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Title page

Integrated food safety and nutrition assessments in the cattle dairy value chain in Tanzania

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Abstract

The consumption of even small amounts of animal-source foods has the potential to improve nutrition, especially in vulnerable households. However, scaling up their production bears food safety risks that are often overlooked due to a disconnect between human nutrition and animal sciences. The aim of this scoping study in Tanzania was to identify opportunities for nutritional and food safety benefits from cow milk.

Questionnaires were administered to 156 producers and 157 consumers in 10 villages in Lushoto and Mvomero districts. Farmers reported that veterinary medicines such as oxytetracyclines, penicillin and streptomycin were frequently given to cattle, and a majority did not discard milk during or after treatment. Less than half of the producers boiled milk, although sale of fermented milk, made by spontaneous fermentation of raw milk, was common. Cattle management was characterised by low levels of biosecurity, hygienic practices and disease control. A majority of consumers reported not to have enough food to meet their family needs. The Food Consumption Score was acceptable for all households, but significantly higher for households with dairy cattle. When making purchasing decisions, the appearance of milk and trust in the supplier were more important considerations than hygiene practices observed. A total of 26% of consumers reported to consume raw milk “usually” or “sometimes” and 54% of consumers reported to drink fermented milk “usually” or “sometimes”. Consumers had a positive attitude towards milk and concern for quality but most thought there was no risk of illness from milk consumption.

The findings promote understanding of the complexity surrounding the local food environment and practices related to the production and consumption of dairy products and allow shaping recommendations for nutrition-sensitive livestock interventions.

Keywords

Dairy value chain, Tanzania, food safety, food security

1. **Introduction**

Livestock value chains support the livelihoods of millions of rural and urban poor and can act as pathways out of poverty (Hawkes and Ruel, 2006; Randolph et al., 2007; Upton, 2004). Animal source foods (ASF) are important sources of micro and macro nutrients and even regular consumption of only small amounts have been shown to improve growth, physical activity and cognitive function (Neumann et al., 2003). But at the same time ASF can be an important source of food-borne disease (Grace, 2015). Interventions to develop ASF value chains need to consider explicitly impacts on food safety and quality, nutrition and livelihoods to avoid policies that improve one aspect, but negatively impact another. Food quality can be defined as "all those characteristics of excellence that make it acceptable to the food buyer" (Ferree, 1973), encompassing both objective and subjective factors (Grunert, 2005). Food safety is concerned with the production of food that does not pose a threat to human health (Henson and Traill, 1993), traditionally considering biological (e.g. bacteria, viruses), chemical (e.g. veterinary drug residues, disinfectants), or physical hazards (e.g. plastic, metal, bone) that can cause adverse effects in humans if consumed (FSA, 2009).

In Sub-Saharan Africa, the majority of meat, milk, eggs and fish is sold in informal markets, where food safety regulation is not available or often poorly enforced. Consequently, microbial and chemical hazards in food (e.g. brucellosis, tuberculosis, salmonellosis, chemicals, mycotoxins, antimicrobial residues) are commonly identified in studies investigating them (Alonso et al., 2011; Kikuvi et al., 2010; Namanda et al., 2009; Paudyal et al., 2017), even though the risk to consumers is not always high due to mitigating practices such as cooking (Grace et al., 2010). Diarrhoeal diseases are one of the main causes of morbidity and mortality from infectious diseases (Murray et al., 2012); in 2010 the global burden of foodborne disease was estimated at 33 million Disability Adjusted Life Years with the highest burden falling on the African, South-East Asian and "Eastern Mediterranean D"[1] sub-regions (Havelaar et al., 2015). Many food-borne diseases go underreported without laboratory confirmation. The full extent of the burden and cost of unsafe food is therefore unknown. It is

[1] Afghanistan; Djibouti; Egypt; Iraq; Morocco; Pakistan; Somalia; South Sudan; Sudan; Yemen

estimated that diarrhoea alone is the cause of mortality in 1.9 million children a year, with a significant proportion of these cases due to food- and water-borne disease (WHO, 2008).

Concerns over food safety among consumers in low income countries can lead to reducing ASF consumption with marked structural changes in elasticity (Kraipornsak, 2010), changing to outlets perceived as safer (ILRI, 2010) or cleaner (Otieno and Kerubo, 2016), asking retailers for health certificates (ILRI and DVS, 2008), or a willingness to pay for safer food products (Alphonce and Alfnes, 2012). On the other hand, improving availability and accessibility of even small amounts of ASF helps to ensure that diets include sufficient quality protein and micronutrients particularly for vulnerable populations (Iannotti et al., 2017, 2014; Randolph et al., 2007). These population groups often depend on the competitive prices offered by the informal sector. Consequently, common calls to tackle problems of food safety and disease by moving to Northern-style agro-food systems that are commonly characterised by processing and cold chains, can create unintended consequences in that they may decrease the availability and affordability of ASF for poor population groups (Grace, 2015). Moreover, large numbers of small informal sectors actors who are difficult to monitor or train in combination with ineffective rules, regulations, and governance hinder upgrading of informal sectors (Grace, 2015).

Milk contains energy, readily-digestible protein and bio-available micronutrients such as calcium, magnesium, phosphorus, potassium, selenium, zinc, thiamin (vitamin B1), riboflavin (vitamin B2), and vitamin B12 (cobalamin) (Latham, 1997). Milk alone is a good source of many of these micronutrients and populations that consume large amounts of milk along with other foods seem to have fewer micronutrient deficiencies, as observed for example in pastoralist populations in Kenya (Fratkin et al., 2004; Fratkin EM, Roth EA, 1999) or in school children in Kenya where vitamin B12 plasma concentrations were improved with milk supplementation (McLean et al., 2007). While highly nutritious, it is at the same time highly perishable and an ideal growth medium for microorganisms (Schoder et al., 2013; Swai and Schoonman, 2011).

The dairy sub-sector in Tanzania, as in other East and Central African countries, is dominated by informal markets, which handle 80-90% of all milk sold (Swai and Schoonman, 2011). Milk production is predominantly rural and is divided between two types of production systems, namely extensive and semi-intensive/intensive systems. Extensive systems are characterised by displacement of cattle from one place to another in search of fodder (seen in pastoralist or agropastoralist contexts), intensive systems by cutting and carrying of fodder and supplementation, and semi-intensive systems by a combination of grazing and stall feeding. Milk production is pre-dominantly rural with about 95% of all cattle in the country (predominant breed is the Tanzania shorthorn zebu) raised extensively by pastoral and agro-pastoral farmers (Msalya, 2017). Milk is sold either in rural areas, mainly to neighbours and local restaurants, or in the neighbouring urban centres to obtain additional income; the volume of milk imports match local production (Kurwijila et al., 2012). There is abundant feed during the “long”, intense (March to May) and short, less intense (between October and December) rainy seasons, leading to high milk production and lower prices. The inverse trend is observed during the dry season (Kurwijila et al., 2012). Because of low fodder quality, scarcity of land for production, lack of technical knowledge, capital and market chains, feed preservation is limited (Lukuyu et al., 2016). Seasonal milk production, poorly organised marketing procedures, limited processing, transport and storage options, lack of inspection or disease control, and fluctuating prices constitute be hindrances to the commercialisation of dairy products (Kurwijila et al., 2012; Msalya, 2017).

A range of studies reported on milk safety in Tanzania. They included concerns over milk hygiene because of a lack of clean water, inadequate transport containers, poor refrigeration and a lack of understanding of hygiene (Schoder et al., 2013); documentation of bacteria in milk samples from milk marketing agents in Tanga city (Swai and Schoonman, 2011), and from smallholder dairy farmers, street vendors and outlet shops in Arusha and Arumeru districts (Lubote et al., 2014). Schoder et al. (2013) tested milk in the regions of Dar es Salaam and Lake Victoria and isolated *E. coli O157:H7* as well as *Salmonella* spp. from a tenth of raw milk samples. However, these were absent in heat treated samples except for coliforms which were detected in 41% of processed milk samples possibly due to recontamination attributable to unhygienic packaging at the plants. In 54 milk samples from cattle owning households, milk collectors, and retailers in ten villages in Tanga region, more than 90% of all handled milk samples were above the East African Community maximum acceptable standard for bacterial total plate counts (Hyera, 2015). In a related study in Morogoro region, milk samples from 82 producers tested negative for *E.coli 0157:H7* and 17.1% were positive for *Brucella abortus* (Joseph, 2013). In another study, 238 out of 328 (73%) raw (fresh) milk samples from the regions Morogoro, Coast, and Tanga in Tanzania tested positive for ten groups or species of bacteria including a range of foodborne pathogens (Msalya, 2017).

Heat treatment is a common strategy to reduce bacterial contamination in milk. Commercial pasteurisation protocols improve milk safety considerably without perceptibly changing the nutritional value of milk (Claeys et al., 2013). However, boiling of milk at high temperatures for a prolonged period of time decreases the nutritional value as vitamins like B12, thiamin, B6 and C get destroyed or reduced; for example heat treatment of skimmed milk at 100°C for 30 minutes caused a loss of vitamin B12 by 86% (Kilshaw et al., 1982). Many rural and urban populations in Tanzania consume raw milk, increasing their risk to zoonotic disease. In previous studies it was found that smallholder dairy farmers claimed to boil milk for home consumption but not the milk for sale; 80% of agro-pastoralists claimed to boil milk whilst the practice was uncommon among pastoralists (Shirima et al., 2003).

To the authors' knowledge, there are no studies available that look at food safety and nutritional gains in the informal dairy value chain in Tanzania in an integrated way. There are several studies that focus on single aspects, such as breeding performance or marketing studies that may affect food and nutrition security, or foodborne hazards at one node in the supply chain but none aims to link producer and consumer practices and perceptions that influence the relationships between food safety and nutrition and the availability and safety of milk. The aim of this scoping study therefore was to conduct a rapid integrated assessment looking explicitly at both food safety and nutritional risks and to get an understanding of trade-offs in the informal dairy value chain in Tanzania with a focus on major constraints to increasing production of milk (e.g. genetics, feed, disease). The objectives were (1) to characterise the production and consumption patterns of milk in the informal dairy value chain in Tanzania, (2) to identify factors influencing its availability and safety, and (3) to describe linkages between nutritional and food safety outcomes.

2. Materials and methods

2.1 General overview

For the purpose of this study, questionnaire surveys were conducted among producers and consumers in Morogoro and Tanga regions, Tanzania. The consumer survey in households (HH) included open and closed questions on the respondent's sex, age, ethnicity, education, role in the household, HH members, HH assets, livestock keeping or work in the dairy sub-sector, household food security, milk purchasing, processing and consumption practices, human illness, and statements to enquire about people's knowledge and attitude regarding milk intake. The producer survey included open and closed questions on the respondent's sex, age, ethnicity, education, number and type of cattle kept, use of inputs, biosecurity, milking and milk hygiene, outputs, and statements to enquire about people's knowledge and attitude regarding milk safety. For all surveys, questionnaires and checklists were developed in English and translated by enumerators to Swahili. The interview protocols and questionnaires were discussed and explained to the enumerators, pilot tested and refined using the feedback provided. The interview team comprised six enumerators who worked in pairs; one asking questions and another recording the answers. The fieldwork was supervised by a senior academic. In addition to questionnaires, enumerators were asked to register their observations of the environment in observation checklists. All instruments are available upon request from the corresponding author. This study was conducted from October 2012 to May 2013.

2.2 Study areas and study sites

The study regions Morogoro and Tanga in Tanzania were selected as part of a long term commitment to research in Tanzania by the International Livestock Research Institute (ILRI) and Sokoine University of Agriculture (SUA). The selection process for the regions, districts and villages is documented in detail here: http://livestock-fish.wikispaces.com/Site%20selection. The districts Lushoto (Tanga region) and Mvomero (Morogoro region) were selected after a process of stakeholder consultation and scoping studies to represent rural production to rural consumption and rural production to urban consumption (Lukuyu et al., 2012) with a representation of different human and livestock population densities, income, market access, consumption patterns, and livestock production systems.

Within each district, a longlist of 35 cattle keeping villages was created in consultation with district livestock officials. Based on the density of cattle keeping households and available information on potential research impact and ease of assistance for the research, a shortlist of 25 suitable villages was created. 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 (Supplementary Material 1).

2.3 Producer survey

With a 95% confidence interval, a margin of error of 5% and assuming a design effect of 2, the targeted number of producers to be interviewed in the 10 villages was 300, i.e. 30 households per village. Enumerators obtained a list of producers per village from the local livestock field officer from which 30 producers for the interviews were randomly selected using Microsoft Excel random number generator function. Enumerators contacted the households and scheduled visits with the producers obtaining the contact details from the district livestock officer. Where the cattle owners were not available, another adult person in the household with knowledge of the livestock enterprise was interviewed. In villages where not enough producers were available for interview, as many producers as available were included in the sample. Structured interviews were conducted to collect data using the relevant questionnaire. Oral informed consent was obtained from each participant.

2.4 Consumer survey

The sample size calculation for the consumer survey was based on the following key indicator estimates: Prevalence of a key hazard – unknown, anticipated 50%; proportion of milk and dairy products in diet by weight – unknown, anticipated 5%; self-reported gastro-intestinal illness in last 2 weeks – unknown, anticipated 10%. With a 95% confidence interval, a margin of error of 5% and assuming a design effect of 2, the targeted number of households to be interviewed in the 10 villages was 300, i.e. 30 households per village. Enumerators obtained a list of households per village from the local livestock field officer from which 30 households for the interviews were randomly selected using Microsoft Excel random number generator function. They contacted the households and scheduled visits with the head of the household or any other person authorised to talk to the enumerators. Consumers were interviewed separately from producers by two distinct groups of enumerators on the same day to avoid overlap in respondents. Structured interviews were conducted to collect data using the relevant questionnaire. Oral informed consent was obtained from each participant at the beginning of the interview.

2.5 Ethical approval

The sampling protocols were granted ethical approval from the ethics committee of the Royal Veterinary College, London, UK (reference number URN 2012 1191), the Sokoine University of Agriculture (reference number SUA: SUA/ADM/R.1/8) and the ILRI Institutional Research Ethics Committee (reference number ILRI: IREC2013-03). Because no biological samples were taken from living animals or people or exported to another country, no further approvals or permits were needed.

2.6 Data handling and analysis

The questionnaire data were entered into a Microsoft Excel spreadsheet. Data cleaning was performed to exclude data that were contradictory, or duplicated. A respondent was excluded from the analysis at the village level if the village names or coordinates were not given, but was kept for the district analysis. Contradictory answers by individual respondents were recorded as invalid values and not included in the analysis. For questions with check-lists, an answer was considered valid if at least one box was ticked.

Obvious spelling mistakes were corrected and differing ways of spelling for the same item were changed to one; synonyms were listed as one category. For open questions, answers were categorised according to characteristics defined by the analyst using professional judgment and/or official resources. Where many people gave similar answers under "other" in check-lists, new categories were formed.

The Food Consumption Score (FCS), a composite score based on dietary diversity, food frequency, and relative nutritional importance of different food groups was used to measure food security following the World Food Programme guidelines (World Food Programme, 2008). All the food items from the seven-day recall were grouped into specific food groups as defined in the FCS (Electronic Supplementary Material 2) and the sum of consumption frequencies was made and recoded with a maximum value of 7 days/week for each food group. The Food Consumption Score was calculated for the household and for the index individual. The index individual was the female or male person more vulnerable to food insecurity in the household; either the youngest child between 2 and 5 years of age, or an adult woman if there was no child in the household. The FCS was calculated as follows:

$$FCS = a_{staple}x_{staple} + a_{pulse}x_{pulse} + a_{veg}x_{veg} + a_{fruit}x_{fruit} + a_{animal}x_{animal} + a_{sugar}x_{sugar} + a_{dairy}x_{dairy} + a_{oil}x_{oil}$$

Where

x_i Frequencies of food consumption = number of days for which each food group was consumed during the past 7 days by the household or by the index individual.

a_i Weight of each food group

The thresholds used for FCS were poor (score from 0-21), borderline (21.5-35), acceptable (> 35) based on the recommendations made by the World Food Programme (2008); no context specific adjustments were made.

Descriptive and inferential analyses were conducted using IBM SPSS Statistics for Windows, Version 21.0 Armonk, NY: IBM Corp. Fisher's Exact test or Pearson's Chi square test were used to determine the statistical significance between the categorical outcomes of two groups, for example when studying each variable by district. For continuous variables such as the Food Consumption Score or expenditures for health problems, parametric methods such as the independent t-test to compare means between two groups, and One Way ANOVA to compare means among three or more groups, were used when the distribution was normal. Their equivalent non-parametric methods Mann-Whitney U test and Kruskal-Wallis H were conducted when the data were not normally distributed. Univariate and multivariate ordinal logistic regression models were used to compare frequencies of milk and milk products sale channels as well as knowledge, attitude and practices in producers. Explanatory variables included in the univariate analysis were district, village, ethnicity, use of antibiotics, use of oxytetracyclin, source of drugs (government officer, pharmacy), discarding milk while/after antibiotic treatment, uses of milk from sick animals (home consumption, sale, animal feed, discard), practices in case of clinical mastitis (stop milking, give milk to calves, sell milk, consume milk), pre-storage treatment (boil, filter, no treatment), sale of raw or boiled product, and sales channels. Variables with a p-value <0.05 were included in the multivariate analysis. A back-ward stepwise elimination process was used to remove variables whose multivariate p-value was ≥0.05. The models were fitted through maximum likelihood estimation.

3. **Results**

A total of 156 producers and 157 consumers, respectively, were interviewed; six interviews had to be discarded for the village level analysis. The demographic data for producers and consumers interviewed are summarised in Table 1. In Lushoto, Islam was found to be the predominant religion (around 75%) among both consumers and producers and the most prevalent ethnicities were Sambaa, with 83% of producers and 84% of consumers, followed by Pare (14% of producers and 9% of consumers). In Mvomero, Christianity was the most common religion (80%) and a wider range of ethnicities was reported: 50% of producers and 16% of consumers were Maasai, followed by Zigua (14% of producers and 20% of consumers), Chaga (12% of producers) and Luguru (19% of consumers).

3.1 Characterisation of dairy production and producers

Out of 144 valid responses in the producer group, the majority of respondents were cattle owners, followed by wives, other household members and workers. Key cattle herd and production characteristics are shown in Table 2.

More than half of the producers (55%) reported to use some degree of pasture; either by grazing the animals in the field (32%) or providing green fodder (68%). Further, 31% said to use legumes, 27% hay, and 34% concentrates. Concentrate feed was used by 40% non-Maasai respondents while only one Maasai respondent reported this practice.

When asked about routine practices, 89% of producers reported administering some kind of treatment to their animals. The use of antibiotics was mentioned significantly more often in Mvomero than Lushoto districts (81% vs 61%, p=0.0148) and by 100% of Maasai respondents. The most common reported antibiotic was oxytetracycline (significantly different by ethnicity and district, OR=11.63, p-value=0.000), followed by penicillin and penicillin/streptomycin. Vaccination was used by less than the half of the producers and only by three Maasai respondents; the immunisation against viral diseases such as foot and mouth disease, lumpy skin disease, or contagious bovine pleuropneumonia was found to be infrequent. Half of producers from Mvomero and 18% from Lushoto used anti-parasitic drugs. Measures against trypanosomiasis were only listed in the villages of Kidudwe, Lusanga and Wami Dakawa. The most common sources for treatment were private veterinarians (43%), government services (44%) and dispensaries (27%). At the district level, respondents from Lushoto relied significantly more on government services and on livestock officers' knowledge than those from Mvomero (60% vs 15%, p-value=0.000). Mvomero respondents acquired treatments significantly more often from pharmacies than producers in Lushoto (48% vs 16%, p-value=0.000).

Asked whether they acquire new dairy stock, nearly two thirds of producers (88% of the Maasai producers) said yes. The main route of obtaining cattle was by purchasing (66%); 5% reported bartering. Acquiring cattle as gifts and dowries was more common among Maasai producers (32% and 23%, respectively, compared to 4% and 1% in non-Maasai producers). Neighbouring farms were the most common source of new stock (69%). Sourcing animals from markets was significantly more frequent among Maasai (68%) than other producers (10%); markets were a source to obtain predominantly local cattle (55%), followed by cross-bred cows (40%). Other acquisition sources such as commercial farms, development projects, or calving in family holdings were much less frequent. Almost 75% of respondents obtaining new stock required health checks, commonly based on the observation of general physical appearance (90%), signs of ill health (e.g. rough hair coat) or specific diseases such as brucellosis, foot-and-mouth disease or trypanosomiasis (25%), or emaciation status (9%). A total of 26% producers quarantined new animals for varying amounts of time. In Lushoto, the quarantine length reported was an average of 24 days (n=14 min=0.5, max=90, SD=27.97) while in Mvomero it was 55 days (n=4, min=1.5, max=120, SD=59.49). During that period two thirds of those using quarantine stated to check physical signs of body development, feed intake, general health status, and occasionally piroplasmosis.

Fig. 1 shows producers replies regarding potentially risky practices for food safety, such as not discarding milk during antibiotic therapy. When asked about practices in relation to sick cows, almost 40% of producers reported to consume milk at home, 16% to sell the milk and 16% to give it to calves. All Maasai producers said that they never throw milk away, but rather consume it at home (72%), sell it (36%) or give it to calves (20%).

The most common reasons reported by respondents that stated to throw the milk away, stop milking or leave it for other animals (n=56), were clinical mastitis (59%; not mentioned by any Maasai respondent), followed by East Coast Fever and other piroplasmosis (25%), trypanosomiasis (20%), and respiratory problems (9%; more often mentioned among Maasai). Mastitis checks were performed by 80% of respondents (n=143), with visual observation being the most frequent method (60%) followed by palpation (30%). More than 50% of producers from Mvomero and 30% from Lushoto reported to discard the milk from infected quarters.

Almost all respondents hand milked their cows; 11% of respondents did so without cleaning the udder. Less than half of the producers mentioned to boil or filter the milk before storage. Respondents from Kidudwe and Lubungo (both Mvomero district), and Manolo (Lushoto district) reported the longest median milk storage times of 7 to 12 hours, which was significantly different from other villages which reported 0.5 to 2.5 hours (p=0.000).

Overall, 93% of respondents (n=150) stated to sell milk or milk products either as raw, fermented or boiled milk or ghee through different sales channels , with raw milk sales being most common.

Table 3 shows the significant explanatory variables for each sales channel. Producers that tend to sell milk from sick animals were more likely to sell often to retailers (OR=3.76, CI 95%=1.29-11.11) than respondents that do not sell milk from sick animals. None of the respondents sold their products to supermarkets while few producers (4%, from Kidudwe and Ngulwi) sold to restaurants.

Fig. 2 and Table 4 illustrate knowledge and perceptions among producers and potential predictors for food safety and food security relevant practices. Maasai producers that get drugs from private veterinarians and producers that stop milking when the quarter is infected were less likely to know about the effect of potential hazards for consumers related to milk and milk products from cows under treatment. Producers that sell milk from sick cattle were more likely to think that milk from cows under treatment cannot affect consumer. Respondents whose farms underwent business inspections and those that filtered milk before storage were more likely to agree that consumers would refuse non-high quality products. Maasai producers expressed more difficulties in the accessibility to customers, compared to the rest of the respondents.

Checklist data of producers' biosecurity, workers' conditions, storage conditions and management protocols are summarised in Fig. 3.

3.2 Characterisation of consumers

A third of the respondents were head of the household (of which 20% were females), 38% were mother of the head, and the rest were other family members. Demographic information is given in Table 1. The median number of inhabitants was six (min=2, max=19, IQR=3). Adult females (over 18 years old) were present in 96% of the households, while children under 5 years old in 50%.

More than 75% of the households (n=155) declared they participated in crop-farming activities. It represented the only activity for half of them while the other half mentioned other income-generating activities, such as animal keeping (15%) or non-agricultural business or trade (7%). More than a quarter of all respondents kept animals, 23% did non-agricultural business or trading while 5% mentioned agricultural trading and 8% unemployment.

Asked about cattle ownership, 32% of all consumer respondents said that they own cattle with a significant difference between districts, namely 22% in Mvomero and 41% in Lushoto district (p-value=0.009). In Mvomero, the proportion of cattle owners by village was between 0% and 42.9% and in Lushoto between 14.3% and 68.8%. A significantly higher number of households in Lushoto district had a small number of cattle with a median of one cow (n=34, min=1, max=4, IQR=1), compared to Mvomero, where the herds appeared to be larger with a median of 8 cows (n=12, min=1, max=55, IQR=37).

A total of 77% of the consumers reported to “not have enough food to meet the family needs” at some point during the year (Fig. 4). There was a significant difference at the district level with 66% of households in Mvomero, and 87% of households in Lushoto suffering from lack of food ($p<0.05$). The most affected villages were Handei (100%), Manolo and Mbokoi (94% each) (all Lushoto district).

A total of 126 households (%) answered the dietary consumption questions. Of the index individuals, 63% were females and 37% were males, the median age was 11.5 years (min=0.25, max=72, IQR=35.25). The FCS was found to be above the threshold for undernutrition of 35 for all households. Differences were non-significant by district, but significant differences in the FCS of the index cases were found between Mlandizi (FCS=96), Manolo and Wami Dakawa (FCS=150-145), (p-value<0.05) (Table 5). There was a significant difference (p-value=0.000) in FCS between dairy cattle and non-dairy cattle owning HHs: The median FCS-HH for cattle owners was 139 (min=72, max=217, SD=34.22) and for non-cattle owners 112 (min=38, max=207, SD=39.39); the median FCS-Index was 141 (min=56, max=217, SD=33.98) for cattle owners and 113 (min=14, max=207, SD=39.91) for non-cattle owners.

Regarding the question how consumers judge the milk quality (n=155), colour (45%), trusted supplier (45%) and viscosity/density (39%) had a high and similar importance among consumers. Odour was considered to be important by 26% of consumers in Mvomero, but only by 5% in Lushoto. Similarly, 39% in Mvomero and

18% in Lushoto indicated taste as an important criterion when purchasing milk. Hygiene or safety aspects were generally regarded as a factor of minor importance in both districts.

The most common routes and sources of purchasing milk and products are shown in Fig. 5. Overall, the main way of acquisition was by purchasing (>70%), followed by the production in own farm.

Boiled milk was the product reported to be consumed most frequently (85%), followed by chai, i.e. tea with raw milk (63%), and fermented milk. All villages reported at least occasional consumption of raw and fermented milk; 25.5% of consumers reported to consume raw milk "usually" or "sometimes" and 53.5% of consumers reported to drink fermented milk "usually" or "sometimes" (Fig. 6). A total of 85% of consumers (83% in Lushoto and 87% in Mvomero) reported to consume boiled milk "usually" or "sometimes".

Most of the consumers (89%, n=124) reported to transport the milk in their own container. The most common material was plastic (92%), only 6% used traditional clay pots. The median transportation time was 0.25 hours (n=102, min=0.02, max=53.00, IQR=0.33) with a median storage time of 0.5 hours (min=0.03, max=53, IQR=1.8). The most reported occasions of hand washing were before eating (84%), after going to the toilet (60%) and after cooking (60%). Some of the respondents stated to clean their hands after other dirty activities (20%) or before feeding the children (28%).

More than a third of consumers (n=150) stated that someone in the household had health problems in the two weeks previous to the interview. Of those 52 households that reported problems, 35% described flu-like symptoms with general malaise, 29% malaria, 15% diarrhoea, vomiting, and/or stomach pain, 17% respiratory problems, 6% skin rash, 6% blindness, and 10% other symptoms such as ear problems, eclampsia or heart disease. Among the consumers that reported health problems in the household, 8% did not seek any treatment.

Fig. 7 illustrates knowledge and perceptions related to dairy consumption showing that almost all consumers believed that milk is good and has a high nutritional value. Only around 31% of consumers (n=143) agreed that milk can be a cause of sickness.

4. Discussion

In this descriptive study food security and food safety aspects in the dairy value chain in Tanzania were assessed taking into account producer and consumer knowledge, attitudes and practices.

Food security

Food security indicators (FCS of the household and index) were acceptable for all households, but higher in cattle keeping households indicating that cattle ownership has potential to impact positively on food security through either the income pathway or own (household) consumption of milk. The FCS estimated for Morogoro region were higher than in a study in 2012 where acceptable values were 73% for the planting season, 75% for the pre-harvest season, and 83% for the post-harvest season (Lambert and Biesalski, 2015). Repeated measurements of the FCS in the study villages would provide a more accurate picture of the fluctuations throughout the year.Generally, there was a widespread belief in the “goodness” of milk and a readiness to consume more milk implying that an increase in production could help to promote food and nutrition security. However, because of the common practice of selling raw milk directly to consumers and milk collectors and frequent consumption of raw or fermented milk, upscaling of dairy production should not be promoted unchecked, but take into account cooking practices and food safety risks to consumers.

The low average daily milk production and best cow milk yield found in this study indicate challenges in terms of supply. Such low production is likely caused by several factors. First, local or indigenous cattle – which were predominantly kept by study participants - are characterised by very low production levels and are the main breed in Tanzania (Ministry of Livestock and Fisheries Development, 2011; Njombe and Msanga, 2007). Indigenous cattle are resilient and able to endure unfavourable climatic conditions and infectious diseases, while pure bred or improved cattle are more productive, but also more sensitive to many infectious diseases and extreme climatic conditions. Complementary information gathered (data not shown) illustrated how producers generally admitted to be unable to afford and keep pure bred cattle. Second, the lack of technology, especially poor control of infectious diseases such as brucellosis or tuberculosis, affects the performance and is a direct cause of infertility and reduced production. Similarly, management of resources such as feed or water impacts substantially on production. While green fodder (grazing and cut fodder) was described in this study to be used by almost all producers, concentrates were used primarily by non-Maasai.

Concerns about the lack of grazing land and climate change in combination with unaffordability of concentrates severely constrains the potential for upscaling dairy production both in pastoralist and more sedentary systems.

Despite the low productive performance and an increasing demand, Maasai reported difficulties to access markets and find customers, more so than other producers. These problems are commonly exacerbated during wet seasons when the milk production is generally higher (Kurwijila et al., 2012). This can lead to reduced income for these populations and therefore jeopardise household food security by reducing access to food. Maasai and Mvomero producers in general, reported to sell products predominantly directly to consumer or to retailers and use informal channels, which was different from Lushoto where more formal channels were used too.

Food safety

Milk and dairy products due to their biological and perishable nature, constitute a potential source and vehicle for pathogens that can cause food-borne diseases in consumers. Risky practices were frequent among some producers in the study, such as home consumption and sale of milk from sick animals. A majority of producers indicated that buyers would not just buy any milk, but refuse milk of insufficient quality, which was reflected in the consumer survey, where people described the quality criteria they use to assess whether the milk is of adequate quality, such as smell or consistency or trust into a seller. However, only 30% of consumers showed awareness of the potential negative impact of milk consumption on health due to food-borne hazards. In the absence of controls for quality and safety, consumers need to rely on sensory attributes or on trust relationships with providers they know. Dairy value chain actors recognising such demand from consumers may consider implementing stricter milk quality and safety standards. It is important to note that hazard occurrence in (fresh) milk does not mean that there is always a risk for the consumer. Heat treatment of milk (e.g. boiling) is known to reduce substantially the bacterial load in milk, even though it is no guarantee for a safe product.

Another important challenging aspect identified in this study were limited levels of biosecurity and hygiene as well as regular use of antimicrobials without observation of withdrawal periods. While antimicrobials have an important therapeutic function and contribute to animal health, welfare and productivity (Bengtsson and Greko, 2014), resistance can develop if they are not used prudently (Ungemach et al., 2006). This includes consumption of milk or selling milk for human consumption during or after antimicrobial therapy as reported by producers in this study. Such practice can lead to development of antimicrobial resistant bacteria with the potential to affect consumers, other animal populations and contaminating the environment (Aidara-Kane, 2012; Chantziaras et al., 2014) including the possibility for resistant pathogens to be found in species that were not treated with the relevant drugs (Dulo et al., 2015). Antimicrobial resistance and prudent use guidelines become particularly pressing topics when considering the use of less disease-resistant dairy cattle breeds to promote increases in productivity, as disease susceptibility may lead to an increase the use of antimicrobial drugs. In food and income scarce settings, farmers will be reluctant to discard milk due to antibiotic residues and thereby reduce food security. This is likely to be of particular importance for pastoralist populations with high milk intake (Iannotti and Lesorogol, 2014). The use of oxytetracyclin was common among Maasai producers. Private veterinarians were reported to be the main source of antibiotics, but the understanding of the term veterinarian was not verified and it may well be that this category included also other related professions such as drug sellers or technicians. Furthermore, a lack of training about food safety and hygienic handling of milk was found. Producers using risky practices, such as the sale of milk from sick animals or milking when the udder presents infection as well as producers using informal supply and sale channels were less aware of the risk that cows under treatment can pose to the consumers' health. While biological sampling was not used in this study, related studies in the same regions documented contamination of milk samples with foodborne bacteria in the dairy value chains including in boiled milk samples thereby demonstrating that the foodborne disease risks were not negligible (Hyera, 2015; Joseph, 2013; Msalya, 2017). Cooking patterns can be a crucial factor in food safety, but consumers interviewed did not seem to be aware of that, as they gave the same importance to the two statements "one can get sick from drinking milk" and "one can get sick from drinking boiled milk". Future studies should look in detail at cooking practices and investigate them in conjunction with biological sampling and data on foodborne disease.

Potential trade-offs food security and food safety

The risky practices found in the producer group stood in stark contrast with a general belief in the goodness of milk. Milk was considered a good and highly nutritious food by almost all consumers and a large number of respondents believed they would consume more in the future. All consumers reported to obtain milk or dairy products for the household thereby highlighting the importance and popularity of this product. All households were found to have values of FCS over the threshold of undernutrition set by the World Food Programme (2008).

Developments in the past two decades have seen growth in the dairy sub-sector in Tanzania with an increase in investments into milk quality and processing industries accompanied by an improvement of regulatory activities (Njombe et al., 2011). Despite this progress, our findings highlight the continued challenges related to productivity, food safety and food security. Productivity deficiencies could be tackled with feeding management and the use of cross-bred cattle with higher production than the indigenous cattle and sufficient resilience to limit the negative impact of endemic diseases. Producers lacking education and knowledge about how their actions impact food safety hazards and risks would benefit from training that aims to reduce hazardous practices. Simultaneously, on the consumer side, people should be made aware of the potential health hazards related to food-borne pathogens and the safe handling of milk and dairy products. Consequently, training, education and capacity building should be offered to both producers and consumers based on an integrated strategy. There is evidence of a positive impact of education training on informal actors of the value chain (Campbell, 2011; von Holy and Makhoane, 2006), which could for example be achieved by investing further into extension services or new technologies reaching farmers (i.e. mobile phones).

Limitations

Despite the positive finding of acceptable FCS in all households, food insecurity in the previous year was reported by a very large number of households, which highlights the limitations of seven-day recall nutrition surveys. To be able to gain an accurate picture of food security, households should be interviewed in regular intervals in a longitudinal study. The type of products obtained did not produce significant differences in the FCS of the household or the index person. This might be due to the fact that the information does not capture the actual amount of product consumed but only the category, i.e. small quantities of dairy intake would also be considered in the FCS. It was not possible to recruit enough people in the villages selected due to pastoralist producers having moved with their cattle to other areas of the country and many potential consumer participants being occupied with work in the fields and not being available for interview. Such effects could also be mitigated with a longitudinal study design.

Conclusions

The ownership of cattle appeared to be a positive factor for food security, since consumers with dairy cattle presented a significantly higher FCS for the household and the index person. Despite the reported growth of GDP, the price of milk was still an important barrier for some consumers, as about two thirds acknowledged that they would purchase more products if the price was lower. While potential for nutritional gains and promotion of food security has been identified, we also documented risky practices for food safety that necessitate further research into household food handling, cooking and consumption practices in combination with biological sampling and data on disease to understand in detail the risk of milk-borne hazards to consumers. Efforts to upgrading the dairy value chain in Tanzania should focus on a multi-intervention, multi-sectorial approach to promote food security and food safety simultaneously.

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FIGURE CAPTIONS

Fig. 1 Reported hazardous consumption practices of producers related to animal disease, antimicrobial usage and use of milk by district and ethnicity

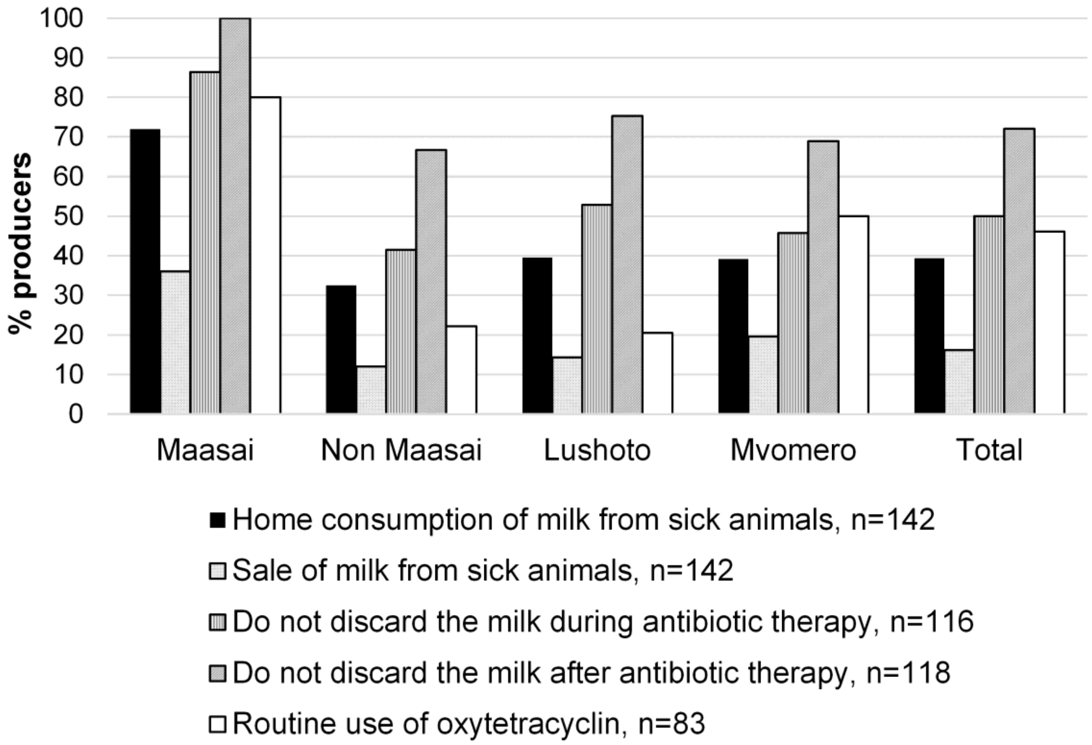


Fig. 2 Knowledge and perceptions among producers about food safety, dairy product acceptance, demand and accessibility of customers

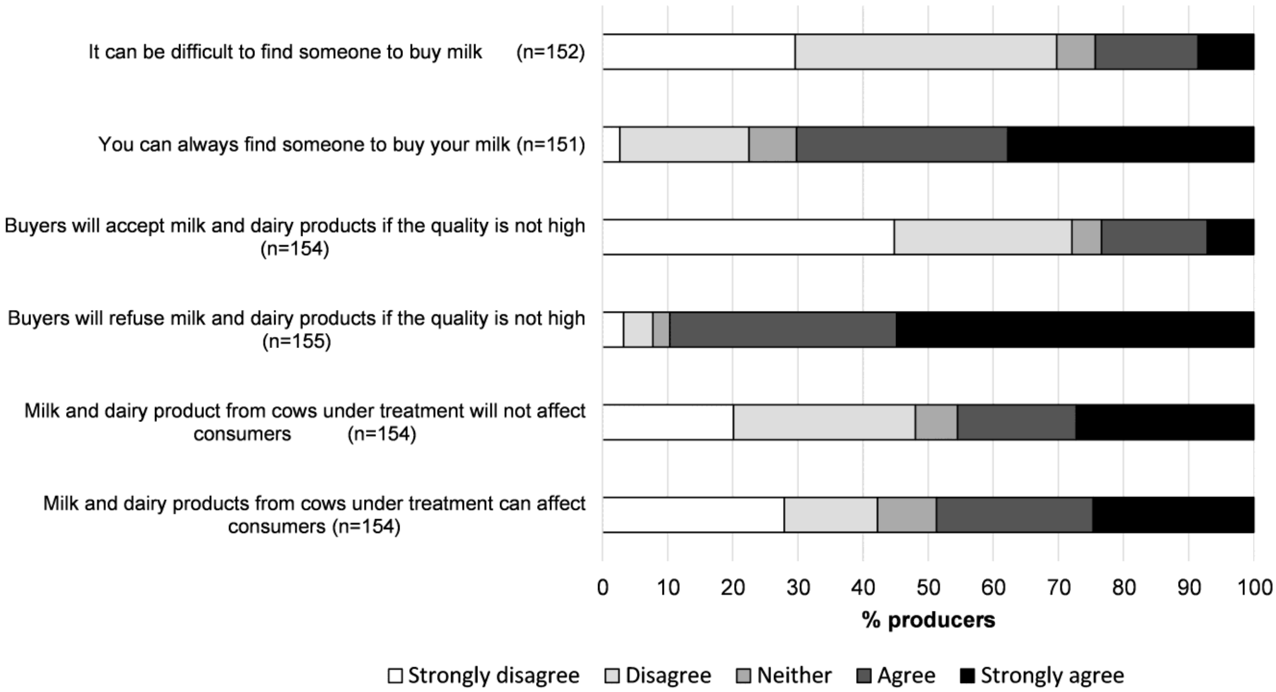


Fig. 3 Observed conditions on dairy farms related to biosecurity, cleanliness, storage, and management protocols

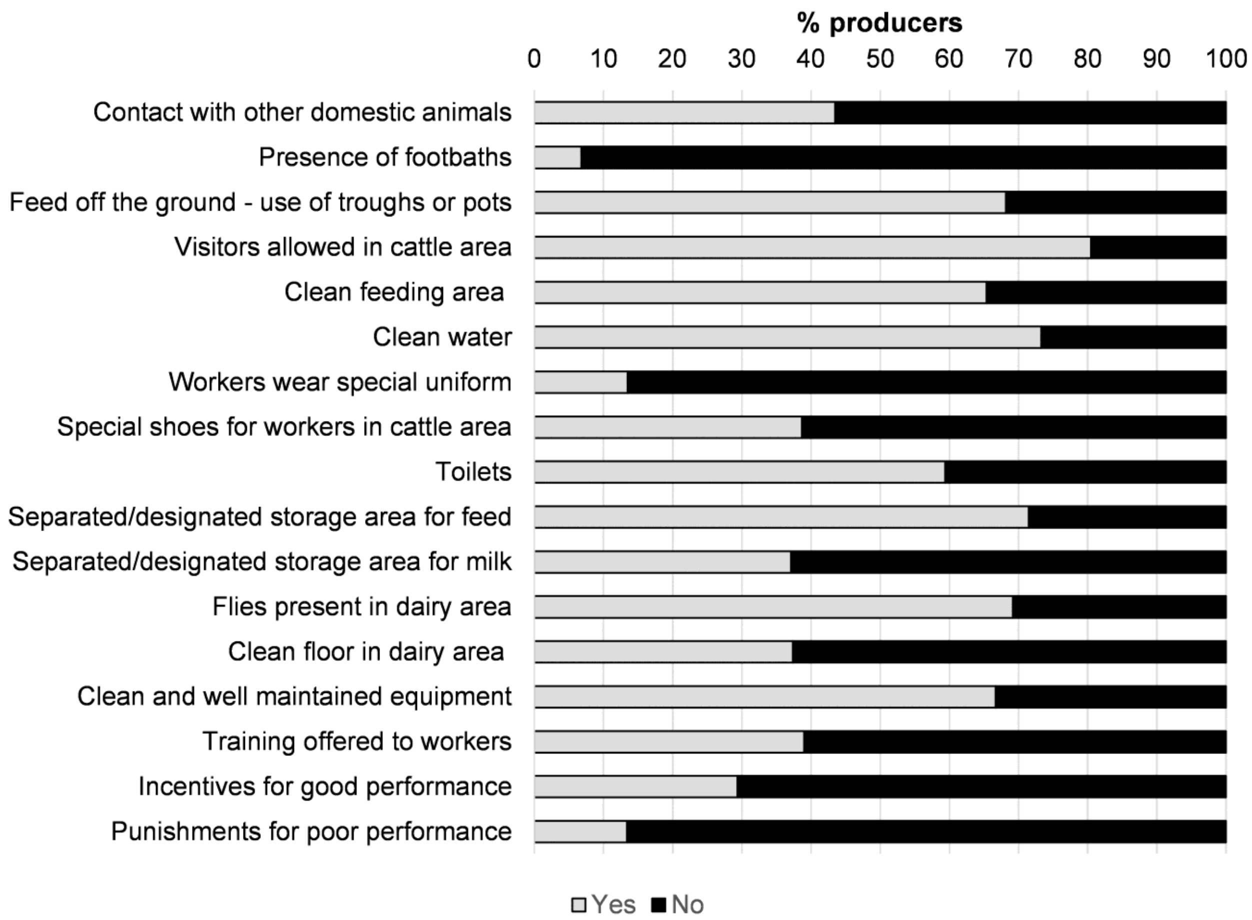


Fig. 4 Food insecurity reported by consumers for the previous year by district and total (n=157). The numbers indicate significant differences between districts

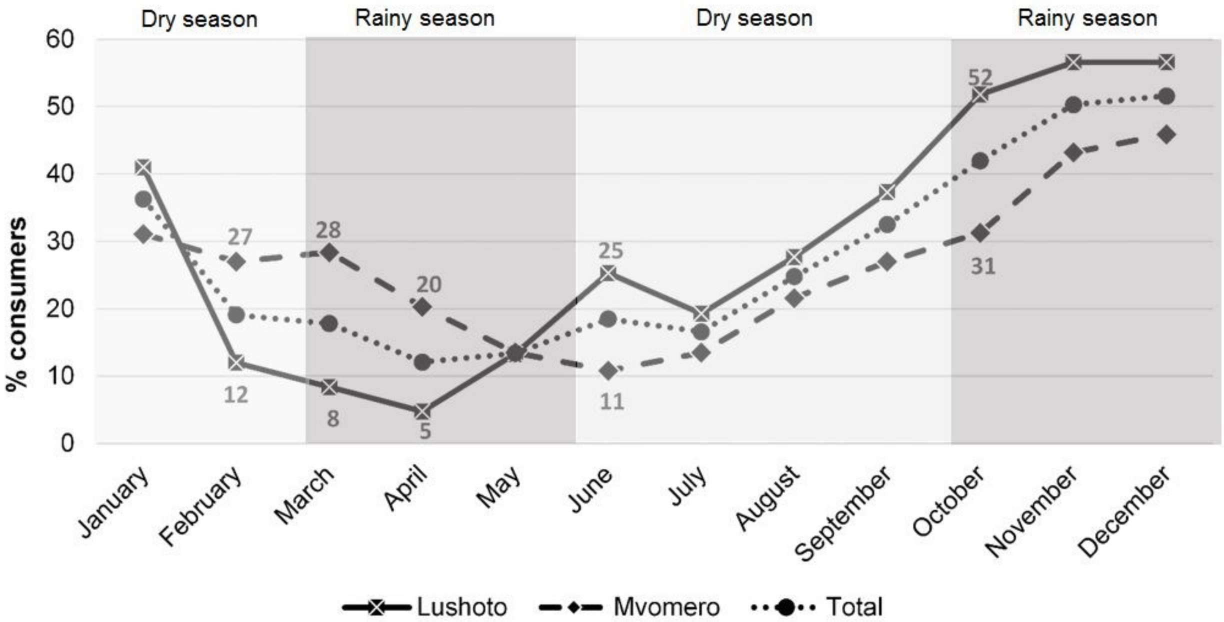


Fig. 5 Frequency of consumption of raw and fermented milk among consumers in ten villages in Mvomero and Lushoto districts in Tanzania, n=153. Information by district is presented when the difference is significant.

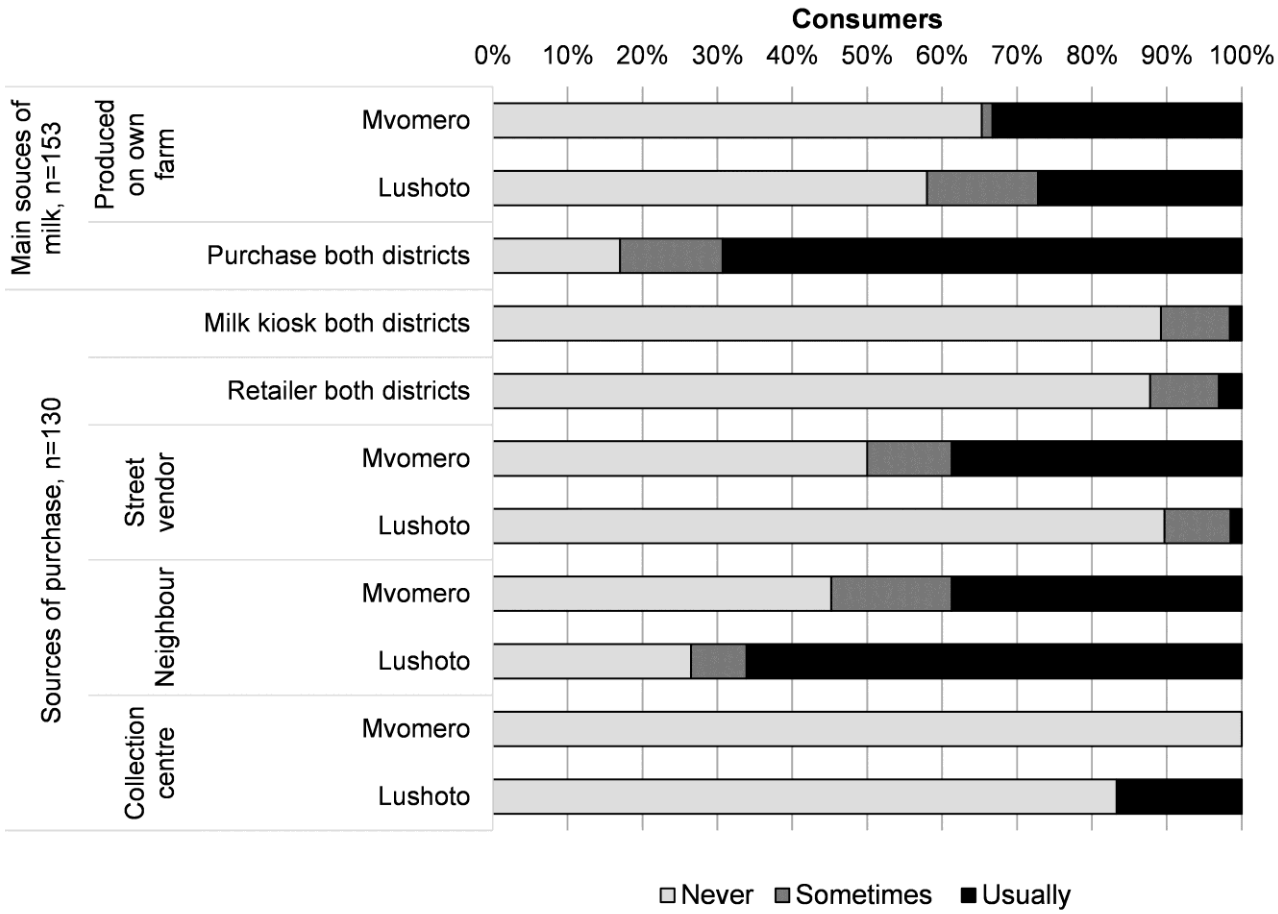


Fig. 6 Frequency of main routes (n=153) and sources of purchasing milk and products (n=130). The values are indicated for the population (total) and per district (Mvomero, Lushoto) when the differences are significant

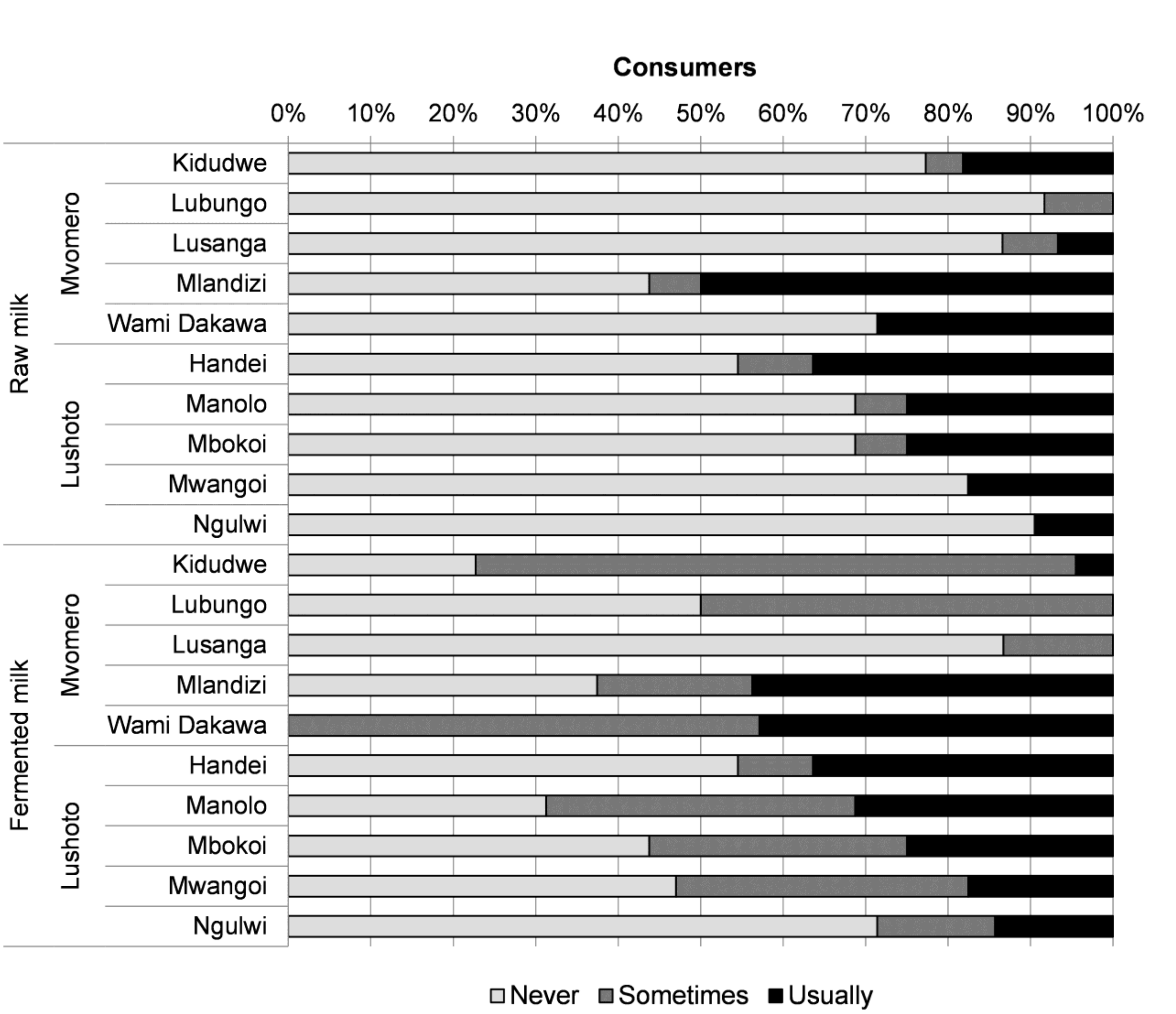
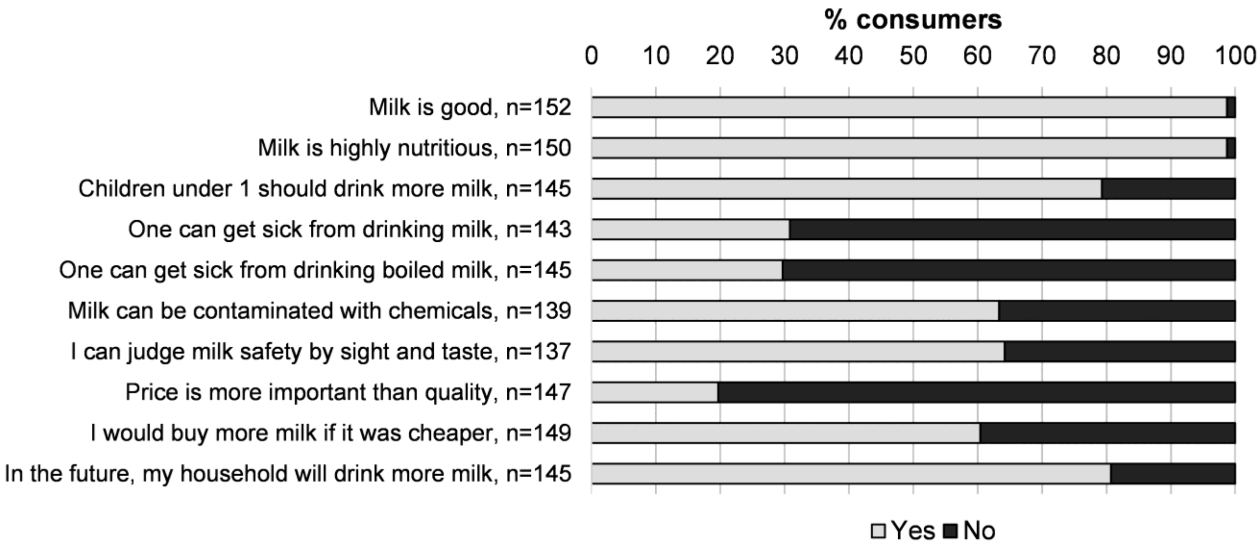


Fig. 7 Knowledge and practices among consumers related to the value, safety and consumption of milk



TABLES

Table 1: Summary of demographic information for producers and consumers interviewed on dairy production and consumptions in ten villages in the districts Mvomero and Lushoto in Tanzania

	Age				Sex		Level of education[2]				Ethnicity	
	Min	Max	Mean	SD	Male	Female	1	2	3	4	Maasai	Non-Maasai
PRODUCERS (n=156)												
Kidudwe	24	56	40.6	10.9	62.5	37.5	0.0	100	0.0	0.0	0.0	100.0
Lubungo[1]	29	60	46.9	12.9	9.1	90.9	90.9	9.1	0.0	0.0	100.0	0.0
Lusanga	35	67	47.6	9.4	46.7	53.3	0.0	86.7	6.7	6.7	0.0	100.0
Mlandizi	23	62	36.3	13.1	100	0.0	57.1	14.3	28.6	0.0	100.0	0.0
Wami Dakawa	34	61	46.5	12.0	83.3	16.7	33.3	33.3	16.7	16.7	66.7	33.3
Mvomero	23	67	44.2	11.6	52.0	48.0	38.0	50.0	8.0	4.0	50.0	50.0
Handei	16	77	44.7	18.3	100	0.0	10.0	90.0	0.0	0.0	0.0	100.0
Manolo	18	72	38.0	12.5	76.2	23.8	10.0	81.0	9.5	0.0	0.0	100.0
Mbokoi	34	67	48.9	9.2	65.0	35.0	10.0	85.0	5.0	0.0	0.0	100.0
Mwangoi	23	80	46.1	14.6	56.5	43.5	13.0	82.6	4.3	0.0	0.0	100.0
Ngulwi	22	82	53.1	13.8	68.4	31.6	0.0	94.7	5.3	0.0	0.0	100.0
Lushoto	16	82	46.0	14.6	72.1	27.9	9.6	85.6	4.8	0.0	0.0	100.0
CONSUMERS (n=157)												
Kidudwe[1]	29	72	46.4	11.0	54.5	45.5	0.0	95.5	4.5	0.0	-	-
Lubungo[1]	23	46	35.4	6.6	53.8	46.2	8.3	83.3	8.3	0.0	-	-
Lusanga	20	82	43.6	17.6	40.0	60.0	0.0	80.0	13.3	6.7	-	-
Mlandizi[1]	20	76	46.1	14.7	17.6	82.4	54.5	45.5	0.0	0.0	-	-
Wami Dakawa[1]	21	60	35.8	13.6	14.3	85.7	25.0	50.0	25.0	0.0	-	-
Mvomero	20	82	42.8	13.6	39.2	60.8	12.5	78.1	7.8	1.6	-	-
Handei	24	69	45.9	13.5	72.7	27.3	9.1	81.8	0.0	9.1	-	-
Manolo[1]	13	70	33.9	15.0	18.8	81.3	6.7	86.7	6.7	0.0	-	-
Mbokoi	33	68	45.1	9.9	68.8	31.1	6.3	87.5	6.3	0.0	-	-
Mwangoi	24	68	39.1	11.9	21.1	78.9	5.3	78.9	15.8	0.0	-	-
Ngulwi	23	61	44.2	12.7	19.0	81.0	4.8	90.5	4.8	0.0	-	-
Lushoto	13	70	41.5	13.1	36.1	63.9	6.1	85.4	7.3	1.2	-	-

[1] Villages with missing cases for the categories of "Age" or "Level of education" : In Producers, Lubungo -3 in age; in Consumers: Kidudwe, Mlandizi and Wami Dakawa -1 in age; Manolo -1, Lubungo -1, Mlandizi -6 and Wami Dakawa -3.

[2] 1=no education, 2=primary education, 3=secondary education, 4=tertiary education

Table 2: Number of cattle owned, average daily milk yield and best cow milk yield by producer ethnicity and district

Response	Producers (%)	Factor	n	median	min	max	IQR/SD	p-value
No of indigenous cattle owned	22.44	Maasai	20	36	2	400	80	0.000
		Non-Maasai	13	1	1	6	1	
		Lushoto	11	1	1	6	1	0.000
		Mvomero	24	32.50	1	400	90	
No of cross-bred cattle owned	80	Maasai	3	2	1	2	>0.05	>0.05
		Non-Maasai	121	2	1	11	2	
		Lushoto	96	2	1	8	2	>0.05
		Mvomero	28	2	1	11	2	
No of exotic cattle owned	3.2	Maasai	2	8	4	10	4.24	-
		Non-Maasai	3	1	1	8	4.04	
		Lushoto	2	-	1	1	>0.05	-
		Mvomero	3	8	4	10		
Milk yield of best cow (litres)		Maasai	20	2.58	0.50	5	1.34	0.000
		Non-Maasai	120	4	0.50	14	3	
		Lushoto	95	4	0.50	10	3	0.015
		Mvomero	45	5	0.50	14	5.25	
Average daily milk production (litres)		Maasai	20	0.50	0.12	3	0.95	0.000
		Non-Maasai	120	2.50	0.30	10	2.21	
		Lushoto	95	2	0.30	10	1.75	>0.05
		Mvomero	45	2.22	0.12	10	3.55	

Table 3: Frequency of using different milk sale channels and associated predictors from the multivariate analysis

	Predictor		Never	Sometimes	Usually	OR	95% C.I.	p-value
Sale directly to consumer	District	Lushoto	34.8	7.9	57.3	0.286	0.12 – 0.66	0.003
		Mvomero	8.0	10.0	82.0	1		
	Fermented milk sale	No	31.3	7.5	61.3	0.348	0.13 - 0.93	0.035
		Yes	6.1	12.1	81.1	1		
Sale to retailer	District	Lushoto	85.4	5.6	9.0	0.281	0.10 – 0.73	0.009
		Mvomero	62.0	10.0	22.0	1		
	Ethnicity	Non-Maasai	80.9	8.7	10.4			>0.05
		Maasai	58.3	12.5	29.2			
	Treatment before storage	Yes	70.3	11.9	17.8	10.69	1.33 – 86.1	0.026
		No	97.1	2.9	0.0	1		
	Sale of milk from sick animals	No	82.2	7.5	10.3	0.266	0.09 – 0.77	0.015
		Yes	60.9	8.7	30.4	1		

Table 4: Knowledge and perceptions among producers about food safety, dairy products acceptance, demand and accessibility of customers and associated predictors from the multivariate analysis. SD=strongly disagree, D=disagree, N=neither, A= agree, SA= strongly agree.

Response	Predictor	Category	n	SD	D	N	A	SA	OR (95% C.I.)	p-value
Milk and dairy products from cows under treatment can affect consumer	Ethnicity	Maasai	25	52.0	28.0	8.0	4.0	8.0	1	
		Non-Maasai	129	23.3	11.6	9.3	27.9	27.9	11.21 (3.37-37.3)	0.000
	Source of drugs	Private vet	59	52.2	6.8	8.5	18.6	13.6	1	
		others	77	9.1	19.5	9.1	31.2	31.2	6.53 (2.54 – 16.75)	0.000
	Stop milking when quarter is infected	Yes	33	75.8	6.1	9.1	3.0	6.1	1	
		No	79	20.3	12.7	8.9	20.3	38.0	10.18 (3.19- 32.53)	0.015
	Sale directly to the consumer	Yes	104	20.2	14.4	9.6	28.8	27.9	1	
		No	35	48.6	17.1	5.7	11.4	17.1	0.28 (0.10-0.78)	0.000
	Total		154	27.9	14.3	9.1	24.0	24.7		
Milk and dairy product from cow under treatment will not affect consumer	Sale of milk from sick cattle	Yes	23	0.0	17.4	4.3	30.4	47.8	1	
		No	119	25.2	25.2	7.6	16.0	26.1	0.199(0.071-0.56)	0.002
	Stop milking when quarter is infected	Yes	33	9.1	3.0	6.1	9.1	72.2	1	
		No	79	29.1	27.8	6.3	16.5	20.3	0.101 (0.04-0.25)	0.000
	total		155	3.2	4.5	2.6	34.8	54.9		
Buyers will refuse milk and dairy product if the quality is not high	Business inspection	Yes	50	5.6	0.0	1.9	18.5	74.1	1	
		No	90	2.1	7.4	3.2	41.5	45.7	0.29 (0.13-0.63)	0.002
	Pre storage treatment	Filtration	63	1.5	1.5	3.0	23.9	70.1	1	
		Other	77	5.0	7.5	2.5	41.3	43.8	0.29 (0.14- 0.59)	0.001
	Total		151	2.6	19.9	7.3	32.5	37.7		
Buyers will accept milk and dairy product if the quality is not high	Ethnicity	Maasai	21	32.0	16.0	8.0	32.0	12.0	1	
		Non-Maasai	88	47.3	29.5	3.9	13.2	6.2	0.30 (0.12- 0.75)	0.011
	Stop milking if a quarter is infected	Yes	33	75.8	6.1	3.0	6.1	9.1	1	
		No	76	45.6	22.8	6.3	17.7	7.6	4.84 (1.81-12.96)	0.001
	Total		154	20.1	27.9	6.5	18.2	27.3		
You can always find someone to buy your milk	Ethnicity	Maasai	24	12.5	25.0	8.3	41.7	12.5	1	
		Non-Maasai	127	0.8	18.9	7.1	30.7	42.5	3.33 (1.46-7.61)	0.004
	total		154	44.8	27.3	4.5	16.2	7.1		
It can be difficult to find someone to buy milk	Ethnicity	Maasai	24	16.7	37.6	0	33.3	12.5	1	
		Non-Maasai	128	32.0	40.6	7.0	12.5	7.8	0.417 (0.19 – 0.93)	0.032
	Total		152	29.6	40.1	5.9	15.8	8.6		

Response	Predictor	Category	n	SD	D	N	A	SA	OR (95% C.I.)	p-value
Milk and dairy products from cows under treatment can affect consumer	Ethnicity	Maasai	25	52.0	28.0	8.0	4.0	8.0	1	
		Non-Maasai	129	23.3	11.6	9.3	27.9	27.9	11.21 (3.37-37.3)	0.000
	Source of drugs	Private vet	59	52.2	6.8	8.5	18.6	13.6	1	
		others	77	9.1	19.5	9.1	31.2	31.2	6.53 (2.54 – 16.75)	0.000
	Stop milking when quarter is infected	Yes	33	75.8	6.1	9.1	3.0	6.1	1	
		No	79	20.3	12.7	8.9	20.3	38.0	10.18 (3.19- 32.53)	0.015
	Sale directly to the consumer	Yes	104	20.2	14.4	9.6	28.8	27.9	1	
		No	35	48.6	17.1	5.7	11.4	17.1	0.28 (0.10-0.78)	0.000
Milk and dairy product from cow under treatment will not affect consumer	Sale of milk from sick cattle	Yes	23	0.0	17.4	4.3	30.4	47.8	1	
		No	119	25.2	25.2	7.6	16.0	26.1	0.199(0.071-0.56)	0.002
	Stop milking when quarter is infected	Yes	33	9.1	3.0	6.1	9.1	72.2	1	
		No	79	29.1	27.8	6.3	16.5	20.3	0.101 (0.04-0.25)	0.000
Buyers will refuse milk and dairy product if the quality is not high	Business inspection	Yes	50	5.6	0.0	1.9	18.5	74.1	1	
		No	90	2.1	7.4	3.2	41.5	45.7	0.29 (0.13-0.63)	0.002
	Pre storage treatment	Filtration	63	1.5	1.5	3.0	23.9	70.1	1	
		Other	77	5.0	7.5	2.5	41.3	43.8	0.29 (0.14- 0.59)	0.001
Buyers will accept milk and dairy product if the quality is not high	Ethnicity	Maasai	21	32.0	16.0	8.0	32.0	12.0	1	
		Non-Maasai	88	47.3	29.5	3.9	13.2	6.2	0.30 (0.12- 0.75)	0.011
	Stop milking if a quarter is infected	Yes	33	75.8	6.1	3.0	6.1	9.1	1	
		No	76	45.6	22.8	6.3	17.7	7.6	4.84 (1.81-12.96)	0.001
You can always find someone to buy your milk	Ethnicity	Maasai	24	12.5	25.0	8.3	41.7	12.5	1	
		Non-Maasai	127	0.8	18.9	7.1	30.7	42.5	3.33 (1.46-7.61)	0.004
It can be difficult to find someone to buy milk	Ethnicity	Maasai	24	16.7	37.6	0	33.3	12.5	1	
		Non-Maasai	128	32.0	40.6	7.0	12.5	7.8	0.417 (0.19 – 0.93)	0.032

Table 5: Food consumption score of the household respondent (FCS HH) and the index case (FCS Index) in ten villages in Mvomero and Lushoto districts. Only details of significant differences between villages in the ANOVA test are shown.

Location	FCS HH	n	SD	min	max	FCS Index	n	SD	min	max
Kidudwe	123.14	22				129.25	20			
Lubungo	103.38	13				106.86	11			
Lusanga	121.13	15				123.40	15			
Mlandizi	96.09	16	38.7	38	183	96.59	16	38.8	38	183
Wami Dakawa	155.55	7	56.8	79	214					
Mvomero	116.36	73	44.4	38	214	117.16	68	45.4	14	214
Handei	121.70	11				119.10	11			
Manolo	145.00	16	33.7	87	217	144.90	16	33.3	87	217
Mbokoi	131.75	16				139.07	15			
Mwangoi	122.11	19				117.26	19			
Ngulwi	114.56	21				114.38	21			
Lushoto	126.51	83	34.4	64	217	126.16	82	34.8	56	217
Total	121.91	156	39.0	3	217	122.08	150	40.1	14	217

Supplementary materials 1 – Location of the study villages

Fig. 1 Location of the study villages visited in Lushoto district

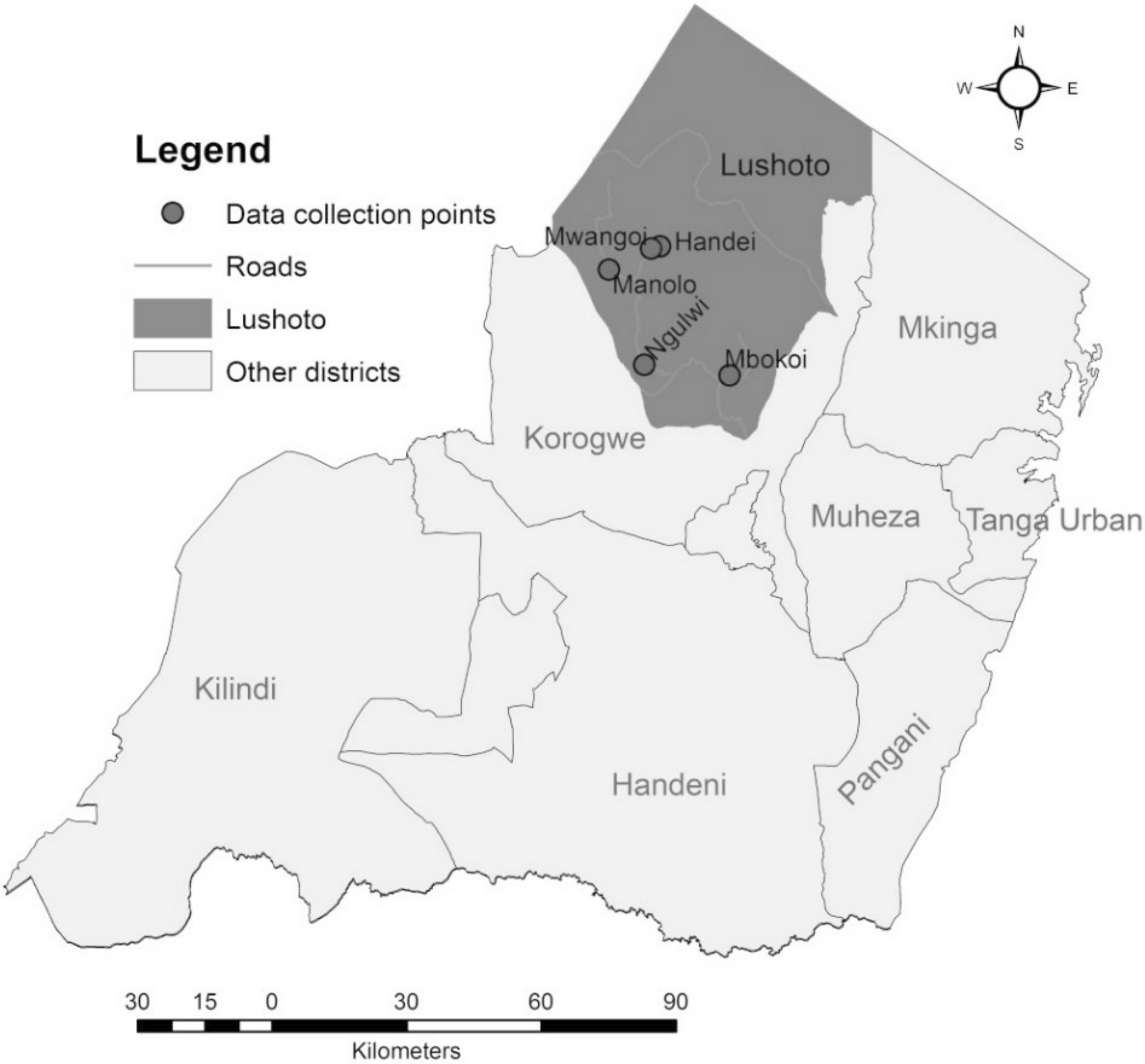


Fig. 2 Location of the study villages visited in Mvomero district

Electronic supplementary material 2

Food groups and their weights used to calculate the food consumption score

The table below lists the food groups and their weights used to calculate the food consumption score as recommend by the World Food Programme (2008).

Electronic supplementary material 2, Table 1: Food groups and their weights used to calculate the food consumption score (World Food Programme 2008)

	Food Item (examples)	Food groups (definitive)	Weight (definitive)
1	Maize, maize porridge, rice, sorghum millet pasta, bread and other cereals	Main staples	2
	Cassava, potatoes, other tubers, plantains		
2	Beans, peas, groundnuts, cashew nuts	Pulses	3
3	Vegetables, relish, leaves	Vegetables	1
4	Fruits	Fruit	1
5	Beef, goat, poultry, pork, eggs, fish	Meat and Fish	4
6	Milk, yogurt, other dairy	Milk	4
7	Sugar and sugar products	Sugar	0.5
8	Oil, fats and butter	Oil	0.5
9	Spices, salt, fish powder, small amounts of milk for tea	Condiments	0

Reference

World Food Programme. (2008). Food consumption analysis - calculation and use of the food consumption score in food security analysis. *Technical Guidance Sheet*. http://home.wfp.org/stellent/groups/public/documents/manual_guide_proced/wfp197216.pdf