effect of the l^{th} period of recording within the i^{th} season; $(SF)_{ij}$ stands for interaction effect between the i^{th} season of the year and j^{th} farming system; E_{ijklm} represents the random effects peculiar to each observation. The villages within farming system (V_{jk}) were used to test the differences between farming systems while the periods within season (P_{il}) were used to test the differences between seasons. Further analysis of data was performed to break down an interaction effect of independent variables using "simple effects analysis technique" (Andy, 2005).

RESULTS

Weights of the crop contents

Results on effect of season and farming system on the weights of crop contents and their physical compositions are presented in Tables 2 and 3, respectively. The mean fresh weights of the crop contents were higher (P<0.05) in the dry season (34.5 g) than in the rainy season (28.4 g). The mean fresh weight of the crop contents in the dry season ranged from 33.7 g for the chickens from the maize-bean-sunflower farming system to 35.3 g for the chickens from the sorghum-pearl millet-groundnut farming system; and in the rainy season the mean fresh weight of the crop contents from each farming system was 28.4 g. The mean weights of the crop contents on dry basis also were higher (P<0.05) in the dry season (18.1 g) than in the rainy season (14.9 g). The mean dry weights of the crop contents in the dry season ranged from 16.3 g for the chickens from the maize-bean-sunflower farming system to 19.9 g for the chickens from the sorghum-pearl millet-groundnut system. The mean dry weights of the crop contents in the rainy season ranged from 14.8 g for chickens from the sorghum-pearl millet-groundnut system to 15.2 g for the chickens from the maize-bean-sunflower farming system. There were no significant differences (P>0.05) between the types of farming system practiced. However, there was a significant interaction between season and type of farming system practised where in the sorghum-pearl millet-groundnut system the mean dry weight of crop contents was lower (P<0.05) in the rainy season (14.7 g) compared to the dry season (19.9 g). The overall mean air dry matter contents of the crop contents was 50.3 % and ranged from 43.9 to 56.3 % in the dry season and from 40.1 to 53.1 % in the rainy season and were not different (P>0.05).

Physical composition of the crop contents

The crop contents of the chickens were visually categorized into nine main components: kitchen and brew wastes; tree and forage leaves and flowers; insects and worms; sand and grit, inert materials; oil seeds and cakes; tree and fruit seeds, cereal grains and their by-products and other feed materials (Table 3). Results show that the overall physical crop contents varied with season and farming system. The proportion of cereal grains and bran was higher (P<0.05) in the dry season than in the rainy season. The occurrence of kitchen and local brew wastes, sand and grit and other feed materials was higher (P<0.05) in the rainy season compared to the dry season. Also, the proportions of tree leaves and flowers, insects and worms, inert materials, oil seeds and cakes, and tree and fruit seeds were fairly high during the rainy season although they were not different from those in the dry season. Occurrence of cereal grains and sand/grit was higher (P<0.05) for the crop contents of chickens from the sorghum-pearl millet-groundnuts based farming system, whereas proportions of cereal bran, and oil seeds and their by-products were higher (P<0.05) in the crop contents of the chickens from the maize-bean-sunflower based farming system. The proportions of kitchen and brew wastes, tree leaves and flowers, insects and worms, inert materials and other feed materials, though relatively high in the crop contents of chickens from the maize-bean-sunflower based farming system, were not different in both systems. There was no significant interaction effect between season and farming system on most of the physical components of the crop contents except for the cereal grains and sand/grit. The proportions of cereal grains were higher (P<0.05) in the sorghum-pearl millet-groundnut farming system during the dry season (15.1 g) than the rainy season (8.25 g) while sand and grit were higher (P<0.05) in both farming systems during the rainy season than in the dry season.

Table 2. Effect of season and farming system on the fresh and dry weights of crop contents of scavenging village chickens in central Tanzania

Crop contents of village chickens	Seasons		Farming systems		Pooled standard error of the mean (SE±)	Season x Farming system
	Dry	Rainy	Sorghum-pearl millet-groundnut	Maize-bean-sunflower		
Average fresh weight (g)	34.5^{a}	28.4^{b}	31.9	31.1	1.21	NS
Average dry weight (g)	18.1^{a}	14.9^{b}	18.3	15.7	0.67	*
Oven dry matter (%)	50.1	50.5	49.4	51.2	1.19	NS

^{ab} Means within a row and factor having different superscripts are different at $P<0.05$; NS = Not significant, and * = Significant different at $P<0.05$

Table 3. Effect of season and farming system on the physical components of crop contents of scavenging village chickens in Central Tanzania

Physical components (% of total, dry basis)	Seasons		Farming systems		Pooled standard error of the mean (SE±)	Season x Farming system
	Dry	Rainy	Sorghum-pearl millet-groundnut	Maize-bean-sunflower		
Kitchen/brew wastes	6.99^{b}	18.9^{a}	11.9	12.9	0.27	NS
Tree leaves/flowers	0.64	0.80	0.66	0.76	0.03	NS
Sand and grit	0.28^{b}	1.54^{a}	1.49^{a}	0.14^{b}	0.05	*
Insects and worms	1.22	1.85	1.45	1.57	0.07	NS
Inert materials[1]	0.40	0.54	0.43	0.51	0.02	NS
Oil seeds and cakes[2]	6.25	7.11	4.36^{b}	9.14^{a}	0.18	NS
Tree and fruit seeds[3]	0.75	1.07	1.01	0.76	0.05	NS
Cereal bran[4]	12.2^{a}	7.70^{b}	5.78^{b}	15.0^{a}	0.27	NS
Cereal grains[4]	67.1^{a}	52.4^{b}	67.5^{a}	52.8^{b}	0.63	**
Other materials[5]	4.13^{b}	8.09^{a}	5.47	6.40	0.12	NS

^{ab} Means within a row and factor having different superscripts are different at $P<0.05$; NS = Not significant; *Significant at $P<0.05$; **significant at $P<0.01$; [1]Bones, buttons, piece of shoes, plastics, pieces of glass, wood particles and fibrous materials; [2]Groundnuts, sesame, sunflower seeds and sunflower cakes; [3]Acacia tortilis, water melon, pumpkin and pawpaw; [4]Maize, pearl millet and sorghum; [5]Fish meal, cassava peelings and chips, vegetable trimmings, feathers, egg shells and other feed materials.

Chemical composition of crop contents

Results on the effect of season and farming system on the chemical composition of crop contents are presented in Table 4. Results show that DM, CF, EE, Ca, P and K contents of the crop contents did not vary between the seasons and farming systems. However, EE and K contents were relatively higher in the dry season compared to the rainy season while CF, Ca, and P were fairly high in the rainy season. The CP and ash contents were higher (P<0.05) for crop contents of chickens in the rainy season than in the dry season. Also the metabolizable energy (ME) contents were higher (P<0.05) in the crop contents of chickens in the dry season than in the rainy season. The NFE and Mg contents of the crop contents did not show any significant difference (P>0.05) between seasons but NFE had higher values in the dry season than in the rainy season. Ash contents were higher (P<0.05) in the crop contents of the chickens from the sorghum-pearl millet-groundnut farming system while the metabolizable energy (ME) contents were higher (P<0.05) in the crop contents of the chickens from the maize-bean-sunflower farming system. The CP contents did not vary between the farming systems, but relative high CP values were found in the cop contents of the chickens from the sorghum-pearl millet-groundnut farming system. The NFE values were higher (P<0.05) in the maize-bean-sunflower; whereas Mg values were higher (P<0.05) in the sorghum-pearl millet-groundnut farming system. Moreover, there were no significant interaction effects of season and farming system for all chemical parameters studied.

Live bodyweights and carcass characteristics of the village chickens

The overall mean live body weight of chickens at slaughter was 1063±9 g. The mean live body weights were higher (P<0.05) in the dry season (1238 g) than in the rainy season (890 g). Likewise, the mean carcass weights of the chickens were higher (P<0.05) in the dry season compared to the rainy season. There were no significant differences in the carcass dressing percentages, liver and proventriculus weights between the seasons (P<0.05). The mean weights for the heart, lung, spleen, gizzard, gastro-intestinal tract (GIT), and caeca length and thigh circumference were higher (P<0.05) in the dry season than in the rainy season. Chickens from the maize-bean-sunflower farming system had significant higher (P<0.05) mean body weights (1144 g) than those from the sorghum-pearl millet-groundnut farming system (984 g). Similarly, mean carcass weights followed the same trend for the two farming systems. There were no significant (P>0.05) differences for mean carcass dressing percentage and mean weights of the lung, heart, spleen and proventriculus, GIT and caeca lengths between both farming systems. However, chickens from the maize-bean-sunflower farming system had lower gizzard weights and higher (P<0.05) thigh circumferences than those from the sorghum-pearl millet-groundnut farming system. There were significant (P<0.05) interaction effects for mean live body and carcass weights and thigh circumferences while other carcass parameters studied did not vary very much between the seasons and farming systems. In both farming systems, village chickens had significant (P<0.05) live body and carcass weights and thigh circumferences during the dry season compared to the rainy season.

Table 4. *Effect of season and farming system on the chemical composition (% of DM) of the crop contents of village chickens in Central Tanzania*

Composition (%)	Seasons		Farming systems		Pooled standard error of the mean (SE±)	Season x Farming system
	Dry	Rainy	Sorghum-pearl millet-groundnut	Maize-bean-sunflower		
Dry matter	90.1	90.8	90.9	90.1	0.73	NS
Crude fibre	4.02	4.88	5.03	3.87	0.52	NS
Ether extract	6.83	5.45	6.80	5.48	0.54	NS
Crude protein	8.40^{b}	10.1^{a}	9.58	8.90	0.36	NS
Crude ash	18.2^{b}	24.9^{a}	25.0^{a}	18.2^{b}	3.08	NS
Nitrogen free extract	62.5	54.6	53.5^{b}	63.6^{a}	3.33	NS
Calcium	0.45	0.60	0.57	0.47	0.06	NS
Phosphorus	0.58	0.66	0.67	0.57	0.05	NS
Magnesium	0.22	0.22	0.27^{a}	0.17^{b}	0.03	NS
Potassium	1.08	0.96	1.08	0.96	0.11	NS
ME ($MJ/kgDM^{-1}$)	12.2^{a}	10.8^{b}	10.8^{b}	12.1^{a}	0.54	NS

^{ab} Means within a row and factor having different superscripts are different at $P<0.05$ and NS = Not significant at $P<0.05$

Table 5. Effect of season and farming system on live body and carcass weights and organ characteristics of scavenging village chickens in central Tanzania

Carcass characteristics	Season		Farming system		Pooled standard error of the mean (SE±)	Season x Farming system
	Dry	Rainy	Sorghum-pearl millet-groundnut	Maize-bean-sunflower		
Live weight (g)	1238^{a}	890^{b}	984^{b}	1144^{a}	32.37	*
Carcass weight (g)	799^{a}	563^{b}	623^{b}	739^{a}	23.85	*
Carcass dressing (%)	64.3	63.2	63.3	64.1	0.66	NS
Liver weight (g)	38.4	29.9	36.9	31.4	3.89	NS
Heart weight (g)	8.12^{a}	5.90^{b}	6.78	7.24	0.40	NS
Lung weight (g)	9.08^{a}	7.14^{b}	7.62	8.60	0.42	NS
Spleen weight (g)	2.95^{a}	2.08^{b}	2.51	2.52	0.24	NS
Gizzard weight (g)	61.9^{a}	55.9^{b}	61.5^{a}	56.3^{b}	1.76	NS
Proventriculus weight	8.39	7.66	8.31	7.74	0.32	NS
GIT length (cm)	187^{a}	167^{b}	176	178	2.41	NS
Caeca length (cm)	17.6^{a}	16.0^{b}	17.0	16.6	0.34	NS
Thigh circumference (cm)	12.3^{a}	10.7^{b}	11.2^{b}	11.8^{a}	0.17	**

^{ab}Means within a row and factor having different superscripts are different at $P<0.05$; NS = Not significant; *Significant at $P<0.05$; **significant at $P<0.01$

DISCUSSION

Weights of the crop contents of scavenging chickens

The higher mean crop content weights in the dry season than in the rainy season could be attributed to the large consumption of cereal grains and their by-products, oil seeds and their by-products, which were more abundantly available during this period. Cereal grains such as sorghum and pearl millet and oil seeds such as groundnuts and sesame are the most important crops grown in the sorghum-pearl millet-groundnut farming system, while cereal grains such as maize and oil seeds such as sunflower are the most important crops grown in the maize-bean sunflower farming system. The grains and seeds of these crops and their by-products are the most important scavengeable feed resources for village poultry and their availability is high during the dry season when these feed stuffs are harvested (Goromela *et al.*, 2007). The lower mean fresh weights of crop contents in the rainy season (Table 2) could be explained by the fact that in the rainy season the availability of cereal grain, bran, oil seeds and oil seed cakes in the households is usually very low. Lower availability of cereal grains, oil seeds and their by-products was also confirmed by Goromela *et al.* (2007) who reported that supplementation of these feedstuffs decreases and sometimes disappears during the wet season in most of the households due to their scarcity. However, in the present study lower weights of the crop contents could be found in the chickens slaughtered in the morning compared to those slaughtered at later periods of the day during the rainy season which indicates that in both farming systems farmers do not supplement their chickens in the morning because they spend most of their time in ploughing, sowing and weeding their crops. As a result, supplementation of village poultry is normally done in the afternoon or evening when farmers are back at home. Also the lower weights of the crop contents in the morning could be due to the chickens behaviour because when released for scavenging they tend to restrict their scavenging area close to the household compounds due to wet and chilly conditions in the morning. However, the higher mean weights of the crop contents in the dry season found in chickens slaughtered in the morning and in the evening might be due to supplementation of locally available feed resources. In a previous study, Goromela *et al.* (2007) reported that supplementation of local chickens with cereal grains and their by-products and household wastes is generally done in the morning or evening depending on their availability in the households. Also the higher mean weights of the crop contents in the morning and evening could be due to the fact that in these periods of the day it is not very hot, as a result the chickens tend to consume more diet. Thus the lower feed intake in the afternoon was most likely due to hot conditions prevalent in the study area during this period of the year. Heat stress may cause reduction in food intake in farm animals (Smith, 1990). However, tropical breeds have developed heat tolerance attributed to heat dissipation mechanisms such as sweating, thermal panting and reflection of incoming solar radiation by the coat (Webster, 1983).

Physical composition of the crop contents

Visual observations indicated that scavenged feed consisted of two major components: household materials and environmental materials (Table 3). The amount of household materials formed a major proportion of the total diet consumed per day ranging from 69 % in the rainy season to 90 % in the dry season. On the other hand, a smaller proportion of 10 % and 31 % of the diet in the dry season and in the rainy season, respectively, came from scavenging in the surrounding environment. This probably means that over two-third of the scavengeable feed resources consumed per day by a scavenging chicken is obtained from household materials. These observations are in agreement with those reported by other authors (Gunaratne *et al.*, 1993; Tadelle, 1996; Mwalusanya et al., 2002; Rashid *et al.*, 2004; Sonaiya, 2004; Pousga *et al.*, 2005) who found that a greater part of the diet consumed by scavenging birds came from household materials and the remaining part came from environmental materials.

The physical composition of the diet consumed per day varied considerably between individual birds within the households in the farming systems, and also between seasons and farming systems. The higher proportion of cereal grains and oil seeds and oil seed by-products in the crop contents during the dry season could be explained by the fact that in this season farmers in the study area were harvesting their cereal and oil seed crops. As a result, both grains and seeds and oil seed by-products were readily available in the household backyards. Nevertheless, a higher proportion of cereal grains were generally found in the crops of chickens from the sorghum-pearl millet-groundnut farming system practised in Kisokwe and Chitemo. In these villages, sorghum and pearl millet are the most grown cereal crops. More importantly, higher proportions of cereal grains, oil seeds and their by-products in the crop contents were found in the chickens slaughtered at 10.0h and 14.0h during the dry season probably due to the fact that in these periods of the day, most of the farmers were threshing and winnowing cereal and oil seed crops. The high occurrence of kitchen and local brew wastes in the rainy season could be attributed by the fact that in this period, usually there is a scarcity of cereal grains and oil seeds and seed cakes and, as a result, most farmers have a tendency to supplement their chickens mainly with kitchen wastes or kitchen leftovers and some local brew wastes. A higher proportion of kitchen/local brewers waste was noticed in the maize-bean-sunflower farming system practised in Bumila and Chamkoroma villages, probably due to assured household food security in these villages. Irrespective of their locations and seasons, higher proportions of kitchen and local brew wastes were found in the crop contents of chickens slaughtered at 14.0h and 18.0h than at 10.0h. This could be explained by the fact that, at this time of the day, farmers were taking lunch and others drinking their local brew. The higher proportion of sand/grit and inert materials in the crop contents during the rainy season was most likely due to a low availability of scavengeable feed resources such as cereal grains and their by-products as noted above. As a result the chickens were strained to ingest such large amount of sand/grit and inert materials to fill their crops which would alternatively prevent the chickens from ingesting adequate amounts of feedstuffs to meet their requirements. The higher proportion of forage leaves and flowers, tree and fruit seeds, insects and worms and vegetable trimmings in the crop contents of scavenging chickens in the rainy season may be explained by the high availability of these feedstuffs during the rainy season as compared to the dry season (Goromela *et al.*, 2007). Nevertheless, higher proportions of forage leaves/flowers and insects/worm in the crop contents were found in chickens slaughtered at 10.0h and 18.0h probably because of the favourable conditions. In the study area, it is usually sunny and hot at 14.0h and as a result insects and worms tend to hibernate and forage leaves and flowers become shrunken. Moreover, the proportions of other feed materials such as vegetable trimmings were relatively high in the crop contents of chickens from the maize-bean-sunflower farming system practiced in Chamkoroma village and Bumila villages. In these villages particularly Chamkoroma village, horticulture is their mainstay. The occurrence of high proportion of cereal bran in the crop contents of the chickens from the maize-bean-sunflower farming system was likely due to the fact that chickens had access to bran fed to other animals. Most of the contact farmers in Bumila village kept pigs and to some extent improved goats; whereas in Chamkoroma they kept pigs and dairy cattle in open pens and maize bran was the most commonly used supplemental feed. These findings are in agreement with Mwalusanya *et al.* (2002) in Tanzania who found chickens from the cool zone and wet zone had higher content of bran in their crops which was scavenged from pigs kept in the open pens.

Chemical composition of crop contents

The proximate and mineral composition observed in the present study were within the range reported by Tadelle (1996), Mwalusanya *et al.* (2002), Rashid *et al.* (2004) and Pousga *et al.* (2005). The higher proportion of forage leaves and flowers, tree and fruit seeds and insects and worms could explain the higher CP content in the crop contents during the rainy season compared to the dry season. In the rainy season, protein-rich feedstuffs accounted for 19 % of the total diet consumed by chickens compared to 13 % in the dry season (Table 2). These results are supported by Tadelle (1996) who reported higher CP contents in the crops of scavenging hens in the Central Highlands of Ethiopia during the rainy season (10.2 % of DM) compared to the dry season (7.6 % of

DM) due to higher intakes of worms and green plants. However, they are in contrast with Pousga et al. (2005), who found higher levels of CP contents in the crop contents of scavenging pullets in Burkina Faso during the dry season (11.5 % of DM) compared to the rainy season (10.5 % of DM) due to increased availability of insects and worms at the end of dry season, as a result of occasional showers. Using the results in Table 2, where the daily DM intake was 18.1 g in the dry season and 14.9 g in the rainy season, and assuming that the birds fill their crops in four-hour cycles of eating (Feltwell and Fox, 1978), it appears that the actual intake from scavenging would have been around 54 g/day in dry season and 45 g/day in the rainy season, with an average intake of 4.6 g CP per bird per day. These results are lower than the estimated daily requirement of 6.0 g CP for a scavenging indigenous hen laying at a rate of 20 % (Farrell, 2000) and 6.8 g CP per day per laying hen obtained from the scavengeable feed resources in Bangladesh (Rashid *et al.*, 2005). The results are below the protein requirements (11.3 g/day) for a local laying hen with an average weight of 1.14 kg producing an egg weighing 35-38 g assuming daily DM intake of around 100 g (Tadelle, 1996).

The higher EE contents in crop contents of chickens during the dry season compared to the rainy season was likely due to higher consumption of oil seeds and seed cakes in the dry season than in the rainy season. Oil seed crops such as groundnuts and sesame were commonly grown in the sorghum-pearl millet-groundnut farming system, whereas sunflower was commonly grown in the maize-bean-sunflower based farming system. The ME concentrations of the crop contents were higher in the dry season compared to the rainy season which might be explained by the high consumptions of energy-rich feedstuffs such as cereal grains and their by-products and oil seeds and oil seed cakes. The energy rich feedstuffs accounted for 86 % of the total diet consumed by chickens during the dry season compared to 79 % of energy-rich feedstuffs consumed during the rainy season (Table 2). However, the ME concentrations obtained were comparable to the ME content of 11.6 MJ kg DM^{-1} found in the dry season and lower than an ME content of 13.5 MJ kg DM^{-1} during the rainy season (Pousga *et al.*, 2005). According to Scott *et al.* (1982) the ME values obtained could therefore meet the requirement of a non-laying hen. However for laying hens the limitations in scavengeable feed resources in terms of nutrient supply may not be sufficient to support reasonably high levels of poultry productivity.

The higher ash content in the present study could be due to higher proportions of sand/grit, inert materials and green forage materials in the crop contents of the birds during the rainy season. Plant materials have higher contents of ash, Ca and CP than seeds (Martin *et al.*, 1976) as cited by Tadelle (1996). Calcium and phosphorus contents, though not different, were higher in the rainy season than in the dry season probably due to high consumption of forage leaves and flowers (Table 2). Forage leaves and flowers contain high contents of calcium and phosphorus than cereals (Ali, 1995). The levels of Ca in the crop contents was very low in all seasons and farming systems which is below the requirement of 3.5 % for high producing birds kept under semi intensive or free-range system for egg production (Feltwell and Fox, 1978).

Live weights and carcass performance

The higher mean live body (1238 g) and carcass dressing weights (799 g) in the dry season could be explained by the higher intakes of cereal grains and oil seeds and cakes. A previous study indicated that in the dry season there are substantial amounts of cereal grains and oil seeds and their by-products spilled on the ground during harvesting, threshing and winnowing activities (Goromela *et al*., 2007). This finding could further be confirmed in the present study where the diet consumed had higher ME content (12.2 MJ/kg) in the dry season than in the rainy season (10.8 MJ/kg), an indication that supplementation of energy sources is needed more in the rainy season. Also the higher live bodyweights of the chickens (1144 g) in the maize-bean-sunflower farming system is an indication that differences in farming systems and climatic conditions had significant effect on the type and availability of scavengeable feed resources consumed by chickens. However, the mean live body weights observed in the dry season (Table 5) was higher than the mean live body weights of 924 g as reported by Kondombo *et al.* (2005), but only slightly higher than the 1121 g as reported by Tadelle (1996) for mature village chickens during the dry season. The same authors reported higher mean live body weights of 1279 g in Burkina Faso and 1168 g in Ethiopia, respectively, in the rainy season, resulting from high consumption of insects, worms and green plants. The mean carcass dressing percentage observed in the present study (63-64 %) was lower than the mean dressing percentage of 83 % reported by Kondombo *et al.* (2005) and 65.6 % reported by Tadelle (1996) for village chickens, probably due to the heavier weights of the gastro-intestinal tract (GIT) and their contents (Table 5). Also it may be attributed to the higher percentage of giblets in females than in males (Sing and Essary, 1974) as cited by Tadelle (1996) and higher proportion of late maturing organs mainly used for egg production (Havez, 1955) as cited by Teketel (1986). However, the dressing percentage in the present study was comparatively higher than the mean dressing percentage of 60.6% for scavenging pullets in Burkina Faso (Pousga *et al.*, 2005). The lower gizzard weights and higher thigh circumferences in chickens from the maize-bean-sunflower farming system could be due to a lower consumption of sand and grit indicating that chickens were very selective as a result of a sufficient amount of scavengeable feed resources, especially in the dry season. Based on the estimated DM intake, it is apparent that scavenging chickens in the present study were probably getting between 45%

and 54% of their total DM intake from scavenging during the rainy season and dry season respectively, resulting in differences in body weights between seasons. Thus additional supplementation of around 46% and 55% of their requirement in the dry season and rainy season respectively, may be necessary to improve the nutritional status of the village poultry which in turn may possibly improve their productivity. Supplementation of energy and protein sources for scavenging local birds have been reported to improve egg production, egg weight, feed efficiency, survival rates, growth rate, carcass quality and economic efficiency (Tadelle, 1996; Minh, 2005).

CONCLUSION

The present study indicated that the quantity of scavengeable feed resources scavenged by chickens and their chemical composition varied considerably with seasons and farming systems. In the dry season, availability of cereal grains, oil seeds and their by-products and kitchen wastes were high resulting into higher dry matter intake and subsequent higher body weights. The lower weights of the crop contents in the rainy season with a consequent lower body weight of the village chickens demonstrate that scavengeable feed resources were not enough to meet the chickens' requirements. Thus additional supplementation with locally available energy feeds in the rainy season may consequently have more impact on the performance of village chickens. However, further investigations on the effect of supplementation of protein and energy using locally available feed resources on the performance of village chickens in different seasons and farming systems in Central Tanzania are needed.

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CHAPTER 5

EFFECTS OF PROTEIN AND ENERGY SUPPLEMENTATION AND WEANING STRATEGIES ON GROWTH AND EGG PRODUCTION OF SCAVENGING CHICKENS UNDER VILLAGE CONDITIONS IN CENTRAL TANZANIA

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Abstract

The effects of protein and energy supplementation and weaning management practices on the reproductive performance of broody hens and subsequent performance of their chicks was studied in two factorial experiments in a six-month period each, with a total of 384 broody hens and 2304 chicks. The broody hens and their chicks were randomly allocated to four dietary treatments: A: scavenging only (control); B: scavenging + high protein, low energy diet; C: scavenging + low protein, high energy diet; and D: scavenging + high protein, high energy diet; and to three weaning periods: 4 weeks (WK4), 8 weeks (WK8); and 12 weeks (WK12). Chicks supplemented with diets B, C or D showed a significant higher body weight gain of 1530 g, 1575 g and 1669 g, respectively, than the non-supplemented chicks (1203 g). Similarly, hens supplemented with diets B, C and D showed a higher egg production of 44 eggs, 45 eggs and 47 eggs, respectively, compared to 33 eggs for the non-supplemented hens ($P<0.05$). Chicks weaned at WK4 showed lower body weight at 4 weeks (106 g) and 12 weeks of age (258 g) than those weaned at WK8 and WK12 ($P<0.05$), but had similar body weights at 24 weeks. The number of clutches increased from 2 clutches with 29 eggs when chicks were weaned at WK12 to 3 clutches with 42 eggs and 4 clutches with 56 eggs when chicks were weaned at WK8 and WK4, respectively (P<.0.05). Survival rate of chicks which relied on scavenging only was lower (65%) than for the supplemented chicks ($P<0.05$). Survival of chicks in the treatment WK4 was lower (67%) compared to those in WK8 (77%) and WK12 (73%) ($P<0.05$). It can be concluded that supplementation of chicks and their mother hens increased body weight gain and egg production, respectively. The highest body weight gains and egg output were recorded on dietary treatment D. Moreover, weaning chicks at WK4 and WK8 of age has an advantage of improving the reproductive performance of the hens without compromising chicks' survival or growth rate.

Key words: Scavenging, supplementation, weaning, local chickens, egg production, growth rate, survival rate

INTRODUCTION

Poultry production in most developing countries like Tanzania is based mainly on a scavenging system or a traditional poultry production system (Guèye, 1998; Goromela *et al.*, 2006). Despite the important role it plays in supplying local populations with additional income and high-quality protein from meat and eggs, the scavenging system in Tanzania is characterized by low productivity indices (Minga *et al.*, 2000). A number of authors (Smith, 1990; Sazzad, 1992; Tadelle, 1996; Minga *et al.*, 2000) have indicated that under free-range conditions a hen can lay a maximum of 40 to 60 eggs year^{-1}. The average growth rate is very low ranging from 4.0 g to 10.2 g/day at an age of 10 weeks (Wilson *et al.*, 1987; Mwalusanya *et al.*, 2001) with a high mortality rate ranging between 50 and 80 % (Smith, 1990; Kitalyi, 1998; Pedersen, 1999). This low productivity under traditional scavenging systems is generally caused by multiple factors, although some factors such as a poor nutrition, disease outbreaks (particularly Newcastle disease) and a sub-optimal management practice have a much greater effect on production than the genetic blueprint, under these scavenging systems (Sazzad *et al.*, 1988; Pandey, 1992; Bagust, 1994 and 1999; Permin and Bisgaard, 1999). Improved feeding systems, health care and housing for scavenging birds have been suggested to directly increase optimum production (Tadelle, 1996; Minga *et al.*, 2000; Mwalusanya *et al.*, 2001).

Previous studies in Central Tanzania (Goromela *et al.*, 1999; 2007) have indicated that, under the traditional management system, indigenous chickens mostly rely on scavenging with a minimum or no supplementary feeding. Most often chickens derive their diets mainly from locally available scavengeable feed resources such as food-leftovers, cereal grains and their by-products, oil seeds and oil seed cakes, forage leaves, flowers, seeds, garden vegetables, insects and worms. However, availability of these feed resources is erratic due to a seasonal influence and in general they contain a low content of energy and protein. This supply cannot meet the requirements of free-ranging poultry for optimal production (Goromela *et al.*, 2008). Moreover, the prevalence of high mortality among the free-ranging birds due to diseases, predators and bad weather pose another challenging constraint (Minga *et al.*, 2000; Mwalusanya *et al.*, 2001). Because of poor management, high mortality rates in the early life of broods ranges between 40 to 60% at an age of 8 weeks (Wilson *et al.*, 1987; Mwalusanya *et al.*, 2001) with a total mortality of 80% at the age of one year (Wilson *et al.*, 1987). Broodiness, which refers more precisely to incubation and brooding behaviour (maternal care of chicks), is common in indigenous birds. Mollah *et al.* (2005) referred to broodiness as being a problem because it is associated with the cessation of egg-laying under traditional management systems. According to Sazzad (1993), indigenous hens have a pronounced instinct of brooding and a long period of nursing baby chicks. Under traditional management, chicks are hatched during natural incubation with broody hens sitting on clutches of eggs. The chicks are then protected from enemies, and raised by their mother hens until they are naturally weaned by their mothers (Sazzad, 1993; Bishop, 1995; Sarkar and Bell, 2006). Under the traditional system of Tanzania, a mother hen takes approximately three to four months to incubate and brood her batch of chicks (Chiligati *et al.*, 1995; Goromela *et al.*, 1999). Such a long reproductive cycle is very common under traditional management and is one of the factors that causes a low productivity in village poultry (Smith, 1990; Sarkar and Bell, 2006). Providing a minimum of supplementary feed containing adequate nutrients and, additionally, improving some management aspects, could improve egg production and growth performance of village poultry. Moreover, combined with early weaning of the brood will hopefully reduce the reproduction cycle and further improve productivity of indigenous chickens. The objective of this study was to evaluate the effects of protein and energy supplementation to hens and to evaluate early weaning management practices with regard to growth and carcass yield of the growing chickens and on egg production in scavenging mother hens under smallholder conditions in Central Tanzania.

MATERIALS AND METHODS

Location, selection of the study area and farmers

The study was conducted in two farming systems: the sorghum-pearl millet-groundnut farming system (Kisokwe and Chitemo villages) in Mpwapwa district and the maize-bean-sunflower farming system (Bumila and Chamkoroma villages) in Mpwapwa and Kongwa districts, respectively. These districts are in the Dodoma region of Central Tanzania. A total of 192 village farmers were chosen to participate in the two on-farm experiments during the rainy and dry seasons. The farmers were purposively chosen during village meetings from a population of farmers who keep indigenous chickens in each village using a stratified random sampling procedure. The farmers were selected when they had at least two broody hens with at least six-healthy chicks at 1 to 2 weeks of age. These broody hens must have attained at least their first reproductive cycle. The farmers were further selected based on owning permanent chicken shelters for keeping the broody hens and their chicks during the experimental period, and willing to participate in the study. Before the commencement of the experiments, all selected farmers were given four training seminars to build their capacity on how to implement these experiments. An agreement research contract was signed by the farmers, the village leaders and the research team to ensure that all selected farmers would participate in the study and provide cooperation during the experimental period. Technical inputs such as feeds and veterinary drugs were provided by the research team. Participatory meetings with the selected farmers were conducted regularly in each village to monitor and evaluate the experiments.

Preparation of experimental feeds and distribution to the farmers

The experimental diets were made from common locally available feedstuffs such as maize bran, sorghum and pearl millet grains, sunflower cake and fish meal. Sorghum grains were crashed by a milling machine in order to reduce its grain size for the purpose of improving its intake by young chickens. The feedstuffs were thoroughly mixed and bulked in 100 kg batches of experimental diets. Weekly feed allocations were weighed out in plastic bags and distributed to each participating farmer.

Experimental design, birds and diets

Two on-farm factorial experiments comprising of four dietary treatments and three weaning management practices in each of the experiments were set up in the two farming systems. The first experiment was carried out in the rainy season (January-June) and the second experiment was carried out in the dry season (July-December). The four dietary treatments were; A: scavenging only (control); B: scavenging + a high protein, low energy diet; C: scavenging + a high energy, low protein diet; and D: scavenging + a high protein, high enegy diet. The compositions and nutrient concentration of the experimental diets were identical in both experiments as presented in Table 1. Dietary treatment D was included in order to determine the growth potential of chicks and egg production potential of indigenous hens when neither protein nor energy supply are limiting.

Table 1. Composition and nutrient concentration of the experimental diets

Feed composition (%)	Treatment A	Treatment B	Treatment C	Treatment D
Pearl millet grain	-	82.5	3.0	70.0
Sorghum grain	-	2.0	45.0	8.5
Maize bran	-	2.0	44.5	10.0
Sunflower seed cake	-	5.0	4.0	4.0
Fish meal	-	7.0	2.0	6.0
Vitamin premix	-	0.4	0.4	0.4
Limestone	-	0.6	0.6	0.6
Salt	-	0.5	0.5	0.5
Calculated nutrient composition				
Crude protein (%)	-	20.0	15.0	20.0
Metabolizable energy (MJ/kg)	-	13.5	14.5	14.5

Treatment A = scavenging only (control); Treatment B = scavenging + a high protein, low energy diet; Treatment C = scavenging + a high energy, low protein diet; and Treatment D = scavenging + a high protein, high enegy diet.

The weaning management practice consisted of three weaning practices set at 4 weeks after hatch (WK4), 8 weeks (WK8), and 12 weeks (WK12). The WK12 weaning practice was included to simulate normal practice under village conditions, where chicks are hatched and naturally weaned when they are about 12 weeks of age or even older. The three weaning management practices were imposed within the four dietary treatments in a factorial design. In each experiment, the chickens were allocated to these groups by restricted randomization on a body weight basis. Thus a total of eight broody hens and 48 chicks (24 male chicks and 24 female chicks) were allocated to each dietary treatment x weaning management combination. So we had a total of 192 indigenous broody hens and 1152 chicks (Table 2) in the experiment.

Table 2. On-farm experimental design containing four treatments and three weaning periods in two farming systems during the rainy season and dry season in central Tanzania

Farming systems		Seasons		Diet treatment	Weaning periods	No. of farmers	No. of hens per farmer	No. of chicks
FS-A	FS-B	Rainy	Dry	A	WK4	4	2	48
FS-A	FS-B	Rainy	Dry	A	WK8	4	2	48
FS-A	FS-B	Rainy	Dry	A	WK12	4	2	48
FS-A	FS-B	Rainy	Dry	B	WK4	4	2	48
FS-A	FS-B	Rainy	Dry	B	WK8	4	2	48
FS-A	FS-B	Rainy	Dry	B	WK12	4	2	48
FS-A	FS-B	Rainy	Dry	C	WK4	4	2	48
FS-A	FS-B	Rainy	Dry	C	WK8	4	2	48
FS-A	FS-B	Rainy	Dry	C	WK12	4	2	48
FS-A	FS-B	Rainy	Dry	D	WK4	4	2	48
FS-A	FS-B	Rainy	Dry	D	WK8	4	2	48
FS-A	FS-B	Rainy	Dry	D	WK12	4	2	48
No. of farmers, broody hens and chicks in one farming system in a season						48	96	576
No. of farmers, broody hens and chicks in two farming systems in a season						96	192	1152

Note: FS-A = Maize-bean-sunflower farming system in Bumila and Chamkoroma villages; FS-B = Sorghum-pearl millet-groundnut farming system in Kisokwe and Chitemo villages and; A = treatment A (also for treatments B, C and D).

Differentiation of the sex of chicks

The composition by sex of the chicks at day old was assumed to be 1:1. Thus sex differentiation of the chicks was carried out between day 2 and 14 after hatching and was based on "farmers' expert opinion" using sex attributes. The male sex attributes included thick and giant legs, big sized head, sharp-rudimentary comb (*konzogolo*) and lack of primary tail feathers (late feathering characteristics). The female sex attributes included thin and less giant legs, small sized head, blunt-rudimentary comb and early appearance of tail feathers (early feathering characteristics). The chicks were separated into male and female chicks by first examining of these sex attributes in a period of 14 days after hatching .

Feeding of hens and chicks

The broody hens and their chicks on treatment A (scavenging only) were released from individual pens at 7.00 am each day to scavenge their own diets around the household compounds and in nearby gardens and crop fields until 7.00 pm. The broody hens on dietary treatments B, C, and D were separated from their chicks and were confined in an individual pen from 7.00 am until 1.00 pm and were given 50 g of the supplementary feed per bird on a daily basis. Similarly, the chicks from each broody hen were confined in a group pen from 7.00 am until 1.00 pm and were given 20 g (0-3 weeks), 30 g (4-7 weeks), 40 g (8-15 weeks) and 50 g (16-24 weeks) of supplementary feed per bird on a daily basis (Table 3). The pens for the chicks were separated by a chicken wire-mesh to prevent the mother hens from getting access to the feeds given to the chicks and it enabled also each broody hen to see her own chicks during the feeding period. From 1.00 pm onwards the hens and their chicks were released out to scavenge similar to their counterparts in treatment A until 7.00 pm when they returned to their own pens. At night, all hens stayed with their chicks in order to warm them until the next day at 7.00 am when they were separated again.

Table 3. The amount of supplementary feeds (g dry weight) given bird^{-1} day^{-1} from 0-1 week to 24 weeks

Age in weeks	Class of chickens	Amount of supplementary feeds (g) bird^{-1} day^{-1}
0 - 1 week	Chicks	20
1 - 2 weeks	Chicks	20
3 - 7 weeks	Chicks	30
8 - 15 weeks	Growers	40
16 - 24 weeks	Growers	50

Weaning of chicks

At the age of weaning (i.e. WK4, WK8 and WK12) all the hens were completely separated from their chicks. However, the hens and their chicks on treatments B, C and D continued receiving their respective supplementary feeds on an individual basis for the hens and on-group basis for the chicks of each hen. Separation of broody hens from their chicks after each weaning period allowed the hens to mate with cocks when they were released for scavenging. Clean drinking water was provided *ad libitum* throughout the experimental period and hens were vaccinated against Newcastle disease using I-2 vaccines and treated against common diseases (collibacillosis, fowl pox, infectious coryza, fowl typhoid, and gumboro disease, fowl cholera, pullorum and salmonelossis). Apart from diseases, worms and ecto-parasites like fleas and mites were also treated. All broody hens were wing tagged for identification.

Data collection and evaluation of carcass characteristics

In each village, data collection started after one week of adaptation to the diets and pens. The data collected from chicks and growers included: chick mortality and body weight gain; whereas data collected from broody hens included: number of eggs per hen per clutch, weight of the eggs and laying interval and number of clutches per hen per experimental period. Slaughter weight, carcass weight and carcass percentage of the chicks were measured in the last week (24 week) of the experimental period by slaughtering 48 birds (24 males and 24 females) per treatment. Before slaughtering in the morning, the chickens were not fed for 12 hours. The birds were slaughtered in accordance to the procedures outlined by Goromela *et al.* (2008). All weights were recorded using an electronic balance (Salter max 2000 g with dimension of 1.0 g).

Chemical analysis of feed ingredients

Samples of maize bran, sorghum, pearl millet grains, sunflower seed cake and fish-meal were analyzed for the determination of dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE) and ash, in accordance with AOAC (1990). Nitrogen Free Extract (NFE) was determined by calculating NFE% = 100 % DM – (CP + EE + CF + Ash); where EE = ether extract (%), CP= crude protein (%) CF = crude fibre (%), Ash = ash (%), NFE (%) = Nitrogen free extract. The metabolizable energy corrected for nitrogen equilibrium (ME_n) of feed ingredients was determined from proximate composition using regression equations (Janssen, 1989).

Statistical data analysis

The data were analysed in accordance with the 2x2x3x4 factorial design (i.e. for two seasons, two farming systems, three weaning management practices, and four dietary treatments), using the General Linear Model procedure of the SPSS software version 15.0 for windows (2006). The Least Square Difference was used to compare means for each variable as outlined in the statistical model below:

$Y_{ijklm} = \mu + F_i + V_{ij} + P_k + N_l + W_m + S_n + A_o + (FP)_{ik} + (FN)_{il} + (FW)_{im} + (FS)_{in} + (PN)_{kl} + (PW)_{km} + (PS)_{kn} + (NW)_{lm} + (NS)_{ln} + (WS)_{mn} + E_{ijklmnop}$.

Where $Y_{ijklmnop}$ is an observation on the p^{th} bird in the n^{th} sex receiving m^{th} weaning period and l^{th} level of protein and energy supplementation within the k^{th} season in the i^{th} farming system; μ = General mean common to all observations for a given variable in the study; F_i is the effect of the i^{th} farming system in the study area (i = 1, 2); P_k is the effect of k^{th} season of the year (i = 1, 2); N_l is the effect the l^{th} level of protein and energy supplementation (j = 1, 2, 3, 4); W_m is effect of the m^{th} weaning period (m = 1, 2, 3); S_n is the effect of n^{th} bird sex (n = 1, 2); A_o is the covariete effect due to o^{th} initial age in weeks (o =1, 2); V_{ij} is the effect j^{th} villages of within the i^{th} farming system and were used to test the difirrences between the farming systems; $(FP)_{ik}$ stands for interaction effect between the i^{th} farming system and k^{th} season of the year; $(FN)_{il}$ stands for interaction effect between the i^{th} farming systems and the l^{th} level of protein and energy supplementation; $(FW)_{im}$ stands for interaction effect between the i^{th} farming system and m^{th} chick weaning period; $(FS)_{jk}$ stands for interaction effect between the i^{th} farming system and the n^{th} sex of the bird; $(PN)_{kl}$ stands for interaction between the k^{th} season and the l^{th} level of protein and energy supplementation; $(PW)_{km}$ stands for interaction effect between the k^{th} season and the m^{th} weaning period; $(PS)_{kn}$ stands for interaction effect between the k^{th} season and the n^{th} sex of the bird; $(NW)_{lm}$ stands for interaction effect between the l^{th} level of protein and energy supplementation and the m^{th} weaning period; $(NS)_{ln}$ stands for interaction effect between the l^{th} level of protein and energy supplementation and the n^{th} sex of the bird; $(WS)_{mn}$ stands for interaction effect between the m^{th} weaning period and the n^{th} sex of the bird and $E_{ijklmnop}$ represents the random effects peculiar to each observation.

RESULTS

Chemical composition of experimental feeds

The results on the chemical composition of the feed ingredients are given in Table 4. All cereals had slightly higher crude protein contents than anticipated but lower than sunflower seed cakes and fish meal. The energy content was higher in fish meal and in cereals than in sunflower seed cakes. Maize bran and sunflower seed cake had the highest crude fiber content. Ether extract was high in maize bran, sunflower seed cake and fish meal. Ash content was high in pearl millets and low in fish meal and sunflower seed cake. Nitrogen free extract was higher in cereals than in sunflower cakes and fish meal.

Table 4. Chemical composition of feed ingredients (g $kgDM^{-1}$)

Feed ingredients	DM	Chemical composition (g $kgDM^{-1}$)					ME_n*
	(g/kg)	CP	CF	EE	ASH	NFE	(MJ/kg)
Maize bran	897	142	186	105	62.7	504	13.8
Sorghum grain	899	111	136	48.1	42.9	662	14.3
Pearl millet	885	130	109	32.0	139	590	12.0
Sunflower seed cake	915	307	202	145	38.1	308	10.6
Fish meal	910	443	100	105	37.8	314	15.0

*The ME_n of the feeds was calculated according to Janssen (1989)

Body weight gains and growth rates of chicks

Weekly body weight gains of chicks up to 24 weeks of age are presented in Table 5. Initial body weights at week 1 were similar in all seasons and farming systems. Subsequent mean weekly body weight gains at weeks 8, 12 and 16 were significantly lower in the rainy season than in the dry season (P<0.05). Comparing farming systems, higher body weight gains were found in the sorghum-pearl millet-groundnut farming system from 8-24 weeks than in the maize-bean-sunflower farming system (P<0.05). There was also a significant interaction between season and farming system from 4 to 20 weeks (P<0.05). Higher body weight gains were found in the sorghum-pearl millet-groundnut farming system during the dry season than in the maize-bean-sunflower farming system during this season. Additionally, body weight gain was significantly influenced by feeding regime. Supplemented chicks showed significantly higher mean body weight gains than non-supplemented chicks (P<0.05). Between the supplemented groups, weight gains were significantly higher for the chicks supplemented with dietary treatment D than those supplemented with dietary treatments B and C (P<0.05). The mean body weight gains for the chicks under weaning practices WK4 and WK8 were similar during weeks 12 and 16 of age, but they were significantly higher than those chicks under weaning practice WK12 (P<0.05). There were, however, no significant differences in body weight at slaughter (week 24) between weaning practices. All chicks on dietary treatment A and in weaning practices WK4, WK8 and WK12 showed significant lower body weight gain than supplemented chicks (P<0.001). The mean body weight gain for the supplemented chicks in relation to weaning practices in different growth stages was not consistent from 4 to 24 weeks, with chicks on dietary treatments B and C under weaning practices WK4 and WK8 showing significantly lower body weight gain than those under weaning practice WK12 ($P<0.001$). At week 24, chicks on dietary treatment D under weaning practice WK12 (1711 g) showed higher body weights than those under weaning practices WK4 (1687 g) and WK8 (1691 g) ($P<0.05$). There was a significant interaction between weaning practice and sex of the chicks from 8 to 24 weeks. From 8 to 20 weeks, male chicks under weaning practice WK4 showed significant lower body weight gain than other male chicks under weaning practices WK8 and WK12 ($P<0.001$). However, at 24 weeks of age, male chicks did not show any significant difference while female chicks did show some differences.

Table 5. Least square means for weekly body weight gain from 1 up to 24 weeks of age for chicks, subjected to different experimental factors (Mean ± SEM)

		Week 1	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24
Seasons	Rainy	36 ± 0.4^{a}	106 ± 0.5^{a}	257 ± 0.9^{a}	494 ± 1.4^{a}	$816\pm.1.7^{a}$	1167 ± 1.4^{a}	1499 ± 1.8^{a}
	Dry	36 ± 0.4^{a}	110 ± 0.5^{a}	261 ± 0.9^{b}	498 ± 1.4^{b}	819 ± 1.7^{b}	1171 ± 1.4^{a}	1503 ± 1.8^{a}
Farming systems	FS-A	36 ± 0.4^{a}	104 ± 0.5^{a}	254 ± 0.9^{a}	491 ± 1.0^{a}	813 ± 1.2^{a}	1165 ± 1.4^{a}	1497 ± 1.8^{a}
	FS-B	36 ± 0.4^{a}	111 ± 0.5^{a}	263 ± 0.9^{b}	500 ± 1.0^{b}	822 ± 1.2^{b}	1173±1.4b	1505 ± 1.8^{b}
Dietary treatments	A	36 ± 0.6^{a}	100 ± 0.7^{a}	225 ± 1.2^{a}	433 ± 1.4^{a}	692 ± 1.8^{a}	$956\pm2.^{0a}$	1203 ± 2.7^{a}
	B	34 ± 0.6^{ab}	104 ± 0.7^{b}	245 ± 1.2^{b}	480 ± 1.4^{b}	811 ± 1.8^{b}	1182 ± 2.0^{b}	1530 ± 2.7^{b}
	C	36 ± 0.6^{c}	106 ± 0.7^{c}	264 ± 1.2^{c}	503 ± 1.4^{c}	845 ± 1.8^{c}	1220 ± 2.0^{c}	1575 ± 2.7^{c}
	D	38 ± 0.6^{d}	120 ± 0.7^{d}	300 ± 1.2^{d}	568 ± 1.4^{d}	921 ± 1.8^{d}	1318 ± 2.0^{d}	1669 ± 2.7^{d}
Weaning practices	WK4	38 ± 0.5^{a}	106 ± 1.1^{a}	258 ± 1.1^{a}	499 ± 1.2^{a}	822 ± 1.5^{a}	1173 ± 1.8^{a}	1503 ± 2.3^{a}
	WK8	37 ± 0.5^{a}	109 ± 1.1^{b}	261 ± 1.1^{b}	498 ± 1.2^{a}	818 ± 1.5^{a}	1168 ± 1.8^{bc}	1497 ± 2.3^{a}
	WK12	35 ± 0.5^{b}	107 ± 1.1^{ac}	257 ± 1.1^{ac}	490 ± 1.2^{b}	812 ± 1.5^{b}	1165 ± 1.8^{c}	1503 ± 2.3^{a}
Sex of chicks	Male	37 ± 0.4^{a}	114 ± 0.5^{a}	282 ± 0.9^{a}	541 ± 1.0^{a}	889 ± 1.2^{a}	1266 ± 1.4^{a}	1624 ± 1.9^{a}
	Female	35 ± 0.4^{b}	101 ± 0.5^{b}	235 ± 0.9^{b}	450 ± 1.0^{b}	746 ± 1.2^{b}	1072 ± 1.4^{b}	1378 ± 1.9^{b}
Season x Farming system		NS	***	**	**	*	*	NS
Dietary treatment x Weaning		NS	***	***	***	***	***	*
Dietary treatment x Sex of chicks		NS	***	***	***	***	***	***
Weaning policy x Sex of chicks		NS	NS	**	***	***	***	*

a-c Means with different superscript letters within a column and factor are significant at $P<0.05$; SEM = standard error of the mean; *** = Significant at $P<0.001$; ** = Significant at $P<0.01$; * = Significant at $P<0.05$; NS = Not significant ; A = scavenging only (control); B = scavenging + a high protein, low energy diet; C = scavenging + a high energy, low protein diet; and D = scavenging + a high protein, high enegy diet; FS-A = maize-bean-sunflower farming system; FS-B = sorghum-pearl millet-groundnut farming system; WK4 = 4 weeks; WK8 = 8 weeks; WK12 = 12 weeks

Growth rates of village chicks

Results for daily growth rates up to 24 weeks are presented in Table 6. The results show that the mean growth rate for the chicks in all seasons did not differ significantly during various growing periods. Significant seasonal effect on the daily growth rate was observed only during week 1-4 ($P<0.05$). The daily growth rate was significant higher in the sorghum-pearl millet-groundnut farming system during the dry (2.8 g/day) and the rainy season (2.6 g/day), than the average of 2.4 g/day in both seasons in the maize-bean-sunflower farming system ($P<0.001$). There were significant differences between dietary treatments where non-supplemented chicks had the lowest daily growth in all growing periods ($P<0.05$). Chicks supplemented with dietary treatment D had the highest average growth rate compared to treatments B and C ($P<0.05$). During the growing period of 1-4 weeks, chicks under weaning practice WK4 showed less daily growth than those under one of the other weaning practices. However, during the growing periods of 5-8 weeks, 17-20 weeks and 21-24 weeks, chicks under weaning practices WK4 and WK8 showed similar average daily growth rates. During growing periods 9-12 weeks; 13-16 weeks, 17-20 weeks and 21-24 weeks, supplemented chicks under all weaning practices did not show any significant difference on daily growth rate, but they were significant different from those on dietary treatment A ($P<0.05$). There was also a significant interaction between feeding regime and sex of the chicks on daily growth rate. The results show that during the subsequent growing periods (5-24 weeks), all supplemented male and female chicks had higher daily growth rate than non-supplemented chicks of both sexes. Male chicks had a higher daily growth rate than female chicks in all dietary treatments. Chicks in dietary treatment D in both sexes had the highest daily growth rate while chicks in dietary treatment B had the lowest daily growth rate. There was also significant interaction between weaning practice and sex on daily growth rate. In the first 2 growing periods (1-4 weeks and 5-8 weeks) male and female chicks under weaning practice WK4 showed significant lower daily growth rates than those under weaning practice WK8 and WK12 ($P<0.001$). However, in the subsequent growing periods (9-24 weeks) male chicks in all weaning practices did not show any significant difference on daily growth rate, but female chicks under weaning practice WK12 showed significant higher daily growth rate than those in weaning practices WK4 and WK8.

Table 6. Least square means for daily growth rates up to 24 weeks for chicks (Mean ± SEM)

		Week 1-4	Week 5-8	Week 9-12	Week 13-16	Week 17- 20	Week 21-24
Seasons	Rainy	2.4±0.02^{a}	2.3±0.02^{a}	6.7±0.01^{a}	8.8±.0.01^{a}	9.4±0.02^{a}	8.7±0.03^{a}
	Dry	2.6±0.02^{b}	2.3±0.02^{a}	6.7±0.01^{a}	8.8±0.01^{a}	9.4±0.02^{a}	8.7±0.03^{a}
Farming systems	FS-A	2.4±0.02^{a}	4.3±0.02^{a}	6.7±0.01^{a}	8.8±0.01^{a}	9.5±0.02^{a}	8.7±0.03^{a}
	FS-B	2.7±0.02^{b}	4.3±0.02^{a}	6.7±0.01^{a}	8.8±0.01^{a}	9.4±0.02^{b}	8.7±0.03^{b}
Dietary treatments	A	2.3±0.7^{a}	3.5±0.03^{a}	5.8±0.02^{a}	7.1±0.02^{a}	7.0±0.03^{a}	6.4±0.05^{a}
	B	2.5±0.7^{b}	4.0±0.03^{b}	6.6±0.02^{b}	9.1±0.02^{b}	9.9±0.03^{b}	9.2±0.05^{b}
	C	2.5±0.7^{bc}	4.5±0.03^{c}	6.7±0.02^{c}	9.3±0.02^{c}	10.0±0.03^{c}	9.4±0.05^{c}
	D	2.9±0.7^{d}	5.2±0.03^{d}	7.4±0.02^{d}	9.7±0.02^{d}	10.7±0.03^{d}	10.0±0.05^{d}
Weaning practices	WK4	2.5±0.02^{a}	4.3±1.1^{a}	6.8±0.02^{a}	8.8±0.02^{a}	9.3±0.02^{a}	8.7±0.04^{a}
	WK 8	2.6±0.02^{b}	4.3±1.1^{a}	6.6±0.02^{b}	8.7±0.02^{b}	9.3±0.02^{a}	8.6±0.04^{a}
	WK 12	2.6±0.02^{ab}	4.2±1.1^{b}	6.5±0.02^{c}	8.8±0.02^{a}	9.4±0.02^{b}	8.9±0.04^{b}
Sex of chicks	Male	2.8±0.02^{a}	4.8±0.02^{a}	7.3±0.01^{a}	9.5±0.01^{a}	10.1±1.4^{a}	9.4±0.03^{a}
	Female	2.3±0.02^{b}	3.8±0.02^{b}	6.0±1.01^{b}	8.1±0.01^{b}	8.7±1.4^{b}	8.0±0.03^{b}
	Season x Farming system	***	NS	NS	NS	NS	NS
Interactions	Treatment x Weaning	***	***	***	*	*	*
	Treatment x Sex	***	***	***	***	***	**
	Weaning x Sex	NS	***	***	*	*	***

$^{a-c}$ Means with different superscript letters within a column and factor are significant at P<0.05; SEM = standard error of the mean; *** = Significant at P<0.001; ** = Significant at P<0.01; * = Significant at P<0.05; NS = Not significant; A = scavenging only (control); B = scavenging + a high protein, low energy diet; C = scavenging + a high energy, low protein diet; and D = scavenging + a high protein, high enegy diet; FS-A = maize-bean-sunflower farming system; FS-B = sorghum-pearl millet-groundnut farming system; WK4 = 4 weeks; WK8 = 8 weeks; WK12 = 12 weeks

Survival rate of chickens

Survival rate of chickens up to 24 weeks in each treatment and weaning practice is presented in Figures 1 and 2. Survival rate was 100% in the first week in all treatments but in the subsequent weeks there was a significant difference between treatments. Chicks died by ageing for several reasons as can be seen from the survival rates in weeks 2 and 3 (93% and 91%) as compared to weeks 4, 5 and 6 (89%, 86% and 84%). Survival of chickens on dietary treatment A (scavenging only) was significantly lower (65%) up to week 15 compared to all other treatments (75%) ($P<0.05$). Treatment B (76%) and C (78%) resulted in higher survival rates than treatment D (70%), but these data were not significantly different. When weaning practices were compared; it was found that overall survival of chickens under weaning practice WK4 was slightly lower (67%) at an age of 15 weeks compared to WK8 (77%) and WK12 (73%) at the same age. The survival rate of the chicks at the age of weaning differed among the groups. Chicks weaned at the attainment of 4 weeks (4WK group) of age had survival rate of 86%; whereas chicks weaned at the attainment of 8 (8WK group) and 12 weeks (12WK group) of age had survival rate of 85% and 75%, respectively.

Figure 1: Survival of chickens up to 24 weeks

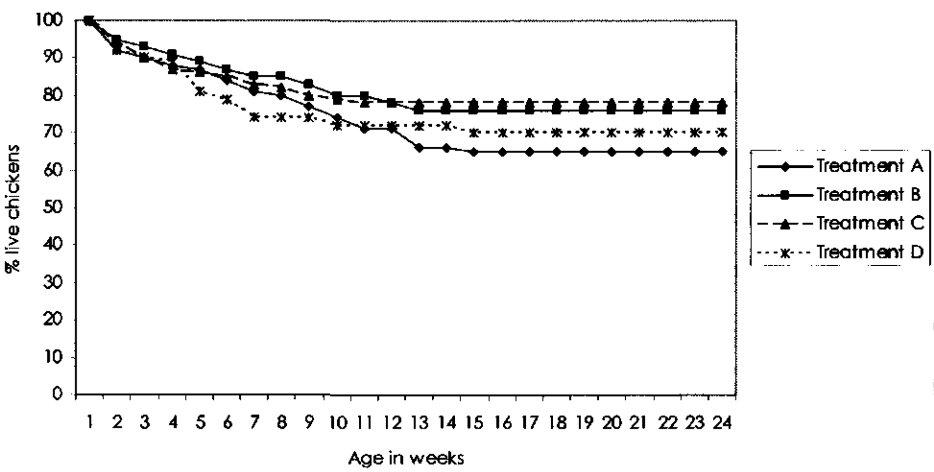
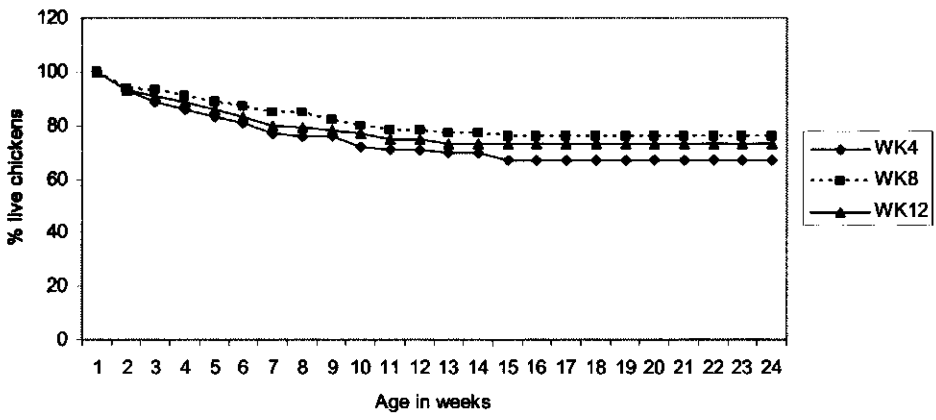


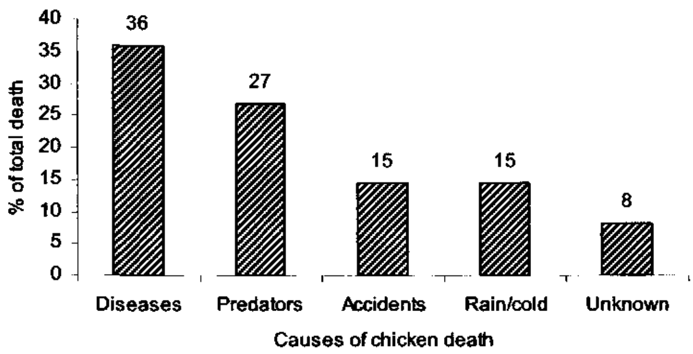
Figure 2:Survival of chickens up to 24 weeks in each weaning policy



Causes of deaths in experimental birds

Various causes of chicken deaths during the experimental period are presented in Figure 3. The most common cause of death was diseases followed by predators, accidents and rain/cold. Infectious coryza, fowl pox and diarrhoea were the most common diseases while predators included wild cats, domestic carnivores (cats and dogs), rodents, pigs and birds of prey. Accidents included chicks drowning and stepping on by human or animal. Unknown causes constitute part of chickens that died and farmers did not record any cause, either because they forgot or they did not know the actual cause of death. The proportion of chickens which died from predation was large in week 2 (24%) and then tended to decrease until week 13 (5%). Younger chickens more often died due to predation, accidents and rainy or cold weathers compared to older chickens.

Figure 3: Various causes of chicken death during experimental period



Slaughter weight, carcass weight and carcass percentage

Slaughter weight, carcass weight and carcass percentage at 24 weeks of age are presented in Table 7. These parameters were significantly lower in the rainy season than in the dry season ($P<0.05$) but did not vary much between farming systems. Chickens that relied on scavenging only had a significant lower slaughter weight, carcass weight and carcass percentage compared to the supplemented chickens ($P<0.05$). Significant differences could also be observed among the supplemented chickens where chickens on diet D had higher values for these parameters ($P<0.05$). Weaning periods did not influence these parameters while sex of the chicks had a significant influence on these parameters: male chickens had higher values than female chickens ($P<0.05$). The interaction effect between season and feeding regime was significant different in both seasons. Non supplemented Chickens had significant lower values of the parameters both in the rainy and dry seasons. Similarly interaction effects were significantly higher between season and sex, treatment and farming system, sex and farming system and between treatment and sex. The difference between sexes was more pronounced in all seasons and farming systems where, male chickens had significant higher body weight, carcass weight and carcass percentage than females ($P<0.05$). There were, however no significant differences among males and females chicks with respective to seasons and farming systems.

Table 7. Least square means for slaughter live body weight, carcass weight and carcass percentage at 24 weeks of age for chicken (Mean ± SEM)

Factors	Sub-factors	Slaughter weight (g/bird) at 24 weeks	Carcass weight (g/bird)	Carcass (%)
Seasons	Rainy	1496 ± 3.5^{a}	1027 ± 5.7^{a}	68 ± 0.36^{a}
	Dry	1507 ± 3.5^{b}	1050 ± 5.7^{b}	70 ± 0.36^{b}
Farming systems	FS-A	1504 ± 3.5^{a}	1042 ± 5.7^{a}	69 ± 0.36^{a}
	FS-B	1500 ± 3.5^{a}	1035 ± 5.7^{a}	69 ± 0.36^{a}
Diet treatments	A	1204 ± 5.0^{a}	777 ± 8.0^{a}	64 ± 0.50^{a}
	B	1524 ± 5.0^{b}	1100 ± 8.0^{b}	72 ± 0.50^{b}
	C	1573 ± 5.0^{c}	1105 ± 8.0^{bc}	70 ± 0.50^{c}
	D	1706 ± 5.0^{d}	1171 ± 8.0^{d}	69 ± 0.50^{d}
Weaning practices	WK4	1508 ± 4.3^{a}	1036 ± 6.9^{a}	68 ± 0.44^{a}
	WK 8	1494 ± 4.3^{b}	1043 ± 6.9^{a}	66 ± 0.44^{a}
	WK 12	1503 ± 4.3^{ab}	1036 ± 6.9^{a}	69 ± 0.44^{a}
Sex of chicks	Male	1626 ± 3.5^{a}	1124 ± 5.7^{a}	69 ± 0.36^{a}
	Female	1377 ± 3.5^{b}	953 ± 5.7^{b}	68 ± 0.36^{b}
Interactions	Season x treatment	*	*	*
	Season x sex	*	*	*
	Treatment x Farming system	*	*	*
	Sex x Farming system	*	*	*
	Treatment x Sex	***	***	***

$^{a-c}$ Means with different superscript letters within a column and factor are significant at $P<0.05$; SEM = standard error of the mean; **** = Significant at $P<0.001$; * = Significant at $P<0.05$; NS = Not significant; A = scavenging only (control); B = scavenging + a high protein, low energy diet; C = scavenging + a high energy, low protein diet; and D = scavenging + a high protein, high enegy diet; FS-A = maize-bean-sunflower farming system; FS-B = sorghum-pearl millet-groundnut farming system; WK4 = 4 weeks; WK8 = 8 weeks; WK12 = 12 weeks

Egg production, egg weight and hatchability

The results on egg production, egg weight and hatchability are presented in the Tables 8, 9 and 10. The results indicate that weaning management practices increased the number of clutches from 2 at normal weaning (12 weeks) to 4 and 3 clutches when chicks are weaned at 4 weeks and 8 weeks of age, respectively. In all cases, the mean number of eggs per cluctch did not differ between weaning practices. The overall mean number of eggs per clutch was around 14 eggs per hen. Weaning chicks at an early age of 4 weeks increased egg production to 56 eggs in a period of six months. This was higher than weaning chicks at 8 and 12 weeks ($P<0.05$). Likewise, the feeding regime had a significant effect on egg production across the 4 clutches. Egg production was higher in the clutches 1 and 2 for the hens that received supplementary diets compared to those not supplemented ($P<0.05$). Among all supplemented hens, values were similar. There were differences in number of eggs between suppplemented hens at clutch 3 and clutch 4 ($P<0.05$). The total number of eggs differed clearly between dietary treatments ($P<0.05$). The effect of season was only evident in the fourth clutch. Farming system had less effect on the cluch size in clutch 1 and 2, but this effect was significant in clutch 3 and 4 ($P<0.05$), but only in the sorghum-pearl millet farming system. There were no signficant differences between farming systems on mean total egg production. Overall mean egg weight recorded in all clutches ranged from 40.5 g to 41 g. Treatment D showed sigficannt increase in egg weight as the clutches progressed from first through fourth clutch.

Hatchability was high with an overall mean, ranging from 90 to 92%. There were no significant differences found between farming systems and between seasons in the percentage of eggs hatched. There were no clear effect of supplementtaion on hatchability as non supplemented tended to have higher hatchability percentage than supplemented chickens. Only sigificant differences between weaning periods in the hatchability of eggs were showed in clutch 2 for hens under weaning practices of 8 and 12 weeks which had higher values than hens under weaning practice week 4. The number of eggs incubated was high in the sorghum-pearl millet-groundnut farming system than in th maize-bean-sunflower farming system and was singificantly higher in treatment A and lower in all hens receieved supplementary diets. Brooding and rearing days differed significantly between the farming systems ($P<0.05$). Hens in the sorghum-pearl millet-groundnut farming system had significant lower brooding days than hens in the maize-bean-sunflower farming system. Hens in the dry season had significant lower brooding and rearing days than hen in the rainy season ($P<0.05$). As expected weaning management practices of WK4 and WK8 had significant shorter brooding and rearing days than weaning management practice of WK12 ($P<0.05$).

Table 8. Least square mean number per clutch of eggs produced by hens in central Tanzania in relation to the farming stems, seasons, feeding strategies and weaning periods

	Farming ystems			Seasons			Dietary treatments					Weaning practice				
Clutches	FS-A	FS-B	SEM	Rainy	Dry	SEM	A	B	C	D	SEM	WK4	WK8	WK12	SEM	Overall
1	13.9	13.9	0.14	13.8	14.0	0.14	11.1^{a}	14.5^{b}	14.9^{b}	15.3^{b}	0.20	13.8	14.0	14.1	0.18	13.9±0.10
2	14.2	14.1	0.15	14.4	13.9	0.15	11.0^{a}	15.1^{b}	15.1^{b}	15.5^{b}	0.21	13.9	14.4	14.2	0.18	14.2±0.10
3	13.5^{a}	14.5^{b}	0.16	14.2	13.9	0.16	10.9^{a}	14.7^{b}	14.9^{b}	15.9^{c}	0.22	14.1	14.1	-	0.16	14.0±0.11
4	13.7^{a}	14.4^{b}	0.21	14.5^{a}	13.6^{b}	0.21	10.6^{a}	14.4^{b}	14.7^{b}	16.4^{c}	0.30	14.0	-	-	0.16	14.0±0.15
Total	42.2	42.6	0.28	42.5	42.2	0.28	33.3^{a}	44.2^{b}	44.8^{b}	46.8^{c}	0.40	55.9^{a}	42.4^{b}	28.7^{c}	0.35	42.4±0.20

Note: $^{a-c}$ Means with different superscript letters within a column and factor are significant at $P<0.05$; SEM = standard error of the mean; A = scavenging only (control); B = scavenging + a high protein, low energy diet; C = scavenging + a high energy, low protein diet; and D = scavenging + a high protein, high enegy diet; FS-A = maize-bean-sunflower farming system; FS-B = sorghum-pearl millet-groundnut farming system; WK4 = 4 weeks; WK8 = 8 weeks; WK12 = 12 weeks

Table 9. Least square mean weight of eggs (g) produced by hens in central Tanzania in relation to the farming stems, seasons, feeding strategies and weaning periods

	Farming ystems			Seasons			Dietary treatments					Weaning practice				
Clutches	FS-A	FS-B	SEM	Rainy	Dry	SEM	A	B	C	D	SEM	WK4	WK8	WK12	SEM	Overall
1	40.5	40.5	0.24	40.5	40.5	0.24	40.3	40.4	40.6	40.8	0.34	40.5	40.5	40.6	0.30	40.5±0.17
2	40.6	40.6	0.23	40.5	40.8	0.23	40.4^{a}	40.4^{a}	40.3^{a}	41.4^{b}	0.33	40.3	40.8	40.7	0.29	40.6±0.17
3	40.9	40.9	0.23	40.9	41.1	0.23	41.0^{ab}	41.0^{ab}	40.5^{a}	41.4^{b}	0.33	41.0	41.0	-	0.23	40.9±0.16
4	40.9	40.9	0.26	40.7	41.2	0.26	41.0	41.0	41.1	41.1	0.36	41.0	-	-	0.18	41.0±0.18
Total	40.7	40.7	0.16	40.6	40.8	0.16	40.5	40.6	40.5	41.2	0.19	40.7	40.8	40.7	0.19	40.7±0.11

Note: $^{a-c}$ Means with different superscript letters within a column and factor are significant at $P<0.05$; SEM = standard error of the mean; A = scavenging only (control); B = scavenging + a high protein, low energy diet; C = scavenging + a high energy, low protein diet; and D = scavenging + a high protein, high enegy diet; FS-A = maize-bean-sunflower farming system; FS-B = sorghum-pearl millet-groundnut farming system; WK4 = 4 weeks; WK8 = 8 weeks; WK12 = 12 weeks

Table 10. Least square means for hatchabaility, percent of eggs incubated and brooding and rearing days

	Farming ystems			Seasons			Dietary treatments					Weaning practice				
Clutches	FS-A	FS-B	SEM	Rainy	Dry	SEM	A	B	C	D	SEM	WK4	WK8	WK12	SEM	Overall
1	90.6	90.8	0.74	90.5	90.9	0.74	93.9^{a}	90.3^{b}	89.0^{b}	89.7^{b}	1.04	90.5	91.2	90.4	0.90	90.7±0.52
2	91.2	92.1	0.61	91.5	91.8	0.61	92.2	90.7	92.2	91.4	0.86	90.5^{a}	91.7^{b}	92.7^{b}	0.74	91.7±0.43
3	91.7	91.7	0.76	92.1	91.3	0.76	93.6^{a}	91.7^{b}	90.2^{b}	91.3^{b}	1.07	91.3	92.1	-	0.76	91.7±0.54
4	87.9	91.6	1.02	88.7	90.7	1.02	95.8^{a}	87.3^{b}	88.4^{b}	87.5^{b}	1.44	89.7	-	-	0.72	89.7±0.72
Total	91.0	91.5	0.45	91.1	91.4	0.45	93.4^{a}	90.9^{b}	90.3^{b}	90.4^{b}	0.63	90.5	91.7	91.6	0.55	91.3±0.32
% eggs	85.8^{a}	87.8^{b}	0.63	86.4	87.2	0.63	94.2^{a}	84.9^{b}	84.1^{b}	84.0^{b}	0.88	87.7	85.6	87.2	0.77	86.8±0.44
BR days	80.2^{a}	79.0^{b}	0.18	80.2^{a}	79.1^{b}	0.18	79.9^{a}	79.5^{ab}	80.1^{a}	78.9^{b}	0.26	50.6^{a}	76.9^{b}	111.4^{c}	0.22	79.6±0.13

Note: $^{a-b}$ Means with different superscript letters within a column and factor are significant at $P<0.05$; SEM = standard error; % eggs = percentage of eggs incubated; BR days = brooding and rearing days; A = scavenging only (control); B = scavenging + a high protein, low energy diet; C = scavenging + a high energy, low protein diet; and D = scavenging + a high protein, high enegy diet; FS-A = maize-bean-sunflower farming system; FS-B = sorghum-pearl millet-groundnut farming system; WK4 = 4 weeks; WK8 = 8 weeks; WK12 = 12 weeks

DISCUSSION

Feeds and chemical composition

The feeds used to formulate the experimental diets are commonly available in the villages except fish-meal that was bought in town. Generally, these feedstuffs are often given in handful amounts to village poultry as supplements during daytime besides natural scavenging. The chemical composition of the feeds are within the range reported earlier for locally available poultry feeds in Tanzania (SAREC, 1986; Goromela *et al.*, 2007). The relatively low crude protein contents in cereals could be due to a high fiber content which have some diluting effect in grains (McDonald *et al.*, 2002). *Sunflower seed cakes and fish meal had high crude protein contents indicating that* these feeds could be used as potential source of protein in poultry diets (Smith, 1990; McDonald *et al.*, 2002). However, the high fiber content in sunflower suggest that its inclusion in poultry diets should not exceed 10 % as recommended by Smith (1990) and McDonald *et al.* (2002), because above that level it may impair digestibility. The inclusion levels of sunflower cakes in the experimental diets ranged between 4-5% of the diet (Table 1). In this range no detrimental effects on digestibility are expected. The metabolizable energy corrected for nitrogen equilibrium (ME_n) was relatively high, ranging from 10.6 MJ/kg in sunflower cakes to 15 MJ/kg in fish meal and in all cereals the energy content was 12.0 to 14.8 MJ/kg which is in the range reported by McDonald *et al.* (2002) and Rajaguru and Ravindran (1985).

Body weight gain and growth rate of chickens

The lower body weight gain and carcass weight in the rainy season than in the dry season is related to the availability of scavengeable feed resources. These seasons are distinct and it has been reported that during the rainy season (January-April) the availability of energy-rich feedstuffs such as grains of maize, sorghum and pearl millet and some protein-rich feedstuffs such as sunflower seed cakes and groundnut seeds is relatively low (Goromela *et al.*, 2007). Thus, when chickens were set free to scavenge they were more likely to pick protein-rich feedstuffs (insects and earthworms) and mineral/vitamin-rich feedstuffs than energy feedstuffs. Protein-rich feedstuffs and mineral/vitamin-rich feedstuffs are abundantly available in the rainy season than energy-rich feedstuffs which normally are highly available in the dry season. The significant higher body weight gain in the sorghum-pearl millet-groundnut farming system during the dry and rainy seasons can be related to the difference in climatic conditions which in most cases is the key determinant of the availability of scavengeable feed resources. In this farming system, sorghum ugali, maize ugali, pearl millet ugali, pearl millet brew wastes, sorghum brew wastes and maize brew wastes and protein feedstuffs such as garden vegetables, termites, grasshoppers, cutworms, earth-worms and maggot larvae were readily available than in the maize-bean-sunflower farming system. Farmers in the study area, provide supplement feeds to their chickens, mainly with cereal grains and their by-products and household refuse and kitchen wastes not on a regular basis. The clearly higher body weight gain for supplemented chicks suggest that scavengeable feed resources consumed by the chicks when released out for scavenging had deficiencies in terms of quality and quantity. The higher body weight gain (1669 g/bird) for the chicks supplemented with dietary treatment D compared to the body weight gains for the chicks supplemented with dietary treatments B (1530 g/bird) and C (1575 g/bird) demonstrate that both protein and energy were limiting in the scavengeable feed resources. These findings are in agreement with Roberts (1999) and Goromela *et al.* (2008) who reported that the protein and energy contents of the scavengeable feed resources are not sufficient for optimal growth of village chickens. The results in the present study demonstrate that chicks have higher requirements for protein and energy than obtainable from natural scavenging and that if they are provided with a high protein (20% crude protein) and high energy (14.5 MJ ME/kg) diet from day 1 to 24 weeks, it seems to be adequate for scavenging chickens. However, the average body weights of the supplemented chicks (1240 g/bird) at 20 weeks of age clearly indicate that local chickens in Tanzania have poor growth rate when compared to improved stocks. Assuming that generally local chickens are marketed at body weights of around 1 kg and above (Pedersen, 2002; Theerachai, 2006), this implies that market weight of the local chickens in Tanzania is attained at rather late ages compared to 8 weeks of age for meat type chickens and 12 weeks for the crosses between local chickens and meat type chickens (Theerachai, 2006) under intensive management.

The higher body weight gain of the chicks under weaning practices WK4 and WK8 up to 16 weeks as compared to those chicks under weaning practice WK12 might be related to the fact that they learned techniques for scavenging and get familiar with scavengeable feed resources earlier than their counterparts which dependent on their mothers to find food for them. On the other hand, these chicks had to learn how to scavenge for their own food as well as how to compete for food with the adult chickens and wild scavengers compared to those who were still under the care of the mother hens (WK12). This could explain why the chicks in weaning practices WK4 and WK8 had similar weight gains with those in WK12 at the end of the experiment (24 week). The higher body weight gains for male chicks than for female chicks from week 1 throughout the experimental period could be due to sexual dimorphism. These observations were also made by Msoffe *et al.* (2004) and Wilson *et al.* (1987) demonstrating sexual dimorphism from hatching up to 13 weeks of age respectively. However, when comparing means, all supplemented males and females had higher body weight gain than the non-supplemented male and female chicks, suggesting that preferential supplementation of chicks had a positive response on their growth performance. However, chicks supplemented with dietary treatment D had the highest body weight gain than chicks in dietary treatments B and C, indicating that treatment D contained all nutrients that were essential for optimum growth of the chicks.

Slaughter weight, carcass weight, carcass percentage and sexual maturity

The higher values of the slaughter weight, carcass weight and carcass percentage during the dry season could be related to the high availability of scavengeable feed resources (Goromela *et al.*, 2007). However these parameters did not vary between the farming systems in a season indicating that the availability of scavengeable feed resources was similar in both farming systems (Table 7). Chickens which relied on scavenging only had significant lower slaughter body weight, carcass weight and carcass percentage compared to the supplemented chickens. The lower values of these parameters for the non supplemented chickens were mainly due to their slower growth (Tables 5 and 6). However slaughter body weight, carcass weight and carcass percentage were higher for the chickens supplemented with diets containing high level of energy contents (14.5 ME MJ/kg) suggesting that energy is the most critical element in the diet of scavenging chickens. The carcass weights observed in the present study are within the range reported by Theerachai (2006) in Thai native chickens and crosses. In Africa, van Köster and Webb (2000), as cited by Theerachai (2006), evaluated carcass characteristics of different types of native African chickens and commercial broilers (Cobb). In this study, they found that the proportion of dressed carcass of Cobb broilers was significant higher than that of native chickens. The native ecotypes had low carcass yield and fat contents and higher bone contents than the commercial broilers. This may be due to the fact that native chickens have not been selected for growth or carcass traits but for household food security. In addition, the higher bone content in native chickens may be associated with adaptation to flight and scavenging behaviour (Theerachai, 2006). As earlier noted, village chickens are characterized by their delayed maturity; some authors show that sexual maturity in hens is estimated to be 24 to 32 weeks (Guèye (1998), 28 weeks (Tadelle and Ogle (2001) and about 25.5 weeks (Gondwe (2004). By improving feeding and husbandry systems, female chickens attained sexual maturity earlier (i.e. 24 weeks) than the range proposed by these authors. In the present study most of the female chickens received supplements had eggs in their ovaries and others had already started laying eggs when they were slaughtered at an age of 24 weeks. Moreover, crossbreeding indigenous chickens with exotic strains may also bring sexual maturity earlier from 28-36 weeks to 18-20 weeks (Assan, 1990) and to 12 weeks for the crosses between local chickens and meat type chickens under intensive management (Theerachai, 2006) .

Survival rate of village chicks

Survival rate of chickens on scavenging only was clearly lower (65%) compared to all other treatments over the study period. The lower survival rates observed for these chicks are probably related to their lower growth rates. Since these chicks can only rely on scavengeable feed resources, their body weight gains were significantly lower and they were smaller and may be weaker so that they could not compete with older chickens for scavengeable feeds. Similar findings have been reported by Roberts (1999), who showed that young chicks and growers are the weakest member of the population and hence cannot favourably compete with older chickens. This condition may have predisposed them to predators and diseases. Diseases (*infectious coryza, fowl pox and diarrhoea*) and predators (*wild cats, domestic carnivores*, rodents, pigs and birds of prey) were the most causes of chicken death during rainy and dry seasons (Figure 3). Low survival rate for chicks and growers under scavenging conditions have also been reported in Indonesia (Kingston, 1980), Thailand (Janviriyasopak *et al.*, 1989) and in Sri Lanka (Gunaratne *et al.*, 1993), and the chicks and growers which died tended to have lower growth rates (Wickramaratne *et al.*, 1993). Under scavenging conditions, malnutrition and subsequent starvation are the main cause of mortality in young chickens (Prawirokusomo, 1988; Ologhoho, 1992; Roberts and Senaratne, 19992). As a result, these conditions make them more vulnerable to predators and diseases (Cumming, 1992; Roberts, 1999). However, by supplementing and confining the chicks in the pens for six hours in a day besides natural scavenging increased survival rate and improved growth rate (Figure 1; Tables 5 and 6). The high survival rate in the present study might be related to a better nutritional status of the supplemented birds, because this may have increased their immune response to a disease challenge (Sonaiya and Swan, 2004). Moreover, the improved growth rate suggests that chicks were larger and heavier than those on the control, so that when they are released for scavenging they are able to compete for feeds as well as running away from predators. Losses due to predation were as high as 27% up to 15 weeks of age, which is lower than 65% up to 12 weeks, as reported by Mushi *et al.* (2005) in chicks under free-range conditions in Botswana. Lower losses due to predation for the supplemented chicks in this study could have been affected by confinement in the pens for six hours (i.e. half a day), thereby reducing the risk of a predator attack during scavenging. It was further noted that as the chicks grew older, less chicks fall victim to predation and as a result more chickens die due to diseases. Gunaratne *et al.* (1994) reported that chick mortality rates could be reduced by the use of creep feed. Creep feeding of chicks with a high protein diet under confinement during the vulnerable period of their life increased their survival rate (88%) up to 10 weeks in Bangladesh (Sarkar and Bell, 2006). In an experiment where household waste was supplemented with protein and fed in a creep feeder, both survival rate and growth rate of chicks increased (Roberts *et al.*, 1994). Similarly, Chandrasiri *et al.* (1994) indicated that a very high survival rate and improved growth rate could be observed, if chicks were reared in a pen with choice feeding. Regarding the weaning practices, the lower survival rate (67%) under weaning practice WK4 could be related to diseases and predation rather than to early weaning itself. Thus these results suggest that early weaning of village chicks at WK4 and WK8 is much safer and can be used as a possible way to increase egg production in indigenous chickens. The results suggest that early weaning management could beneficial when preferential feeding of chicks and growers using locally available feed resources rich in protein and energy are adopted to enhance their survival and growth rate.

Egg production, egg weight and hatchability

The present study indicates that feeding and weaning strategies increased the number of eggs produced per hen over the study period. The number of clutches increased from 2 clutches with 29 eggs in a period of six months when chicks were weaned at an age of 12 weeks to 3 clutches with 42 eggs and 4 clutches with 56 eggs, when these chicks were weaned at 8 weeks and 4 weeks of age, respectively. This would mean that on an annual basis, hens that have weaning at WK12 would only produce 4 clutches and 58 eggs per hen per year, which is significantly lower than those weaned their chicks at earlier ages. These numbers are somewhat similar to data of the local chickens in Ethiopia with 3-4 clutches per year and 15-20 eggs per clutch (Tadelle and Ogle, 2001) and 2-3 clutches per year in Marocco with about 78 eggs (Benabdeljelil and Arfaoui, 2001). This is lower compared to the production data obtained in this study when chicks were separeted from their mothers at an early age (i.e. at 4 and 8 weeks of age). Annually, weaning at WK8 and WK4 would result in 6 clutches with 84 eggs per hen per year and 8 clutches with 112 eggs per hen per year, respectively. These findings are supported by observations reported by Prasetyo *et al.* (1985) in Indonesia, and Sazzad (1993) and Sarkal and Bell (2006) in Bangladesh. The study shows that weaning at an early stage has the advantage of increasing egg production per hen because of an increased laying time for the hens (i.e. it increases frequency of egg production by indigenous chickens). It was clearly shown here that early weaning itself did not increase the number of eggs per hen per clutch (Table 7). The overall mean number of eggs per clutch was around 14 eggs per hen which is similar to data reported by Wilson *et al.* (1987) in Burkina Faso for local chickens.

Regarding feeding strategies, it was observed that hens which relied on scavenging only produced fewer eggs (33 eggs) than those with suppplementary diets. This indicates that scavengeable feed resources alone cannot increase egg production under village conditions.

Previous studies have shown that scavengeable feed resources have generally low protein, energy and minerals particularly calcium and phosphorus contents (Goromela *et al.*, 2007 and 2008). They concluded that scavengeable feed resources can just cover requirements for maintenance and for some low egg performance. In the study area, chickens are supplemented with cereal grains and their by-products and also with household refusals. This kind of supplementation depends firstly on the availability of grain and household refusals and is not practised regularly. Secondly, in most cases supplements provided may contain just one source of nutrient (mainly energy) while other nutrients are lacking especially during the dry season (Goromela *et al.*, 2008); and thirdly, when these supplements are provided, laying hens and (very) young chicks are not given preferential access to feed supplementation. Normally, these supplements are provided through an in-situ system where each bird has to compete for the supplements. It is apparent that giving supplements indiscriminately can result into high competition pressure among chickens of various ages and sexes (Goromela *et al.*, 2006). Adult birds especially cocks may be overfed while young chicks starve. As observed in the present study, supplemenation of scavenging chickens with both nutrients (protein and energy) incresead egg production most. The effect of season on the clutch size could not be demonstrated clearly in the present study. This indicates that it has hardly any effect on egg production. Farming systems did hardly affect clutch size. Highest clutch sizes were recorded in the sorghum-pearl millet-groundnut farming system. The results show that most of the variables investigated (farming system, season and weaning periods) did not influence the overrall mean egg weight recorded in all clutches, ranging from 40.5 g to 41 g (Table 8). Only a small increase in egg weight was noted in hens supplemented with both high protein and high energy.

Hatchability was high with an overall mean ranging from 89.7 to 91.7 (Table 7) and these data are within the range reported by other authors in developing countries (Wilson, 1979; Mourad *et al.*, 1997; Minga *et al.*, 1989). However, the precent hatchability observed in the present study were higher than those reported by Wilson *et al.* (1987) in Mali, Van Veluw (1987) in Ghana, and Shanawany and Banerjee (1999) in Ethiopia. There were no seasonal and farming system differences in our study, as compared to the case of Mali where hatching was lower in the hot-dry season. Generally, over 90% of the eggs laid will be incubated. This is related to the small clutch sizes as well as that no eggs are used for home consumption or for sale. Moreover, farmers prefer poulty meat over eggs, which in most cases led them to leave more eggs to incubate so as to increase flock size. In general, weaning length did not affect hatchability of eggs. Number of eggs set for incubation were higher in the sorghum-pearl millet-groundnut farming systems than in the maize-bean-sunflower farming system. Number of brooding days were less in the sorghum-pearl millet-groundnut farming system than in the maize-bean-sunflower farming system, while between seasons, number of brooding and rearing days were less in the dry season than in rainy season. Hens on supplemented energy tended to spend more days on brooding and rearing than the hens in the other dietary treatments. Regarding the weaning treatment, it was expected that brooding and rearing days were directly related to weaning strategy: earlier weaning meant shorter brooding and rearing periods. Consequently, a shorter brooding period increased egg production per hen because more time was available for egg production.

CONCLUSIONS

The study reveals that in the traditional management system, hens perform a wide range of production and management activities. These include laying a clutch of eggs, hatching chicks, brooding and rearing them until they are naturally weaned at around 12 weeks of age or older. Under such a system, reproductive efficiency is very low (i.e., 4 clutches per hen per year) because a hen spends less time (35 days) for productive purposes and spends a lot of time (76 days) on brooding and rearing of chicks. From this study, it was revealed that when small interventions are made in a few aspects of this traditional husbandry practice, indigenous chickens are able to improve their production efficiency. Weaning of chicks at an early stage of life (i.e. at 4 or 8 weeks of age) and practicing a half-day confinement of chicks in a house increased the survival rate of chicks and increased the frequency of egg production by the indigenous hen. Moreover, minimum supplementation of protein and energy diets, along with weaning, helps to reduce the length of the reproduction cycle and to maximize laying performance of scavenging hens. Supplementation, besides natural scavenging, improved body weight gain and growth rate in chicks. In conclusion, early weaning of chicks at 4 weeks and 8 weeks of age had an advantage over weaning at 12 weeks of age by improving reproductive performance of hens, without compromising chicks' survival or growth rate. Further studies are suggested to investigate the effect of supplementary feeding and laying management practices on egg production and body weight changes in scavenging hens under farmers' conditions.

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CHAPTER 6

EFFECTS OF PROTEIN AND ENERGY SUPPLEMENTATION AND LAYING MANAGEMENT STRATEGIES ON EGG PRODUCTION AND BODY WEIGHT CHANGES OF SCAVENGING HENS UNDER VILLAGE CONDITIONS IN CENTRAL TANZANIA

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Abstract

Two factorial experiments with a total of 144 indigenous laying hens were conducted over a period of about six months in two villages in Central Tanzania to evaluate the effect of protein and energy supplementation and laying management strategy on egg production and body weight gain. The hens were each subjected to one of four dietary treatments: A: scavenging only (control); B: scavenging + high protein, low energy diet; C: scavenging + high energy, low protein diet; and D: scavenging + high protein, high energy diet; and three egg-laying management strategies i.e. L-H-R: lay, hatch, and rear chicks for 12 to 16 weeks; L-H: lay, hatch and rear chicks for 1 week only; and L: lay only. Hens that could only scavenge (treatment A) produced fewer eggs (47 eggs) than those that received supplemental diets B, C or D ($P<0.05$). Furthermore, hens that received diet D produced more eggs (59 eggs) than those in the other groups ($P<0.05$). Hens in L-H-R group produced only about 30 eggs compared to the 53 eggs in the L-H and 73 eggs in the L groups ($P<0.05$). Final body weights and body weight gains were higher in all hens receiving diets B, C and D than in non-supplemented hens and hens under the L-H and L management systems ($P<0.05$). Hens in the L-H-R and L-H groups consumed more feed during the study period than hens in the L group ($P<0.05$). From these results, it can be concluded that low production performance of indigenous chickens is mainly due to inappropriate management conditions under which the birds are raised. The results clearly reveal that the productivity of indigenous hens under traditional management systems can be increased by supplementary feeding and relieving the hens from some aspects of reproductive activities such as from brooding and rearing.

Key words: *Supplementary feeding, laying management, indigenous chickens, egg production, body gain.*

INTRODUCTION

Rural poultry accounts for about 90 % of the total poultry population in Tanzania. Indigenous chickens account for about 95 % of total poultry kept in the traditional poultry sub-sector (MoAC, 1995). Indigenous chickens are robust and well adapted to hash environmental conditions like hot or cold weather, rain and periodic feed shortages (Guèye, 1998; Aganga *et al.*, 2003). Due to these wide adaptation capabilities in many ecological zones, indigenous chickens in Tanzania make a considerable contribution to livelihoods of most of the rural households in terms of food supply, manure and traditional ceremonies (Melewas, 1998; Goromela *et al.*, 1999). According to Melewas (1998), more than 75 % of human food supply in terms of animal protein in rural areas of Tanzania comes from indigenous chickens. Despite their contribution, little is known about the production potential of the indigenous chicken. Consequently, it has been very common among poultry specialists to point-out that the production potential of indigenous chicken is very low. This low productivity has been attributed to their small body size, low egg production, small egg size (Veluw, 1987; Wilson *et al.*, 1987; Bourzat and Saunders, 1989; Smith, 1990; Sonaiya, 1990; Sazzad, 1992; Guèye, 1998) and low hatchability (Veluw, 1987); Wilson *et al.*, 1987; Aganga *et al.*, 2000). Under village conditions, the annual egg production per bird ranges from 20 to 100 eggs with weights ranging from 30 to 50 g (Guèye, 1998).

In a traditional management system, such as in Tanzania, a laying hen performs a number of production and management activities. Production activities include laying a clutch of eggs and hatching young chicks and management activities include brooding and rearing of young chicks for a considerable period of time (Smith, 1990). All these activities take place in an orderly fashion called a reproduction cycle (Sarkar and Bell, 2006). It has been reported that a complete reproduction cycle in a traditional management system can take around 90 to 130 days (Wilson et al., 1987; Smith, 1990; Missohou *et al.*, 2002; Sarkar and Bell, 2006). Several authors have indicated that most of the time in the hen's reproduction cycle is spent for brooding, rearing and taking care of chicks including a recuperation period for the depleted body condition (Prasetyo *et al.*, 1985; Huque *et al.*, 1990; Smith, 1990; Sazzad, 1993; Aganga *et al.*, 2000; Sarkar and Bell, 2006). Low productivity of indigenous chickens could also be due to the consumption of low quality and low quantity scavengeable feed resources during egg-laying, incubation, and the recuperation period. In Tanzania, indigenous chickens mostly rely on scavenging with minimal or no supplementation (Goromela *et al.*, 1999, Mwalusanya *et al.*, 2001). Previous studies have shown that scavengeable feed resources consumed by free ranging chickens vary from 45 g in the rainy season to 54 g per bird per day in the dry season. The average intake of crude protein was 4.6 g per bird per day. This is not sufficient to fulfill their protein needs (Goromela *et al.*, 2008).

Furthermore such scavengeable feed resources are mostly low in crude protein (8-10%), energy (10-12 MJ/kg) and minerals in particular calcium (0.5-1.2%) and phosphorus (0.5-0.7%) (Goromela *et al.*, 2006; 2007; 2008). As a consequence, nutrient deficiencies and imbalances under such low input low output poultry production systems are a common phenomenon in scavenging birds and can certainly influence the productivity of laying hens (Huque et al., 1999; Sonaiya et al., 1995; Goromela et al., 2008). Therefore, the objectives of the present study were to evaluate the effects of supplementation of protein and energy sources and egg-laying management strategies on egg production, body weight gain and production efficiency of scavenging chickens under smallholder conditions in Central Tanzania.

MATERIALS AND METHODS

Location, selection of villages and farmers

The study was conducted in two neighbouring villages i.e. Bumila in Mpwapwa district and Chamkoroma in Kongwa district. Both districts are located in the Dodoma region in Central Tanzania. The above two villages are located in the agro-pastoral farming system zone characterized by a long dry season between July and December, and a short single rainy season with about 85 % rainfall falling between January and April, followed by extended showers between May and June. The major crops grown are maize, beans, sunflower, groundnuts and cassava; livestock species kept include indigenous chickens, goats, cattle, pigs, donkeys and sheep. The villages were chosen based on the existing farming system as well as on the ease of monitoring of this on-farm study. The villages were also selected based on the co-operation of local farmers and our previous experience in on-farm research activities for village chicken production. A total of thirty-six farmers were selected from the above two villages to participate in this study. The farmers were purposively chosen during village meetings from a population of farmers who keep chickens in each village using a stratified random sampling procedure and based on the following criteria: willingness to participate in the on-farm study; ownership of at least two indigenous laying hens that have completed at least the first reproductive cycle. This was done to ensure that any bird entering the experiment has at least attained sexual maturity and is productive with good laying capacity and mothering ability. In addition, the farmers should possess permanent chicken shelters.

Preparation of experimental diets and distribution to the farmers

The experimental diets were composed from the following locally available feedstuffs: maize bran, sorghum and pearl millet grains, sunflower cake and fish meal. The feedstuffs were thoroughly mixed and the experimental diets were bulked in 100 kg batches. Weekly feed allocations were weighed out in plastic bags and distributed to each participating farmer.

Experimental design and layout, birds, diets and experimental period

Two on-farm factorial experiments were set up. They were each comprised of four dietary treatments and three laying management strategies. The first exepriment was carried out in the rainy season (January-June) and the second experiment was carried out in the dry season (July-December). The four dietary treatments were; A: scavenging only (control); B: scavenging + high protein, low energy diet; C: scavenging + high energy, low protein diet; and D: scavenging + high protein, high enegy diet. The ingredient and nutrient composition of the diets is presented in Table 1. Dietary treatment D was included in order to provide an estimate of the egg production potential of indigenous hens when neither protein nor energy supply is limiting. The three egg-laying management strategies were; L-H-R: lay, hatch and rear chicks for 12 to 16 weeks [(+) (+) (+)]; L-H: lay, hatch and rear chicks for 1 week only [(+) (+) (--)] and L: lay only [(+) (--) (--)]. The L-H-R management strategy was used as a control to simulate a typical village management strategy under traditional poultry production systems. The three laying management strategies were imposed within the four dietary treatments in a factorial manner, with a total of six laying hens per each dietary-laying management treatment combination. The overall scheme for the four dietary treatments and the three laying management strategies is shown in Table 2.

Table 1. Ingredient and nutrient composition of the experimental diets

Feed ingredients (%)	Scavenging only or control (A)	Scavenging + high protein, low energy diet (B)	Scavenging + high energy, low protein diet (C)	Scavenging + high protein, high enegy diet (D)
Pearl millet grain	-	82.5	3.0	70.0
Sorghum grain	-	2.0	45.0	8.5
Maize bran	-	2.0	44.5	10.0
Sunflower seed cake	-	5.0	4.0	4.0
Fish meal	-	7.0	2.0	6.0
Vitamin premix	-	0.4	0.4	0.4
Limestone	-	0.6	0.6	0.6
Salt	-	0.5	0.5	0.5
Nutrients*				
Crude protein (%)	-	20.0	15.0	20.0
Metabolizable energy (MJ/kg)	-	13.5	14.5	14.5

* Crude protein and metabolizable energy contents of the diets were calculated based on chemical composition of feed ingredient

Table 2. Scheme for the on-farm experiment summarised by feeding regimes and egg-laying management strategies and hen's production and management activities

Feeding regimes	Laying management strategies	Laying	Hatching	Rearing	No. of farmers per treatment	No. of laying hens per treatment
A	L-H-R = lay, hatch and rear chicks for 12 to 16 weeks	(+)	(+)	(+)	3	6
	L-H = lay, hatch and rear chicks for 1 week only	(+)	(+)	(--)	3	6
	L = lay only	(+)	(--)	(--)	3	6
B	L-H-R	(+)	(+)	(+)	3	6
	L-H	(+)	(+)	(--)	3	6
	L	(+)	(--)	(--)	3	6
C	L-H-R	(+)	(+)	(+)	3	6
	L-H	(+)	(+)	(--)	3	6
	L	(+)	(--)	(--)	3	6
D	L-H-R	(+)	(+)	(+)	3	6
	L-H	(+)	(+)	(--)	3	6
	L	(+)	(--)	(--)	3	6
Total					36	72

Note: A: scavenging only - control; B: scavenging + high protein, low energy diet; C: scavenging + high energy, low protein diet; and D: scavenging + high protein, high enegy diet; + means Yes; and -- means No

In each experiment, a total of 72 indigenous laying hens of around 7-8 months of age were randomly allocated to the four dietary treatments and to the three egg-laying management strategies. These hens were provided by participating farmers after ensuring that the hens have attained sexual maturity and are productive with good laying capacity and mothering ability.

Feeding and management of experimental birds

The hens in dietary treatment A were released from their shelters at 7.00 am each day to scavenge their own diets around the household compounds and in nearby gardens and crop fields until 7.00 pm. On the other hand, the hens on dietary treatments B, C, and D were confined in individual pens from 7.00 am until 1.00 pm and were offered 50 g of supplementary feed per bird on a daily basis. From 1.00 pm onwards, these hens were released from their pens to additionally scavenge their own diets similar to their counterparts in dietary treatment A until 7.00 pm when they returned to their pens. Hens in L-H-R and L-H groups continued to receive the same amount of supplementary feeds throughout the reproductive cycle (laying, incubation and rearing; including recuperation period). The laying hens in the L group were not allowed to incubate their eggs and instead these eggs were either given to other laying hens or sold and were sometimes consumed by family members. The hens in L-H group were separated from their chicks 7 days after hatching. The chicks were kept either in local brooding boxes out of sight of broody hens or they were given to sarrogate brooding mothers at night-time. Furthermore, the chicks from the hens in L-H group were provided with diet D while chicks from hens in L-H-R were provided similar diets as given to their mother hens before they could scavenge in the afternoon. The broody hens which had been seperated from their chicks were allowed to mate with cocks when they were released for scavenging. The chicks for the hens in L-H-R group were left to stay with their mother hens until they were naturally weaned at around 12 to 16 weeks. Data of chicks of all hens are not included in this study. Local nests were provided to the hens that were laying and incubating eggs. Clean drinking water was also provided daily *ad libitum* throughout the experimental period. All the hens were wing-tagged for identification and were vaccinated against Newcastle disease and treated against common diseases infectious coryza, fowly pox, diarrhoea and parasites such as worms, fleas and mites.

Data collection and parameters studied

Data collection started after one week of adaptation to the experimental feeds and pens. Data collected included: body weight gain, eggs produced per hen per clutch, egg weight, number of clutches, length of laying period per clutch, length of brooding (i.e.number of days spent from hatching until weaning) and length of one full reproduction cycle (i.e. total number of days spent on laying, hatching, brooding and rearing; including recuperation period). The body weight of each hen was recorded at the beginning of the experiment (laying period) and at the end of the experiment (brooding and rearing period). Feed consumption was measured in oder to determine supplementary feed intake. Feed refusals were recorded randomly twice a week in a month from each participating farmer. Supplementary feed intake was calculated by subtracting feed refusals from the feed offered per hen per day. Egg weights were recorded twice a week using digital balance (Salter max 5000 g with dimension of 1 g). Egg hatchability of the hens in L-H-R and L-H groups was calculated as follows:

$$\text{Hatchability \%} = \frac{\text{Number of chicks hatched}}{\text{Number of eggs set per hen for hatch}} \times 100$$

Economic assessment of supplemental feeding and egg laying management strategies was evaluated on the basis of total variable costs related to the purchase of veterinary drugs, experimental feeds and transport of feeds in Tanzania shillings (TZS). Veterinary costs were 898.00 TZS per hen and the costs for transporting feeds was 208.00 TZS per hen. Feed costs during the experimental period were calculated by multiplying total feed intake by price per kg of experimental feed. These worked out to be 142.55, 138.80 and 141.54 TZS for dietary treatments B, C and D, respectively. Total revenues were obtained by adding estimated revenues from sales of eggs and hens. Revenues for the eggs were calculated by multiplying eggs produced per bird by farm gate price of 100 TZS per egg. Revenues for the hens were calculated by multiplying final weight per bird by farm gate price of 2500 TZS per kg live weight of bird (farm gate price was determined from an average selling price for 310 indigenous hens in four villages). Initial value of hens obtained by multiplying initial body weight per bird by farm gate price per kg live weight was used as covariate for the adjustment of the final value of the hens. Net profit was calculated by subtracting total variable cost from total revenue. Costs for labour, housing and hens including rearing of chicks were not considered in the analysis as they were provided free by the family members.

Statistical analysis

The data was analysed in accordance with the 2x3x4 factorial design (i.e. for two seasons by three laying management strategies by four dietary treatments), using the General Linear

Model procedure of the SPSS software version 15.0 for windows (2006). The Least Square Difference was used to compare means for each variable as outlined in the statistical model below:

$Y_{ijkl} = \mu + S_i + F_j + L_k + (S*F)_{ij} + (S*L)_{ik} + (F*L)_{jk} + (S*F*L)_{ijl} + E_{ijkl}$

Where Y_{ijkl} is an observation from the l^{th} bird in the k^{th} laying management strategy and j^{th} feeding regime within the i^{th} season; μ is the general mean common to all observations in the study; S_i is the effect of the i^{th} season of the year ($i = 1, 2$); F_j is the effect of the j^{th} feeding regime ($j = 1, 2, 3, 4$); L_k is the effect of the k^{th} laying management strategy ($k = 1, 2, 3$); $(S*F)_{ij}$ stands for interaction effect between the i^{th} season of the year and j^{th} feeding regime; $(S*L)_{ik}$ stands for interaction effect between the i^{th} season of the year and k^{th} laying management strategy; $(F*L)_{jk}$ stands for interaction effect between the j^{th} feeding regime and k^{th} laying management strategy; $(S*F*L)_{ijl}$ stands for interaction effect between season, feeding regime and laying management and E_{ijkl} represents the random effects peculiar to each observation.

RESULTS

For all traits tested, only a few interaction terms proved to be significant. Therefore, it was decided to summarize only the main effects in the Tables that follow in the subsequent section.

Egg production, egg weight and hatchability

The main effects of season, diet supplementation and management strategy on egg number, egg weight and hatchability are presented in Table 3. There were no significant differences between seasons for the most of these performance variables. However, the overall mean number of eggs produced during the study period tended to be higher (54 eggs) in the dry season than in the rainy season (53 eggs). The mean number of eggs produced per clutch and the percent hatchability were similar in both seasons. Nevertheless, there was a significant difference between seasons with respect to weight of eggs ($P<0.05$). Cumulative total egg weight (2183 g) and overall mean egg weight were significantly higher for the hens in the dry season than in the rainy season (2183 vs. 2089 g and 41 vs. 39 g, respectively). The results in Table 3 show that there was a significant difference between the dietary treatments on the number of eggs produced per hen per clutch in both seasons. Scavenging hens without supplementation produced fewer eggs (13 eggs) than the hens that received any of the supplements in addition to scavenging ($P<0.05$). Among supplemented hens, diet D produced more eggs per than diets B and C ($P<0.05$).

Supplementation had no significant effect with respect to the overall mean egg weights and percent hatchability, but was significant for cumulative egg weight ($P<0.05$). The hens on dietary treatment D had higher cumulative total egg weight than supplemented hens on dietary treatments B and C; whereas hens which relied only on scavenging had the lowest cumulative total egg weight. There were significant laying management effects on total number of eggs produced ($P<0.05$). The hens that reared their chicks up to 12 or 16 weeks (L-H-R group) produced fewer eggs (30 eggs) than the hens in the L-H group (53 eggs) and those in the L group (73 eggs) ($P<0.05$). There were no significant differences between the laying management strategies in mean number of eggs produced per clutch, mean egg weight and percent hatchability of eggs. Cumulative total egg weight was higher (2889 g) for the lay-only group (L group) than for the other two groups ($P<0.05$). The lay-hatch-rear (L-H-R) group had the lowest mean cumulative egg weight.

Table 3. Mean values (and SEM) for egg production, egg weight and hatchability of eggs under village conditions in Central Tanzania

Main factor	Levels of factor	No. of eggs produced	No. of eggs clutch^{-1}	Total egg weight (g)	Egg weight (g)	Hatchability (%)
Season	Rainy	53^{a}	15^{a}	2089^{a}	39^{a}	88^{a}
	Dry	54^{a}	15^{a}	2183^{b}	41^{b}	88^{a}
	SEM	0.5	0.3	25.4	0.3	0.8
Feeding strategy	Scavenging only (A)	47^{a}	13^{a}	1847^{a}	39^{a}	86^{a}
	Scavenging + high protein + low energy (B)	53^{b}	14^{a}	2122^{b}	40^{a}	88^{a}
	Scavenging + high energy + low protein (C)	55^{c}	15^{b}	2186^{bc}	39^{a}	88^{a}
	Scavenging + high protein + high energy (D)	59^{d}	17^{c}	2387^{d}	40^{a}	88^{a}
	SEM	0.7	0.2	35.9	0.4	1.1
Laying management	Lay, hatch and rear (L-H-R)	30^{a}	15^{a}	1174^{a}	40^{a}	88^{a}
	Lay and hatch (L-H)	58^{b}	15^{a}	2343^{b}	40^{a}	88^{a}
	Lay only (L)	73^{c}	15^{a}	2889^{c}	39^{a}	-
	SEM	0.6	0.3	31.1	0.4	0.8

$^{a-d}$ Means with different superscript letters within a column and factor are significantly different ($P<0.05$); SEM = Standard error of the mean;

Number of clutches and length of reproductive cycles

The overall total number of days for laying eggs and the mean number of days a hen was laying per clutch were similar between seasons. The overall number of days for brooding and rearing of chicks differed significantly between seasons (P<0.05). The hens in the rainy season spent on average a total of 51 days on brooding and rearing of young chicks compared to 49 days during the dry season. The mean lengths of the reproduction cycle were similar between the seasons. The overall total number of days to complete at least two reproduction cycles was similar in both seasons. On average, there were 6.7 clutches and 98 eggs per hen per year.

The results in Table 4 show that supplementation strategies had a significant effect on most of the production parameters. Hens that relied on scavenging only had fewer number of days spent on laying eggs compared to those which received supplementary feeds in addition to scavenging (P<0.05). There was a significant increase in the number of days spent on laying eggs among the supplemented hens. The hens that received high energy and high protein diets spent more days (54 days) on laying eggs than the hens that received diets which were low either in protein or in energy. Hens which relied on scavenging only had a significantly shorter period of days for laying eggs per clutch (13 days); whereas hens that received high energy and high protein supplements had a longer period of days for laying eggs (16 days) and this differed significantly for the hens that received a high protein and low energy diet (14 days) and those that received a high energy and low protein diet (15 days) (P<0.05). The total number of days for brooding and rearing was significantly higher (55 days) for the hens that relied on scavenging only, and hens that received high energy and high protein supplements spent the fewest number of days (46 days) on brooding and rearing chicks. The mean length of the reproduction cycle differed significantly between the treatments. The hens that relied on scavenging only took more days (71 days) to complete one reproduction cycle than those that received supplementary feeds in addition to scavenging (P<0.05). The total number of days for the reproduction cycle within the experimental period was significantly higher (193 days) for the hens that relied on scavenging only than in those that received some supplementary feeds (P<0.05); although these were not significantly different. The number of clutches per hen per year was generally similar for the hens that relied on scavenging only and all the hens that received diets which were low either in protein or in energy, but were slightly lower for the hens that received high energy and high protein supplements. There were significant differences between dietary treatments with respect to the total number of eggs per hen per year (P<0.05). The hens which depended on scavenging only produced fewer eggs (88 eggs) than those receiving supplementary feeds in addition to scavenging. Hens that received high energy and high protein supplements produced more eggs (107 eggs) than those receiving a high protein and low energy diet (97 eggs) and those on a high energy and low protein diet (102 eggs) ($P<0.05$).

Results in Table 4 also clearly demonstrate that laying management strategies had a significant effect on most of the variables investigated ($P<0.05$). The total days spent on laying was significantly less (30 days) for the hens on the lay-hatch-rear programme than for those on the lay-hatch (43 days) and the lay-only (78 days) programmes. The mean length of period for laying was not significantly different between hens in the lay-hatch-rear and lay-only groups, but hens in these two groups differed significantly from those hens in the lay-hatch group. The total number of brooding and rearing days was significantly more (128 days) in the lay-hatch-rear group than the 21 days recorded in three clutches of the lay-hatch group ($P<0.05$). The mean length of the reproduction cycle for the lay-hatch-rear group was 117 days and was significantly longer than the 56 days for the lay-hatch group and the 34 days for the lay-only group. The hens on the lay-hatch-rear programme took more days (232 days) to complete two cycles of production than those on the lay-hatch programme who took 177 days to complete three cycles, and those on the lay-only programme who took 164 days to complete five cycles ($P<0.05$). In a year, assuming that these birds lived that long, the hens in the lay-hatch-rear group could complete only 3.1 clutches per hen per year compared to 6.2 clutches for hens in the lay-hatch programme and 11.2 clutches in the lay-only group ($P<0.05$). Corresponding, egg output for the hens in the lay-hatch-rear group was only 47 eggs per hen per year compared to 98 eggs for hens in the lay-hatch group and 160 eggs for hens in the lay-only group ($P<0.05$).

Table 4. Mean values (and SEM) of traits for laying eggs, brooding and rearing, production cycle, numbers of clutches and eggs per hen $year^{-1}$

Main factor	Levels of factor	Total days for laying eggs	Length of laying eggs $clutch^{-1}$	Total days for brooding and rearing	Length of production cycle	Total days for production cycles	No. of clutches hen^{-1} $year^{-1}$	No. of eggs hen^{-1} $year^{-1}$
Season	Rainy	48^{a}	15^{a}	51^{a}	70^{a}	192^{a}	6.7^{a}	98^{a}
	Dry	49^{a}	15^{a}	49^{b}	69^{a}	191^{a}	6.7^{a}	99^{a}
	SEM	0.5	0.2	0.4	0.2	0.6	0.03	0.8
Feeding strategy	Scavenging only (A)	43^{a}	13^{a}	55^{a}	71^{a}	193^{a}	6.8^{a}	88^{a}
	Scavenging + high protein + low energy (B)	48^{b}	14^{b}	50^{b}	69^{b}	191^{ab}	6.6^{bc}	97^{b}
	Scavenging + high energy + low protein (C)	50^{c}	15^{c}	48^{c}	68^{bc}	190^{b}	6.7^{ab}	102^{c}
	Scavenging + high protein + high energy (D)	54^{d}	16^{d}	46^{d}	67^{cd}	191^{ab}	6.6^{c}	107^{d}
	SEM	0.7	0.2	0.6	0.3	0.8	0.04	1.1
Laying management	Lay, hatch and rear (L-H-R)	30^{a}	15^{a}	128^{a}	117^{a}	232^{a}	3.1^{a}	47^{a}
	Lay and hatch (L-H)	43^{b}	14^{b}	21^{b}	56^{b}	177^{b}	6.2^{b}	98^{b}
	Lay only (L)	78^{c}	15^{a}	-	34^{c}	164^{c}	11.2^{c}	160^{c}
	SEM	0.6	0.2	0.5	0.6	0.7	0.03	0.4

$^{a-d}$ Means with different superscript letters within a column and factor are significantly different ($P<0.05$); SEM = Standard error of the mean;

Supplementary feed intake and body weight gain

Supplementary feed intake was similar in seasons and among dietary treatments. Only a significant difference in feed intake was found between laying management strategies. The hens in the lay-hatch-rear group consumed more supplementary feed than those that had short reproduction cycles ($P<0.05$). Final body weights and body weight gain rates showed differences between seasons, dietary treatments and laying management strategies. At the end of the experiment, mean final body weight (1738 g) and mean body weight gain rate (2.9 g/day) for the hens in the dry season were significantly higher than those in the rainy season ($P<0.05$). Final body weight (1638 g) and rate of body weight gain (2.3 g/day) were significantly lower for the hens that relied only on scavenging compared to those that received supplementary diets in addition to scavenging. When a contrast was made between the supplemented hen groups; final body weight and body weight gain rate differed significantly from each other ($P<0.05$). The hens that received supplementary diet with high protein and high energy contents had a higher mean final body weight (1814 g) and mean body weight gain (3.3 g/day) than those receiving supplementary diets either low in protein or in energy. The hens in the lay-hatch-rear and the lay-hatch groups had a higher final body weight and body weight gain than those in the lay-only group ($P<0.05$).

Table 5. Mean values (and SEM) for feed intake, initial and final weights and body weight gains of hens allocated to different feeding strategies and laying management strategies in the rainy and dry seasons

Main factor	Levels of factor	Total feed intake(g/hen)	Average feed intake (g/hen/day)	Final body weight (g)	Body weight gain (g/day)
Season	Rainy	7067	37.1	1716^{a}	2.7^{a}
	Dry	7089	36.9	1738^{b}	2.9^{b}
	SEM	21.7	0.12	5.1	0.03
Feeding strategies	Scavenging only (A)	-	-	1638^{a}	2.3^{a}
	Scavenging + high protein + low energy (B)	7085	37.0	1700^{b}	2.7^{b}
	Scavenging + high energy + low protein (C)	7111	37.2	1755^{bc}	3.0^{c}
	Scavenging + high protein + high energy (D)	7037	36.8	1814^{d}	3.3^{d}
	SEM	26.6	0.14	7.3	0.04
Laying management strategies	Lay, hatch and rear (L-H-R)	8731^{a}	37.3^{a}	1768^{a}	2.5^{a}
	Lay and hatch (L-H)	6379^{b}	36.0^{b}	1763^{a}	3.2^{b}
	Lay only (L)	6125^{c}	37.6^{a}	1649^{b}	2.8^{c}
	SEM	26.6	0.14	6.3	0.03

a-d Means with different superscript letters within a column and factor are significantly different ($P<0.05$); SEM = Standard error of the mean;

Economic assessment of feeding strategy and laying management strategies

Results on the sale value of the hens and eggs (total revenues) and costs of veterinary drugs, feed costs and transport costs are presented in Table 6. Feed costs per hen in both seasons were similar. There were significant differences in feed costs between dietary supplementary regimes and between laying management strategies ($P<0.05$). Feed and total costs were highest for the high protein and low energy diet compared to both other supplementations. The feed costs and, as a consequence, total costs were highest for the hens in the lay-hatch-rear group and lowest in for the lay-only group. Total costs were significantly higher during the dry season as compared to the rainy season ($P<0.05$). Returns from the hens (based on the assumption that they were sold) were significantly different between seasons, feeding strategies and laying management strategies. The returns from the hens were highest in the dry season and lowest in the rainy season ($P<0.05$). The returns were highest for the hens which had received a high protein and high energy diet and lowest for the hens which relied on scavenging only. Furthermore, the returns were highest for the hens in the lay-hatch-rear and the lay-hatch groups, and lowest for the hens in the lay only group ($P<0.05$). Seasons, feeding strategies and laying management strategies showed differences for returns of eggs. The high protein and high energy diet gave the highest returns on eggs and scavenging only gave the lowest returns on eggs. When returns are arranged according to the laying management strategies, returns on eggs for the hens in the lay-only group were significantly higher than returns on eggs for the hens in the lay-hatch and the lay-hatch-rear groups. Total revenues were significantly different between seasons, feeding strategies and laying management strategies ($P<0.05$). During the rainy season, revenues were higher than during the dry season. Farmers, who supplemented their hens with additional feed obtained more revenues than those who did not supplement their hens. The highest total revenue was obtained by supplementing hens with a high protein and high energy diet. Farmers who applied the lay-only management system had higher revenues than those practiced the lay-hatch-rear or lay-hatch management systems. Net profit was significantly higher in the rainy season than in the dry season; whereas ranking according to the different feeding strategies showed that the highest net profit would be obtained on the high protein and high energy diet and the lowest net profit on the scavenging system ($P<0.05$). Regarding the type of laying management strategies, net profit was significantly higher for the lay-only group and lowest for the lay-hatch-rear group.

Table 6. Mean values (and SEM) for the costs and returns on different dietary treatments and laying management strategies during rainy and dry seasons

Main factor	Levels of factor	Variable costs (TZS)				Revenues (TZS)			Net profit
		Veterinary drugs (A)	Feed transport(B)	Feed (C)	Total (A+B+C)	Hens (D)	Eggs (F)	Total (D+F)	((D+F) – (A+B+C))
Season	Rainy	898	208	999	1803^{a}	4284^{a}	4817^{a}	9089^{a}	7286^{a}
	Dry	898	208	996	1853^{b}	4416^{b}	4888^{b}	8211^{b}	6358^{b}
	SEM			3.1	2.3	14.0	47.1	56.5	56.6
Feeding strategies	Scavenging only (A)	898	-	-	898^{a}	4070^{a}	4271^{a}	6302^{a}	5403^{a}
	Scavenging + high protein + low energy (B)	898	208	1010^{a}	2116^{b}	4244^{b}	4764^{b}	9022^{b}	6906^{b}
	Scavenging + high energy + low protein (C)	898	208	987^{bc}	2093^{c}	4383^{c}	5021^{c}	9389^{c}	7296^{c}
	Scavenging + high protein + high energy (D)	898	208	996^{c}	2102^{cd}	4530^{d}	5353^{d}	9889^{d}	7787^{d}
	SEM			3.7	3.2	18.4	66.5	79.9	80.0
Laying management strategies	Lay, hatch and rear (L-H-R)	898	208	1231^{a}	2003^{a}	4432^{a}	2946^{a}	6796^{a}	4793^{a}
	Lay and hatch (L-H)	898	208	899^{b}	1754^{b}	4444^{a}	4328^{b}	8253^{b}	6499^{b}
	Lay only (L)	898	208	863^{c}	1728^{c}	4146^{b}	7283^{c}	10902^{c}	9175^{c}
	SEM			3.7	2.8	17.0	57.6	69.2	69.3

[a-d] Means with different superscript letters within a column and factor are significantly different ($P<0.05$); SEM = Standard error of the mean;
TZS=Tanzania shillings (1200 TZS =1.00 USD)

DISCUSSION

Egg production, egg weight and hatchability

The present study shows that season had only a small effect on overall egg production in local hens under village conditions in Central Tanzania. It was noted that hens in the dry season produce one egg more (and 2 g heavier) than those in the rainy season. This somewhat higher egg production in the dry season compared to the wet season noted in the hens that depend only on scavenging might be related to a higher intake of scavengeable feed resources. These results are in agreement with previous studies that indicated that feed intake as determined from the crop contents of scavenging chickens was significantly higher in the dry season than in the rainy season and that differences in feed intake may have a clear effect on performance of free ranging chickens (Goromela *et al.*, 2007; 2008). In these studies, protein and energy intake were the limiting factors for the free ranging chickens in both seasons. Protein contents were relatively high in the crop contents during the rainy season while energy levels were fairly high in the dry season and thus some additional inputs and improvements in management were required for optimum performance.

When hens were supplemented with protein and energy diets in addition to scavenging they produced more eggs in both seasons compared to those hens that relied on scavenging only. It was noted, however, that supplementation of scavenging hens by any of the diets increased egg production much more during the rainy season (an increase between 20 and 36 %) than during the dry season (an increase between 6 and 15 %). This shows that supplementation of scavenging hens increased egg production per hen per household.

Although the hens in all treatments were scavenging during the day, the higher performance of hens in the rainy season might be related to scavenging in areas rich in green biomass and where presumably there was considerable opportunity to find more fauna and flora rich in protein and minerals.

Previous studies have indicated that protein rich feedstuffs (insects and earth worms); and mineral/vitamin-rich feed stuffs were abundantly available during the rainy season while in the dry season these feedstuffs were much less available (Goromela *et al.*, 2007). The considerable increase in egg production with additional protein and energy shows that protein and energy are the major limiting factors for egg production in hens that scavenge in the rainy season. This reality could be clearly demonstrated by the highest egg production per household that was obtained by supplementing with a balanced level of protein and energy during the rainy season. Thus depending on seasonal availability of scavengeable feed resources, supplementation of free ranging hens with a balanced protein and energy in the rainy season appeared to be more rewarding than in the dry season.

These results are in agreement with the results obtained by a number of authors in developing countries who reported an increase in egg production in scavenging hens when supplemented with diets rich in protein and energy. Hadiyanto *et al.* (1994) reported an increase of 47 to 103 eggs per hen per year and an increase of clutch number from 3 to 7 by improving management and increasing the amount of energy feed supplement. Tadelle (1996) reported an increase in egg production from 24 eggs without supplementation to 57 eggs for local hens with separate supplementation of 30 g per bird per day of maize and noug cake in Ethiopia.

The effect of supplementation gave similar results for egg weight compared to scavenging only. Overall mean egg weight was 41 g. It ranged from 32 to 50 g which appears to be similar to the mean egg weight of 41 g in a range from 27 to 72, as reported by Minga (1989) and Msoffe *et al.* (2002) for local chickens in Tanzania. Moreover, mean egg weight in the present study did not differ from that reported in other African countries under traditional management: 39 g in Nigeria (Omeje and Nwonsu, 1984), 40.6 g in Sudan (Wilson, 1979), between 30 and 40 g in Burkina Faso (Bourzat and Saunders, 1990), and between 35 and 42 g in Ethiopia (Tadelle, 1996). Egg weights increase with an increase in the age of the hens. In the present study, egg weight did not differ between feeding treatments nor laying management strategies. This gives a strong indication that small egg weights in indigenous chickens are genetically determined. According to Smith (1974), a small egg size is a characteristic of indigenous tropical breeds and that trait may have been evolved because of adaptation to the tropical climate.

Overall mean hatchability was 87.9% and it ranged from 75% to 100%. This figure is similar to those reported by Minga *et al* (1989) in Tanzania, Bourzat and Saunders (1990) in Burkina Faso, Wilson (1979) in Sudan and Mourad *et al.* (1997) in Guinea. Our results on hatching rate were clearly higher than the 69% reported in Mali (Wilson *et al.*, 1989); 39 to 42 % reported in Ethiopia (Shanawany and Banarjee, 1991) and 62% reported in Botswana (Aganga *et al.*, 2000). In Mali, Wilson (1987) found significant seasonal differences in hatching rate. Brood incubated in the late dry season had a lower hatching percentage than those in the rainy season. These seasonal differences were most probably related to the high ambient temperature in the late dry season. In addition, the incubating hens had high need for water and feed and spend a considerable period of time out of the clutch in search for water and feed. The higher hatching rate in the present study could be due to the fact that the cocks given to mate with the local hens had a good reproductive performance. A fertility of 70% was reported by Msoffe *et al.* (2004) for the local chickens in Tanzania and 95% for the Sudanese domestic fowl (Wilson, 1979). This high level of hatching can also be due to the selection of eggs. We only used eggs which had short storage period after laying for incubation. In addition, it may be related to the good incubation capacity of the hens as well as to the provision of nests and water and food during the incubation period.

Furthermore, the present study shows that by intervening with improved management strategies such as a reduction of the brooding and rearing period under the traditional poultry system some increase in egg production can be obtained even for non-supplemented hens. The lower number of eggs for hens in the lay-hatch-rear group is likely to be due to longer time spent on brooding and rearing activities. In the lay-hatch-rear group hens spent about 36 days (31% of time in a reproduction cycle) for production (laying and incubation) and 81 days (69%) for management activities (64 days for brooding and rearing and 17 days for recuperation) in one reproduction cycle with 117 days. These findings are in agreement with Sarkar and Bell (2006) who reported that a hen can spare only about 128 days (35%) for production and about 237 days (65%) in a year on brooding, rearing and maintenance of her depleted body conditions. Aganga *et al.* (2000) reported in Tswana a rearing period of, on average, 85 days yielding only 3 clutches a year with an annual output of 28-38 eggs per hen. In our study, it was found that hens in the lay-hatch-rear group took 232 days to complete two cycles on reproduction. This indicates that in a year such local hens can potentially complete only 3.1 clutches with a total egg production of 47 eggs per hen (mean length of laying period per clutch is 15 days). These findings are similar with those reported in various other developing countries under the traditional management system. In Bangladesh, a local chicken can produce 43 eggs per hen per year under scavenging conditions (Huque and Haque, 1990) and Ahmed and Hasnath (1983) reported 40-45 eggs per hen per year. The native chickens of Ethiopia can produce 40 eggs per hen per year (Tadelle *et al.*, 2000), whereas in Nigeria, Bessei (1987) and Sonaiya (2005) reported only 30 eggs per hen per year. This shows that considerable lower egg production under traditional management is related to a long brooding and rearing period. Our results indicate that by intervening with improved laying management strategies it was possible to reduce the length of the reproduction cycle in hens. The hens which were in the lay-hatch group could complete three reproduction cycles within 177 days, whereas the hens which were in the lay-only group could complete five reproduction cycles within 164 days. Thus in a year, assuming that the hens live that long, they can complete 6.2 and 11.2 clutches per hen per, respectively. Taking this into consideration, the total egg output per hen per year for the hens in the lay-hatch group is estimated to be 98 eggs, while the hens in the lay-only group is estimated to be 160 eggs. This is a considerable level of egg production compared with 3.1 clutches and 47 eggs per hen per year that could be obtained from hens in the lay-hatch-rear group, which is the normal laying management strategy at rural villages. In

Bangladesh, Prasetyo *et al.* (1985) reported a brooding period of 257 days and egg production of 52 eggs in a year, when village hens were laying eggs, hatching and rearing chicks. However, when chicks were separated from their mothers at an early stage of their life, the brooding period was significantly reduced to 145 days and egg production increased to 115 eggs per year. Moreover, when the brooding period was reduced to 125 days by restricting hens from both incubating and rearing, their egg output increased to 132 eggs per hen per year. Sarkar and Bell (2006) reported that a hen spends 80 to 90 days per batch for brooding, rearing and scavenging. By shortening the length of the reproduction cycle through early weaning, it was possible to increase the number of clutches from 4.2 to 7 per year and egg production also increased from 55 to 110 eggs per hen per year. Sazzad (1993) found that indigenous hens under rural conditions in Bangladesh produced 42 eggs per hen during the 240 days of the study period, but after separating the chicks from the hen at 4 weeks of age and reducing the interval between the broody period from 9 to 5 weeks, the number of eggs laid per hen increased to 60 eggs. Similarly, the number of clutches under the traditional management system increased from 3.5 to 5 clutches per hen after reducing the nursing period.

Supplemental feed intake and body weight gain

Total feed intake was similar in all seasons and between treatments. This suggests that in the present study, hens did not eat a certain amount based on the diets' energy concentration. However, total feed intake differed significantly according to the type of laying management strategy applied. The hens in the lay-hatch-rear group consumed more supplementary feeds than hens in the lay-hatch and lay-only groups which had short reproductive cycles. Feed intake per bird per day was significantly lower for the hens in the lay-hatch group than those in the lay-hatch-rear groups which might be caused by paying more attention to the chicks after separating them leading to have less time for eating. The higher final body weights (1738 g) and high mean rate of body weight gain (2.9 g/day) at the end of the experiment in the dry season than in the rainy season is undoubtedly related to differences in availability of scavengeable feeds. Previous studies have shown that scavengeable feed resources consumed by free ranging chickens vary from 45 g in the rainy season to 54 g per bird per day in the dry season with an average intake of 4.6 g crude protein per bird per day which can not fulfill their nutrient requirements (Goromela *et al.*, 2008). The higher mean final body weights (1814 g) and mean body weight gains (3.3 g/day) for the hens that received supplementary diet with high protein and high energy than those which received supplementary diets either low in protein or in energy, indicates that both protein and energy were inadequately available in the scavenged diets. The hens in the lay-hatch-rear groups had a significantly higher mean final body weight and body weight gain than those hens in the lay-only group. This indicates a high demand of nutrients to support high egg production.

Economic assessment of feeding strategy and laying management strategies

Differences in feed costs between supplementary diets occurred because of differences in the prices of the feed ingredients. Feed costs were highest for the high protein and low energy diet, because of the high proportion of protein feedstuffs needed to give 20% crude protein in the diet. Protein feedstuffs in the present study were fish meal and sunflower cakes and these are fairly expensive. Feed costs were highest for the hens in the lay-hatch-rear and lay-hatch groups than for the hens in the lay-only group. These hens needed more days to complete their reproductive cycles. Total costs were significantly higher during the dry season than the rainy season. This is likely due to a high inflation as a result of devaluation of Tanzania shillings at the end of experiment two. The returns from the hens were highest in the dry season and lowest in the rainy season: this might be related to the differences in body weight. Similarly, the highest returns for the hens in the lay-hatch and lay-hatch-rear groups were related to their heavier body weights than the hens in the lay-only group. Generally, a high protein and high energy diet and the lay-only management had the highest returns on eggs. Net profit was significantly higher in the high protein and high energy diet and the lowest net profit was obtained from the scavenging only hens. This indicates that supplementing indigenous hens using locally available feed supplements will increase income over relying the birds on scavenging only. The best performance with a high protein and high energy diet was due to the combined effect of both protein and energy. From this economic analysis, it is possible to recommend that supplementation of high protein and high energy contents under traditional management system in combination with the lay-hatch and lay-only management strategies are economically most feasible.

CONCLUSION

From the present results, it can be concluded that the low performance of indigenous chickens is mainly due to an inappropriate management and deficient nutritional conditions, and not to a low genetic potential. Separation of chicks from their mother hens at an early stage (lay-hatch only group) and preventing hens from incubating eggs (lay-only group) increased considerably the number of clutches and egg production per hen per year. Supplementation of either protein or energy in addition to normal scavenging increased egg production and body weight gain in hens under village conditions. However, providing around 50 g of a balanced diet with high protein as well as high energy per hen per day can significantly improve egg production and body weight gain. Substantial impact can be achieved when supplementation of a balanced protein and energy diet is applied in the rainy season, rather than in the dry season. The present study clearly revealed that the productivity of indigenous hens under traditional management systems can be increased by supplementary feeding and relieving the hens from some aspects of the reproductive cycle such as from brooding and rearing. However, further studies are suggested to investigate the current performances of village poultry in biological and economic terms and to explore the impact of these management options on system dynamics of the village flock output in a traditional management system.

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CHAPTER 7

GENERAL DISCUSSION

GENERAL DISCUSSION

INTRODUCTION

A review of existing literature has demonstrated that chickens, raised under the traditional or village management system, are of a local breed (indigenous), their level of production is extremely low, and the flock size is rather small (Chapter 1). This low productivity has been attributed to the – suggested - inherent low genetic potential of these local birds and the existing management system at village level. Nevertheless, inadequate bird management and the variability in the nutritional quality and quantity of scavengeable feed resources (SFR) appear to be the major factors contributing to the low productivity of indigenous chickens (Sonaiya, 1995). In most developing countries, the scavenging or free range system is the most dominant poultry production system in rural areas. This system has existed for many centuries and is characterized by inappropriate bird management practices. The chickens in this system are left to search for their own food around the homesteads and in surrounding crop-fields during daytime. At night, they are kept in shelters or in the houses together with the family members for security reasons (Goromela *et al.*, 1999). Sometimes, these birds roost in kitchens or in tree branches (Kitalyi, 1998).

The scavenging system is characterized by seasonal fluctuations in the availability of scavengeable feed resources, thereby limiting the intake of essential nutrients like protein, energy and minerals (Chapters 2, 3 and 4). Scavenging birds do not find enough feed resources for optimal production (Chapters 2 and 4). In addition, long reproductive cycles in hens due to natural brooding and rearing of chicks and lack of alternative management of baby chicks after hatching won't help either to increase performance. Under traditional management, chicks are usually hatched by means of natural incubation with broody hens sitting on clutches of eggs. These chicks are then fed, protected from enemies, and raised by their mother hens until they are able to look after themselves (Sazzad, 1993; Sarkar and Bell, 2006). These chicks are often exposed to predators and diseases including harsh environmental conditions (cold, rain or hot) when they are scavenging with their mother hens. As a result, high chick mortality rates of 40 to 80% at an age of 6 or 8 weeks have been reported under the traditional management system (Minga *et al.*, 1989; Wilson, *et al.*, 1987; Mwalusanya *et al.*, 2001). Improving feeding systems for scavenging birds and their husbandry conditions in particular of the baby chicks can minimize these reproductive losses (Cumming, 1992). Moreover, it has been stated that supplementation of scavenging birds with protein and energy sources according to age and production status can result in considerable improvements of their growth rate and egg production performance (Roberts, 1992).

The present study focused on improving the feeding system and management practices under the traditional scavenging poultry system. The first study focused on identification, characterization and quantification of different and potential scavenging feed resources and the constraints that affect the availability of these feed resources for rural poultry in the free-range system. The second study aimed at determining the effect of season and farming system on the quantity and nutritional quality of SFR by investigating the effect of SFR in interaction with management practices on the nutritional status and productivity (performance and carcass yield) of scavenging chickens. Finally, the third study aimed at evaluating the effects of supplementation of protein and energy resources and management strategies (i.e. weaning and laying management strategies) on growth and carcass yield of growing chickens and egg production in laying hens under village conditions.

Seasonal variations of Scavengeable Feed Resources (SFR) in traditional poultry production

In developing countries such as Tanzania, poultry feeding systems in the villages are based on locally available scavengeable feed resources (SFR; Chapter 2). SFR for local chickens have been studied in developing countries by a number of authors (Gunaratne *et al.*, 1993; Tadelle, 1996; Roberts, 1999; Sonaiya, 2004). Basically, SFR comes from two sources; household food waste and leftovers, and materials from the environment, i.e. crop by-products, insects, worms, forage materials, garden waste, etc (Chapters 2, 3 & 4). Our studies indicated that SFR available to scavenging chickens can be distinguished into three types: energy, protein and mineral/vitamin-rich feedstuffs. Normally, the proportion of energy feedstuffs is usually higher than protein and mineral/vitamin-rich feedstuffs in the diets consumed by scavenging chickens (Chapters 3 and 4). This might be related to the fact that household materials – waste rich in fibrous carbohydrates - form a major proportion of the total diet consumed per day ranging from 69% in the rainy season to 90% in the dry season (chapter 4). These findings were confirmed by others (Gunaratne *et al.*, 1993; Tadelle, 1996; Roberts, 1999; Sonaiya, 2004; Mwalusanya *et al.*. 2002; Rashid *et al.*, 2005) who made a similar conclusion. The observation that availability of SFR in scavenging systems is not always constant and differs from place to place (Cumming, 1992; Tadelle, 1996; Sonaiya, 2004) is in agreement with our results (Chapters 3 and 4). Our results demonstrated that factors such as season (rainy and dry seasons);

farming activities, land size available for scavenging and village flock biomass can have significant effects on the availability of these feed resources for scavenging chickens. In Central Tanzania, feedstuffs such as cereal grains (maize, sorghum and pearl-millet) and their by-products, oil seeds (sunflower and ground nuts) and oil seed cakes (sunflower) are readily available in the dry season during harvesting and post harvest activities; whereas forage leaves, flowers, seeds, garden vegetables, insects and worms are abundantly available in the rainy season (Chapter 3). These results are in line with several studies that reported that the availability of SFR depends on several factors such as population density, food crops grown (Roberts, 1999); their processing methods and rate of decomposition (Kitalyi, 1998) as well as the number of scavenging animals (Sonaiya, 2004). Thus, it can be concluded that a bird kept on free-range and backyard systems can certainly not find all the nutrients it needs for optimal production all the year round (Sonaiya, 2004; Chapters 2 and 4).

Feed intake and performance of chickens under scavenging conditions

Feeding of mammals and birds is a complex activity which may include actions such as searching for food, recognition of food and movement towards it, sensory appraisal of food, and the initiation of eating and ingestion (McDonald *et al.*, 2002). Although these activities may appear to be similar in all classes of farm animals, there are differences between those animals kept in an intensive system and those kept under scavenging conditions. For chickens kept under scavenging conditions, feed intake can be influenced by factors such as season, temperature, rainfall, farming systems, social habits and the economic status of the households, as it was reported in Chapters 3 and 4. But also factors such as the physical form of feed ingredients (hardness), composition of the feed, village chicken biomass, physiological age (chicks, growers, hens, cockerels), sex, production status and scavenging behaviour can significantly affect their feed intake (Chapter 2). Additionally, stressful factors like predators, disease or parasites due to poor health care under traditional management can also affect the feed intake of scavenging birds.

Therefore, when considering how to improve the scavenging feeding system, these factors have to be taken into consideration. Thus, understanding of how much feed the chickens may consume when they are scavenging and what nutritional values they may derive from the available SFR, can provide the baseline of estimates for energy and nutrients available to the bird. Knowing this, it can help to determine the nutritional status and subsequent production performance of scavenging chickens. Few studies and surveys, conducted in developing countries using crop content analysis, have concluded that for most of the scavenging chickens, feed intake and nutrient intake is comparatively lower than their requirements (Tadelle, 1996; Kitalyi, 1998; Mwalusanya *et al.*, 2002; Rashid *et al.*, 2005).

In view of this, the effect of season and farming system on the quantity and nutritional quality of SFR performance was studied in Central Tanzania. The results indicated that scavenging birds can consume around 54 g DM of feed/day during the dry season and about 45 g DM of feed/day during the rainy season (Chapter 4). Consequently, the differences in feed intake had a significant impact on the performance of scavenging chickens, as summarized in Table 1. Chickens with a higher feed intake during the dry season had also higher body weights and carcass weights in that period. These findings were also reported by Pousga *et al.* (2005) who found in Burkina Faso that pullets had higher crop contents in the dry season (34 g) than in the rainy season (27 g). Consequently, pullets in the dry season had higher body weight (884 g) than in the rainy season (803 g; Table 1).

Table 1. Effect of seasonal availability of SFR on the performance of scavenging village chickens

Parameters	Rainy season	Dry season	References
Body weight (g)	1034	770	Kondombo, 2005*
	803	884	Pousga et al., 2005
	890	1238	Chapter 4
Carcass weight (g)	673	633	Kondombo, 2005*
	491	533	Pousga et al., 2005
	563	799	Chapter 4

* Body weight is the mean value of cocks, hen, pullets and cockerels per season.

Contrary to these findings, Kondombo (2005) found opposite results in Burkina Faso. Feed intake on a fresh basis was significantly higher during the rainy season (ranging from 32 to 54 g) than during the dry season (between 18 and 27 g), and, as a consequence, also body weight was higher in the rainy season (Table 1). The reason for these opposite results is not clear, but may be due to several farming and socio-cultural differences between different regions even in the same country.

Impact of supplementary feeding on growth rate and survival rate of village chicks

The beneficial effects of feed supplementation and disease control has been shown earlier in Zimbabwe by Pedersen (2002). The supplements that were tested were maize meal and sunflower seed cake meal. Supplementation had a positive effect on growth rate (+ 14 %) and survival of chickens.

In our study (Chapter 5), the effect of supplementation of protein and energy sources on growth and carcass yield of growing chickens was tested in four villages. The effects of these interventions on body weight gain, growth rate and survival rate are summarized in Table 2 in comparison with normal village management practices (i.e. normal scavenging systems), as well as compared to other references.

The results show that providing chicks with supplementary diets with protein and energy results in a proportional increase in growth rate and survival rate. The higher survival rate of chicks might be related to the preferential access to household refuse and supplemental feeds for the young chicks and reduction of predator attacks because the chicks remained closer to the creep feeder (and the house), thereby limiting their scavenging.

In general, the results show that there is a close relationship between chick weight or growth and mortality rates as reported by Sonaiya and Swan (2004). Most of the chicks that died in our experiments were those on the control treatment (scavenging only) which had in fact lower body weights than others (Chapter 5). The lower growth rate of chicks in the scavenging treatment might have been a result of the low nutritional quality (i.e. protein, energy and minerals) of the SFR in the study villages as indicated by their chemical composition (Chapters 3 and 4). From these studies, it is clearly demonstrated that a very high survival rate and improved growth rate can be achieved when village chicks are confined in a pen and given supplementary feeds both containing high protein and energy contents.

Impact of supplementary feeding on final body weight and egg production

Improved feeding systems for scavenging birds have been suggested by various authors (Sonaiya, 1995; Tadelle, 1996; Mwalusanya *et al.*, 2001) as a way of attaining an optimum production. Studies on supplementation of village chickens with protein and energy supplements resulted in an increased egg production, egg sizes and feed efficiency (Huchzermeyer, 1973; Tadelle, 1996). These findings are supported by the conclusion made by Roberts (1992), after analysing SFR for local birds in different production systems in Sri Lanka and Indonesia, that supplementation of local birds according to age and production status can result in considerable improvement of egg production performance. The effects of supplementary feeding with protein and energy sources on body weight and egg production was studied in two on-farm experiments (Chapters 5 and 6).

Table 2. Impact of improved feeding on production parameters in scavenging village chickens

Production parameters	Normal village management practice[1]	Supplementary feeding[2]	Reference
Body weight (g)	1203 – 1638	1530 - 1814	Chapters 5 and 6
Carcass weight (g)	600	–	Boki, 2000
	777	1100 - 1171	Chapter 5
Eggs (hen^{-1} year^{-1})	40	–	Tadelle and Ogle, 1996
	88	97 - 107	Chapters 5 and 6
Eggs per clutch	13	–	Mwalusanya *et al.*, 2001;
	11	14 - 17	Chapters 5 and 6
Survival rate (%)	60	80	Roberts *et al.*, 1994 (10 weeks)
	60	68 - 88	Gunaratne, 2000
	88	–	Sarkar and Bell, 2006 (10 weeks)
	60	–	Mwalusanya *et al.*, 2001 (10 weeks)
	65	70 - 78	Chapter 5 (15 weeks)
Growth rate (g/day)	4.2	5.0 – 11.1	Gunaratne, 2000
	5.0	–	Mwalusanya *et al.*, 2001 (10 weeks)
	6.4	9.2 – 10.0	Chapter 5(17-20 weeks)
Brooding and	80	–	Chiligati *et al.*, 1997
rearing (days)	128	46 - 80	Chapters 5 and 6

Note: [1]Normal scavenging systems with no regular supplementation of chickens with protein, energy or both; no day housing of chicks and no early weaning of chicks; no medication and vaccination; [2]Supplementation with either protein or energy or both

In general, supplementation of chicks or hens with either high protein or energy, in addition to scavenging, resulted in improved body weight gains and egg production (Table 2). Additionally, an even higher performance of chickens offered a diet with high protein and energy, leads to the conclusion that both high levels of protein and energy are crucial for improving productivity of scavenging chickens. Importantly, the degree of response will depend on the quantity and nutritional quality of the available SFR in both seasons and some bird management aspects.

Impact of early weaning on the reproductive cycle and productivity of indigenous hens

Indigenous chickens are often blamed as bad egg producers because of their low genetic potential. This low production potential of indigenous chickens, however, is mainly attributed to the inadequate bird management and limited feed supply (Chapters 1and 2). It has been shown that under the traditional system of management, a hen performs numerous activities. These include production activities such as laying eggs, incubation and hatching of chicks. Immediately followed by several management activities like brooding and taking care of the chicks, protection chicks from predators, familiarizing chicks with scavengeable feed resources, teaching them how to scavenge and how to escape from predators.

Observations by Sarkar and Bell (2006) in Bangladesh show that in a year, a hen spends 237-262 days (65-72%) undertaking management activities (brooding and rearing chicks) and 40-65 days ((11-18%) for laying eggs and 63 days (17%) for incubation. According to Sarkar and Bell (2006), a local hen in Bangladesh takes a clutch length of 11-21 days, incubation of eggs takes 21 days, and for brooding and rearing of chicks a hen spends 70-90 days, thus accomplishing one reproduction cycle within 102-132 days and in a year only 3 reproduction cycles.

Similarly, In Tanzania a free range local chicken takes 108 to 161 days to accomplish brooding and rearing chicks in 60 to 90 days with a regaining period of 7 to 30 days and spends 20 days laying 15 eggs in a clutch and incubating eggs in 21days in one complete reproduction cycle (Tibamanya, 1994). This indicates that about three production cycles can be achieved in a year with an output of 45 eggs.

In our studies the effect of early weaning of chicks (early separation of chicks from their mother hens) was studied by setting up three weaning management strategies (Chapter 5) and three laying strategies (Chapter 6) with the aim to reduce the long reproductive cycles. It can be seen from Table 3 that all of these interventions increased annual performance of hens.

The effects of long reproductive cycles on egg production has been studied by several other researchers too (Prasetyo *et al.*,1985; Huque *et al.*, 1990; Sazzad *et al.*, 1990; Moreki *et al.*, 1997). The results of these studies confirm our findings that weaning of chicks through early separation from their mother, in order to reduce the length of the reproduction cycle of indigenous hens, will definitely increase egg production in comparison to traditional management of village chickens (Table 3).

Table 3. Impact of early weaning of chicks and laying management strategy on reproductive performance and productivity of indigenous hens

Production parameters	Village management practices[1]	Early weaning of chicks[2]	Laying management strategies[3]	Reference
Eggs	52	115	–	Prasetyo *et al.*, 1985
(hen^{-1} year^{-1})	64	91	–	Sazzad *et al.*, 1990
	40	–	–	Tadelle and Ogle, 1996
	47 - 58	84 - 112	98 - 160	Chapters 5 and 6
Eggs per	13	–	–	Mwalusanya *et al.*, 2001
clutch	11	14	15	Chapters 5 and 6
Brooding and	108 - 161	–	–	Tibamanya, 1994
rearing (days)	80	–	–	Chiligati *et al.*, 1997;
	128	50 - 77	0 - 21	Chapters 5 and 6

Note: [1]No regular supplementation of chickens with protein, energy or both protein and energy and no early weaning of chicks; [2]Early weaning of chicks (i.e. at week 4 and week 8 of age); [3]Laying management strategies (Lay, hatch and rear chicks for 7 days only and Lay only)

These results clearly show that long reproductive cycles can potentially limit the laying performance of a hen and thus is one of the factors that cause low productivity in village poultry. The results demonstrated that early separation of the hen from chicks certainly increases the productivity of indigenous hens and confirms that management plays a key role in regulating the production potentials of indigenous chickens rather than their inherent characteristics. However, our findings showed that early weaning should be accompanied by supplementary feeding of village chicks with balanced diet and the chicks should be confined in a warm house or local brooders to increase their growth and survival rates respectively (Chapter 5). The mortality of chicks in creep feeding system of management was very low (7-8%) in Bangladesh (Sarkar and Bell, 2006) which was lower than 25% mortality rate recorded in our study (Chapter 5). This lower mortality might be due to the fact that the chicks were totally confined in the house and given a balanced diet whereas in our case they just confined half a day where they received supplementary diets and thereafter they were released out where they were exposed to predators and diseases at an early stage of life.

Economic implications of strategies on feeding and laying management

Costs, benefits and returns of different interventions were only performed in chapter 6. Feed supplementation was effective economically. Although feed costs - logically - increased due to additional feed intake and prices of expensive ingredients such as fish meal, net profit was about 30 to 50 % higher as compared to scavenging only (Table 4).

Table 4. Costs, benefits and returns on different interventions (based on data from Chapter 6); default situation = 100 %

Intervention	Variable costs (A)	Revenues (B)	Net profit (B-A)
Feeding strategy			
Scavenging only	898	6302	5404 (100 %)
Scavenging + high protein / low energy	2116	9022	6906 (130 %)
Scavenging + high energy / low protein	2093	9389	7296 (138 %)
Scavenging + high protein / high energy	2102	9889	7787 (147 %)
Laying management strategy			
Lay, hatch and rearing	2003	6796	4793 (100 %)
Lay and hatch	1754	8253	6499 (136 %)
Lay only	1728	10902	9175 (191 %)

The highest net profit was calculated for the balanced protein and energy diet, suggesting that both limiting nutrients are really deficient in available SFR, as shown in chapters 2, 3, and 4. Similarly, laying management that reduces the reproductive cycle showed a positive response in the net returns. The highest net profit for the hens in the lay-only and lay-hatch groups were related to the high egg outputs compared to the hens in the conventional lay-hatch-rear system. Preventing laying hens from mothering tasks by management interventions in the scavenging system almost doubled net profit. Combinations of additional feeding and improved laying management may even increase net profit more.

From this economic analysis, we would recommend that supplementation of high protein and high energy contents under the traditional management system in combination with the lay-hatch or the lay-only management strategy is economically feasible. It can be stated, however, that these economic results depend very much on the local available supplements, as well as on environmental and cultural conditions.

CONCLUSIONS

- Village poultry production plays an important role in the rural livelihoods of the farming communities in Tanzania and other developing countries. These chickens supply the local people with additional income and high-quality protein food and can be used in social activities.
- Despite its contribution, the development of traditional village poultry production in the country is small due to a slow rate of growth and low egg numbers.
- Relying on the scavenging system, characterized by low quantities of SFR with a poor nutritional quality (energy and protein), the lack of supplementary feeds and a poor control of diseases, long reproductive cycles coupled with low genetic potential are the underlying factors of this low productivity.
- The provision of supplementary diets containing all critical nutrients (i.e. protein, energy and minerals), in addition to scavenging, improves the birds' performance (i.e. growth rate and egg production) and survival rate.
- With regard to the long reproductive cycles (laying, hatching, and rearing), the study shows that an early separation of chicks from their mother hens increases the hen's laying performance without compromising chick's survival rate and growth rate.
- In general, the study clearly shows that the productivity of indigenous hens under traditional management systems can be increased by improving their husbandry conditions through adoption of supplementary feeding, and confining chicks during vulnerable periods and relieving the hens from some aspects of the reproductive cycle such as from brooding and rearing.

RECOMMENDATIONS

These recommendations are based on the major findings in this thesis and are intended to be used as a way forward to disseminate the results.

- Strategic supplementation of both protein and energy feed resources in addition to scavenging must be promoted in order to improve growth rate, survival rate and egg production in indigenous chickens. This can be done by providing at least 50 g of feed/day for a scavenging chicken.

- Early weaning of chicks at 4 and 8 weeks of age has shown to improve laying performance of indigenous hens without compromising chicks' survival rate and growth rate; this should be adopted and promoted in the traditional poultry sector.
- Confining young chickens in a house until an age of 8 weeks with access to a balanced diet and water should reduce mortality rate caused by predation, bad weather, diseases and competition among flock mates.
- Basic skills on poultry management and health and access to extension services must be promoted to farmers in order to improve the productivity of village poultry and increase the income and food security in the traditional poultry sector.

FUTURE RESEARCH

- Study on a year-round feed and nutrient (energy, protein and minerals) availability for scavenging chicken of various age and sex under scavenging conditions.
- Study of on nutritional evaluation of various conventional and unconventional feed resources as potential feed poultry under scavenging conditions.
- Study of how much and what combination of feed ingredients is most economical as a feed for seasons and farming systems.
- Study on production of and utilization of non-conventional feed earthworms, maggots and termites as protein sources for scavenging poultry.
- Study on the amount and composition and digestibility of available feeds for scavenging poultry (chickens, guinea fowls and ducks) and their seasonal variations.

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SUMMARY

Poultry production in Tanzania, as well as in most other African countries, can be divided into traditional and commercial poultry production systems. Traditional poultry production is characterized by small-scale farming, where the majority of village poultry (indigenous chickens) are raised under extensive management or free ranging in rural areas. Commercial poultry production is characterized by small-scale to large-scale poultry production systems under intensive management where layers and broilers are kept for egg and meat production, respectively. The commercial sector is practiced in urban and peri-urban areas with markets for eggs and meat. According to the Agriculture Sample Census of 2003, the total poultry population in Tanzania is estimated at 33.3 million herds of poultry, where 31.5 million are indigenous poultry, 1.2 million are exotic layers and 0.6 million are broilers. As it can be seen from these statistics, indigenous poultry account for about 95% of the total poultry population in Tanzania. In general, the traditional poultry production system is the largest poultry sub-sector compared to the commercial poultry production system. The traditional sector comprises various poultry species such as chickens, ducks, turkeys, geese, pigeons and guinea fowls. Nevertheless, indigenous chickens or rural chickens or more precisely village chickens are the largest poultry species and widely distributed over all agro-ecological zones in the country. Indigenous chickens normally vary in body size, conformation, plumage colour and other phenotypic characteristics. The chickens are classified as dual purpose, producing low to moderate levels of both meat and eggs. Indigenous poultry play an important contribution to household food security and income for most of the rural people in Tanzania as compared to commercial chickens. In spite of the social and economical importance of the free-range system, village poultry production in the country is constraint by high chicken mortalities, low egg production and a slow rate of growth. In general, very few initiatives have been undertaken in Tanzania to improve the overall productivity of village poultry as it has been described in the General Introduction of this thesis (Chapter 1). Such initiatives geared towards improving only the genetic potential of indigenous chickens with less emphasis on improving feeding and management systems. The current thesis aimed at developing appropriate feeding and management strategies for rural poultry in Central Tanzania that would help to increase overall productivity of indigenous chickens for the improvement of rural livelihoods. Its specific objectives were: (i) To identify, characterize and quantify different and potential scavengeable feed resources (SFR) and study the constraints to the availability of these feed resources for rural poultry in the free-range system; (ii) To determine the quantity

and nutritional quality of SFR by investigating the effect of SFR in interaction with management practices on the nutritional status and productivity (performance and carcass yield of scavenging chickens; (iii) To study the combined effects of supplementation of protein and energy resources and management strategies, i.e. weaning and laying management practices on growth and carcass yield of growing chickens and egg production in scavenging hens.

In Chapter 2, a review study gives an overview on traditional poultry production systems in developing countries (in particular Africa) based on existing literature information. The study showed that traditional poultry production accounts for about 80% of the poultry population in Africa. Moreover, four poultry production systems in developing countries can be distinguished and their important production characteristics were described. These production systems include the free-range system or traditional village system; the backyard or subsistence system; the semi-intensive system and the small-scale intensive system. The free-range system and the backyard system appears to be the main types of poultry husbandry practiced in the traditional poultry sector in Africa. The free-range system is commonly practiced by the majority of rural families. Flock sizes vary from 1-10 birds of indigenous poultry per rural household. The birds are owned mostly by women and children and kept for home consumption, small cash income, social and cultural activities. The chickens are left to scavenge around the homesteads during daytime eating household leftovers, waste products and environmental materials such as insects, worms, seeds and green forages. In addition, the birds are not regularly provided with water and other inputs such as supplementary feeds, housing, vaccination and medication. The system is characterized by high chick mortalities during the pre-weaning period due to starvation, diseases and predation; and by a low level of productivity in terms of eggs produced (30-50 eggs $hen^{-1}year^{-1}$) and a slow growth rate (5-10 g day^{-1}). The scavenging system is the dominant system and provides most of the SFR for the rural poultry. The study showed that the quantity and nutritional quality of SFR for scavenging poultry vary with season, altitude, climatic conditions, farming activities as well as social, management and village flock biomass. In addition, the study showed that diets consumed by scavenging poultry had low nutrient concentrations of protein (100 g kg DM^{-1}), energy (11.2 MJ kg DM^{-1}) and minerals such as Ca (11.7 g kg DM^{-1}) and P (5 g kg DM^{-1}); levels too low to support optimal growth and egg production of scavenging poultry. From this review study, it was suggested that the nutrients that could not be optimally supplied by the SFR should be provided in the form of supplementary feeds.

In Chapter 3, a participatory study was carried out in four villages in Dodoma region in Central Tanzania to appraise existing and potential SFR available for rural poultry. First of all, a reconnaissance survey was conducted to obtain background information on the existing farming system in these four villages using a group interview of 20-30 key informants in each village. This background information was used to develop a structured questionnaire for the formal survey. The questionnaire basically explored feed resources and nutrients eaten by rural poultry in the villages at different times of the year; it focused on factors affecting quantity and quality of SFR and interventions that should be used to improve feed resource availability. A total of 318 households from the four villages were interviewed with a sample size of 70 - 80 households per village. In addition, a group of 40 farmers from each village participated in the formal survey; they were selected for group interviews to obtain qualitative information on seasonal availability of SFR and constraints with regard to the availability of these feed resources using pair-wise ranking; matrix scoring and direct observations. Samples of existing and potential feed resources were collected from interviewed farmers and taken to the laboratory for chemical analyses. Additionally, a total of 141 scavenging chickens of both sexes with an average live weight of 1.2 kg ± 0.3 were randomly purchased from farmers and slaughtered at 11.00 and 16.00 h. Crop and gizzard contents were physically analyzed and dried for subsequent chemical composition. Survey results indicate that in the dry season the most important SFR were cereal grains (maize, sorghum and pearl millet) and their by-products, oil seeds (sunflower, groundnut and sesame) and sunflower seed cakes, whereas in the rainy season the most important SFR were forage leaves, flowers, seeds, garden vegetables, insects and worms. Factors such as seasonal conditions, farming activities, land size available for scavenging and flock size had a significant influence on the availability of SFR. The mean dry matter (DM) of the feed resources was 888 g/kg. Gross energy ranged from 17.1 to 29.3 MJ/kgDM^{-1} and crude protein from 64.5 to 418 g kg DM^{-1}. Crude fibre ranged from 33.3 to 230 g kg DM^{-1} and ether extract ranged from 16.0 to 488 g kg DM^{-1}. Mineral composition ranged from 1.5 to 18.4 g kgDM^{-1} for calcium; and 3.6 to 17.3 g kg DM^{-1} for phosphorus; 9.5 to 34.5 g kgDM^{-1} for potassium and 0.2 to 8.5 g kgDM^{-1} for magnesium. Visual analysis of crop and gizzard contents showed that diets consumed by scavenging chickens consisted of cereals and cereal by-products (29.0%), vegetables and forage materials (1.8%), seeds and seed by-products (3.4%), insects and worms (0.2%), egg shells, feathers and bones (0.3%), unidentified feeds (41.5%), inert materials (0.8%) and sand/grit (23.0%). The crop and gizzard contents had mean DM of 479 g per kg and metabolizable energy (ME) of 10.1MJ kgDM^{-1}. Nutrient composition (kgDM^{-1}) of the crop and gizzard contents was: 80.4 g CP; 70.7g EE; 45.7 g CF; 234 g Ash; 6.6 g Ca; 6.5 g P; 12.1g K and 2.6 g Mg. From this study, It was concluded that the nutrient concentrations of SFR consumed by rural poultry were below the recommended levels for optimum growth and egg production.

In Chapter 4, a 2x2 factorial study was conducted to assess the effects of season and farming system on the quantity and nutritional quality of SFR and the performance of village poultry. The study was carried out on-farm in two farming systems: sorghum-pearl millet-groundnut farming system in Chitemo and Kisokwe villages and maize-bean- sunflower farming system in Bumila and Chamkoroma villages in Central Tanzania. The study consisted of two experiments. The first experiment was conducted in the rainy season (January-June) and the second experiment in the dry season (July-December). In the rainy season samples were taken between January-February; March-April, and May-June while in the dry season sample were taken between July-August; September-October, and November-December. A total of 648 scavenging chickens purchased from farmers were slaughtered after they had spent 4 hours scavenging at 10.00 h in the morning, at 14.00 h in the afternoon and at 18.00 h in the evening and their crop contents were subjected to physical and chemical analysis. The results showed that mean intake was significantly higher (18.1g DM) in the dry season than in the rainy season (14.9g DM). Based on the assumption that the birds fill their crops in four-hour cycles of eating, the actual intake was estimated around 54g/day in the dry season and 45g/day in the rainy season; this being 54% and 45% of their total DM intake, respectively. Moreover, the results showed that mean live body weights at slaughter of chickens were higher in the dry season (1238 g) than in the rainy season (890 g). Visual observations of the crop contents showed that kitchen/brew wastes, sand and grit, oil seeds and cakes, cereal bran, cereal grains, and other feed materials were the main physical components and varied with seasons and farming systems. The overall chemical compositions (% dry matter) of the crop contents showed that crude protein (9.24), ash (21.6), magnesium (0.22), nitrogen free extract (58.8) and metabolizable energy (11.5 MJ/kgDM^{-1}) contents varied with seasons and farming systems. The crop contents had both higher crude protein content (10.1% of DM) and ash (24.9% of DM) in the rainy season than in the dry season (8.4% CP and 18.2% ash; whereas the ME content of the crop contents was significantly higher (12.2 MJ/kg) in the dry season than in the rainy season (10.8 MJ/kg), an indication that supplementation of energy is needed more in the rainy season. It was concluded that quantity and nutritional quality of SFR varied considerably between seasons and farming systems; and the nutrient contents were below the birds' requirements for high productivity. Thus additional supplementation with locally available energy feeds was needed to meet their feed intake while supplementation of energy and protein was more needed in the rainy season and dry season, respectively.

In Chapter 5, a study on the effects of protein and energy supplementation and weaning management strategies on the reproductive performance of broody hens and subsequent performance of their chicks was conducted in the same four villages mentioned above. A total of 192 village farmers were chosen to participate in the study. Two on-farm factorial experiments comprising of four dietary treatments and three weaning management strategies in each of the experiments were set up in the two farming systems. The first exepriment was carried out in the rainy season (January-June) and the second experiment was carried out in the dry season (July-December). A total of 384 broody hens and 2304 chicks were randomly allocated to the four dietary treatments were; A: scavenging only; B: scavenging + high protein, low energy diet (20% CP, 13.5 ME MJ/kg); C: scavenging + high energy, low protein diet (15% CP, 14.5 ME MJ/kg); and D: scavenging + high protein, high enegy diet (20% CP, 14.5 ME MJ/kg) and to three weaning periods: 4 weeks, 8 weeks, and 12 weeks. The diets were composed from common locally available feedstuffs like maize bran, sorghum and pearl millet grains, sunflower cake and fish meal. The results showed that chicks supplemented with diets B, C and D had a significantly higher body weight gain of 1530 g, 1575 g and 1669 g, respectively, than the non-supplemented chicks (1203 g). Similarly, hens supplemented with the diets B, C and D had a higher egg production of 44, 45 and 47 eggs, respectively, compared to the 33 eggs in the non-supplemented hens. Regarding weaning of chicks, the results showed that chicks weaned at 4 weeks had a lower body weight at 4 weeks (106 g) and 12 weeks of age (258 g) than those weaned at 8 or 12 weeks of age, but had similar body weights at 24 weeks of age. The number of clutches increased from 2 clutches with an output of 29 eggs when chicks were weaned at 12 weeks of age to 3 clutches with an output of 42 eggs and 4 clutches with 56 eggs when chicks were weaned at 8 and 4 weeks of age, respectively, over a period of six months. Survival rate of chicks that relied on scavenging only was lower (65%) than that of the supplemented chicks. Survival of chicks in the weaning programme of 4 weeks was lower (67%) compared to the weaning programme of 8 weeks (77%) and weaning at 12 weeks (73%). The lower survival rate of the chicks weaned at 4 weeks was largely due to diseases and not to the weaning management itself. The study concluded that supplementation of chicks and their mother hens increased body weight gain and egg production, particularly when they received the diet with both high protein and energy. Moreover, weaning chicks at 4 and 8 weeks of age had an advantage of improving the reproductive performance of the hens without compromising chicks' survival or growth rate.

In Chapter 6, further two factorial experiments were conducted over a period of about six months each in Central Tanzania. The objectives were to evaluate the effects of supplementation of protein and energy sources and egg-laying management strategies on egg production, body weight gain and production efficiency of scavenging chickens under smallholder conditions. A total of 72 farmers were selected from Bumila village in Mpwapwa district and Chamkoroma village in Kongwa district to participate in this study. Two on-farm factorial experiments were set up. The first exepriment was carried out in the rainy season (January-June) and the second experiment was carried out in the dry season (July-December). A total of 144 hens were randomly allocated to the four dietary treatments: A: scavenging only; B: scavenging + high protein, low energy diet (20% CP, 13.5 ME MJ/kg); C: scavenging + high energy, low protein diet (15% CP, 14.5 ME MJ/kg); and D: scavenging + high protein, high enegy diet (20% CP, 14.5 ME MJ/kg) and to three egg-laying management strategies: Lay, hatch and rear chicks for 12 to 16 weeks; Lay, hatch and rear chicks for 1 week only and Lay only. The results showed that hens on diet A produced fewer eggs (47 eggs) than those receiving diets B, C and D (on average 56 eggs). Hens in the Lay-hatch-rear group produced only about 30 eggs compared to the 53 eggs from the Lay-hatch and 73 eggs from the Lay-only groups. Final body weights and body weight gains were higher in all hens receiving supplemental diets than in non-supplemented hens and in hens under the Lay-hatch and Lay-only management systems. Hens in Lay-hatch-rear and Lay-hatch groups consumed more feed during the study period than hens in the Lay-only group. From these results, it can be concluded that the commonly observed low production performance of indigenous chickens is mainly due to inappropriate management under which the birds are raised. The results clearly reveal that the productivity of indigenous hens under traditional management systems can be increased by supplementary feeding and relieving the hens from some aspects of the (long) reproductive cycle such as from brooding and rearing. Economic analysis showed that supplementation with high protein and high energy diets under the traditional management system in combination with the lay-hatch and lay-only management strategies are economically justifiable.

In the General Discussion (Chapter 7), the results presented in the chapters 1 to 6 are discussed in relation with other studies. The recommendations are highlighted and future research areas are suggested.

The following conclusions can be drawn from the several studies described in the current thesis:

- Village poultry production plays an important role in the rural livelihoods of the farming communities in Tanzania and other developing countries. These chickens supply the local people with additional income and high-quality protein food and can be used in social activities. Despite its contribution, the development of traditional village poultry production in the country is small due to a slow rate of growth and low egg numbers.
- Relying on the scavenging system, characterized by low quantities of SFR with a poor nutritional quality (energy and protein), the lack of supplementary feeds and a poor control of diseases, long reproductive cycles coupled with low genetic potential are the underlying factors of this low productivity.

- The provision of supplementary diets containing all critical nutrients (i.e. protein, energy and minerals), in addition to scavenging, improves birds' performance (i.e. growth rate and egg production) and survival rate.
- With respect to the long reproductive cycles (laying, hatching, and rearing) the study shows that an early separation of chicks from their mother hens increases the hen's laying performance without compromising chick's survival rate and growth rate.
- Confining chicks in a house with access to feed and water reduces risks of being affected by predators and diseases ultimately improve their growth rate and survival rate.
- In general, the study clearly shows that the productivity of indigenous hens under traditional management systems can be increased by improving their husbandry conditions through adoption of supplementary feeding, and confining chicks during vulnerable periods and relieving the hens from some aspects of the reproductive cycle such as from brooding and rearing.

In the follow up of the above conclusions, recommendations are suggested to be used as a way forward to disseminate the results in this thesis:

- Strategic supplementation of both protein and energy feed resources in addition to scavenging must be promoted in order to improve growth rate, survival rate and egg production in indigenous chickens. This can be done by providing at least 50 g of feed/day for a scavenging chicken.
- Early weaning of chicks at an age of 4 and 8 weeks have shown to improve laying performance of indigenous hens without compromising chicks survival rate and growth rate; this should be adopted and promoted in the traditional poultry sector.
- Confining young chickens in a house until an age of 8 weeks with access to a balanced diet and water should reduce mortality rate caused by predation, bad weather, diseases, and competition with flock mates.
- Basic skills on poultry management and health and access to extension services must be promoted to farmers in order to improve the productivity on village poultry and increase the income and food security in the traditional poultry sector.

SAMENVATTING

Pluimveeproductie in Tanzania kan, evenals in de meeste andere Afrikaanse landen, worden onderverdeeld in twee typen houderij: een traditionele en een commerciële houderij. De traditionele pluimveehouderij wordt gekenmerkt door een kleinschalige productie, waar koppels (tot 20 dieren) van met name inheemse dorpskippen worden gehouden onder zeer extensieve – scharrel – omstandigheden. Dit type systeem komt vooral veel voor op het platteland. De meer commerciële pluimveehouderij wordt daarentegen gekenmerkt door grotere eenheden kippen (> 20 dieren) die intensiever gehouden worden, veelal met aparte dieren voor ei- dan wel vleesproductie. Dit type systeem komt vooral voor in verstedelijkte gebieden waar eieren en vlees verhandeld worden op markten. Volgens de Agriculture Sample Census (2003) bedraagt de totale pluimveestapel 33.3 miljoen stuks pluimvee, waarvan 31.5 miljoen inheemse dorpskippen zijn, 1.2 miljoen legkippen en 0.6 miljoen vleeskuikens. Dorpskippen maken dus zo'n 95% uit van de totale kippenstapel in Tanzania. De *traditionele* pluimveehouderij is dus verreweg de belangrijkste pluimveesector, en omvat naast inheemse dorpskippen ook eenden, kalkoenen, ganzen, duiven en kwartels. De dorpskippen vormen hierbinnen echter de grootste categorie en komen verspreid over het hele land voor. Dorpskippen verschillen sterk van elkaar: er is een grote variatie in lichaamsgrootte, omvang, kleur van het verenkleed en andere fenotypische kenmerken. Het zijn zogenaamde 'dubbeldoel' kippen, die kleine hoeveelheden eieren en vlees produceren. Desalniettemin zijn de dorpskippen belangrijk in het kader van voedselzekerheid en inkomen voor veel boerenfamilies in Tanzania. Ondanks het sociaal en economisch belang van deze vorm van kippenhouderij wordt het systeem gekenmerkt door veel sterfte onder de dieren (ziekte, predatie), een te lage eiproductie en een trage groei van de dieren. Zoals beschreven in de Inleiding van dit proefschrift (Hoofdstuk 1) zijn er in het verleden slechts enkele initiatieven geweest om de productiviteit van de pluimveestapel op het platteland te verbeteren. De meeste initiatieven waren gericht op het verbeteren van de genetische status van de kippen maar met te weinig oog voor interventies gericht op een verbeterde voeding en/of een beter management.

Deze studie was gericht op het ontwikkelen van adequate voer- en management strategieën voor inheemse dorpskippen in Centraal Tanzania teneinde de productie van de kippen te verhogen en daarmee de levensstandaard van de boerenbevolking te verbeteren.

Specifieke onderzoeksvragen waren:

- Het identificeren, karakteriseren en kwantificeren van verschillende en potentieel beschikbare voedselbronnen die via scharrelen door de kippen werden verkregen (kortweg: 'scharrelvoedsel'); welke beperkingen in het aanbod van scharrelvoedsel zijn er?
- Het bepalen van de kwantiteit en nutritionele kwaliteit van dit scharrelvoedsel door de nutritionele status van de kippen te onderzoeken alsmede hun productiviteit (eiproductie en geslacht gewicht), onder verschillende managementcondities te meten en te vergelijken.
- Het bestuderen van het gecombineerde effect van enerzijds het bijvoederen van eiwit en energie en anderzijds het toepassen van een managementstrategie (waarbij een verkorte reproductiecyclus werd nagestreefd), op groei en slachtopbrengst van de kuikens en ei productie van de hennen.

Hoofdstuk 2 omvat een literatuurstudie over traditionele pluimveehouderijsystemen in ontwikkelingslanden (met name Afrika). De studie laat zien dat meer dan 80 % van alle kippen in Afrika traditioneel gehouden worden. Vier typen van pluimveehouderij worden onderscheiden en in dit hoofdstuk uitvoerig beschreven: (1) het traditionele of vrije uitloop systeem (kippen scharrelen vrij rond en vinden zo hun voedsel); deze studie richt zich op dit systeem; (2) het erfdierhouderijsysteem (dieren deels binnen omheining; 's nachts binnen en iets bijvoedering); (3) semi-intensief (meer bijvoedering; betere huisvesting; op het platteland); en (4) kleinschalig, maar wel intensief (gebalanceerde voeders; grote stallen dicht bij verstedelijkt gebied).
Het vrije uitloopsysteem en de erfdierhouderij vind je het meest op het platteland van Afrika. Vrije uitloop ('scharrel') systemen vindt men het meest bij boerenfamilies. Het aantal kippen per familie varieert van 1 tot 10. De dieren worden verzorgd door de vrouwen en kinderen en worden gehouden voor consumptie, als cash flow, en voor sociale en culturele activiteiten. De kippen scharrelen overdag rond de boerderijen en voeden zich met keukenafval, oogstverliezen en ander voedsel, zoals insecten, wormen, zaden en groen bladmateriaal. De dieren ontberen vaak de beschikbaarheid van water, bijvoeding, huisvesting, vaccinatie en medicatie bij ziekte. Het systeem wordt gekenmerkt door een hoge kuikensterfte tijdens de periode dat ze met de kloek rondscharrelen, tengevolge van te weinig voedsel (verhongering), het oplopen van ziekten en predatie; daarnaast kenmerkt het systeem zich door een zeer lage eiproductie (30-50 eieren per kip per jaar) en een lage groeisnelheid (5-10 g per dag).

De studie laat zien dat de kwantiteit en nutritionele kwaliteit van het scharrelvoedsel voor kippen varieert met het seizoen, de hoogteligging, klimatologische omstandigheden en oogstactiviteiten op het boerenbedrijf, maar ook met sociale en managementfactoren en de grootte van de kippenstapel. Het bleek dat het scharrelvoedsel per kg droge stof (DS)die de kippen consumeerden weinig eiwit (100 g), energie (11.2 MJ) en mineralen zoals Ca (11.7 g) and P (5 g) bevatte; concentraties aan voedingsstoffen die in ieder geval te laag zijn voor een optimale groei en eiproductie van scharrelende dorpskippen. Er werd geconcludeerd dat deze voedingsstoffen via bijvoeding zouden moeten worden aangeboden.

In Hoofdstuk 3 wordt een participatief onderzoek beschreven, uitgevoerd in vier dorpen in de Dodoma regio in Centraal Tanzania, naar de beschikbaarheid en het gebruik van lokale scharrelvoedselbronnen voor dorpskippen. Allereerst werd door middel van groepsbijeenkomsten met 20-30 sleutelfiguren uit elk dorp getracht informatie te verkrijgen en inzicht te verwerven omtrent de specifieke kenmerken van de bestaande kippenhouderij in elk dorp. Deze informatie werd gebruikt om een enquête op te stellen voor het uiteindelijke (verdiepende) onderzoek. De enquête moest antwoord geven op vragen als: Welke scharrelvoedselbronnen eten de kippen gedurende de verschillende seizoenen van het jaar ? Welke factoren bepalen in uw beleving de kwantiteit en kwaliteit van deze scharrelbronnen en welke maatregelen zouden moeten worden genomen om de beschikbaarheid van scharrelvoedsel te vergroten?
In totaal werden 318 huishoudens in de vier dorpen bevraagd via de enquête (70-80 huishoudens per dorp). Daarbovenop deed een groep van 40 boeren mee in het uitgebreide onderzoek: zij werden geselecteerd voor verdiepende interviews om kwalitatieve informatie te verstrekken over de seizoensbeschikbaarheid van scharrelvoedsel. De uitkomsten van deze interviews werden geanalyseerd door middel van paarsgewijze rangschikking, matrix scores en directe observaties. Voermonsters van bestaande en potentiële voedselbronnen werden verkregen via de geïnterviewde boeren en geanalyseerd in het laboratorium. Vervolgens werden 141 dorpskippen van beide sexen aangekocht (met een gemiddeld lichaamsgewicht van 1.2 kg ± 0.3) en geslacht op twee tijdstippen (11.00 and 16.00 h). Krop- en spiermaaginhoud werd visueel geanalyseerd en vervolgens gedroogd voor nadere chemische analyse.

Uit de resultaten van de participatieve studie naar het gebruik van scharrelvoedsel door dorpskippen kwam naar voren dat in het droge seizoen vooral granen (maïs, sorghum en parelgierst) en de bijproducten, en oliezaden (zonnebloem, aardnoten en sesamzaad) en zonnebloemzaadcake werden gegeten door de dieren, terwijl in het regenseizoen vooral ruwvoerresten, plantendelen, zaden, groenten, insecten en wormen werden gegeten. De beschikbaarheid van scharrelvoedsel werd significant beïnvloed door factoren als seizoen, boerderijactiviteiten, beschikbaar scharrelareaal en aantal kippen per huishouden. Scharrelvoedsel voor dorpskippen bevatte gemiddeld 888 g/kg DS. Bruto energie varieerde van 17.1 tot 29.3 MJ/kg DS^{-1} en eiwit van 64.5 tot 418 g kg DS^{-1}. De ruwvezelfractie varieerde van 33.3 tot 230 g kg DS^{-1} en ruwvet varieerde van 16.0 tot 488 g kg DS^{-1}. De minerale compositie varieerde van 1.5 tot 18.4 g kg DS^{-1} voor Ca; en van 3.6 tot 17.3 g kg DS^{-1} voor P; van 9.5 tot 34.5 g kg DS^{-1} voor K en van 0.2 tot 8.5 g kg DS^{-1} voor Mg.

Uit de visuele analyse van krop- en spiermaaginhoud kwam naar voren dat de dorpskippen 29.0 % granen en graanbijproducten, 1.8 % groente en ruwvoermateriaal, 3.4 % zaden en bijproducten hiervan, 0.2 % insecten en wormen, 0.3 % eischalen, veren en botjes, 0.8 % inert materiaal, 23.0 % zand en grit en 41.5 % ongedefinieerd materiaal consumeerden. Krop- en spiermaaginhoud bevatten een gemiddelde droge stof inhoud van 479 g per kg en een omzetbare energie van 10.1 MJ kg DS^{-1}. Nutriëntcompositie (kg DS^{-1}) van krop- en spiermaaginhoud was: 80.4 g ruw eiwit; 70.7g ruwvet; 45.7 g ruwvezel; 234 g as; 6.6 g Ca; 6.5 g P; 12.1 g K and 2.6 g Mg.

Uit deze studie kon geconcludeerd worden dat de concentraties aan voedingsstoffen in de zogenaamde scharrelvoedselbronnen onder de behoeftenorm liggen voor een optimale groei en eiproductie bij dorpskippen.

Een 2x2 factorieel experiment werd uitgevoerd om de effecten van seizoen en bedrijfssysteem op de kwantiteit en nutritionele kwaliteit van de scharrelvoedselbronnen en de productie van de dorpskippen te bepalen (Hoofdstuk 4). Het onderzoek werd lokaal uitgevoerd in dorpen met een specifiek bedrijfssysteem: (1) het sorghum- parelgierst-grondnoten bedrijfssysteem in de dorpen Chitemo en Kisokwe en (2) het maïs-bonen-zonnebloem bedrijfssysteem in de dorpen Bumila en Chamkoroma in Centraal Tanzania. De studie bestond feitelijk uit twee experimenten in de tijd. Het eerste experiment werd uitgevoerd tijdens het regenseizoen (januari-juni) en het tweede tijdens het droge seizoen (juli-december).

In totaal werden 648 dorpskippen van plaatselijke boeren aangekocht en geslacht nadat de dieren 4 uur gescharreld hadden, om 10 uur in de ochtend, om 2 uur in de middag en om 6 uur in de avond. De inhoud van de krop van de geslachte dieren werd fysisch en chemisch geanalyseerd. In het regenseizoen werden de monsters uit de krop genomen in de perioden januari-februari, maart-april en mei-juni, en in het droge seizoen in de perioden juli-augustus, september-oktober en november-december.

De gemiddelde droge stof opname was significant hoger (18.1g DM) in het droge seizoen ten opzichte van het regenseizoen (14.9g DM). Op basis van de aanname dat de dieren hun krop vullen tijdens 4 uur durende eetcycli, werd de voeropname geschat op zo'n 54 g per dag tijdens het droge seizoen en op 45 g per dag tijdens het regenseizoen. Het gemiddeld gewicht van de kippen vlak voor slachten was hoger in het droge seizoen (1238 g) dan in het regenseizoen (890 g). Visuele inspectie van de kropinhoud leverde de volgende bestanddelen op: keukenafval, bierbostel, zemelen, zand, grit, oliezaden en bijproducten, granen en andere voedermiddelen. Deze samenstelling varieerde sterk onder invloed van seizoen en bedrijfssysteem. De chemische samenstelling (% DS) van de kropinhoud bestond uit eiwit (9.24), as (21.6), magnesium (0.22), ruwvet (58.8) en omzetbare energie (11.5 MJ/kg DS^{-1}), en ook hier was er een effect van seizoen en bedrijfssysteem. De hoeveelheid eiwit en as in de kropinhoud was hoger in het regenseizoen (respectievelijk 10.1% en 24.9% in de DS) ten opzichte van het droge seizoen (respectievelijk 8.4% eiwit en 18.2% as), terwijl de omzetbare energie in de kropinhoud juist hoger was in het droge seizoen (12.2 MJ/kg) dan in het regenseizoen (10.8 MJ/kg), een indicatie dat een tekort aan energie vooral optreedt in het regenseizoen.

De conclusie was dat de kwantiteit en nutritionele kwaliteit van scharrelvoedsel nogal varieert tussen seizoenen en bedrijfssystemen en dat de nutriëntgehalten in het scharrelvoedsel niet voldeed aan de behoefte voor een optimale productie. Bijvoedering van zowel energie (vooral in het regenseizoen) alsook eiwit (vooral in het droge seizoen) is hard nodig, bij voorkeur via lokaal aanwezige voedselbronnen.

Hoofdstuk 5 beschrijft een experiment waarbij de effecten van een eiwit en energie bijvoedering enerzijds en een gewijzigde opfokstrategie anderzijds werden bestudeerd op de reproductiecapaciteit van broedse hennen en de prestaties van de kuikens. Het experiment werd uitgevoerd in dezelfde, reeds genoemde, vier dorpen, zowel in het regenseizoen (januari-juni) alsook in het droge seizoen (juli-december). In totaal werden 192 boeren (en hun dieren) geselecteerd om te participeren in deze studie. 384 aan de leg zijnde dorpskippen en 2304 kuikens werden random toegewezen aan een combinatie van behandelingen. Proeffactoren waren vier voerbehandelingen A: alleen scharrelen; B: scharrelen + hoog eiwit, laag energie voer (20% eiwit, 13.5 MJ/kg omzetbare energie); C: scharrelen + hoog energie, laag eiwit voer (15% eiwit, 14.5 MJ/kg omzetbare energie); en D: scharrelen + hoog eiwit, hoog energie voer (20% eiwit, 14.5 MJ/kg omzetbare energie) en drie opfokstrategieën: kuikens bij de moederkloek weghalen op 4, 8 of 12 weken.

De bijvoedering bestond uit lokaal aanwezige voedermiddelen zoals maïszemelen, sorghum, parelgierst, zonnebloemzaadcake en vismeel. Kuikens die werden bijgevoerd met eiwitrijk voer, energierijk voer, of beide, lieten meer groei zien (respectievelijk 1530 g, 1575 g en 1669 g) dan de

niet-bijgevoerde dieren (1203 g). Ook de hennen produceerden navenant beter als er werd bijgevoerd (respectievelijk 44, 45 en 47 eieren) tegenover 33 eieren in de niet-bijgevoerde groep. Met betrekking tot de opfokstrategie: kuikens die al op 4 weken bij de moederkloek werden weggehaald hadden een lager lichaamsgewicht op 4 weken (106 g) en 12 weken (258 g) dan de kuikens die pas op 8 of 12 weken bij de kloek vandaan weren gehaald, maar deze gewichtsverschillen tussen de opfokstrategieën waren verdwenen op 24 weken leeftijd. Het aantal legseries in een half jaar nam toe van 2 series met een output van 29 eieren bij het scheiden van de moeder op 12 weken, tot 3 series met 42 eieren bij het scheiden op 8 weken en tot 4 series met 56 eieren bij scheiden op 4 weken. De overlevingskans van de kuikens die alleen scharrelden (zonder bijvoedering) was lager (65%) dan van de bijgevoerde kuikens. Kuikens die reeds op 4 weken bij de moederkloek vandaan werden gehaald hadden een lagere overlevingskans (67%) dan de kuikens die 8 (77%) of 12 weken (73%) bij de moeder bleven. De oorzaak van de hoge sterfte bij de 4 weken-kuikens was vooral een gevolg van de uitbraak van ziektes, en had minder met het scheiden van de moederhen per sé te maken.
Concluderend kan gesteld worden dat bijvoedering van moederkloek en kuikens zowel de groei van de kuikens als de eiproductie verbeterd, met name wanneer zowel eiwit als energie wordt verstrekt. Het eerder weghalen van kuikens bij de moederkloek had geen nadelige gevolgen voor het later gewicht van de kuikens en slechts marginale effecten op de overlevingskans. De eiproductie van de moederkloek op halfjaarbasis steeg aanmerkelijk bij het erder weghalen van de kuikens.

In Hoofdstuk 6 worden twee factorieele experimenten beschreven die identiek van opzet zijn maar waarvan het ene experiment in het regenseizoen is uitgevoerd en het andere experiment in het droge seizoen, over een periode van ongeveer 6 maanden. Doel was om de effecten van bijvoedering van eiwit en energie en de reproductiestrategie op eiproducttie van de hennen en de groei van de kuikens te bestuderen. In totaal deden 72 boeren met elk 2 dorpshennen uit de dorpen Bumila in het Mpwapwa district en Chamkoroma in het Kongwa district mee in dit project. De dorpskippen werden random toegewezen aan één van de behandelingscombinaties, te weten een voerfactor (4 groepen: A: alleen scharrelen; B: scharrelen + hoog eiwit, laag energie voer (20% eiwit, 13.5 MJ/kg omzetbare energie); C: scharrelen + hoog energie, laag eiwit voer (15% eiwit, 14.5 MJ/kg omzetbare energie); en D: scharrelen + hoog eiwit, hoog energie voer (20% eiwit, 14.5 MJ/kg omzetbare energie) en een reproductiestrategie (3 groepen: (1) hennen leggen alleen de eieren; (2) hennen leggen de eieren en broeden deze uit, met een korte kloekperiode van 1 week; en (3) hennen leggen de eieren, broeden ze uit en brengen de kuikens groot (tot ongeveer 12-16 weken).

De resultaten lieten zien dat de hennen die slechts konden scharrelen minder eieren produceerden (47 eieren) dan de bijgevoerde hennen (gemiddeld 56 eieren). Hennen die alle moedertaken uitvoerden legden slechts 30 eieren; dit is beduidend minder dan het aantal eieren van hennen die na leg en broeden weer bij de haan werden gezet (53 eieren) of zelfs direct na de legserie weer bij de haan werden gezet (73 eieren). Eindgewichten en totale groei van de hennen was beter in de bijgevoerde groepen en bij de hennen die een kortere reproductiecyclus hadden (slechts leggen en broeden). De dieren die een langere of kortere tijd bij de kuikens verbleven namen wel meer voer op dan de dieren die slechts eieren hoefden te produceren.
Uit de resultaten kan geconcludeerd worden dat de vaak geciteerde lage productiviteit van inheemse dorpskippen vooral een gevolg is van een inadequate management, en sterk kan worden verbeterd door bijvoedering en een verkorting van de reproductiecyclus (minder moedertaken door de kloek laten uitvoeren). Dit levert ook economisch gewin op voor de plattelandsboeren.

In de Algemene Discussie (Hoofdstuk 7) worden de resultaten uit de hoofdstukken 1 t/m 6 bediscussieerd in relatie tot vergelijkbare studies. Vervolgens worden aanbevelingen gedaan voor toekomstig onderzoek.
De volgende conclusies kunnen getrokken worden naar aanleiding van de resultaten uit de studies zoals beschreven in dit proefschrift:

- Dorpskippenhouderij speelt een belangrijke rol op het platteland van Tanzania en andere ontwikkelingslanden. Deze kippen zorgen voor hoogwaardig dierlijk eiwit en extra inkomen en dienen vaak ter ondersteuning van sociaal-culturele activiteiten. Ondanks dit belang lijkt de dorpskippenhouderij zich nauwelijks te ontwikkelen. Het systeem blijft dan ook gekenmerkt door een (zeer) lage productiviteit.
- Deze lage productiviteit wordt vooral veroorzaakt door een te lage nutritionele waarde van het scharrelvoedsel, het ontbreken van adequate bijvoederstrategieën, een zeer matige ziektebestrijding, en lange reproductiecycli gekoppeld aan een mager genetisch potentieel bij de dorpskippen.
- Het verstrekken van extra voer ('bijvoedering'), voorzien van de meest waardevolle bestanddelen als eiwit, energie en mineralen, verbetert de productiviteit en overlevingskansen van dorpskippen.
- Het reeds vroegtijdig scheiden van moederkloek en kuikens verhoogt op jaarbasis de eiproductie bij de moederhen en heeft geen nadelige gevolgen voor de groei en de overlevingskansen van de kuikens.

- Het deels binnen huisvesten van jonge kuikens (met voer en water) verkleint het risico op predatie en ziektes, en vergroot dus automatisch de overlevingskans.
- Samenvattend heeft deze studie aangetoond dat de productiviteit van dorpskippen in een traditioneel scharrelsysteem aanmerkelijk kan worden verbeterd door managementinterventies als enerzijds bijvoedering en het deels opsluiten van de kuikens, en *anderzijds verkorten van de reproductie -moeder- activiteiten van de* kloek.

Aanbevelingen naar aanleiding van de conclusies kunnen gebruikt worden als start voor de implementatie van de resultaten uit dit proefschrift:

- Het bijvoeren met energie en eiwit (als aanvulling op het scharrelrantsoen) dient gestimuleerd te worden teneinde de productiviteit van de dorpskippen te verhogen; daartoe dienen de dieren 50 g extra bijvoedering per dag te krijgen.
- Het vroegtijdig scheiden van de moederkloek en haar kuikens verbetert de eiproductie van de hennen en dient geadopteerd en aangemoedigd te worden als kansrijke interventie in de traditionele dorpskippenhouderij.
- Het binnen een afrastering houden van jonge kuikens tot een leeftijd van 8 weken, met toegang tot water en voer verlaagt de sterfte onder de kuikens die veroorzaakt wordt door predatie, slechte weersomstandigheden, ziektes en competitie voor bijvoedering met oudere toomgenoten.
- Het stimuleren van boeren om basisvaardigheden aan te leren gericht op het (gezond) houden van pluimvee in de tropen, alsook het promoten om meer gebruik te maken van een voorlichtingsdienst is van essentieel belang in de ontwikkeling van de dorpskippenhouderij; de voedselzekerheid zou hiermee beter gewaarborgd kunnen worden.

MUHTASARI

Mfumo wa ufugaji wa kuku hapa Tanzania na katika nchi nyingine za kiafrica unaweza kugawanywa katika mifumo ya uzalishaji wa kuku wa kiasilli na kuku wa kibiashara. Sekta ya uzalishaji wa kuku wa kiasili inaundwa na wafugaji wadogo ambapo kuku wengi wa kiasili hufugwa katika mazingira huria ya vijijini au mashambani. Sekta ya uzalishaji wa kuku wa kibiashara inahusisha wafugaji wadogo, wafugaji wa kati na wafugaji wakubwa katika mazingira yenye uangalizi maalum ambapo kuku wa kisasa wa mayai na wa nyama hufugwa kwaajili ya mayai na nyama. Uzalishaji wa kuku wa kibiashara hufanyika katika maeneo ya miji na yale pembezoni mwa miji ambapo kuna masoko kwaaajili ya ya mayai na nyama. Kulingana na sensa ya Kilimo ya mwaka 2003 idadi ya kuku wote wanaofugwa hapa Tanzania inaonyesha jumla ya kuku milioni 33.3 ambapo kuku milioni 31.6 ni wa kiasili, kuku milioni 1.27 ni wa kisasa wa mayai na kuku 570,000 ni wa kisasa wa nyama. Kama inavyoonesha katika takwimu hizi, kuku wa kiasili hufikia asilimia 95 ya idadi ya kuku wafugwao Tanzania. Kwa ujumla mfumo wa uzalishaji wa kiasili ndio mfumo mkubwa ukilinganisha na mfumo wa uzalishaji wa kuku wa kibiashara. Katika sekta ya uzalishaji wa kiasili kuna aina tofauti za ndege kama vile kuku, bata, bata mzinga, mabata bukuni, njiwa na kanga au kololo. Hata hivyo, kuku wa asili au kuku wa mashambani au kwa usahihi zaidi kuku wa vijijini ndio aina ya ndege walio wengi na waliosambaa katika maeneo ya kanda mbalimbali ndani ya nchi. Kuku wa asili au kienyeji kwa kawaida hutofautiana katika ukubwa wa mwili (umbo), umbile la mwili, rangi ya manyoya, na tabia au hulka za maumbile ya nje. Kuku wa asili wanahesabiwa kuwa kwenye matabaka yenye matumizi ya aina mbili, ambayo wanaweza kuzalisha viwango vya chini hadi viwango vya kati vya nyama na mayai. Kwa ujumla kuku wafugwao wanatoa mchango mhuhimu wa uhakika wa chakula katika kaya na wa kipato kwa watu katika Tanzania ukilinganisha na kuku wa kisasa wa aina zote mbili. Licha ya umuhimu wake kiuchumi na kijamii, uzalishaji wa kuku wa asili katika wa mfumo huria katika nchi yetu unakabiliwa na vifo vingi vya kuku, utagaji mdogo wa mayai na kiwango kidogo cha ukuaji wa makinda. Kwa ujumla katika siku za nyuma kumekuwepo na mikakati michache ya kuboresha uzalishaji wa kuku wa asili kama ilivyoelezwa katika sura ya kwanza ya utangulizi wa tasinifu hii. Mikakati hiyo ililenga katika kuendeleza ubora wa vinasaba vya kuku wa kiasili na huku kukiwa na msisitizo au mkazo kidogo katika kuboresha mfumo wa ulishaji na matunzo ya kuku hawa. Kwahiyo, lengo kuu la tasinifu ya hii lililenga katika kuboresha ulishaji na mikaka mizuri ya matunzo ya uzalishaji wa kuku wa kiasili katika Kanda ya Kati ambayo itasaidia kuongeza kwa ujumla uzalishaji wa kuku wa asili ili kuinua hali ya maisha ya wananchi vijijini. Ili kufikia lengo kuu hili, tasinifu hii ikikuwa na malengo mengine madogo kamaifuatavyo (i) Kufanya uchambuzi, kuainisha na kufanya tathmini ya kina ya rasilimali ya vyakula mbalimbali wanavyokula kuku na

kuchunguza kwa makini vikwazo vinavyochangia katika upatikanaji wa rasilimali hizi za vyakula vya kuku wa kiasili katika mfumo wa ufugaji huria (ii) Kutathmini viwango na ubora waviinilishe vilivyo katika rasilimali ya vyakula vya kuku kwa kufanya uchunguzi wa athari za mwingiliano na matunzo katika mazingira ya mkulima juu ya hali ya lishe na uzalishaji (uzito wa kuku na wingi wa nyama) kwa kuku wanaojitafutia chakula wenyewe; (iii) Kutathmini athari za ulishaji wa vyakula vya ziada vyenye viinilishe vya protini na wanga (kutia nguvu) na mikakati ya matunzo bora, yaani, kutenganisha makinda au vifaranga na mama zao katika umri mdogo na kuwafanya kuku kutaga mayai kwa ustadi juu ya kiwangao cha ukuaji wa kuku wadogo na uzalishaji wa mayai kwa kolowa wanaofugwa huria.

Katika sura ya pili (2), utafiti-hakiki unatoa maelezo ya ujumla juu ya ya mfumo wa fugaji wa asili wa kuku katika nchi zinazoendelea (hasa nchi za kiafrika) kwa kuzingatia taarifa za tafiti zilizokwisha fanyika. Utafiti huu unaonyesha kuwa asilimia 80 ya kuku wanaofugwa katika Afrika hufugwa katika mfumo wa kiasili. Aidha, ipo mifumo minne ya uzalishaji wa kuku wanaofugwa katika nchi zinazoendelea na zipo sifa bainifu za kila mfumo ambazo zimeelezwa kwa uwazi. Mifumo hiyo inajumuisha ufugaji huria au ufugaji wa asili kama vile ule wa vijijini. Ufugaji wa kwenye uzio, ufugaji wa nusu ndani-nusu nje kwa siku na ufugaji mdogo wa ndani kabisa. Ufugaji huria au ufugaji wa asili kama ule wa vijijini na ufugaji wa kwenye uzio ndio unaofanyika kwa kiwango kikubwa katika nchi za kiafrika. Ufugaji huria hufanyika mahali pengi na hufanywa na familia nyingi za vijiini. Kuku wanafugwa mara nyingi hufugwa na wanawake na watoto kwaajili ya matumizi ya nyumbani, kipato na kwaajili ya mila na desturi za jamii husika. Kuku wanaofugwa hufunguliwa nje na huachwa huru ili kujitafutia chakula chao wenyewe katika maeneo yaliyo karibu na makazi ya watu wakati wa mchana kutwa huku wakiokota na kula mabaki ya vyakula, taka na vyakula vingine kama wadudu, minyoo, mbegu za miti au majani ya miti na nyasi. Aidha, kuku wanaofugwa katika mfumo huria hawapewi mara kwa mara maji, chakula cha ziada, nyumba ya kulala, chanjo na madawa dhidi ya magonjwa. Kutokana na matunzo hafifu, mfumo huu wa huria una sifa ya kuwa vifo vingi vya makinda na vifaranga kutokana na njaa kwasababu ya kukosa chakula, magonjwa na mbuai (wanyama wenye kula wanyama wengine); na vile vile mfumo huria una sifa ya kuwa kiwango kidogo cha cha uzalishaji wa mayai (yaani mayai 30-50 kwa kuku kwa mwaka) na kiwango kidogo cha ukuaji kwa makinda au vifaranga (5-10 gramu kwa siku). Ufugaji huria ndio ulioenea maeneo yote ya vijijini na kupitia mfumo huu kuku hujipatia chakula chao cha kila siku. Utafiti uliofanywa unaonyesha kuwa kiasi na ubora wa lishe ya vyakula wanavyojitafutia kuku wafugwao huria hutofautiana kutokana majira, miinuko, hali ya hewa, shughuliza kilimo na ufugaji, hali ya uchumi katika jamii, matunzo ya vyakula vyenyewe na idadi ya kuku wanafugwa katika vijiji. Zaidi ya hayo, utafiti unaonyesha kuwa vyakula ambavyo kuku wanajitafutia vina viwango vya chini vya viinilishe vya protini (100 g kg DM^{-1}), nguvu (11.2 MJ kg DM^{-1}) na madini kama kama vile kalisiumu (11.7 g kg DM^{-1}) na fosifolasi (5 g kg DM^{-1}) ambavyo haviwezi kukithi mahitaji ya ukuaji mzuri wa makinda na vifaranga and utagaji wa mayai kwa kolowa (kuku jike) pale wanapojitafutia chakula weneyewe. Kutokana na utafiti huu, inapendekezwa kuwa viinilishe ambavyo havipatikani kwa kiwango kinachotakiwa vinaweza kuboreshwa kwa kuwapa kuku vyakula vya ziada vyenye viinilishe hivyo.

Katika sura ya tatu (3), utafiti shirikishi ulifanyika katika vijiji vinne vya mkoa wa Dodoma katika Kanda ya Kati kuchunguza vyakula vilivyopo na vile vyenye uwezekano wa kutumika kuwa vyakula vya kuku. Kwanza kabisa, uchunguzi wa awali ulifanyika ili kupata taarifa za msingi juu ya shughuli za kilimo na ufugaji katika vijiji hivi viinne kwa kuwahoji watu muhimu wenyeuelewa wa hali halisi ya kila kijiji. Taarifa hizi za msingi zilitumika katika kuandaa dodoso la uchunguzi. Dodoso hili hasa lilichunguza rasilimali ya vyakula na viinilishe wanavyokula kuku katika vijiji kwa nyakati mbalimbali za majira ya mwaka; pia dodoso lilichunguza mambo au vitu vinavyoathiri kiasi na ubora wa vyakula na kubaini ufumbuzi wa unaoweza kutumika kuboresha upatikanaji wa rasilimali ya vyakula hivi. Jumla ya kaya 318 kutoka vjiiji hivyo vinne walihojiwa ambapo kati ya wastani wa kaya 70 hadi 80 zilihojiwa kwa kijiji. Aidha, kundi la wakulima (wafugaji wa kuku) 40 kutoka kila kijiji walishiriki katika uchunguzi huu na walichaguliwa kwaajili ya kupata taarifa za upatiakanaji wa vyakula kulingana na majira na vikwazo vinavyohusiana na upatikanaji wa rasilimali ya vyakula hivi kwa kutumia njia kulinganisha jozi, jedwali la alama na uchunguzi na kwa kutembelea maeneo ambayo kuku hujitafutia chakula. Sampuli ya vyakula vilivyopo na vile vyenye kuwa na uwezekano wa kuwa vyakula vilikusanywa kutoka kwa wakulima/wafguji waliohojiwa na kupelekwa kwenye maabara kwaajili ya uchunguzi wa viinilishe. Kwa nyongeza zaidi, kuku wanaojitafutia wa jinsia zote wapatao 141 wenye uzito wa 1.2 kilogramu ± 0.3 walinunuliwa pasipokuwa na utaratibu maalum kutoka kwa wakulima/wafugaji na kuwachinja kwenye muda wa saa 5.00 asubuhi na saa 10.00 alasiri. Vyakula vilivyokuwa kwenye solelo (tumbo la kuku) na kwenye firigisi vilichunguzwa kwa umakini na kukaushwa kwenye maabara kwaajili ya kuchunguza viinilishe vilivyo katika vyakula hivyo.

Matokeo ya uchunguzi wa dodoso yanaonyesha kuwa wakati wa kiangazi vyakula muhimu vya kuku ni punje za nafaka (mahindi, mtama na uwele) na pumba yake, mbegu za mazao ya mafuta (alizeti, karanga na ufuta) na mashudu ya alizet, na wakati wa masika vyakula muhimu vya kuku ni majani ya miti au nyasi, maua, mbegu, mboga za majani, wadudu na minyoo. Mabadiliko ya majira, shughuli za kilimo na ufugaji, ukubwa wa eneo la kulishia kuku na ukubwa wa kundi la kuku wanaofugwa vijijini vilionekana kuwa na athari kubwa juu ya upatikanaji wa vyakula vya kuku. Matokeo yanaonyesha kuwa wastani wa kiasi cha vyakula kilichokaushwa

(DM) ulikuwa 888 g/kg. Kiwango cha nguvu isiyokuwa halisi ya vyakula kilianzia 17.1 hadi 29.3 MJ/kgDM^{-1} na protini kuanzia 64.5 hadi 418 g kg DM^{-1}. Kiwango cha nyuzi kilianzia 33.3 hadi 230 g kg DM^{-1} na kiwango cha mafuta katika vyakaula kilianzia 16.0 hadi 488 g kg DM^{-1}. Kiwango cha madini kilianzia 1.5 hadi 18.4 g kgDM^{-1} kwa kalisiumu; na 3.6 hadi 17.3 g kg DM^{-1} kwa fosifolasi; 9.5 hadi 34.5 g kgDM^{-1} kwa potasiamu na 0.2 hadi 8.5 g kgDM^{-1} kwa magnesi. Uchunguzi kwa kuona/kutazama vyakula vilivyoko kwenye solelo na firigisi unaonyesha kuwa vyakula wanavyokula kuku kwa kujitafutia vilikuwa na mchanganyiko wa punje za nafaka na pumba zake (29.0%), mboga za majani na majani (1.8%), mbegu na mashudu yake (3.4%), wadudu na minyoo (0.2%), maganda ya mayai, manyoya na mifupa (0.3%), vyakula visvyotambuliwa (41.5%), vyakula visivyosagwa (0.8%) na mchanga au changarawe (23.0%). Vyakula vilivyokuwa kwenye solelo na firigisi vilikuwa na wastani wa uzito uliokaushwa wa 479 g kwa kilogramu na nguvu halisi ya chakula chenye 10.1MJ kgDM^{-1}. Mchanganyiko wa viinilishe wa vyakula vilivyokuwa kwenye solelo na firigisi (kgDM^{-1}) ulikuwa: 80.4 g ya protini, 70.7g ya mafuta; 45.7 g ya nyuzi; 234 g ya jivu; 6.6 g ya kalisiumu; 6.5 g ya fosifolasi; 12.1g ya potasiumu na 2.6 g ya magnesi. Hivyo kutokana na utafiti huu, inahitimishwa kuwa viinilishe katika vyakula wanavyokula kuku wanaofugwa vijijini vilikuwa chini ya viwango vinavyotakiwa kuongeza ukuaji na utagaji mayai.

Katika sura ya nne (4), jaribio la 2x2 lilifanyika ili kutathimini athari za majira na nyanda za kilimo na ufugaji juu ya kiasi na ubora wa lishe ya rasimali vyakula na uzalishaji wa kuku wafugwao vijijini. Utafiti huu ulifanyika vijijini katika nyanda mbili za kilimo na ufugaji: nyanda ya mtama-uwele-karanga katika vijiji vya Chitemo na Kisokwe na katika nyanda ya mahindi-maharage-alizeti katika vijiji vya Bumila na Chamkoroma vyote vikiwa katika kanda ya kati. Utafiti huu ulihusisha maaribio mawili. Jaribio la kwanza lilifanyika wakati wa majira ya masika (Januari-Juni) na jaribio la pili lilifanyika wakati wa majira ya kiangazi (Julai-Disemba). Wakati wa masika sampuli ya vyakula walivyokula kuku zilichukuliwa kutoka kwenye solelo kati ya Januari-Februari; Machi-Aprili, na Mei-Juni na majira ya kiangazi sampuli za vyakula kutoka kwenye solelo zilichukuliwa kati ya Julai-Agosti; Septemba-Oktoba, na Novemba-Disemaba. Jumla ya kuku 648 waliokuwa wanajitafutia chakula walinunuliwa kutoka kwa wakulima/wafugaji na kuku hao walichinjwa baada ya kutumia masaa 4 wakiwa wanajitafutia chakula wakati wa muda wa saa 4.00 asubuhi, saa 8.00 mchana na saa 12.00 jioni. Vyakula kutoka kwenye solelo na firigisi vilichanganuliwa kila kimoja kujua uzito na kisha kuchunguza viinilishe vyake. Matokeo yanaonyesha kuwa wastani wa vyakula walivyokula ulikuwa mkubwa (18.1g DM) wakati wa majira ya kiangazi ukilinganisha na majira ya masika (14.9g DM). Kwa kuzingatia dhana ya kuwa kuku hujaza matumbo yao katika muda wa mzunguko wa masaa manne ya kujitafutia chakula, chakula halisi ambacho walikula kinakadiriwa kuwa 54 g kwa siku wakati wa majira ya kiangazi na 45 g kwa siku wakati wa majira masika; hii ikiwa ni sawa na 54% ya jumla ya kiwango cha mlo wakati wa kiangazi na 45% ya jumla ya mlo wakati wa masika. Aidha, matokeo yanaonyesha kuwa wasitani wa uzito wa kuku wakati wa kuwachinja ulikuwa kubwa wakati wa kiangazi (1238 g) kuliko wakati wa masika (890 g). Uchunguzi wa kutazama chakula kilichopatikana kwenye solelo unaonyesha kuwa mabaki ya vyakula/machicha ya pombe, mchanga na changarawe, mbegu za mazao ya mafuta na mashudu ya alizeti, pumba ya nafaka, punje za nafaka, na vyakula vingine ambavyo havikujulikana vilikuwa ndio chakula kikuu cha kuku na vilitofautiana kulingana na majira ya mwaka na nyanda za kiimo na ufugaji. Kwa ujumla mchanaganyiko wa viinilishe (% ya kitu kilichokaushwa) vya chakula kutoka kwenye solelo ulionyesha kuwa protini (9.24), jivu (21.6), magnesi (0.22), kabohaidreti/chakula cha wanga (58.8) na nguvu ya metabolizabo (11.5 MJ/kgDM^{-1}) vilitofautian kulingana na majira pia nyanda za kilimo na ufugaji. Vyakula hivi vilikuwa na kiwango kikubwa cha protini(10.1% ya DM) na jivu (24.9% ya DM) wakati wa masika kuliko kiangazi (8.4% ya protini na 18.2% ya jivu); ambapo nguvu ya metabolizabo ilikuwa kubwa (12.2 MJ/kg) wakati wa kiangazi kuliko masika (10.8 MJ/kg), hii ikionyesha kuwa chakula cha ziada chenye kuongeza nguvu kinahitajika sana wakati wa masika. Inahitimishwa kuwa kiasi na ubora wa lishe ya rasilimali ya vyakula vya kuku wanavyojitafutia hutofautiana sana kati ya majira ya kiangazi na masika na kati ya nyanda za kilimo na ufugaji; na kiwango cha viinilishe katika vyakula hivi kiko chini ya mahitaji halisi ya kuku kwaajili ya uzalishaji mkubwa. Hivyo vyakula vya ziada vyenye kuwa na nguvu inavyopatikana katika maeneo haya vinahitajika ili kuweza kufikia kiwango cha ulaji kinachohitajika wakati vyakula vyenye nguvu vinahitajika wakati wa masika na protini wakati kiangazi.

Katika sura ya tano (5), utafiti juu ya athari ya ulishaji wa vyakula vyenye protini na nguvu na utaratibu wa kuwaachisha makinda wasilelewe na kolowa (mama zao) juu ya uzalishaji (mayai na uzito) na kisha ukuaji wa makinda uliweza kufanyika katika vijiji viinne vilivyotajwa hapo juu. Jumla ya wakulima/wafugaji 192 walichaguliwa kushiriki katika utafiti huu. Majaribio mawili yakiwa na vyakula vinne na utaratibu wa aina tatu wa kuwaachisha makinda wasiendelee kutunzwa na mama zao uliweza kupangwa na kufanyika katika nyanda mbili za kilimo na ufugaji. Jaribio la kwanza lilifanyika wakati wa masika (Januari-Juni) na la pili lilifanyika wakati wa kiangazi (Julai-Disemba). Jumla ya majike ya kuku 384 wenye makinda 2304 waligawanywa katika makundi kulingana na vyakula vinne kama ifuatavyo, A: kujitafutia chakula wenyewe; B: kujitafutia chakula + chakula chenye protini kubwa, nguvu kidogo (20% protini, 13.5 ME MJ/kg); C: kujitafutia chakula + chakula chenye protini ndgogo, nguvu kubwa (15% CP, 14.5 ME MJ/kg); na D: kujitafutia chakula + chakula chenye protini kubwa, nguvu kubwa (20% CP, 14.5 ME MJ/kg) na kwenye vipindi vitatu vya kuwaachisha makinda: wiki 4, wiki 8, na wiki 12. Vyakula hivi vilitengenezwa kutokana na mchanganyiko wa malighafi za vyakula vinavyopatikana katika maeneo hayo kama vile pumba ya mahindi, punje za mtama na uwele, mashudu ya alizeti na dagaa waliosagwa. Matokeo ya utafiti yanaonyesha kuwa makinda waliokula vyakula B, C na D walikuwa na uzito mkubwa wa gramu 1530, 1575 na 1669 kwa utaratibu huu, kuliko makinda ambao hawakupata chakula cha ziada (1203 g). Vilevile, kolowa ambao walipata chakula B, C na D walitaga mayai mengi ya 44, 45 na 47, kwa utaratibu huo, ukilinganisha na mayai 33 kwa kolowa ambao hawakupata chakula cha ziada. Kuhusu kuwaachisha makinda, matokeo yanaonyesha kuwa makinda walioachishwa wakiwa na umri wa wiki 4 walikuwa na uzito mdogo kwenye wiki ya 4 (106 g) na wiki ya 12 ya umri wao (258 g) kuliko makinda walioachishwa wakiwa na umri wa week 8 au wiki 12, lakini wakati wa kuwachinja wiki ya 24 kuku wote hawa walikuwa na uzito sawa. Idadi ya mitago ya mayai iliongezeka kutoka 2 na mayai 29 kwa kolowa walioachisha makinda wakiwa na umri wa wiki 12 na kufikia mitago 3 na mayai 42 hadi mitago 4 na mayai 56 kwa kolowa walioachisha makinda wakiwa na umri wa wiki 8 na wiki 4 kwa utaratibu huu, katika ikipindi cha miezi sita. Kiwango cha kuishi cha makinda waliokuwa wanajitafutia chakula kilikuwa chini (65%) kuliko makinda waliopata chakula cha ziada. Kiwango cha kuishi kwa makinda walioachishwa wakiwa na umri wa wiki 4 kilikuwa kidogo (67%) ukilinganisha na kiwango cha kuishi cha mainda walioachishwa katika umri wa wiki 8 (77%) na wiki 12 (73%). Kiwango hiki cha chini cha kuishi kwa makinda walioachishwa wakiwa na umri wa wiki 4 kilisababishwa na magonjwa na sio athari za kuwaachisha katika umri huo. Utafiti huu unahitimisha kuwa kwa kuwapa chakula cha ziada makinda na mama zao kunaongeza uzito na utagaji mayai, hasa pale kuku wanapopata chakula chenye viinilishe vingi vya protini na nguvu. Aidha, kuwaachisha makinda wakiwa na umri wa wiki 4 na wiki 8 kuna faida kubwa ya kuongeza uwezo wa kuzaa kwa kolowa bila kuathiri kiwango cha kuishi na ukuaji wa makinda.

Katika sura ya sita (6), majaribio mengine mawili yalifanyika kila moja kwa kipindi cha miezi sita, katika kanda ya kati. Madhumuni ya utafiti huu yalikuwa ni kutathimini athari za kuwapa kolowa chakula cha ziada na athari za utaratibu wa kutaga mayai juu ya utagaji mayai, kuongezaka uzito na ubora wa uzalishaji kwa kuku wanaojitafutia vyakula katika mazingira ya mkulima. Jumal ya wakulima 72 walichaguliwa kutoka kijiji cha Bumila na katika wilaya ya Mpwapwa na kijiji cha Chamkoroma katika wilaya ya Kongwa kushiriki katika utafiti huu. Majaribio mawili yalifanyika ambapo jaribio la kwanza lifanyika wakati wa masika (Januari-Juni) na jaribio la pili lilifanyika wakati wa kiangazi (Julai-Disemba). Jumal ya kolowa 144 waligawiwa katika makundi manne ya vyakula, A: kujitafutia chakula wenyewe; B: kujitafutia chakula + chakula chenye protini kubwa, nguvu kidogo (20% protini, 13.5 ME MJ/kg); C: kujitafutia chakula + chakula chenye protini ndgogo, nguvu kubwa (15% CP, 14.5 ME MJ/kg); na D: kujitafutia chakula + chakula chenye protini kubwa, nguvu kubwa (20% CP, 14.5 ME MJ/kg) na utaratibu wa aina tatu wa kutaga mayai: kutaga, kuangua na kulea makinda kwa wiki 12 hadi 16; kutaga, kuangua na kulea makinda kwa wiki moja na kutaga tu. Matokeo ya utafiti yanaonyesha kuwa kolowa waliokuwa wanajitafutia chakula (A) walitaga mayai machache (47) kuliko waliopewa chakula cha ziada B, C na D (kwa wastani walitaga mayai 56). Kolowa waliokuwa wanataga-kuangua-kulea walitaga wastani wa mayai 30 tu ukilinganisha na mayai 53 kutoka kwa kolowa waliokuwa wanataga na kuangua tu na mayai 73 kwa kolowa waliokuwa wanataga tu. Uzito wa mwisho na ongezeko la uzito lilikuwa kubwa kwa kolowa wote waliopata chakula cha ziada kuliko kolowa waliokuwa wanajitafutia chakula na wale kolowa waliokuwa katika utaratibu wa kutaga na kuangua na wale waliokuwa wanataga tu. Kolowa waliokuwa wanataga-kuangua-na kulea na kutaga-kuangua tu walikula chakula kingi zaidi kuliko kolowa waliokuwa wanataga tu. Kutokana na matokeo haya, inahitimishwa kuwa uzalishaji mdogo uliozoeleka kwa kuku wa kiasili ni kwa sababu ya matunzo mabaya ya kuku hao. Aidha matokeo ya utafiti yanaonysha wazi kuwa uzalishaji wa kuku wa kiasili katika mazingira ya kawaida ya unaweza kuongezeka kwa kuwapa chakula cha ziada na kuwapunguzia kolowa muda wa kuatamia na kulea makinda. Uchunguzi wa kiuchumi unaonyesha kuwa kuwapa kuku chakula cha ziada chenye viinilishe vya kutosha vya protiini na nguvu kuku wanaofugwa katika mazingira ya mkulima na kwa kuweka mikakati sawia ya kutaga-kuangua na kutaga tu kuna manufaa makubwa kiuchumi.

Katika sura ya saba (7), matokeo yaliyopatikana katika sura ya 1 hadi ya 6 yamejadiliwa kuhusiana na matokeo ya tafiti zilizofanyika katika sehemu nyingine. Mapendekezo yametolewa na pia maeneo yatakayofanyiwa tafiti siku za usoni yamependekezwa. Kisha mahitimisho yafuatayo yamependekezwa kutoka katika tafiti kadhaa zilizoelezwa katika tasinifu hii:

- Uzalishaji wa kuku wa kienyeji una mchango muhimu sana katika kujipatia riziki kwa kaya zinazoishi vijijini katika Tanzania na nchi nyingine zinazoendelea. Kuku hawa huwawezesha wafugaji kupata kipato cha ziada na chakula chenye protini yenye ubora wa hali ya juu na pia kuku hawa hutumika katika shughuli za kijamii. Licha ya mchango huu, maendeleo ya uzalishaji wa kuku wakiasili katika nchi yetu ni kidogo kwasababu ya ukuaji mdogo wa makinda na utagaji mdogo wa mayai.
- Utegemezi wa kuku kujitafutia chakula wenyewe, kiasi kidogo cha rasilimali ya vyakula na ubora hafifu wa lishe (nguvu na protini), ukosefu wa vyakula vya ziada na uzuiaji hafifu wa magonjwa, vipindi virefu vya kuatamia na kulea makinda vikiambatana na ubora hafifu wa vinasaba ni mambo ya msingi yanayosababisha uzalishaji mdogo wa kuku wa kienyeji.

- Ulishaji wa chakula cha ziada chenye viinilishe muhimu (yaani protini, nguvu na madini) sambamba na chakula wanachojitafutia, kunaongeza uzalishaji wa kuku (yaani ukuaji wa makinda na utagaji mayai) na kiwango cha kuishi cha makinda.
- Kuhusu vipindi virefu vya uzalishaji (utagaji, kuangua, na kulea makinda), utafiti unaonyesha kuwa kuwatenganisha makinda mapema kutoka kwa mama zao kunamwongezea kuku jike muda wa kutaga mayai bila kuathiri kiwango cha kuishi cha makinda na kiwango cha ukuaji.
- Kuwafungia makinda ndani ya nyumba na kuwapa chakula na maji kunapunguza hatari ya kushambuliwa na mbuai na magonjwa na hatimaye kuongeza kuboresha kiwango cha ukuaji na kiwango cha kuishi cha makinda.
- Kwa ujumla, utafiti unaonyesha wazi kuwa uzalishaji wa kolowa wa kiasili atika mazingira ya ufugaji huria unaweza kuongezeka kwa kuboresha matunzo ya ufugaji kwa kukubali kuwapa chakula cha ziada, na kuwafungia makinda ndani katika umri ambao wanakuwa dhaifu na kuwapunguzia kolowa mzigo wa vipindi virefu vya uzazi kama vile kuwapunguzia muda wa kuatamia na kulea makinda.
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Katika kufuatia mahitimisho hayo hapo juu, mapendekezo yafuatayo yanashauriwa yatumike kama njia mojawapo ya kusambaza matokeo yaliyomo katika tasinifu hii:

- Mkakati wa kuwapa kuku chakula cha ziada chenye protini na nguvu sambamba chakula kile wanachojitafutia ni muhimu kuendelezwa ili kuboresha kiwango cha ukuaji, kiwango cha kuishi cha makinda na utagaji mayai kwa kolowa. Hii inaweza kufanywa kwa kuwapa kuku angalau gramu 50 za chakula cha ziada kwa siku kwa kuku wanaojitafutia chakula.
- Kuwaachisha mapema makinda wasilelewe na mama zao katika umri wa wiki 4 na wiki 8 kumeonyesha kuboresha utagaji wa mayai kwa kolowa bila kuathiri kiwango cha kuishi na kiwango cha ukuaji wa makinda; utaratibu huu unapaswa ukubalike na kundelezwa katika sekta hii ya kuku wa kiasili.
- Kuwafungia ndani ya nyumba makinda hadi wanapokuwa na umri wa wiki 8 huku wakipewa chakula chenye viinilishe na maji unaweza kupunguza kiwango cha vifo vinavyosababishwa na mbuai, hali mbaya ya hewa, magonjwa, na ushindani wa kuku wenza.
- Ujuzi wa kitaalam juu utunzanji na afya ya kuku na kuwapa huduma ya ugani ni lazima viendelezwe kwa wakulima/wafugaji wa kuku ili kuboresha uzalishaji wa kuku wa kiasili na kuongeza kipato na usalama wa chakula katika sekta ya kuku wa asili.

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Ezekiel Hamisi GOROMELA

CURRICULUM VITAE

Ezekiel Hamisi Goromela was born on 3 February 1964 in Kasulu district in Kigoma region of Tanzania. He started primary school education in January 1974 where he completed standard seven in November 1980 at kalela Primary School in Kasulu district. He joined secondary school education in January 1981 and successfully completed Form Four in November 1984 at Milambo Secondary School in Tabora region. Thereafter in July 1985 he joined advanced secondary school education and successfully completed Form Six in May 1987 at Kibaha Secondary School, in Coast Region (Pwani). From July 1987 to June 1988, he joined National Service for one year at Mlale National Service, Songea in Ruvuma region. In January 1989 he was selected to pursue a university education for three years at the Sokoine University of Agriculture (SUA), Morogoro-Tanzania; where he graduated in November 1991 with a Bachelor science degree in Agriculture with specialization in Animal Science. On 5th December 1991 he was employed by the Ministry of Agriculture, Livestock Development and Co-operatives in the Directorate of Research and Training as Livestock Research Officer Grade III at the Livestock Production Research Institute Mpwapwa, Tanzania. In July 1994 he joined Master's degree programme in the Department of Animal Nutrition and Management at the Swedish University of Agricultural Science (SLU), Uppsala, Sweden where he graduated in May 1996 with Master's science degree in Biology with specialization in "Tropical Livestock Systems". In August 2004 he was granted a scholarship by The Netherlands Organization for International Cooperation in Higher Education (Nuffic) under the Netherlands Fellowship Programme (NFP) to pursue PhD studies under a sandwich programme where in January 2005 he was enrolled at the Wageningen University and Research Centre (WUR) The Netherlands, in the Animal Nutrition Group of the Wageningen Institute of Animal science (WIAS). The current PhD thesis presents several studies carried out at the National Livestock Research Institute Mpwapwa, Tanzania, where he works as a "Principal Livestock Research Officer I" in the field of Animal Nutrition with special interest in non-ruminant animal nutrition. Since he was employed as a researcher he has acquired a lot of knowledge and experience in animal science where he has been heading and coordinating several research and development programmes at the national level and participating in multidisciplinary research programmes at the international level.

Ezekiel Hamisi GOROMELA is married and has one son and two daughters.

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Komwihangilo, D.M and E. H. Goromela. 2007. Evaluation of Magole Area Development Programme in Kilosa district - World Vision Tanzania.

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International Scientific conferences		
1st COSTECH Scientific and Technological conference Dar es Salaam,Tanzania (24	2006	0.8
2nd COSTECH Annual National Science and Technology conference Dar es Salaar	2007	0.8
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Seminars and workshops		
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Zonal research and technical - Mpwapwa, Tanzania (November 11-13)	2005	0.6
Arid-land Information Network (ALIN)- Dodoma, Tanzania (October 5-10)	2005	1.0
Presentations		
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Oral presentation 2nd COSTECH Annual National Science and Technology confere	2007	0.8
Oral presentation Tanzania Society of Animal Production Conference - Arusha Tan	2007	0.8
Oral presentation XXIII World's Poultry Congress Brasbane-Australia 30 June-4 July 2	2008	0.8
Disciplinary and interdisciplinary courses		
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