



Using participatory rural appraisal to investigate food production, nutrition and safety in the Tanzanian dairy value chain[☆]



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ABSTRACT

Identifying and implementing interventions that create co-benefits in terms of food and nutrition security as well as food safety requires an interdisciplinary and intersectoral approach. This study was part of a larger project that applied an integrated framework for combined nutritional, food safety and value chain analysis to assess the dairy value chain in two regions of Tanzania, namely Morogoro and Tanga. Here, we report on the use of participatory rural appraisals (PRAs) with producers and consumers to investigate seasonality, constraints and opportunities in cow milk production and consumption in ten villages in Tanzania and describe attitudes and practices surrounding milk quality and safety. The PRAs allowed identifying strong seasonal milk production and consumption practices reflecting rainfall patterns and a dependence on the natural environment. A wide range of production constraints were described by producers including insufficient technical know-how, poor quality breeds, cattle diseases, lack of capital, feed, water and reliable markets. While milk availability had a strong influence on milk consumption, findings showed that there are a range of other factors such as the consistency of milk, purchasing power and the availability of other foods which also influence consumer choice. A dependence on sensory milk quality attributes in the absence of other systems of certification was described. Both producers and consumers showed little concern regarding potentially contaminated milk despite an awareness of the existence of milkborne disease risks. The results indicate great potential for upscaling dairy production and at the same time highlight that any such interventions should carefully consider mitigation measures for food safety risks.

1. Introduction

Rapid urbanisation and economic and population growth in low- and middle-income countries (LMICs) increase pressure on food systems to supply food and nutrients for all (Perry et al., 2018). The livestock and fish sectors in LMICs are rapidly growing, thereby providing opportunities for poverty reduction and improvement of nutrition. A range of studies have demonstrated the importance of animal-source foods (ASF) as a source of essential nutrients such as vitamin B12, iron, and zinc in highly bioavailable forms (Azzarri et al., 2015; Smith et al., 2012); they can improve growth, physical activity and cognitive

function (Neumann et al., 2003). However, such foods also carry a higher risk of foodborne disease due to their biological characteristics and their perishable nature. Foodborne disease constitutes an important health burden worldwide estimated at 33 million Disability Adjusted Life Years in 2010 (Havelaar et al., 2015). It is expected to increase in LMICs due to growing demands for ASF and intensifying development of livestock value chains that does not consider sufficiently safety and hygiene measures probably due to a long-term neglect of food safety in these food systems (Grace, 2015). Hence, interventions to develop ASF value chains for nutrition and food security also need to be sensitive to food safety.

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The Tanzanian livestock sector was found to grow at an annual rate of 2.6% and the contribution of livestock-related activities to the gross domestic product (GDP) was 7.4% in recent years (Michael et al., 2017; MLFD: Ministry of Livestock and Fisheries Development, 2015). Given the very large number of livestock in the country, the economic contribution is considered low compared for example to neighbouring Kenya where the contribution is 12%. The causes of poor performance of the livestock sector include poor genetic potential of the majority of livestock (Msalya et al., 2017a,b), poor nutrition (Msalya et al., 2017a,b), as well as poor management and lack of investment (Michael et al., 2017; MLFD: Ministry of Livestock and Fisheries Development, 2015). The potential for growth with better genetics, feed and health services, and policy support – elements of a new Livestock Master Plan (LMP) to increase productivity and production – was predicted recently (Michael et al., 2017). The LMP used data from 2013 to 2015 from the Ministry of Agriculture, Livestock and Fisheries (MALF) and used the Livestock Sector Investment and Policy Toolkit (LSIPT) to develop a national herd and economic sector model and a baseline assessment of the current state of livestock development in Tanzania. Financed by the Bill and Melinda Gates Foundation and pioneered by the International Livestock research Institute (ILRI), the LSIPT was applied to assess the potential long-term (15–20 years) impact of proposed combined technology and policy interventions. The authors indicated that increased investments will have a positive impact on the growth of the sector and increase productivity. In particular, the dairy value chain in Tanzania was identified by ILRI as one of the livestock value chains of considerable potential for pro-poor development (ILRI, 2011). The 2012 census in Tanzania showed that the number of households engaged in agriculture was 5,962,091 (66%), of which 1,462,279 (16%) were cattle keeping households (National Bureau of Statistics and Office of Chief Government Statistician, 2014). More than 80% of these livestock keeping households were located in rural areas.

Milk contains high levels of energy, readily-digestible protein and bio-available micronutrients (Latham, 1997) and has been shown to be associated negatively with malnutrition in populations that consume large amounts of milk as part of their normal diet (Fratkin et al., 2004) or to improve plasma vitamin B-12 concentration in school children in Kenya when milk was supplemented in an intervention trial (McLean et al., 2007). But milk is also prone to spoilage and an ideal growth medium for microorganisms including milk-borne pathogens such as *Brucella spp.*, *Campylobacter jejuni*, *E. coli* O157:H7, *Listeria monocytogenes*, or *Mycobacterium bovis* (Dhanashekar et al., 2012). Several foodborne pathogens that can be transmitted through dairy value chains have been found in Tanzania, but prevalence estimates can differ widely between studies (Alonso et al., 2016). Milk samples contaminated with *E. coli* O157:H7, *Salmonella spp.*, *Brucella spp.*, and coliform bacteria have been detected at all points in milk value chains in Tanzania including primary producers, milk collectors, bulking points, and various types of retailers (Hyera, 2015; Joseph, 2013; Lubote et al., 2014; Msalya, 2017; Schoder et al., 2013; Swai and Schoonman, 2011).

Apart from the direct impact on health and risks of foodborne disease, there are also several indirect effects caused by contaminated ASF including its impact on food security. Food safety risks associated with ASFs, and the mitigation of these risks can affect all four pillars of food security (FAO, 2006). *Pillar 1: Availability* can be increased or decreased through manipulation (e.g. preservation¹, fortification² or adulteration³); unhygienic practices in the value chain that can cause

contamination and spoilage; and risk management measures such as food recalls. *Pillar 2: Access* to food can be affected negatively through transformation of ASF (e.g. preservation) that can lead to price increases and subsequent exclusion of groups with low purchasing power or avoidance of foods due to food safety scares; or be affected positively through employment in the ASF value chain. *Pillar 3: Utilisation* can be decreased through risk of infection with foodborne pathogens that inhibits nutrient absorption; and unhygienic preparation practices leading to loss of nutrients. *Pillar 4: Stability* can be improved through transformation of ASF such as preservation thereby prolonging shelf-life or negatively affected by cyclical (seasonal) patterns of many pathogens that lead to fluctuating ASF supply during the year or periods of higher and lower risks of foodborne disease, respectively (Häslér et al., 2017). Hence, it is important to understand which types of ASF can realistically make a difference in people's food and nutrition security without causing new problems in terms of foodborne disease emergence, transmission and spread or perpetuating current problems. Because of a traditional disconnect between food safety and nutrition research, assessments of food safety and food security are often disaggregated. Under the CGIAR Research Programs on Livestock and Fish (<https://livestockfish.cgiar.org/>) and on Agriculture for Nutrition and Health (<https://a4nh.cgiar.org/>), ILRI and partner organisations aimed to promote interdisciplinary research and solutions in livestock value chains taking into account all steps from primary production to consumers with the aim to increase production and productivity for food security in livestock and fish value chains while generating opportunities for growth and development of poor populations. As part of this agenda, the project *Rapid integrated assessment of food safety and nutrition* was implemented with the aim to assist rapid integrated assessments of food safety, zoonoses and nutrition in informal value chains as one facet of a comprehensive value chain assessment thereby providing information for value chain managers and decision-makers. Consequently, the research team developed a framework to combine explicitly food safety and food and nutrition security considerations to understand better the relevant dynamics, identify critical research questions and intervention points. The framework includes six analytical dimensions, namely 1) identification of the system of interest; 2) value chain analysis; 3) food safety risk assessment; 4) nutrition assessment; 5) integrative analysis and assessment of risk management options; and 6) recommendations for decision-makers (Häslér et al., 2017).

Following this framework, the rapid integrated assessment (RIA) team coordinated by ILRI (<https://www.ilri.org/node/7007>) developed and applied a range of tools in the dairy value chain in Tanzania including a systematic literature review (Alonso et al., 2016), value chain mapping (Sikira et al., 2013), producer and consumer surveys (Häslér et al., 2018), and biological sampling and laboratory testing (Hyera, 2015; Joseph, 2013; Fortunato Shija, 2013), among other tools. These were developed and applied to assess food production challenges and opportunities, food safety, and nutrition in the dairy value chain represented by two of the major milk-producing regions of Tanzania. Through the systematic literature review it was possible to estimate the prevalence of tuberculosis, brucellosis and trypanosomiasis of cattle in Tanzania (Alonso et al., 2016). The value chain mapping (Sikira et al., 2013) showed that the downstream marketing system had limited capacity to accommodate seasonal peaks due to deficient transport and storage options. Seasonal migration of animals in search for pasture and water was practised during the dry season (i.e. end of July to October). Three main milk channels were identified in extensive systems: through collection centres (Tanga Fresh and Tan Dairies), via local restaurants and neighbours, and through vendors. Milk channels in semi-intensive systems were selling milk to neighbours and local restaurants directly

¹ Food preservation refers to the process of using techniques such as heating, drying, cooling to modify the properties of a product such to prevent microbial growth.

² The process of adding micronutrients (essential trace elements and vitamins) to food.

³ Food adulteration describes the act of altering food intentionally by adding inferior or removing valuable ingredients to food and thereby lowering its

(footnote continued)

quality; a common adulteration practice is to add water to milk.

by the farmers or through vendors. The main incentive for selling milk directly to neighbours and restaurants were high prices and rapid payment. Selling to milk collection centres was preferred by some due to security/supplier loyalty, as collection centres continue to buy large amounts of milk during the long rainy season, when milk production exceeds demand by accessible consumers. For people not selling to collection centres, the lack of market in the rainy season was problematic. Inputs (drugs, vaccines, advice, feed, artificial insemination) were obtained from livestock markets, livestock officers, government officials and retailers. Lack of access to credit due to high interest rates offered by financial institutions was mentioned by input suppliers as a challenge to expand their business. Limited knowledge of disease, farm management, and equipment for milk testing were mentioned as barriers to growth and development. The questionnaire-based survey among 156 dairy cow producers and 157 consumers in ten villages of Lushoto and Mvomero districts raised various food safety and production concerns and provided insights into food security (Häslér et al., 2018). For example, a majority of producers did not discard milk during or after treatment of animals using veterinary drugs (including antibiotics), less than half of the producers boiled milk (although fermentation of raw milk was common), and cattle management was found to have low levels of hygiene, biosecurity and disease control measures. When purchasing milk, respondents stated that they judged the milk quality based on colour, trusted supplier and viscosity of the milk; these considerations were deemed more important than hygiene or safety practices. Almost all households indicated to consume milk regularly; most often boiled, in tea (*chai*) or as fermented milk. The consumption of raw and fermented cow's milk was reported in all villages visited; 26% of consumers indicated consumption of raw milk “usually” or “sometimes”. Nearly all consumers believed that “milk is good” and has a high nutritional value; only about a third thought that milk can cause illness in people. The calculation of a Food Consumption Score (World Food Programme, 2008), i.e. a composite score based on dietary diversity, food frequency, and relative nutritional importance of different food groups, showed that the majority of households had acceptable food access, but it was significantly higher for the households keeping dairy cattle (Häslér et al., 2018). The biological sampling and laboratory testing showed poor microbiological quality of cow's milk with 87% of the samples from farmers and 93% of the samples from vendors showing total plate counts above the stipulated East African community standards of raw milk and all samples were above the recommended level for coliform plate counts (Shija, 2013). These findings were corroborated by another study where 50 cow's milk samples from Mvomero and Kilosa district were tested. The mean natural log CFU/ml for total coliform count was 8.98 for farmers, 12.23 for vendors, 14.68 for collection centres, and 2.44 for selling centres and a mean natural log CFU/ml for total viable count of 9.72 for farmers, 12.18 for vendors, 14.56 for collection centres, and 7.88 for selling centres (Joseph, 2013). Importantly, contamination levels in raw and boiled milk were not significantly different ($p > 0.05$), suggesting poor quality of raw milk, insufficient pasteurisation, and/or a high level of recontamination post-pasteurisation (Shija, 2013).

In summary, these related studies showed that there are both very short food chains and some more complex chains that involve collection centres and processors before the final consumers. Unhygienic production, harvesting, handling and consumption practices and high levels of pathogens detected indicated contamination through exposure to infected animals or people, unclean equipment and handling practices. Cow's milk was consumed frequently with people praising the nutritional value of milk and not being concerned about food safety issues; the majority of household said that they would like to consume more milk in the future. Factors limiting consumption related mainly to the purchasing power of the household implying that poor people may be excluded from milk consumption in particular when milk is scarce, prices high and income low. On the production side, several sub-optimal practices (e.g. high burden of production diseases, low yields)

were noted that offered opportunities for improvement and growth of the sector.

Because of the potential identified for increased milk production and consumption, but also latent food safety risks, the aim of this study was to explore in more depth seasonality, constraints and opportunities in cow's milk production and consumption in selected regions in Tanzania and describe attitudes and practices surrounding milk quality and safety as well as potential solutions. The instruments of choice were participatory rural appraisals (PRAs). Information obtained completes the information gathered in the rapid integrated assessment and helps to consider avenues to overcome production, quality and safety constraints.

2. Materials and methods

2.1. General overview

For the purpose of this study, PRAs were conducted among producer and consumer groups in ten villages in Morogoro and Tanga regions, Tanzania. The protocols were developed in English and were discussed and explained to the enumerators during a training session conducted by members of the project team from Sokoine University of Agriculture (SUA) in Morogoro and ILRI in Nairobi, Kenya. During the training, the protocols were translated to Swahili, were pilot tested and refined using the feedback provided. Swahili is the national and official language of Tanzania spoken by all people. Translation was agreed by all enumerators and members of the project team before the study was conducted. The interview group comprised of six enumerators (4 male and 2 female), all students of SUA in the fields of agricultural economics, human nutrition and animal science (2 MSc and 4 BSc students). The students worked in two teams of three each and were supervised by a senior academic person from SUA, a local supervisor selected in each district, and occasionally a project representative from ILRI. The interviews were carried out in Swahili and were conducted from October 2012 to May 2013.

2.2. Study sites

The study regions Morogoro and Tanga in Tanzania were selected as part of a long-term commitment by ILRI and SUA to research of pro-poor livestock value chains in Tanzania. First, stakeholder consultations and scoping studies were conducted in rural production to rural consumption and rural production to urban consumption value chains (Lukuyu et al., 2012). This information was used to select study districts with the aim to cover a diverse and broad representation of different human and livestock population densities, income, market access, consumption patterns, and livestock production systems. The two districts fulfilling the selection criteria best were Lushoto (Tanga region) and Mvomero (Morogoro region). Following the selection of districts, livestock officials at the level of the district were consulted to create a longlist of 35 cattle keeping villages. For each longlisted village, the density of cattle keeping households, available information on potential research impact and ease of assistance for the research was assessed by the research team and a shortlist of 25 suitable villages was generated.

In these villages, a detailed checklist on production data and practices, market orientation, market outlets, feeding practices, and practical research factors (e.g. willingness to participate, staff security) was applied. From the sample frame of these 25 villages, five per district were randomly selected with the aim to represent extensive (agro) pastoral, semi-intensive sedentary and intensive sedentary systems. Researchers then visited site locations and consulted further with research partners and other stakeholders to assess the willingness of the communities to participate in further studies, and accessibility of the villages to the research team. If a village was found to be unsuitable, another village was randomly selected. The final ten villages included in this study were Mbokoi, Mwangoi, Ngulwi, Handei and Manolo in

Lushoto district and Kidudwe, Lubungo, Lusanga, Wami Dakawa, and Mlandizi in Mvomero district. The location of the study villages can be found in supplementary material 1.

2.3. Participatory rural appraisals

The interview team comprised of six enumerators who worked in two teams of three each involving one moderator who was leading the activities and two note takers who were recording the answers.

In each of the ten villages, two PRA sessions were held: one for milk producers and one for consumers (20 sessions in total). For data collection, local partners with support from collaborating extension officers were asked to invite a group of 15–20 producers and consumers, respectively, to participate in the study. The sampling frame was the list of all household heads received from the local livestock field officer from which producers and consumers were randomly selected using Microsoft Excel random number generator function. Only one representative per household was invited to participate to avoid mixing husband and wife participants in the same group. Oral informed consent was obtained from each participant. At the beginning of the PRAs, ground rules were established to create an open, inviting and respectful atmosphere where everybody felt welcome and could express their views unhindered. Selection of a participant in each household was planned such that either the household head or a spouse was picked. In situation where both were not available, a trusted family member (son, daughter or relative) knowledgeable of livestock production or household nutrition affairs was asked to participate in the study. Participation was voluntary, and all participants were invited either a day before the interview or very early (at least 4 h before the PRA) on the day of the meetings.

The PRAs for producers and consumers included the activities described in Table 1 (for the protocols, see supplementary material 2 and 3).

2.4. Data handling and analysis

During the activity, written detailed notes were taken by the enumerators. After each activity, data were captured in writing according to data capturing guidance provided in the protocols (Supplementary materials 2 and 3); the written notes were later summarised in a report for each producer and consumer group. Data capture included summarising of information from the activity as text or numbers in pre-defined charts, diagrams, or tables. For seasonal calendars, enumerators were encouraged to take a picture of the final calendar. For open questions, key points were written down by the enumerators in Swahili and later translated to English by the enumerators. Semi-quantitative and quantitative data were entered into a Microsoft Excel spreadsheet and cleaned. Obvious spelling mistakes were corrected and differing ways of spelling for the same item were changed to one (e.g. ethnicity Maasai or Masai were listed as Maasai). Descriptive statistics were used to describe the characteristics of the research sample and quantitative data. Qualitative data were summarised in a general narrative. Ranking of constraints was converted to a scoring system (highest rank = highest score) to allow comparison between sites. An importance measure was computed for each ranked criterion as: $(\text{Frequency the criterion is ranked})^2 / (\text{Mean rank when cited})$. The frequency was set to the power of 2 in order to favour the criteria that were cited many times, independent of their average rank. Overall, the importance measure increased if the criterion was cited many times and/or if it was ranked as very important when cited.

2.5. Compliance

The PRA protocols were submitted to the ethics committee of the Royal Veterinary College (RVC), London, UK, and ethical clearance was granted (reference number URN, 2012 1191). Moreover, the protocols

were submitted to and approved by SUA in December 2012 (reference number SUA: SUA/ADM/R.1/8) and to the ILRI Institutional Research Ethics Committee (IREC), from which approval was received in June 2013 (reference number ILRI: IREC2013-03). Because no samples were taken from living animals or exported to another country, no further approvals or permits were needed.

3. Results

3.1. Participation

One consumer PRA and one producer PRA each were conducted in all ten study villages. Although the total number of participants intended for the producer and consumer PRAs was between 15 and 20, the ranges were 10–17 for the producer PRAs and 13 to 19 for the consumer PRAs. For the producer PRAs male participants were dominating with a proportion of 64–80% except in one group (PRA), where men only represented 40% of participants. The number of female participants was larger in the consumer PRAs (proportion of women 53–76%), apart from one group where women only represented 42% of participants.

3.2. Milk production and consumption dynamics

Using the seasonal calendar, producers in both districts described a strongly fluctuating milk production throughout the year reflecting rainfall patterns and the associated availability of pasture, water and by-products from crop production such as maize straws. Described rainfall patterns showed “long”, intense (March to May) and short, less intense (between October and December) rainy seasons (termed “vuli” – the short rains, and “masika” – the long rains). Milk production was described to peak around the months of February to May during the long rains, followed by a gradual decrease from May to August with lowest milk production experienced in July to October (Figs. 1 and 2). In several villages, an increase in production was reported between October and December related to the short rains. For some improved dairy cow breeds, slightly higher milk production was reported in the dry season compared to indigenous cattle breeds; farmers explained this effect to be due to supplementation with feeds from other areas and concentrates. Similarly, fresh milk consumption was described to be highest during the long rains reflecting the high availability of milk. This trend was very clear in Mvomero district, where consumers described that they consume most milk during the rainy seasons when milk supply is high and milk prices are low. Even though milk production was said to increase towards the end of the year with the short rains, milk consumption did not seem to follow the same increase, because consumers perceived the milk to be watery due to the availability of fresh and lush pastures. Milk consumption was described to be lowest during the period of low production and associated high prices. Moreover, during that period purchasing power was reported to be low because the harvesting period was yet to come. In Lushoto district, milk consumption patterns were slightly different influenced by factors other than milk production. For example in Ngulwi consumption was described as low in June but increased in July and August as well as September to October while the low consumption in Mwangoi was reported to be starting from June to August. In these villages, consumption was reported to increase again in November (Ngulwi) and September (Mwangoi). For both sites, milk consumption was said to be related to availability of milk and purchasing power. The differences in consumption levels were thought to be caused by different seasons of harvesting of horticultural crops (mainly fruits) in the villages. In two sites (Manolo and Handei) the trend was the same as the one reported for Mvomero sites i.e. decreased consumption when there was decreased production of milk (June to December). In Mbokoi, milk consumption was reported to be high in the months of July, August, September, and to reach its peak in October caused by conducive weather

Table 1
Participatory rural appraisal activities used among producer and consumer groups.

Activity name	Description	Food security concept(s) addressed	Research questions addressed
Activities for producers			
Seasonal calendars	Counters were used to indicate dairy production and consumption, rainfall, and times of general food shortage during the year	Availability, stability	How does cow's milk production vary by season? What is the role of cow's milk in the diet by season and with respect to seasons where there is less food available?
Pair-wise matrices on constraints	Producers were asked to list constraints on increasing volume or quality of dairy production. Constraints were entered along two sides of a matrix and respondents were asked to identify the most important constraint from each column-row pairing. The total number of times each constraint was listed as the most important of a pair was used to allocate an overall ranking for the whole matrix.	Availability	What are the constraints to producing larger amounts of cow's milk? Among these constraints which are most important?
Problem-opportunity matrix	For the constraints identified, producers were asked about previous, existing and potential solutions and who would have responsibility for those.	Availability	How do producers perceive mitigation options?
Disease description	Listing of cattle diseases, for each disease detailed description (name, clinical signs, animals affected, seasonal patterns, treatment, prevention, effectiveness of treatment, effects of disease)	Availability, stability, access, utilisation	What are the most important diseases that affect dairy cattle in this area?
Proportional piling	Assess proportion of dairy cattle entering and leaving the herd, proportion of deaths attributed by farmers to different causes, proportion of animals affected by different diseases, destination of these animals.	Availability, utilisation	What are the community herd dynamics that affect the production of cow's milk?
Activities for producers and consumers			
Listing, ranking and scoring	Listing, ranking and scoring of attributes producers look for to determine the quality of cow's milk, perceptions of cow's milk safety issues, and mitigation measures.	Utilisation, access	How do producers perceive cow's milk quality including safety?
Problem-opportunity matrix	For the top quality issues identified in the previous activity, producers were asked about previous, existing and potential solutions and who would have responsibility for those.	Utilisation, access	How do producers perceive measures to improve cow's milk quality and safety?
Activities for consumers			
Seasonal calendar	Counters were used to indicate cow's milk production as well a consumption throughout the year and general food availability.	Availability	What is the role of dairy cow products in the diet by season? And with respect to hungry seasons?
Listing, ranking and scoring	Listing, ranking and scoring of attributes producers look for to determine the quality of cow's milk, perceptions of food safety issues, and mitigation measures.	Utilisation, access	How do producers perceive cow's milk quality including safety?
Listing	Women in the consumer groups were asked whether children under 5 years of age consumed cow's milk or dairy products and what the preparation methods and typical quantities were.	Utilisation	What is the role of cow's milk in nutrition of young children?

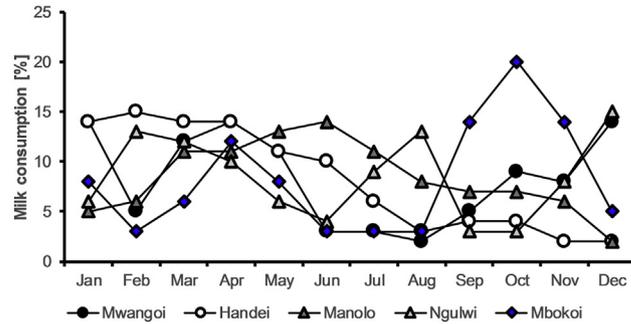
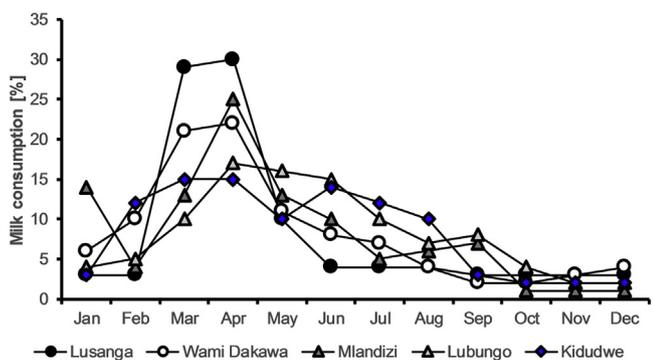
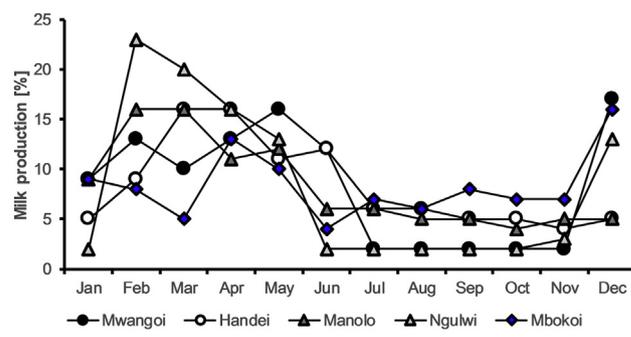
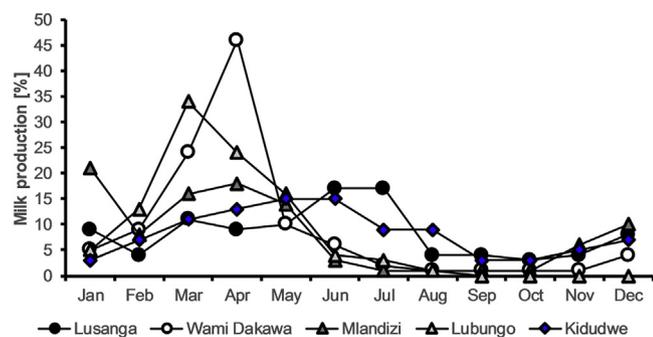


Fig. 1. Cow's milk production reported by producers and cow's milk consumption reported by consumers over the course of a year in five villages in Mvomero district. Data collection activity: Seasonal calendar.

Fig. 2. Cow's milk production reported by producers and cow's milk consumption reported by consumers over the course of a year in five villages in Lushoto district. Data collection activity: Seasonal calendar.

Table 2
Production constraints listed by village and ranked. Data collection activity: Pair-wise matrix.

Constraint	District & village										Importance measure
	Lushoto district					Mvomero district					
	Mbokoi ^a	Mwangoi	Ngulwi	Handei	Manolo	Kidudwe	Lubungo	Lusanga	Wami Dakawa	Mlandizi	
Lack of/inadequate technical knowhow		1	1	1	3	2		1	2	5	32
Poor quality breeds	1	3	3	3	1	1		4			21
Cattle diseases		5	2	2		3		3	5	3	15
Lack of/inadequate capital		2	5	3	2			2	3		13
Lack of/inadequate pasture and/or water	3	4							1	1	7
Lack of or unreliable markets			4		4	5	3			4	6
Poor feed quality	2			2	5	4					5
High input prices							3	5	4	2	5
Lack of grazing land							1				1
Lack of dip tanks							3				0

Top five constraints resulted from pair-wise ranking and are shown in the Table for each village (numbers 1–5).

^a only three top ranks were reported for this village.

conditions, high purchasing power of consumers because of harvesting in general and harvesting time for a nearby sugar company which causes a temporal seasonal influx of workers (cane cutters) and increased demand for milk.

3.3. Production constraints

Table 2 lists the production constraints mentioned by producers and ranked by their importance. The issues most frequently mentioned were limited technical know-how, lack of improved dairy cow breeds, cattle diseases, lack of capital, lack of pasture and/or feeds, and unreliable markets. Lack of capital was said to be associated with poverty in general, dependency on rainfall cultivation and difficult loan terms for farmers. Solutions suggested by producers were the creation of livestock unions or associations, special funds for livestock keepers, and provision of loans (cash or in the form of live cattle). Five of the ten producer PRA groups described issues relating to the availability of land, namely heavy competition between crop production and livestock keeping, and pasture and water shortage in general. Pastoralists in particular reported to be highly dependent on grazing land and pasture. Some schemes to manage land use were described, but the rules were often not respected and fights over land were described to be common and sometimes fatal, exacerbated by competition for land by human settlements and hunting practices that include burning of land.

The perceived causes for the overall top three constraints from Table 2 and producers' views on how to tackle them are listed in supplementary material 4. In terms of technical skills, producers explained that there was a lack of farmer training programmes, low working morale among livestock officers and insufficient government support. Several past and ongoing training opportunities were described including training sessions by livestock officers and non-governmental organisations (NGOs). Nonetheless, producers felt that these were inadequate and suggested more regular provision of training for livestock keepers by government, NGOs, veterinary officers and livestock stakeholders. The problem of low productivity due to a lack of improved dairy cow breeds according to producers was caused by unreliable sources and insufficient capital to acquire improved dairy cow breeds and inadequate capacity to maintain them in the herd. Respondents made reference to previous dairy development projects implemented by the Tanzanian government and development partners. Many of these projects followed a model known in Swahili as “*Kopa Ng'ombe lipa ng'ombe*”, which means “Borrow a Cow; Pay a Cow” and is known in English as Heifer-In-Trust (HIT) scheme, where a farmer is given a pregnant heifer or cow (i.e. foundation heifer) on the condition that he or she repays to the project the first (and sometimes also the second) heifer calf born to each animal. These heifer calves are usually passed

on to other farmers in the group who must also repay the loan in the same manner. This scheme was recommended by the majority of respondents as a potential solution. Producers suggested further that they also need artificial insemination to improve their cows and mentioned the importance of having access to good quality bulls or semen. However, some producers also explained that they failed to keep improved dairy cow breeds in the past due to husbandry and management requirements and stated that there is a need for training to improve management practices. With respect to diseases, some participants were able to name the disease. Whenever participants were not able to recognise and name a disease, the observed clinical signs were described. Where possible, enumerators used this information to identify the disease in consultation with local experts and members of the project team responsible for animal health. Clinical signs of diseases reported and discussed most frequently in producer groups were East Coast fever (theileriosis), “black quarter” (also called “black leg” – an infection with *Clostridia* bacteria characterised by gaseous swelling in large muscles and fever), babesiosis, mastitis (inflammation of the mammary gland), and helminths. Diseases mentioned only by one or two producer groups were tuberculosis, lumpy skin disease, foot and mouth disease, contagious bovine pleuropneumonia, milk fever, anaplasmosis, and diarrhoea. The concern of cattle diseases was reported to be related to a lack of infrastructure (e.g. dipping tanks), technical knowhow, capital to buy drugs and vaccines, and poor management. However, producers informed that they were previously trained on how to detect some diseases through clinical signs of some of the diseases (syndromic disease detection) and how to control some of the diseases through regular dipping and vaccination. They suggested that improved animal health services (including vaccination programmes) and training for farmers should be established and access to drugs and vaccines be facilitated.

Diseases were one of the major reasons for cattle mortality, mentioned by all ten producer groups. The reported mortality per year was a median of 21% (SD = 11, min = 7, max = 45), with cattle diseases causing between 28% and 74% of these deaths (Fig. 3). Ranked second by producers were lack of feed and/or water, and complications at parturition. Reported cattle morbidity ranged between 11 and 69% and was predominantly attributed to production diseases.

3.4. Producers' perceptions of food quality and safety

Milk viscosity, odour and colour were the most important attributes reported to be used by seven producer groups (Table 3) to assess the quality of milk and dairy products. All attributes apart from colour and viscosity in the Mlandizi group were judged to have the potential to indicate that dairy products were less safe. Viscosity was described by producers to be a quality concern because of adulteration (mentioned

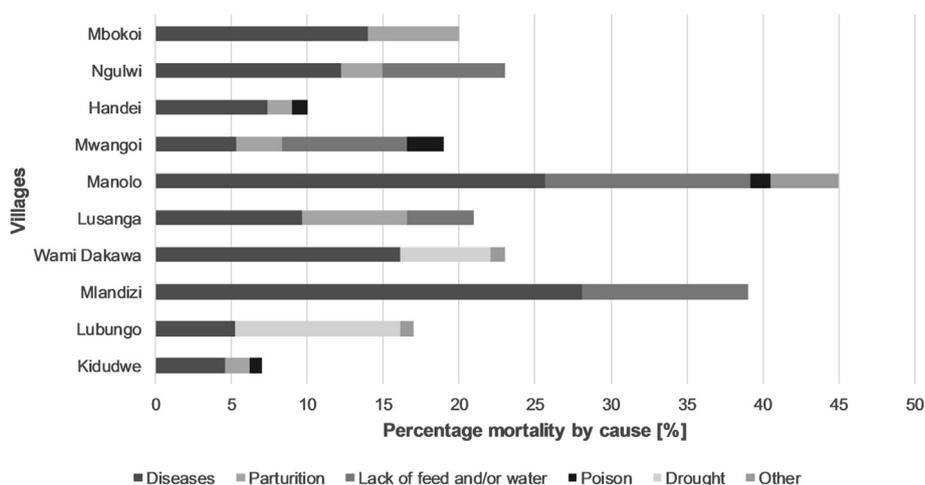


Fig. 3. Reported levels and reasons of cattle mortality in ten villages in Lushoto and Mvomero districts.

by 4 of 7 groups), low butter fat (2 of 7 groups) and public health hazard if adulterated with contaminated water (1 of 7 groups). Smell/ odour was described to be a quality concern because of spoilage risk (2 of 7 groups), public health hazard (2 of 7 groups), adulteration, sick cows, contamination, and unattractive aroma (1 of 7 groups each). Colour was described to be a quality concern because of adulteration (2 of 7 groups), impurities, sick cows, and negative impact on butter making (1 of 7 groups each). Measures producers described to use to promote the quality of milk included managing disease in cattle, washing of hands before and after milking, cleaning utensils, using different shoes for milking and other cattle-related activities to avoid dirt in the milking area, avoiding contamination of milk with dust or dirt during milking, in storage and transportation of milk, cleaning udders of the cattle before milking, having a dedicated milking area and milk filtering.

In terms of potential solutions, producers suggested regular training by government, NGOs and livestock stakeholders for producers and consumers as ways of improving quality of milk and dairy products (e.g. training on hygienic milking, storage and transport; permanent milking spaces; optimal feed management). Moreover, producers believed that consumers should be given more information about the appearance of milk; e.g. to explain that viscosity of milk can fluctuate naturally dependent on inputs like feed and is not always caused by deliberate addition of water.

3.5. Consumers’ perceptions on food quality and safety

Hygiene, cleanliness and viscosity were regarded as the main attributes when judging milk and dairy products safety and quality by ten consumers groups (Table 4). Dairy products consumed were fresh milk, ghee, fermented milk, and sometimes butter and yogurt. Generally, most of the participants gave more importance to hygiene (8/9 villages

that listed the attribute) due to the health impact for the end user, showing awareness about the risks of product safety loss associated with lack of hygiene (i.e. prevention of contamination) and cleanliness (i.e. keeping people, utensils, clothes, and the environment clean). Consumers described that milk and handling material can act as vehicle for infectious pathogens, potentially causing diseases with symptoms such as vomiting and diarrhoea. Even though the common practice among consumers interviewed was to reject a product showing lack of hygiene or cleanliness (6/9), four groups reported to consume often the product despite this condition (three in Mvomero, one in Lushoto).

The second most important quality attribute described by consumers was viscosity, generally associated with milk adulteration by water addition, often to increase the milk quantity. Consumers described the following practices to check themselves for milk adulteration: pouring milk on the ground and observing percolation rate; pouring milk on the palm and blowing it away; or dropping a matchstick into the milk and observing the dripping down. For some groups high-density milk was indicative of high quality, whereas other groups preferred low density or viscosity, explaining a variety of reasons such as adequacy for children or for milk products preparation. All groups explained that viscosity or density can vary naturally due to animal feeding practices, but was mostly affected by water addition practices, in particular during the low productive season to increase the sellable quantity. While participants considered viscosity to be indicative of quality, half of the groups also explained that adulterated milk consumption entails public health risks, causing diarrhoea or vomiting, or was labelled as unhealthy in general. Yet these groups reported still to consume the product. Other participants mentioned that adulteration has a negative nutritional impact because of decreased nutrient density caused by dilution, but indicated to accept the product despite adulteration.

Half of the PRA groups mentioned the assessment of other

Table 3

Milk quality attributes listed and ranked by producers in seven villages in Lushoto and Mvomero districts^a.

	Lusanga	Wami Dakawa	Lubungo	Mwangoi	Kidudwe	Mlandizi	Ngulwi	Importance measure
Viscosity	2	3	4	2	1	1	4	16
Smell/odour	3	4	3	4	2	3		10
Colour	1			3		2	1	7
Cleanliness of milking environment/utensils		2	2		3		2	6
Cattle health		1	1					3
Taste	4	5						1
Cream				1				1
Nutrients							3	1

^a For the villages Manolo, Handei and Mbokoi, this information could not be collected due to time constraints.

Table 4
Milk safety and quality attributes listed and ranked by consumers in ten villages.

	Lushoto					Mvomero					Importance measure
	Handei	Mwangoi	Mbokoi	Manolo	Ngulwi	Lubungo	Mlandizi	Kidudwe	Lusanga	Wami Dakawa	
Hygiene and/or cleanliness	1	1	1	1	1	2	1	1	1		73
Viscosity	2	2	3	2	2	3	2	2	3	1	45
Colour			2		3	1			2	2	13
Smell								3	4		1
Price							3				0
Taste										3	0

organoleptic characteristics. The most important attribute described was milk colour as an indicator to assess potential contamination that can lead to disease, but also of adulteration according to few groups. Some consumers identified the presence of colostrum and symptoms compatible with mastitis as causes of abnormal milk colour and potential loss of safety. Smell and taste were named as other attributes that would lead to the rejection of milk.

To test these attributes, some groups mainly from Lushoto villages explained to acquire milk from collection centres because of milk quality control. However, most of the groups named traditional methods to test milk quality and antibiotic presence in milk, such as the visual assessment of viscosity and the ability to ferment, respectively.

3.6. Milk in children's diets

This activity was conducted with mothers only. They revealed that there are some children who do not consume cow's milk and dairy products, as some of them may vomit, develop allergic conditions or experience stomach ache. Through probing, some of the mothers reported to observe mild diarrhoea, vomiting, and/or skin itching soon after consumption of milk by the child as symptoms for allergic condition. For children without such problems, several mothers described that it was common to feed them cow's milk usually mixed with porridge and sometimes adding egg yolk, butter, potato or banana to the mix (for young children in particular) or as home-filtered (to remove dust and dirt), boiled milk (for older children in particular). The use of fermented milk and raw milk for children was also described, but reported to be rare. One group said to boil fresh milk for children for three minutes to avoid overcooking of milk and destroying nutrients. Another group explained that they do not give milk to sick children, because milk is believed to reduce drug efficiency. However, several other groups described the practice of giving home-filtered and boiled milk or milk in porridge to sick children. Generally, cow's milk was regarded as an important food that support children's growth and helps to maintain good health; mothers described benefits of milk in children to be good and fast growth, increased body weight, good energy, improved/good health overall, good mental capacity, intelligence and fast learning of children, and protection against diseases. The women explained that cow's milk and dairy products were sometimes not consumed by children, because they did not like them. Another reason mentioned was low purchasing power of the household.

4. Discussion

The PRAs provided insights into a wide range of production constraints and potential solutions as perceived by producer groups. These constraints were partly responsible for substantial fluctuations of milk supply (in some cases combined with a decrease in affordability) reported to occur during the year. While milk availability had a strong influence on milk consumption, findings showed factors such as the consistency of milk, purchasing power and the availability of other foods also influenced consumer choice. In terms of milk quality, there was some awareness of public health hazards among producers, in

particular in relation to sick cattle. However, the majority of producers described sensory quality attributes more commonly related to issues other than food safety, such as adulteration and spoilage. Even though most quality attributes were reported to be associated with public health risks, more emphasis was placed on quality attributes which could affect purchasing behaviour in a negative way. Consumers showed awareness of milkborne disease risks, but said to consume milk regularly even in the absence of food safety attributes described. Moreover, milk was commonly fed to children including the occasional use of higher risk products such as raw milk and fermented milk.

High levels of contamination of milk samples in different points in the value chain were found previously in the RIA programme (aligned with and co-funded by A4NH and the Safe Food Fair Food project) and other studies in Tanzania; these included pathogens, antibiotic residues and antibiotic resistant bacteria (Gwandu et al., 2018; Hyera, 2015; Joseph, 2013; Mohammed et al., 2018; Msalya, 2017; Shija, 2013; Suleiman et al., 2017). Multiplication of microbial pathogens along the chain is deemed highly likely, because there is no cold chain, and transport times were found to be substantial between production and selling point as well as between selling point and consumption (data not shown). The milk quality attribute ranking highest in all consumer groups was hygiene and/or cleanliness. Consumers said that they associated cleanliness with good preparation and consequently less contamination and less disease such as diarrhoea or stomach ache thereby indicating an awareness of milk safety. Also, producers seemed to be aware of some foodborne disease risks stating that there was a risk of public health hazards if milk from sick cows was consumed. Despite this knowledge and awareness, consumers would even buy products of low quality or perceived low safety. Likely reasons for this behaviour are the perceived benefits of milk for children that outweigh concerns on food safety (e.g. good growth, health and learning); high demand for milk and milk shortage in the market for most parts of the calendar year, and the absence of alternative foods for consumption (particularly during periods of low food availability).

The availability of milk and other foods was reported to follow closely the rainfall pattern highlighting the dependence on the natural environment including pasture and grazing. Participants described generally low milk production during the dry season – a time when consumers food affordability is low due to limited agricultural production overall. In the months of low food supply, some households would import mainly staple foods such as cereals (grains e.g. maize, rice, sorghum) and beans from other areas, in particular from urban centres and other, more fertile districts. However, various people described poor marketing and supply chains and that in period of low production, not enough food was available in the marketplace.

Consequently, opportunities may lie in diversification in dairy products and long-life (processed) products. The import of milk powder or production of milk powder in-country during times of high supply could support continuous processing and supply of such products. Processing has the advantage of extending shelf-life and increasing stability of supply. However, apart from butter, ghee, and fermented milk, processed dairy products are consumed very rarely in rural areas in Tanzania. Fermentation of milk is a traditional method used to

address quality deterioration and food safety risks associated with a lack of cold chain (Gershon and Ssemakula, 2017; Jans et al., 2017). Given that only a very small proportion of households has access to (stable) electricity, cold storage at the level of the household that would limit microbial growth is not possible for the majority of rural producers and consumers. This is also an important factor in post-harvest losses, as evening milk is often not accepted by collection centres the next day due to the low quality. New technologies for cold storage such as the SimGas biogas milk chiller that provides off-grid, biogas-powered milk cooling on-farm (<https://simgas.org/projects/biogas-milk-chilling/>), or the solar cooler developed by Mueller (<https://uk.paulmueller.com/solar-cooler>) have the potential to reduce microbial growth and spoilage and decrease post-harvest losses. They may also open new avenues for processed products in rural areas. Other opportunities consist in novel approaches to milk collection centres that have a better infrastructure including cooling systems. The FAO explains in a recent report that if such centres are owned and operated by milk producer groups, associations or the private sector they can be profitable with effective management and governance (Moffat et al., 2016).

However, improved storage and processing would depend on a steady supply of milk – a problem in the current system where smallholders dominate and have strong seasonal milk production. A wide range of diverse production constraints related to knowledge, inputs, the environment, capital, markets and diseases was listed by producer groups indicating that multiple intervention points are required if production is to be increased substantially. For example, most producers were keen on some form of continuation of the heifer-in-kind scheme, such as the Southern Highlands Dairy Development Project SHDDP, Tanga Dairy Development Project (TDDP), Kagera Dairy and Development Trust (KADADDET), which were shown to improve breeds and give farmers a form of capital (Msangya, 2013; Njombe et al., 2011; Njombe and Msanga, 2007). They also address the lack of improved dairy cow breeds and capital. The schemes can continue for a very long time and can be seen as a type of revolving credit scheme (Afifi-Affat, 1998). A slightly different form was introduced by the Tanga Fresh dairy company known as a scheme to take loan in a form of cattle with repayment through selling milk at the collection centre, called “*Kopa Ng’ombe Lipa Maziwa*” in Swahili. Producers can join the producers’ association in which an individual farmer is required to pay a monthly contribution for a period of 18 months that could be enough to buy an improved dairy cow. If an individual has no money, he/she needs to deliver milk to the collection centre that will cover the monthly fee. This system addresses several of the issues raised in the PRAs, namely a more regular market for the delivery of milk, quality control, and provision of an in-kind loan for improved dairy cattle. Nonetheless, it does not address the problem of cattle diseases, lack of feed or water shortage. Producers requested more land or better management thereof, access to training and the construction of dams or reservoirs to store water. They thought that this was something to be addressed by the government, NGOs and farmers. Competition for water and land causes a trade-off between production of ASFs and crops, in particular staples. Further, low feed implies low milk production, which may increase the risk of adulteration of milk or unhygienic production to save on production costs. These issues become more urgent with increasing population growth, a higher demand for meat, and increasing animal populations. Some farmers in intensive systems reported feeding crop residues to their cattle (e.g. feeding livestock with maize bran as a by-product of the milling machines), which may be an option to ease some of the pressure created by competition for land.

Several training initiatives were described as well, but producers said that there was limited application of the knowledge and that they needed more training and knowledge transfer. The limited application of knowledge is associated with factors such as cost or affordability of technologies, complexity of some technologies, cultural barriers, and lack of awareness of some technologies, among other factors. Skills training, recognition of local resources and knowledge, peer-learning

and exchange and social organisation may create new opportunities to tackle issues of feed, reproduction, genetics, animal health management and hygiene. So far, the development of the dairy sector in Tanzania has been hampered by ineffective regulation mechanisms that create complex tax burdens and hinders the development of specialised dairy farms and milk processing plants. The Tanzania LMP was planned in 2017 by MALF and ILRI and funded by BMGF; it provides a range of strategies for development of the sector (Michael et al., 2017). It encourages investment interventions for better genetics, feed and health services supported by relevant policies. According to the report, an investment of USD 621 million is needed by the livestock sector of Tanzania to increase successfully its contribution to GDP and employment.

Milk collection centres as private enterprises can already enforce private standards, for example measurement of the water content using lactometers, organoleptic checks, inhibitor tests to check whether the product is free from residues, and Resazurin test (i.e. addition of a dye to milk that changes colour depending on the microbial activity) to assess the bacterial load in milk. These could be supported by incentives (e.g. higher price for high quality milk) and disincentives (e.g. penalties for adulteration or residues). However, penalties can be detrimental for food safety if producers and retailers tend to sell adulterated milk through informal channels to avoid penalties instead of improving quality. One of the problems reported with such schemes in the past was that rejected milk was sold privately to households or restaurants. To avoid this happening, collection centres could keep the milk at a low price and find uses that would not require highest quality (e.g. production of animal feed after heat treatment).

Hence, this study showed that there are multiple production constraints in the dairy value chain in Tanzania that can be addressed by capital development and capacity building schemes as well as the provision of infrastructure. With the implementation of the LMP, several of the constraints described and solutions suggested are expected to be addressed with the potential to better food security, health and the welfare of smallholder dairy producers. However, because of the public health risks mentioned and the reported purchasing and consumption of sub-standard cow’s milk, a cross-sectoral approach is recommended that also supports food safety policies to promote public health.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.gfs.2019.01.006>.

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