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Review

A review of interventions and parameters used to address milk quality in eastern and southern Africa

Şeyda Özkan Gülzari[a,?], Joshua Ombaka Owade[b], Oghaiki Asaah Ndambi[a]

[a] Wageningen Livestock Research, Wageningen University & Research, P.O. Box 338, 6700 AH, Wageningen, the Netherlands
[b] Department of Food Science, Nutrition and Technology, The University of Nairobi, P.O. Box 29053-00625, Nairobi, Kenya

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ABSTRACT

In the last two decades, there has been abundant research directed at improving milk quality and safety all around the world. While some studies limit milk quality to a limited number of bacteriological parameters, it is not unusual to come across papers where quality is assumed or not quantified. The relevant information on milk quality is rather scattered in sub-Saharan Africa. In this study, we conducted a comprehensive review of studies published in eastern and southern Africa in the past two decades, referring to cow milk quality associated with an intervention. This study reports a systematic categorization of the quality parameters related to various interventions where quality was referred to directly and indirectly. It also shows the variation in number and type of parameters used in assessing milk quality in different countries. The microbial quality of milk was the most common quality parameter examined (19 studies), followed by the milk composition (n = 7), then acidity (n = 6) and adulteration with water (n = 4). However, there was no consistency in the quality parameters used to indicate a change in quality associated with these interventions. It is advisable that future studies use the list of parameters presented in this study to build foundation for comparative assessments of change in milk quality for the respective intervention categories.

1. Introduction

Projections show that the demand for milk in sub-Saharan Africa (SSA) will triple by 2050 (Herrero, Havlik, McIntire, Palazzo, & Valin, 2014), reflecting the prominent role of the dairy sector to provide quality and nutritious milk and milk products for the growing human population. It is expected that as dairy farming systems intensify through improved forage production, genetic improvement, and training (Didanna, Wossen, Worako, & Shano, 2018), there will be more demand for a higher quality of milk. Because milk is usually traded within and between countries in SSA, a common understanding of milk quality needs to be established between the seller and buyer.

It is common in the literature that the traditional definitions of milk quality exclusively relate to milk composition (e.g. butterfat, protein, lactose, and density) (Mwendia, Mwungu, Ng'ang'a, Njenga, & Notenbaert, 2018) and microbiological properties (e.g. pathogens, hygiene indicators, and utility parameters) only (Opiyo, Wangoh, & Njage, 2013). With the addition of animal health, environmental sustainability, animal welfare (e.g. stall-feeding or grazing) and organoleptic testing (e.g. good odour, absence of visible external particles in milk, feel of milk temperature at delivery and during milk collection), the concept of milk quality continues to expand (Mataro-Nogueras, 2015). Concomitantly, there is a growing body of research reporting the changes in quality parameters for the above-mentioned definitions, addressing a single or a set of criteria or traits, including, for example, protein content, somatic cell count (SCC), total bacteria count (TBC) and coliforms.

Given the scattered nature of the published results in addressing interventions and/or quality parameters, there is a need to investigate the trends and a potential match between the milk quality and an intervention in different countries. Scrutinising the number and content of studies by country would also reveal the potential knowledge gaps in respective countries, which may provide the scientific community with the opportunity to revise and review the existing approaches in tackling milk quality. The interventions targeting enhanced quality of milk through measurements appear to cover a wide range of factors, including type of production system (Abin, Visser, & Banga, 2018), breeding (Ahmed et al., 2017), hygiene practice (Gran, Mutukumira, Wetlesen, & Narvhus, 2002a), awareness and milk handling along the value chain (Ngasala, Nonga, & Mtambo, 2015), as well as social influences like knowledge integration (Restrepo, Lelea, & Kaufmann, 2018). This is particularly important because as much as the quality can be quantified or assessed using one or some of the above-mentioned concepts (i.e. direct changes in milk quality), it may also be

? Corresponding author.
E-mail address: seyda.ozkan@wur.nl (Ş. Özkan Gülzari).

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assumed (i.e. indirect changes in milk quality) as a result of an intervention. In this study, we aim to systematically review literature published in the last two decades on milk quality to investigate the extent to which they deal with certain quality parameters in response to the versatility in interventions; and the potential lessons that can be adapted for future studies with the ultimate focus of improving the milk quality. Throughout the study, we use interventions and innovations interchangeably. We focus on eastern and southern Africa as countries from these regions are leading in terms of milk production volumes in sub-Saharan Africa (FAOSTAT, 2019) and also have more favourable temperatures for dairy animals in comparison with other parts of SSA (Shaw et al., 2015). The decision to focus on eastern and southern Africa was corroborated by the increased number of dairy development projects in the area (EADD, 2013; SDCP, 2019; SDP, 2019) reflecting that the lessons from these countries may help in further understanding the underlying constraints to improvement of milk quality in the whole region. This study will, therefore, inform the general public, actors in the dairy chain and policymakers about milk quality interventions that have been implemented in the last two decades and their possible contribution towards milk quality improvement. The result provided per country could serve as a guide in the formulation of future strategies to improve milk quality, within and beyond eastern and southern Africa.

2. Materials and methods

2.1. Definition of the study period, key words and justification of search engine

A search of relevant literature capturing the period 2000–2019 inclusive was conducted in July 2019 using the search engines Web of Science and Scopus. The string of key words ((cow AND milk) OR dairy) AND (quality OR composition OR intervention OR innovation OR change OR adapt OR adopt OR improvement) yielded 47019 and 35009 published material from Web of Science and Scopus, respectively. Given the higher number of reference coverage in Web of Science than in Scopus, we decided to use the material found in Web of Science for further analysis. In order to limit the literature to only eastern and southern Africa, we added the following words (alphabetically ordered) to the search string: AND (Angola OR Botswana OR Burundi OR Comoros OR Djibouti OR Eritrea OR Ethiopia OR Kenya OR Lesotho OR Madagascar OR Malawi OR Mauritius OR Mozambique OR Namibia OR Reunion OR Rwanda OR Seychelles OR Somalia OR Somaliland OR (South AND Africa) OR (South AND Sudan) OR Sudan OR Swaziland OR Tanzania OR Uganda OR Zambia OR Zanzibar OR Zimbabwe). The list of eastern and southern African countries was obtained from the United Nations Educational, Scientific and Cultural Organisation (UNESCO, 2015).

2.2. Categorization procedure

Having included the country names, the number of materials found was 922 of which 896 and 802 were published in the English language and in the last two decades, respectively. With this number, only the material published in journals indexed by Web of Science could be found. Subsequently, we searched for additional material (non-exclusive) from the websites of dairy programs and governments in all the countries listed above. The references not relevant to Africa or relevant to the parts of Africa other than the countries selected or not addressing cow milk were excluded.

After scrutinising the grey literature for relevance, adding the relevant non-journal material, adding additional relevant journal materials that were not captured in the first run but were traced back from the found articles (i.e. snowballing), removing the material (both journal and non-journal) that included similar content of same authors, and those not relevant to the selected countries or cow milk, 95 references remained, of which 61 were journal and 34 were non-journal material.

2.3. Inclusion and exclusion criteria

Cambridge Dictionary (2020) defines intervention as *"the action taken to intentionally become involved in a difficult situation in order to improve it or prevent it from getting worse"*. For the purpose of this review, an intervention was defined as any strategy that was not in place 20 years ago and has proven to increase milk quality in measurable terms. We included any socio-technical, technical or social change if they have resulted in measurable improvements in milk quality. To foster tangible results, we adapted the quality criteria by More (2009) relating raw milk quality to both the composition, (e.g. butterfat, crude protein, lactose and milk solids) and the hygiene (e.g. TBC and SCC). The references addressing one or some of the above criteria in relation to at least one intervention were included as 'direct' studies. If references addressed a certain intervention without measuring the quality criteria but implied that the intervention may improve milk quality, then they were named as 'indirect'. This was done to be able to source and spot the potential improvement categories. Articles reporting solely microbial characteristics of milk or antibiotic resistance/prevalence of bacteria at different value chain activities or sampling points without associating the quality with a specific intervention were omitted. Milk yield was not considered as a quality criterion. Therefore, increases in milk yield only, as a result of an intervention or a comparison of milk yield in different systems were not sufficient for inclusion. Similarly, studies describing methods to improve technology adoption were excluded. Sales of products were not considered as an intervention. For consistency reasons, no study was placed in both direct and indirect categories. As long as there was an apparent intervention (even at the reverse side e.g. poor quality of water), the study was evaluated further.

3. Results and discussion

3.1. Direct and indirect studies

The numbers of direct and indirect studies were 29 and 32, respectively. We present the main results as direct and indirect studies in Appendices A and B. For easy reading, in Table A.1, we mostly chose to report a baseline *versus* an intervention, or the seemingly most important interventions, even though the studies may have dealt with more than an intervention, a combination or a variation of the intervention. Table B.1 reports on the results from indirect studies that were searched for with four key words: 'quality', 'improv', 'chang', and 'compos', and also scanned for any additional implication in relation to indirect improvements of milk quality as a result of an intervention. Given the space the main results take, this section captures only the categories of interventions, their associated countries as well as the main quality criteria reported in these papers. Table 1 reveals that the materials published in journals were reported from eight countries only: Ethiopia, Kenya, Rwanda, South Africa, Sudan, Tanzania, Uganda, and Zimbabwe. Tanzania and Zimbabwe were the two countries where most intervention categories were reported. In Rwanda, we identified only one study reporting under the hygiene category, and in Sudan under the breeding category. The intervention most commonly studied was hygiene and milking routine (n = 9). While the number of direct and indirect studies published between 2000 and 2009 (inclusive) was 13, there were 48 studies reported in the last decade (and 11 in 2018 and 2019), showing the increasing interest in the scientific community to focus on the subject in the recent years.

Indirect studies, on the other hand, were generally referring to the same intervention categories in Table 1 except that this time milk preservation and treatment were not encountered as an intervention (Table 2). In addition to the intervention categories identified in direct studies, there was a focus on a Quality Based Milk Payment System (QBMPS), consumer preferences as well as upgrading in the indirect studies. Most indirect studies were conducted in Kenya (n = 8) followed by Tanzania (n = 6). There were no studies reporting any improvements in milk indirectly in Sudan, however, Malawi and

Table 1
Intervention categories and subcategories mentioned in the direct studies across countries. See Table A.1 for the numbers.

Intervention category	Subcategories named	ET[a]	KE[a]	RW[a]	SA[a]	SU[a]	TA[a]	UG[a]	ZI[a]
Feeding	TMR[b], supplemented pasture, tropical grasses, urea-treatment	19	16, 21, 27		1		4		11
Breeding	presence of haplotypes, genetic groups		24			2	6		
Water quality	cleaning of raw milk containers and processed products, water source, boiled water, water shortage	3					17		20
Milk preservation and treatment	pasteurisation, boiling, lactoperoxidase treatment, refrigeration				18		5, 7, 17, 29		8
Hygiene and milking routine	milk handling, value chain actors' practice, teat dipping, hygiene of utensils, cleaning time, milking frequency		15, 25	12			13, 17	10	9, 20, 26
Animal health measures	antibiotic use, CMT[c] score				14		13, 17		
Material used	plastic, jerry can, bucket, metal container						17		
Choice and knowledge actors	mixing milk, delivery time, milker, awareness		27		18		17, 22	28	20
Climate and season	temperature change, season								20
Facilities	parlour, roof type, housing state and system, milking system							28	20, 26
Herd dynamics	calving interval								23
Other factors	street activities						17		

[a] ET: Ethiopia, KE: Kenya, RW: Rwanda, SA: South Africa, SU: Sudan, TA: Tanzania, UG: Uganda, ZI: Zimbabwe.
[b] TMR: Total mixed ration.
[c] CMT: California Mastitis Test.

Mozambique were additional countries where indirect studies were found.

There was a great variation in the number and content of quality criteria used in the direct studies. Microbial parameters, including various bacteria count as well as SCC and California Mastitis Test (CMT), were encountered most often than other parameters (n = 19). Microbial quality and the incidence of mastitis were more comprehensively studied in Zimbabwe and South Africa with five and three studies, respectively. Nutritional composition including milk fat, milk protein, lactose and casein were mentioned in seven studies of which three reported Kenyan conditions.

It was challenging to compare the reported numerical values for certain quality criteria with values that are acceptable or standard in the individual countries. This is because the standards vary in different countries across SSA. However, some studies referred to the quality standards in their respective countries, therefore, we limited the comparison to the studies where this information was available. For example, Gran, Mutukumira, Wetlesen, & Narvhus (2002b) reported the effect of heat treatment of milk on the *E. coli* and coliform counts of milk, and compared them with the standards published by the Zimbabwe Dairy Regulation of 1977. In east African countries, regional standards have been used as a reference for milk parameters. For instance, through hygiene interventions, the total microbial counts in Rwanda were reported to adhere to the regulatory levels set by East African Community (EAC) (Kamana, Jacxsens, Kimonyo, & Uyttendaele, 2017).

3.2. Particularities of non-journal material

The reports we found (n = 34) either documented a situation analysis or a summary of project achievements. The majority of non-journal materials were recent and focussed on knowledge provision and capacity building, indicating the increasing number of capacity development initiatives on milk quality, sometimes independent of research activities. The key role of knowledge provision focussing on demand for quality milk was reported by Rademaker, Koech, Jansen, & van der Lee (2016) and Rademaker, Omedo Bebe, van der Lee, Kilelu, & Tonui (2016) in Kenya, and by The Friesian (2016) in Sudan. Similarly, increasing the share of formal milk in Kenya (Rademaker, Omedo Bebe, et al., 2016), or integration (Kurwijila & Boki, 2003) and/or training (Kurwijila & Boki, 2003; Miriuki, 2003, pp. 1–60) of the actors playing a major role in the informal market in Tanzania and Kenya, respectively, could be facilitated through knowledge provision. There seemed to be more attention directed to capacity building to engage the private sector and trainings of farmers in Kenya (Mutinda, Baltenweck, & Omondi, 2015, pp. 1–99), of farmers in Ethiopia (TAP Consultancy, 2016) as well as cooperatives and other stakeholders in Ethiopia (Brandsma, Mengistu, Kassa, Yohannes, & van der Lee, 2012) and Uganda (AgriPro Focus, 2014; Kasirye, 2003; SNV, 2017) than other countries. Such trainings often create awareness on quality issues along the dairy chain actors and could provide advantages for quality improvement in these countries compared to countries without such training programs. Better skilled farmers and traders, provision of milk coolers (Bonilla et al., 2018, p. 69; IFAD, 2016, 2019), use of aluminium milk cans and shortening the time spent from milking to the reception at the chilling plant (EADD, 2013) delivered better quality milk. Delivering the milk in less than two hours could be achieved through the creation of smallholder dairy schemes in Zimbabwe (SNV, 2012a).

Trainings of farmers focused on adapting breeding as well as improving animal nutrition, animal health measures and hygienic practice in Kenya (Kirui et al., 2016). This is not surprising because breeding strategies have been suggested to improve milk quality in Kenya (Ibrahim & Olaloku, 2000). By incorporating quality pasture into the feed ration, increased volumes of high quality milk were produced in Zambia (even in dry periods) (Kawambwa, Hendriksen, Zandonda, & Wanga, 2014) and in Ethiopia where vocational trainings stimulated the availability of inputs as well (FAO, 2019).

Finally, paying a premium has been proposed to improve quality (e.g., QBMPS) in different SSA countries including Zimbabwe (SNV, 2012b, pp. 4–116), Kenya (Foreman & De leeuw, 2013; Makoni, Mwai, Redda, van der Zijpp, & van der Lee, 2014) and Uganda (SNV, 2017). The mandates and enforcements of dairy boards and authorities in east Africa appear to have been weak, emphasising the importance of both public and private sectors partnering in developing national dairy institutions (Bennett & Kurwijila, 2011). Policy interventions are likely to play a role in developing and complying with the quality standards e.g. in Zimbabwe (SNV, 2014). Here, access to credit, investment in cooling equipment and improved supply chains should be taken into account (Makoni et al., 2014). Overall, the QBMPS in Kenya led to improvements in handling practices through establishments of milk collection centres (MCCs), use of metal cans and instant chillers, and testing of milk (Koge, Njiru, Kilelu, & Ndambi, 2018; Ndambi, Kilelu, Lee, Njiru, & Koge, 2019; Ndambi, Njiru, van Knippenberg, Van der Lee, Ngigi, et al., 2018; Ndambi, Njiru, van Knippenberg, Van der Lee, Kilelu et al., 2018, pp. 1–14; Njiru, 2018). The QBMPS uses different quality criteria in different countries. In Ethiopia, bacterial and milk fat content formed the basis of such payment (Steen & Maijers, 2014). In Kenya, the criteria were total plate count (TPC), antibiotic residues, freezing point and total solids (Ndambi, Njiru, van Knippenberg, Van der Lee, Ngigi,

Table 2
Intervention categories and subcategories mentioned in the indirect studies across countries. See Table B.1 for the numbers.

Intervention category	Subcategories named	ET[a]	KE[a]	RW[a]	SA[a]	TA[a]	UG[a]	ZI[a]	MA[a]	EAC/EA[a]	MO[a]
Feeding	storage					22			8		
Breeding	cross breeding technology, new breeds		3			1			8		13
Water quality	quality	2									
Hygiene and milking routine	cleaning teats, milk hygiene, spoilage		24, 31	14		22	12				13
Animal health measures	diseases, poor health, health care		31			20, 22	30		8		
Material	aluminium cans					17					
Choice and knowledge of value chain actors	knowledge transfer, capacity building. training, dissemination, awareness creation	6	19, 31	14		20	30, 32	26			
Climate and season	adaptation to climate change		3								
Facilities	cooling plants, quality testing, scale of farming, milk storage		3, 16, 18, 31			17, 22		26			
Herd dynamics	calf rearing				23						
Institutional development & policy control	role of dairy board, cooperative membership and establishment, MCCs[b], monitoring, standards, development programs, multi-stakeholder process, dairy hubs, informal market	7	3, 15, 16, 18, 19, 29	14		17, 20, 21, 22, 28	29, 32		8, 9	11, 25	13
QBMPS[c]	economic value				4						
Consumer preferences	retail choice, hygiene in supermarkets	5, 10, 27									
Other factors	quality criteria, upgrading	27			23	17					

[a] ET: Ethiopia, KE: Kenya, RW: Rwanda, SA: South Africa, TA: Tanzania, UG: Uganda, ZI: Zimbabwe, MA: Malawi, EAC/EA: East African Community, MO: Mozambique.
[b] MCC: milk collection centre.
[c] QBMPS: Quality-based milk payment system.

et al., 2018); and in Uganda, butterfat, and solids-not-fat were used (SNV, 2017). The vast variety of quality criteria used in different countries is an indication of the objectives of implementer. Procesors producing fermented products might have a higher value for the absence of antibiotic residues in milk than those who do not produce fermented products. Also processors producing cheese might value total solids and those producing butter would value butterfat content of milk. In each case, the valued criteria would be used as a basis for quality payment. Some criteria such as a lower bacterial count could be used for several reasons: reduction of processing costs, better taste of final product or a legal restriction on its level in products. Processors might also use quality criteria to secure a niche market by guaranteeing consumers of a certain quality of their product.

3.3. *Synthesis of results, constraints for adoption and ways forward*

Milk quality and concepts of milk quality in relation to an intervention have been addressed in the literature from various perceptions, falling into the following categories: social and habitual, technological and economic.

3.3.1. *Social and habitual aspects*

We identified that the social and habitual aspects relate mostly to awareness, value chain and behaviour of consumers. Awareness-raising is necessary for producers and consumers to understand and internalise the potential health risks of (untreated) milk. Pasteurisation, for example, is preferred over boiling by Maasai pastoralist villages in Tanzania (Caudell et al., 2019). Women, in general, are more concerned about quality and hygiene than men (Johnson et al., 2015), and those with awareness and education in SSA prefer to source milk from modern retail and dairy shops, possibly due to perceived better quality of such milk. In contrast, people with high income and living in Addis Ababa make less frequent visits to dairy shops (Bekele, Beuving, & Ruben, 2017), though they could be sourcing it from other outlets like supermarkets since the consumption of raw milk is more common in rural areas than in urban areas (Gizaw et al., 2016). Similarly, quality control mechanisms at the household level were reported to be more important than controlling quality at the cooperative level (Bekele & Pillai, 2011). Consumers are sometimes more concerned about adulteration and milk-borne diseases than about antimicrobial residues. Meanwhile, educated consumers were more concerned about antimicrobial residues as well as milk-borne diseases and were willing to pay a higher price for better quality milk, and if this is the case, efforts should be directed to implementing awareness programs (Tolosa et al., 2016).

At the value chain activities, the delivery time of milk is an important criterion: if the delivery time is reduced, milk quality is improved. Milk has been found to be of better quality at the farm than at delivery (Gran, Mutukumira, Wetlesen, & Narvhus, 2002b). Johnson et al. (2015) reported that quality is compromised between milking and delivery to distant MCCs, and if the quality is maintained, even though higher quality of milk is not rewarded, it was unlikely that the MCC would reject it, in Mozambique. This would also reflect that the quality is likely to be compromised (and milk being rejected) during the transportation of milk to MCCs that are not in close proximity. In Zimbabwe, for example, smallholder farmers delivering their milk to nearby MCCs where milk is pooled, receive a premium based on the quality of the group's milk. Here, the collective action is of utmost importance for two reasons: first, the farmers without awareness of quality may disadvantage those who aim to produce quality milk, and secondly, the transportation time may jeopardise milk quality (Paraffin, Zindove, & Chimonyo, 2018). Storage and handling (including transport) are the other important factors that reduce milk quality on arrival in the urban market. This shows that improvements in milk quality should target all actors along the dairy chain (Grimaud et al., 2009).

The institutional organisation such as the implementation of MCCs is an incentive for milk quality improvement, but the maintenance of MCCs and the training of workers should be continuous. Furthermore, certification and compulsory Hazard Analysis and Critical Control Point (HACCP) implementation by relevant value chain actors may trigger quality improvement at the production level, provided that frequent inspections are done at the retail and wholesale level (Kamana et al., 2017). Eventually, dairies with a commitment to adhere to HACCP or International Organisation for Standardisation (ISO) 22000 standards achieve maximum microbial safety level profile scores, and produce safer products (Opiyo, Wangoh, & Njage, 2013). Note that challenges related to quality and safety are more pertinent to informal markets than companies with HACCP, especially due to the presence of *Salmonella* in cheese and boiled milk sold in small milk shops (Kamana, Ceuppens, Jacxsens, Kimonyo, & Uyttendaele, 2014). Therefore, identifying the vulnerabilities in the value chain is important in improving milk quality as a result of policy interventions: if milk at production level carries high bacterial counts, it would mean that the processor would need to increase the pasteurisation time, implying high costs at the processor level (Kiambi et al., 2018).

3.3.2. Technological aspects

In this respect, three dimensions appeared to stand out: breeding, farm management (including feeding and animal health measures), and hygiene and milk handling.

Even though breeding has been pointed out as one of the most promising technologies, there are constraints related to its uptake in SSA e.g. distance to local markets and access to credit (Abdulai, Huffman, & Curtiss, 2005). Accordingly, the farmers with large proximities to local markets may be unlikely to adopt cross-bred cow technology. It is important to note that the farmers' access to high genetic potential is continuously increasing, which requires feed at an acceptable quality and quantity (Lukuyu, Gachuiri, Lukuyu, Lusweti, & Mwendia, 2012), also considering the seasonal and inter-annual variation.

Regarding farm management, there is a close link between access to veterinary services and adoption of feeding and breeding strategies that improve milk quality. Breeding strategies could target resistance to diseases, especially as diseases may be responsible for the largest proportion of animal exits in farms. Semi- and free-grazing animals are likely to be tick-infected for the majority of year (Bebe, Udo, Rowlands, & Thorpe, 2003) and this is potentially detrimental to milk quality and quantity due, for example, to residues of acaricides found in milk, and the drop in milk production of infected cows, respectively, but further studies are needed to link it to milk quality traits.

As regards milk hygiene and milk handling, many studies have shown the contribution of improved hygiene on milk quality. Milking routine and milk handling practices such as hand washing, udder washing, pre-milking palpation, calves suckling prior to milking, dry udder prior to milking, post-milking treatment, type of milking containers (aluminium vs plastic) and bulking container (aluminium vs plastic) were some of the strategies pointed out for improving quality in the literature (Kashongwe, Bebe, Matofari, & Huelsebusch, 2017a). Improving hygiene, regular monitoring and improving bottling systems are recommended to prevent contamination and improve milk quality (Aaku, Collison, Gashe, & Mpuchane, 2004). Hygiene practices are especially important to be adhered to in the production of fermented products made of unpasteurised milk, for example, the naturally sour milk in Zimbabwe (Gran, Mutukumira, Wetlesen, & Narvhus, 2002a). In this respect, (quality) water plays a key role. Poor quality water used for washing milk containers may pose a high concern for milk quality (Amenu, Shitu, & Abera, 2016), but if water of poor quality is used during milk processing in Ethiopia, it contaminates milk (here *E. coli* was used as a single proxy) (Amenu, Spengler, Markemann, & Zarate, 2014). Also, the absence of good quality water was a constraint to the running of instant milk coolers in Kenya (Ndambi, Kilelu, Van der Lee, Njiru, Koge, 2019).

Knowledge transfer is a vital requirement for desired technologies to reach various dairy chain actors. Karimuribo et al. (2006) reported that knowledge gained (knowledge transfer) through training farmers and extension officers strongly affected mastitis prevention and suggests that knowledge of the impact and awareness of mastitis among smallholder farmers must be the foundation of mastitis controlling programs (also linking to the first point in social and habitual aspects). If cows can be screened for *S. aureus* (despite a low SCC), they can be separated as a management strategy so that they do not infect others, or are milked last (Karzis, Petzer, Donkin, & Naidoo, 2018). Knowledge transfer needs to consider the dynamics of formal and informal markets especially in a context like Kenya and Tanzania where more than 70% of marketed milk goes through informal channels. Individuals buying directly from farmers pay a higher (more attractive) price at farm gate than cooperatives and institutions, and this contributes to the informal sector. However, this might pose concerns of zoonoses such as brucellosis and tuberculosis since the milk is not tested for safety (Kivaria, Noordhuizen, & Kapaga, 2006b).

3.3.3. Economics and finance

Even though economics is an apparent reason for the uptake of an intervention, there were only a few occasions where studies reported a solid connection between intervention and milk quality in relation to economics. Exceptions occurred. Batz, Janssen, & Peters (2003) using net present value as an indicator suggested that interventions that are adopted quickly are likely to be more profitable than those adopted with low rates. The monetary benefit of improving milk quality may, however, not be positive for all value chain actors. For example, Ndambi, Njiru, van Knippenberg, Van der Lee, Kilelu et al., 2018, pp. 1–14) showed that farmers may make a net positive cash benefit from actively participating in a QBMPS, while cooperatives and processors may have to face a net cash loss mainly because of the very high costs for milk testing and training of staff. However, since public health benefits from this system were enormous, they recommended more public investments into the QBMPS to compensate the actors with a net cash loss. Looking back at the successes and lessons learned from QBMPS implemented in Kenya and Uganda (Ndambi, Dido, & Özkan Gülzari, 2020), it is recommended that the quality measures be implemented using few and less-binding parameters and increased gradually. However, this would imply structured monitoring schemes are in place and the control mechanisms are functioning properly.

4. Conclusions

Our search for interventions on milk quality in eastern and southern Africa found journal articles from 10 of the 28 countries, indicating that only about one-third of the countries had scientific materials on milk quality. From these studies, there were slightly fewer direct studies (29) which referred to actual quality parameters than assumed as in the case of indirect studies (32), reflecting a lack of focus on real evidence on quality improvement. The microbial quality of milk (*E. coli*, coliforms, faecal coliforms, TBC, TPC, and total viable bacteria as well as the SCC and CMT) was the most common quality parameter examined (19 studies), followed by the milk composition (fat, protein, SNF; seven studies), acidity (clot on boiling test, titratable acidity and pH; six studies) and adulteration with water (density; four studies)). The majority of direct studies focused on quality improvement through milk hygiene and feeding practices while more of the indirect studies focused on the institutional development of the dairy sector and types of milk facilities. The non-journal articles among others highlighted the importance of capacity building of all dairy chain actors and the use of QBMPS for quality improvement. The QBMPS was found to be impactful in providing incentives for milk quality improvements to farmers and other dairy chain actors. These systems have been recommended and should go hand in hand with robust dairy chain management practices, and enabling environment provided by the public sector, and flexibility of processors to adapt the systems to their clientele. It was noted that most of the studies were published in the last decade, reflecting a growing interest in improvements in milk quality among the scientific community. In order to better address the increasing concerns about milk quality in most of SSA, we suggest that more countries should develop interventions to improve milk quality and have more quantifiable parameters to track quality improvements.

Declaration of competing interest

None.

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Appendix A

Tible A.1
Intervention and parameters used in addressing milk quality in the direct studies.

Country	Baseline x intervention	Quality criteri (on)a/unit	Change in quality criteri (on)a	Reference	No
South Africa	Low input low output systems (LO) x high input high output systems (HI) where feeding plays major role	MF[1], MP[2], SCS[3] (kg/305 day)	LO: MF: 174; MP: 141; SCS: 2.41 HI: MF: 298; MP: 245; SCS: 2.27	Abin et al. (2018)	1
Sudan	Local breeds x Improved breeds for improved milk protein and fat	haplotypes	Low but presence of haplotypes that link favourable protein variants like *CSN2*A^2* and *CSN3*B*	Ahmed et al. (2017)	2
Ethiopia	(Poor) water quality - milk containers and processed milk products in location A x B	Mean *E coli* counts (cfu[4]/mL milk)	Location A: 1068 and 1595 Location B: 360 and 2880	Amenu, Spengler, Markemann, & Zarate, 2014	3
Tanzania	Feeding (a combination of) tropical grass species as ration (R)1 x R2 x R3 x R4	MF, MP, Ash, TS[5] (g/day)	R1: MF: 2390; MP: 1440; Ash: 400; TS: 690 R2: MF: 2280; MP: 1450; Ash: 350; TS: 690 R3: MF: 1890; MP: 1380; Ash: 400; TS: 670 R4: MF: 2280; MP: 1300; Ash: 360; TS: 640	Bwire, Wiktorsson, and Mwilawa (2003)	4
Tanzania	Milk preservation as pasteurisation (PN, PT) x boiling (BN, BT), at pre-intervention (PI), day 7 (D7), day 14 (D14)	TBC[6] (cfu/ml)	PI-PN: 12621; PI-PT: 11041; D7-PN: 73% I; D7-PT: 55% D; D14-PN: 60% D; D14-PT: 3.4% D PI-BN: 11372; PI-BT: 19593; D7-BN: 69% D; D7-BT: 13% D; D14-BN: 36% D; D14-BT: 2.3% D	Caudell et al. (2019)	5
Tanzania	Proportions of exotic genes: 25–49% vs > 84% where the latter mimicking backcross to indigenous zebu	MF, MP, Casein, Lactose, SNF[7], TS (%)	25–49%: MF: 3.3; MP: 3.2; Casein: 3; Lactose: 4.3; SNF: 7.6; TS: 11.5 > 84%: MF: 3.7; MP: 3.2; Casein: 2.8; Lactose: 4.2; SNF: 7.4; TS: 11.5	Cheruiyot, Bett, Amimo, & Mujibi (2018)	6
Tanzania	Milk preservation by activating natural lactoperoxidase (LP) system in the presence of thiocyanate (SCN$^?$) and iodine (I$^?$): Control (00:00 mg/L) x I$^?$:H_2O_2 (15:15 mg/L) x SCN$^?$:H_2O_2 (15:15 mg/mL)	pH, TA[8], AST[9], COB[10] (hour as keeping quality)	Control (0:00): ?10 for all parameters I$^?$:H_2O_2 (15:15): pH: 30; TA: 24; AST: 28; COB: 32 SCN$^?$ and H_2O_2 (15:15): pH: 22; TA: 18; AST: 20; COB: 24	Fweja, Lewis, & Grandison (2007)	7
Zimbabwe	Hygienic practice/microbial quality during processing of fermented product A (naturally sour milk from unpasteurised milk) x B (cultured milk from pasteurised milk)	pH, Coliforms, *E coli* (log_{10} cfu/mL)	A: pH: 4.1; Coliforms: 5; *E coli*: 4.8 B: pH: 4.4; Coliforms: 5; *E coli*: 5.5	Gran, Mutukumira, Wetlesen, & Narvhus, 2002a	8
Zimbabwe	Hygienic practices during milking/microbial quality at farm x on delivery	pH, Milk temperature (°C), Coliforms and *E coli*, AMC[11] (cfu/mL)	Farm: pH: 6.7; °C: 32.6; Coliforms: 195; *E coli*: 0.8; AMC: 20250 On delivery: pH: 6.7; °C: 24.4; Coliforms: 500; *E coli*: 8; AMC: 113000	Gran, Mutukumira, Wetlesen, & Narvhus, 2002b	9
Uganda	Hygiene and quality management at farm x bicycle x MCC[12] in, MCC out x UC[13] in, UC out, vendor (dry season and for some selling points here)	pH. density, resazurin, TPC[14] (10^6 cfu/mL), TC[15], FC[16] (MPN[17]/mL), *E coli*	Farm: pH: 6.4; density: 1; resazurin: 5.9; TPC: 2; TC: 294; FC: 175; *E coli*: 9 Bicycle: pH: 6.4; density: 1; resazurin: 5.2; TPC: 47; TC: 558; FC: 345; *E coli*: 142 UC in: pH: 6.3; density: 1; resazurin: 4; TPC: 1173; TC: 934; FC: 758; *E coli*: 317	Grimaud et al. (2009)	10
Zimbabwe	Supplementing with non-conventional protein sources: TMR x urea-treated stover (UTS) x untreated stover x *M atropurpureum* hay x Veld hay (some interventions here)	Lactose, fat, protein, TS (%)	TMR: Lactose: 4.8; MF: 4.4; MP: 3.5; TS: 13.9 UTS: Lactose: 4.8; MF: 4.1; MP: 3.2; TS: 13.2	Gusha et al. (2014)	11
Rwanda				Kamana et al. (2014)	12

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Tible A.1 (*continued*)

Country	Baseline x intervention	Quality criteri (on)a/unit	Change in quality criteri (on)a	Reference	No
	Hygiene at farm x MCC (raw milk) x MPC[18] (pasteurised) x Wholesale (pasteurised) x Supermarkets (pasteurised) x Milk shops (boiled and fermented) (some selling points here)	pH. Temperature (°C), TMC[19], Coliforms, *S aureus*, *Salmonella spp* (%), *L monocytogenes* (%) (log cfu/mL)	Farm: pH:6.5; MC: 5.2: Coliforms: 2.4; *S aureus*: 2.2; *Salmonella spp*: 5.5; *L monocytogenes*: 0 MCC: pH:6; TMC: 5.2: Coliforms: 2.7; *S aureus*: 2.3; *Salmonella spp*: 5; *L monocytogenes*: 0		
Tanzania	Mastitis intervention post-milking teat dipping (PMTD) x intramammary antibiotic infusion (IMAI) (day 14 here)	CMT[20] positive (+), bacteriologically positive (B+) (%)	PMTD: CMT+: 82; B+: 49 IMAI: CMT+: 70; B+: 30	Karimuribo et al. (2006)	13
South Africa	Udder health management year 1 x year 10	*S aureus* IMI[21], AMP[22], CL[23], CXM[24], DA[25], OB[26], OT[27], P[28], TY[29] (%)	Year 1: *S aureus* IMI: 27; AMP: 50; CL:24; CXM: 15; DA: 54; OB: 43; OT: 38; P: 65; TY:78 Year 10: *S aureus* IMI: 20; AMP: 38; CL: 13; CXM: 13; DA: 38; OB: 25; OT: 13; P: 38; TY: 50	Karzis et al. (2018)	14
Kenya	Milking routine and milk handling practices (e.g. hand washing, udder washing and drying) in SH[27] peri-urban x SH rural	Log10 SCC[30] (cells/mL) Herds with SCC < 200, 200–400 and > 400 x 10^3 cells/mL, Mastitis positive (M+), *S aureus*, *Streptococcus spp* (%)	SH peri-urban: SCC: 5.4; SCC < 200: 41; 200–400: 24; > 400: 35; M+: 53; *S aureus*: 57; *Streptococcus spp*: 22 SH rural: SCC: 5.3; SCC < 200: 36; 200–400: 23; > 400: 41; M+: 71; *S aureus*: 60; *Streptococcus spp*: 27	Kashongwe, Bebe, Matofari, & Huelsebusch, 2017a)	15
Kenya	Feeding (e.g. Napier grass, crop residues, concentrates) SH peri-urban x SH rural	MF, MP (%), density (g/mL)	SH peri-urban: MF: 4.3; MP: 2.8: density: 1027 SH rural: MF: 3.9; MP: 2.8; density: 1027	, Kashongwe, Bebe, Matofari, & Huelsebusch (2017b)	16
/Tanzania	Milk hygiene practices (e.g. frequency of cleaning milk containers, mixing milk etc.)	TBC in 10^6 cfu/mL		Kivaria, Noordhuizen, and Kapaga (2006a)	17
	Milk source smallholder producers x MCC		Smallholder: 8.1; MCC: 9.2		
	Milk storage container plastic x metal		Plastic: 8.3; metal: 7.2		
	Plastic type jerry can x bucket		Jerry can: 8.5; bucket: 7.8		
	Water shortage yes x no		Yes: 9.3; no: 6.4		
	Water source tap x vendors x bore-well		Tap: 3.4; vendors: 9.3; bore-well: 20.1		
	CMT score 0 x + x ++ x +++		0: 8.5; +:18.9; ++: 6.5; +++: 7.6		
	Use of boiled water yes x no		Yes: 5.6; no: 8.5		
	Cleaning time immediately x before use		Immediately: 6.3; before use: 8.9		
	Street activities high x low		High: 18.9; low: 5.8		
	Refrigerator functioning x defective		Functioning: 10.6; defective: 4048		
	Mixing of milk yes x no		Yes: 9.7; no: 1.4		
South Africa	Environmental temperature ET 29 × 5 °C, milk sample temperature MST 24 x 18 °C	*E coli*, Coliforms, TVC[32] (10^3/mL)	ET29& MST24: *E coli*: ± 10^3, Coliforms: 1.9 x 10^3; TVC: 10^6-10^7 ET5&MST18: *E coli* and Coliforms, significantly different from summer; TVC: Remained similar	Lues, Beer, Jacoby, Jansen, and Shale (2010)	18
Ethiopia	Feeding straw x urea-treated teff (UTT) x UT-barley (UTB) straw	MF, MP (%)	Straw: MF: 4.2; MP: 3.5 UTT: MF: 4.4; MP: 3.4 UTB: MF: 4.5; MP: 3.4	Mesfin & Ledin (2004)	19
Zimbabwe	Processing: raw milk x processed milk - total values here	TVB[33], Coliforms, *E coli*, *S aureus* (Log 10 cfu/mL)	Raw milk: TVB: 6.4; Coliforms: 6.4; *E coli*: 6.2; *S aureus*: 5.4 Processed milk: TVB: 6.6; Coliforms: 6.3; *E coli*: 5.7; *S aureus*: 4.7	Mhone, Matope, and Saidi (2011)	20
	Delivery within (30W) x after 30 min (30A)	TBC (mean log10)	30W: 5.1; 30A: 5.9		
	Season dry x wet		Dry: 4.9; wet: 5.8		
	Milker - farmer x others		Farmer: 5.5; others: 5.3		
	Water source closed x open system		Closed: 5.3; open: 5.4		
	Milking parlour x no parlour		Parlour: 5.1; no parlour: 5.4		
	Milking frequency once x twice a day		Once: 5.4; twice: 5.5		
Kenya	Feeding - grazing x oats & vetch forages – all farmers here	BF[1], MP, Lactose, SNF (g)	Grazing: BF: 230; MP: 190; Lactose: 284; SNF: 556 Oats & vetch: BF: 272; MP: 220; Lactose: 330; SNF: 648	Mwendia, Mwungu, Ng'ang'a, Njenga, & Notenbaert, 2018	21
Tanzania	Awareness and milk handling practices SH dairy farms x vendors x retailers – some categories here)	Bad smell, presence of sediments (yes), clot on alcohol test, pH > 6.8, specific gravity (> 1.032 g/mL) (%), TVC (cfu/mL)	SH dairy: smell: 3; sediments: 8; clot: 2; pH: 1; gravity: 2; TVC: 2.7 × 10^4 Vendors: smell: 4; sediments: 9; clot: 10; pH: 3; gravity: 0; TVC: 1.5 × 10^7	Ngasala et al. (2015)	22

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Tible A.1 (*continued*)

Country	Baseline x intervention	Quality criteri (on)a/unit	Change in quality criteri (on)a	Reference	No
			Retailers: smell: 15; sediments: 4; clot: 16; pH: 0; gravity: 1; TVC: 5.4×10^6		
Zimbabwe	Herd management – calving interval (CI) 320 days × 365 days – Red Dane here	MF, MP (kg per 305 days)	320CI: MF: ~280; MP: ~280 365CI: MF: ~325; MP: ~310	Nyamushamba, Halimani, Imbayarwo-Chikosi, and Tavirimirwa (2014)	23
Kenya	Breeding strategies – closed progeny testing (CPT) x progeny of local bulls (PLB) x continuous semen import (CSI); progeny of imported bulls (PIB) - only values representing ?? sires	MF, MP (kg)	CPT: MF: 13.2; MP: 11.1 PLB: MF: 4.4; MP: 4 CSI: MF: 21.6; MP: 21.1 PIB: MF: 4.4; MP: 4	, Okeno, Kosgey, and Kahi (2010a, 2010b) (merged)	24
Kenya	Hands of workers at large (LD) x medium (MD) x small dairies (SD) – CSL1 here	MSLP[31], [34] score for hand swabs, *E coli*, coliform, *Salmonella* (qualitative)	LD: Higher MSLP, no *E coli*, coliforms, *Salmonella* MD + SD: Lower MSLP, *E coli* detected, generally high TVC, no *Salmonella*	Opiyo, Wangoh, & Njage, 2013	25
Zimbabwe	Facilities and hygiene Roof type corrugated sheets x asbestos Milking system hand x machine Hand washing basin clean x dirty Milking buckets clean x dirty	TBC (x 10^3 cfu/mL), SCC (10^3 cells/mL)	 Corrugated: TBC: 87; SCC: 108 Asbestos: TBC: 284; SCC: 515 Hand: TBC: 271; SCC: 672 Machine: TBC: 161; SCC: 496 Clean: TBC: 92; SCC: 187 Dirty: TBC: 313; SCC: 668 Clean: TBC: 166; SCC: 633 Dirty: TBC: 256; SCC: 935	Paraffin, Zindove, and Chimonyo (2019)	26
Kenya	Knowledge integration and co-production on feeding (drought resistant fodder, silage etc.)	Milk density	Increased milk density	Restrepo et al. (2018)	27
Uganda	Informal milk delivery chains zero grazed x grazed - Gulu region here only Knowledge of *Brucellosis* yes x no	Seropositive for *Brucella spp* (%)	Zero-grazed: 9.4 Grazed: 27 Yes: 30; no: 69	Rock, Mugizi, Stahl, Magnusson, and Boqvist (2016)	28
Tanzania	Heat treatment - raw milk x fermentation x pasteurisation	*E coli*, foodborne pathogens (%)	Raw milk: *E Coli*: 9, foodborne pathogens: 10 Fermented and pasteurised samples: *E coli* and foodborne pathogens undetected	Schoder, Maichin, Lema, & Laffa, 2013	29

[1] MF: milk fat (BF: butterfat).
[2] MP: milk protein.
[3] SCS: somatic cell score or somatic cell count transformed to log_{10}.
[4] cfu: colony forming units.
[5] TS: total solids.
[6] TBC: total bacteria counts.
[7] SNF: solids non-fat.
[8] TA: titratable acidity.
[9] AST: alcohol stability test.
[10] COB: clot on boiling test.
[11] AMC: aerobic mesophilic count.
[12] MCC: Milk collection centre.
[13] UC: Urban cooler.
[14] TPC: total plate count.
[15] TC: total coliforms.
[16] FC: faecal coliforms.
[17] MPN: most probable number.
[18] MPC: Milk processing companies.
[19] TMC: total mesophilic count.
[20] CMT: California mastitis test.
[21] IMI: intramammary infection.
[22] AMP: ampicillin.
[23] CL: cephalexin.
[24] CXM: cefuroxime.
[25] DA: clindamycin.
[26] OB: cloxacillin.
[27] OT: oxytetracycline.
[28] P: penicillin.
[29] TY: tylosin.
[30] SH: smallholder.
[31] SCC: somatic cell count.
[32] TVC: total viable counts.
[33] TVB: total viable bacteria.
[34] MSLP: microbial safety level profiles.

Appendix B

Table B.1
Intervention or technology mentioned in the indirect studies.

Intervention or technology mentioned	Country	Reference	No
Cross-bred technology	Tanzania	Abdulai, Huffman, & Curtiss, 2005	1
(Poor) quality water	Ethiopia	Amenu et al., 2016	2
Adaptation to climate change via technological innovation e.g. installation of cooling plants and new breeds; institutional development, the role of KDB[1] to control and regulate quality	Kenya	Asayehegn, Iglesias, Triomphe, Pedelahore, & Temple (2017)	3
Determining the economic values of milk volume, fat yield, protein yield, live weight somatic cell score etc for Holstein and Jersey cows in quality-based milk payment systems	South Africa	Banga, Neser, & Garrick (2014)	4
Retail choice decisions,consumer preferences	Ethiopia	Bekele, Beuving, & Ruben, 2017	5
Training in techniques and standards in quality control at household level	Ethiopia	Bekele & Pillai (2011)	6
Cooperative membership through enhancing market power, knowledge dissemination or quality control	Ethiopia	Chagwiza, Muradian, & Ruben (2016)	7
Four categories of innovation: feeding, breeding, market (through recruitment of skilled staff to monitor quality; and integrating procedures and code of conduct to ensure quality management of milk and standards), animal health	Malawi	Chindime, Kibwika, & Chagunda (2017)	8
Interaction among dairy chain actors, market and organisational innovations, empowering smallholder farmers, services provided by processors including supply of milk quality testing reagents to bulking groups	Malawi	Chindime, Kibwika, & Chagunda (2016)	9
Commercialisation of processed dairy products through supermarkets, pasteurisation, consumer preferences for hygiene at supermarkets	Ethiopia	Francesconi, Heerink, and D'Haese (2010)	10
Addressing non-tariff barriers, including quality and safety standards, market pull	EAC	Gelan & Omore (2014)	11
Hygiene and lack of efficient preservation methods	Uganda	Grimaud, Sserunjogi, & Grillet (2007)	12
Improved dairy cows, training on fodder crop and management, animal husbandry such as cleaning cow teats and milk hygiene, assistance to establish producer-level cooperatives and MCCs[2], proper handling	Mozambique	Johnson et al. (2015)	13
Hygiene practices including training and animal health monitoring, implementation of MCCs (see Table A1 for quality parameters)	Rwanda	Kamana et al. (2017)	14
Policy measures, assessment of various nodes of the value chain, DTA[3] traders	Kenya	Kiambi et al. (2018)	15
Dairy hub, linking farmers to output market, DFBA[4] installing cooling plants	Kenya	Kilelu, Klerkx, & Leeuwis (2017)	16
Multi-stakeholder process, quality testing (e.g. lactometer test, alcohol test), use of aluminium cans in transporting milk, product upgrade	Tanzania	Kilelu, Klerkx, Omore, Baltenweck, Leeuwis, & Githinji (2017)	17
Multi-actor partnership, establishment of DFBA, improvement of facilities	Kenya	Kilelu, Klerkx, & Leeuwis (2013)	18
Enhancing performance of VFTs[5], sharing experiences, role of DFBA in the EADD[6]	Kenya	Kiptot & Franzel, 2015	19
Lack of awareness on mastitis, quality standards, poor animal health and diseases	Tanzania	Kivaria et al. (2006b)	20
Application of a FSMS[7]-diagnostic instrument and microbiological assessment scheme	Tanzania	Kussaga, Luning, Tiisekwa, and Jacxsens (2015)	21
Organisation of control activities, enforcement and monitoring of requirements on milk quality (parameters), safety and hygiene practices, animal health care, hygiene, feed storage control, milk cooling, support of non-commercial program	Tanzania	Ledo, Hettinga, Bijman, and Luning (2019)	22
Calf rearing practices, using quality criteria (colour, smell, water content and taste), respondents' opinions of good quality	South Africa	Mapekula, Chimonyo, Mapiye, & Dzama (2009)	23
Spoilage of milk, marketing	Kenya	Musalia, Wangia, Shivairo, & Vugutsa (2010)	24
EADD support, dairy hubs' engagement with output market	EA	Omondi, Rao, Karimov, & Baltenweck (2017)	25
Scale of farming, education of farmers	Zimbabwe	Paraffin, Zindove, & Chimonyo, 2018	26
Quality upgrading, reduced saturated fat content, removing health treats, market incentives, producers' willingness to invest in quality upgrading, consumer willingness to pay for higher quality	Ethiopia	Ruben, Bekele, & Lenjiso (2017)	27
Improvements in regulations and standards	Tanzania	Twine (2016)	28
Informal sector, traditional preferences for fresh raw milk, low cost	Kenya & Uganda	Vaarst et al. (2019)	29
Animal health, farmer knowledge in mastitis control technologies	Uganda	Vaarst, Byarugaba, Nakavuma, & Laker (2007)	30
Knowledge sharing & training on dairy farm and health management, better milking procedures, on-farm milk storage methods	Kenya	VanLeeuwen et al. (2012)	31
Incentives for value chain actors as a motivation to transform their activities to those that are nutrition sensitive	Uganda	Wesana et al. (2018)	32

[1] KDB: Kenya Dairy Board.
[2] MCC: Milk collection centres.
[3] DTA: Dairy Traders Association.
[4] DFBA: Dairy farmers business association.
[5] VFT: Volunteer farmer trainers.
[6] EADD: East Africa Dairy Development.
[7] FSMS: Food Safety Management System.

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