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1 **Title page**

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

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30

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

32

33 **Abstract**

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

38 Questionnaires were administered to 156 producers and 157 consumers in 10 villages in Lushoto and
39 Mvomero districts. Farmers reported that veterinary medicines such as oxytetracyclines, penicillin and
40 streptomycin were frequently given to cattle, and a majority did not discard milk during or after treatment.

41 Less than half of the producers boiled milk, although sale of fermented milk, made by spontaneous
42 fermentation of raw milk, was common. Cattle management was characterised by low levels of biosecurity,
43 hygienic practices and disease control. A majority of consumers reported not to have enough food to meet
44 their family needs. The Food Consumption Score was acceptable for all households, but significantly higher
45 for households with dairy cattle. When making purchasing decisions, the appearance of milk and trust in the
46 supplier were more important considerations than hygiene practices observed. A total of 26% of consumers
47 reported to consume raw milk “usually” or “sometimes” and 54% of consumers reported to drink fermented
48 milk “usually” or “sometimes”. Consumers had a positive attitude towards milk and concern for quality but
49 most thought there was no risk of illness from milk consumption.

Food safety and nutrition in dairy value chain in Tanzania

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

53 **Keywords**

54 Dairy value chain, Tanzania, food safety, food security

55 **1. Introduction**

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

68 In Sub-Saharan Africa, the majority of meat, milk, eggs and fish is sold in informal markets, where food safety
69 regulation is not available or often poorly enforced. Consequently, microbial and chemical hazards in food
70 (e.g. brucellosis, tuberculosis, salmonellosis, chemicals, mycotoxins, antimicrobial residues) are commonly
71 identified in studies investigating them (Alonso et al., 2011; Kikuvi et al., 2010; Namanda et al., 2009; Paudyal
72 et al., 2017), even though the risk to consumers is not always high due to mitigating practices such as cooking
73 (Grace et al., 2010). Diarrhoeal diseases are one of the main causes of morbidity and mortality from infectious
74 diseases (Murray et al., 2012); in 2010 the global burden of foodborne disease was estimated at 33 million
75 Disability Adjusted Life Years with the highest burden falling on the African, South-East Asian and “Eastern
76 Mediterranean D”¹ sub-regions (Havelaar et al., 2015). Many food-borne diseases go underreported without
77 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

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

80 Concerns over food safety among consumers in low income countries can lead to reducing ASF
81 consumption with marked structural changes in elasticity (Kraipornsak, 2010), changing to outlets
82 perceived as safer (ILRI, 2010) or cleaner (Otieno and Kerubo, 2016), asking retailers for health certificates
83 (ILRI and DVS, 2008), or a willingness to pay for safer food products (Alphonse and Alfnes, 2012). On the
84 other hand, improving availability and accessibility of even small amounts of ASF helps to ensure that diets
85 include sufficient quality protein and micronutrients particularly for vulnerable populations (Iannotti et al.,
86 2017, 2014; Randolph et al., 2007). These population groups often depend on the competitive prices
87 offered by the informal sector. Consequently, common calls to tackle problems of food safety and disease
88 by moving to Northern-style agro-food systems that are commonly characterised by processing and cold
89 chains, can create unintended consequences in that they may decrease the availability and affordability of
90 ASF for poor population groups (Grace, 2015). Moreover, large numbers of small informal sectors actors
91 who are difficult to monitor or train in combination with ineffective rules, regulations, and governance
92 hinder upgrading of informal sectors (Grace, 2015).

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

101 The dairy sub-sector in Tanzania, as in other East and Central African countries, is dominated by informal
102 markets, which handle 80-90% of all milk sold (Swai and Schoonman, 2011). Milk production is pre-

103 dominantly rural and is divided between two types of production systems, namely extensive and semi-
104 intensive/intensive systems. Extensive systems are characterised by displacement of cattle from one place
105 to another in search of fodder (seen in pastoralist or agropastoralist contexts), intensive systems by cutting
106 and carrying of fodder and supplementation, and semi-intensive systems by a combination of grazing and
107 stall feeding. Milk production is pre-dominantly rural with about 95% of all cattle in the country (predominant
108 breed is the Tanzania shorthorn zebu) raised extensively by pastoral and agro-pastoral farmers (Msalya,
109 2017). Milk is sold either in rural areas, mainly to neighbours and local restaurants, or in the neighbouring
110 urban centres to obtain additional income; the volume of milk imports match local production (Kurwijila et
111 al., 2012). There is abundant feed during the “long”, intense (March to May) and short, less intense (between
112 October and December) rainy seasons, leading to high milk production and lower prices. The inverse trend is
113 observed during the dry season (Kurwijila et al., 2012). Because of low fodder quality, scarcity of land for
114 production, lack of technical knowledge, capital and market chains, feed preservation is limited (Lukuyu et
115 al., 2016). Seasonal milk production, poorly organised marketing procedures, limited processing, transport
116 and storage options, lack of inspection or disease control, and fluctuating prices constitute be hindrances to
117 the commercialisation of dairy products (Kurwijila et al., 2012; Msalya, 2017).

118 A range of studies reported on milk safety in Tanzania. They included concerns over milk hygiene because of
119 a lack of clean water, inadequate transport containers, poor refrigeration and a lack of understanding of
120 hygiene (Schoder et al., 2013); documentation of bacteria in milk samples from milk marketing agents in
121 Tanga city (Swai and Schoonman, 2011), and from smallholder dairy farmers, street vendors and outlet shops
122 in Arusha and Arumeru districts (Lubote et al., 2014). Schoder et al. (2013) tested milk in the regions of Dar
123 es Salaam and Lake Victoria and isolated *E. coli O157:H7* as well as *Salmonella* spp. from a tenth of raw milk
124 samples. However, these were absent in heat treated samples except for coliforms which were detected in
125 41% of processed milk samples possibly due to recontamination attributable to unhygienic packaging at the
126 plants. In 54 milk samples from cattle owning households, milk collectors, and retailers in ten villages in Tanga
127 region, more than 90% of all handled milk samples were above the East African Community maximum
128 acceptable standard for bacterial total plate counts (Hyera, 2015). In a related study in Morogoro region, milk

129 samples from 82 producers tested negative for *E.coli* 0157:H7 and 17.1% were positive for *Brucella abortus*
130 (Joseph, 2013). In another study, 238 out of 328 (73%) raw (fresh) milk samples from the regions Morogoro,
131 Coast, and Tanga in Tanzania tested positive for ten groups or species of bacteria including a range of
132 foodborne pathogens (Msalya, 2017).

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

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

154 **2. Materials and methods**

155 **2.1 General overview**

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

171 **2.2 Study areas and study sites**

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

178 a representation of different human and livestock population densities, income, market access, consumption
179 patterns, and livestock production systems.

180 Within each district, a longlist of 35 cattle keeping villages was created in consultation with district livestock
181 officials. Based on the density of cattle keeping households and available information on potential research
182 impact and ease of assistance for the research, a shortlist of 25 suitable villages was created. In these villages,
183 a detailed checklist on production data and practices, market orientation, market outlets, feeding practices,
184 and practical research factors (e.g. willingness to participate, staff security) was applied. From the sample
185 frame of these 25 villages, five per district were randomly selected with the aim to represent extensive (agro)
186 pastoral, semi-intensive sedentary and intensive sedentary systems. Researchers then visited site locations
187 and consulted further with research partners and other stakeholders to assess the willingness of the
188 communities to participate in further studies, and accessibility of the villages to the research team. If a village
189 was found to be unsuitable, another village was randomly selected. The final ten villages included in this
190 study were Mbokoi, Mwangoi, Ngulwi, Handei and Manolo in Lushoto district and Kidudwe, Lubungo,
191 Lusanga, Wami Dakawa, and Mlandizi in Mvomero district (Supplementary Material 1).

192 **2.3 Producer survey**

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

203 **2.4 Consumer survey**

204 The sample size calculation for the consumer survey was based on the following key indicator estimates:
205 Prevalence of a key hazard – unknown, anticipated 50%; proportion of milk and dairy products in diet by
206 weight – unknown, anticipated 5%; self-reported gastro-intestinal illness in last 2 weeks – unknown,
207 anticipated 10%. With a 95% confidence interval, a margin of error of 5% and assuming a design effect of 2,
208 the targeted number of households to be interviewed in the 10 villages was 300, i.e. 30 households per
209 village. Enumerators obtained a list of households per village from the local livestock field officer from which
210 30 households for the interviews were randomly selected using Microsoft Excel random number generator
211 function. They contacted the households and scheduled visits with the head of the household or any other
212 person authorised to talk to the enumerators. Consumers were interviewed separately from producers by
213 two distinct groups of enumerators on the same day to avoid overlap in respondents. Structured interviews
214 were conducted to collect data using the relevant questionnaire. Oral informed consent was obtained from
215 each participant at the beginning of the interview.

216 **2.5 Ethical approval**

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

222 **2.6 Data handling and analysis**

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

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

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

$$241 \text{ FCS} = \alpha_{\text{staple}} \times x_{\text{staple}} + \alpha_{\text{pulse}} \times x_{\text{pulse}} + \alpha_{\text{veg}} \times x_{\text{veg}} + \alpha_{\text{fruit}} \times x_{\text{fruit}} + \alpha_{\text{animal}} \times x_{\text{animal}} + \alpha_{\text{sugar}} \times x_{\text{sugar}} + \alpha_{\text{dairy}} \times x_{\text{dairy}} + \alpha_{\text{oil}} \times x_{\text{oil}}$$

242 *Where*

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

245 α_i Weight of each food group

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

249 Descriptive and inferential analyses were conducted using IBM SPSS Statistics for Windows, Version 21.0
250 Armonk, NY: IBM Corp. Fisher’s Exact test or Pearson’s Chi square test were used to determine the statistical
251 significance between the categorical outcomes of two groups, for example when studying each variable by

252 district. For continuous variables such as the Food Consumption Score or expenditures for health problems,
253 parametric methods such as the independent t-test to compare means between two groups, and One Way
254 ANOVA to compare means among three or more groups, were used when the distribution was normal. Their
255 equivalent non-parametric methods Mann-Whitney U test and Kruskal-Wallis H were conducted when the
256 data were not normally distributed. Univariate and multivariate ordinal logistic regression models were used
257 to compare frequencies of milk and milk products sale channels as well as knowledge, attitude and practices
258 in producers. Explanatory variables included in the univariate analysis were district, village, ethnicity, use of
259 antibiotics, use of oxytetracyclin, source of drugs (government officer, pharmacy), discarding milk while/after
260 antibiotic treatment, uses of milk from sick animals (home consumption, sale, animal feed, discard), practices
261 in case of clinical mastitis (stop milking, give milk to calves, sell milk, consume milk), pre-storage treatment
262 (boil, filter, no treatment), sale of raw or boiled product, and sales channels. Variables with a p-value <0.05
263 were included in the multivariate analysis. A back-ward stepwise elimination process was used to remove
264 variables whose multivariate p-value was ≥ 0.05 . The models were fitted through maximum likelihood
265 estimation.

266 3. Results

267 A total of 156 producers and 157 consumers, respectively, were interviewed; six interviews had to be
268 discarded for the village level analysis. The demographic data for producers and consumers interviewed are
269 summarised in Table 1. In Lushoto, Islam was found to be the predominant religion (around 75%) among
270 both consumers and producers and the most prevalent ethnicities were Sambiaa, with 83% of producers and
271 84% of consumers, followed by Pare (14% of producers and 9% of consumers). In Mvomero, Christianity was
272 the most common religion (80%) and a wider range of ethnicities was reported: 50% of producers and 16%
273 of consumers were Maasai, followed by Zigua (14% of producers and 20% of consumers), Chaga (12% of
274 producers) and Luguru (19% of consumers).

275 **3.1 Characterisation of dairy production and producers**

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

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

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

296 Asked whether they acquire new dairy stock, nearly two thirds of producers (88% of the Maasai producers)
297 said yes. The main route of obtaining cattle was by purchasing (66%); 5% reported bartering. Acquiring cattle
298 as gifts and dowries was more common among Maasai producers (32% and 23%, respectively, compared to
299 4% and 1% in non-Maasai producers). Neighbouring farms were the most common source of new stock
300 (69%). Sourcing animals from markets was significantly more frequent among Maasai (68%) than other

301 producers (10%); markets were a source to obtain predominantly local cattle (55%), followed by cross-bred
302 cows (40%). Other acquisition sources such as commercial farms, development projects, or calving in family
303 holdings were much less frequent. Almost 75% of respondents obtaining new stock required health checks,
304 commonly based on the observation of general physical appearance (90%), signs of ill health (e.g. rough hair
305 coat) or specific diseases such as brucellosis, foot-and-mouth disease or trypanosomiasis (25%), or
306 emaciation status (9%). A total of 26% producers quarantined new animals for varying amounts of time. In
307 Lushoto, the quarantine length reported was an average of 24 days (n=14 min=0.5, max=90, SD=27.97) while
308 in Mvomero it was 55 days (n=4, min=1.5, max=120, SD=59.49). During that period two thirds of those using
309 quarantine stated to check physical signs of body development, feed intake, general health status, and
310 occasionally piroplasmiasis.

311 Fig. 1 shows producers replies regarding potentially risky practices for food safety, such as not discarding milk
312 during antibiotic therapy. When asked about practices in relation to sick cows, almost 40% of producers
313 reported to consume milk at home, 16% to sell the milk and 16% to give it to calves. All Maasai producers
314 said that they never throw milk away, but rather consume it at home (72%), sell it (36%) or give it to calves
315 (20%).

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

322 Almost all respondents hand milked their cows; 11% of respondents did so without cleaning the udder. Less
323 than half of the producers mentioned to boil or filter the milk before storage. Respondents from Kidudwe
324 and Lubungo (both Mvomero district), and Manolo (Lushoto district) reported the longest median milk

325 storage times of 7 to 12 hours, which was significantly different from other villages which reported 0.5 to 2.5
326 hours ($p=0.000$).

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

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

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

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

343 **3.2 Characterisation of consumers**

344 A third of the respondents were head of the household (of which 20% were females), 38% were mother of
345 the head, and the rest were other family members. Demographic information is given in Table 1. The median
346 number of inhabitants was six ($min=2$, $max=19$, $IQR=3$). Adult females (over 18 years old) were present in
347 96% of the households, while children under 5 years old in 50%.

348 More than 75% of the households ($n=155$) declared they participated in crop-farming activities. It
349 represented the only activity for half of them while the other half mentioned other income-generating

350 activities, such as animal keeping (15%) or non-agricultural business or trade (7%). More than a quarter of all
351 respondents kept animals, 23% did non-agricultural business or trading while 5% mentioned agricultural
352 trading and 8% unemployment.

353 Asked about cattle ownership, 32% of all consumer respondents said that they own cattle with a significant
354 difference between districts, namely 22% in Mvomero and 41% in Lushoto district (p -value=0.009). In
355 Mvomero, the proportion of cattle owners by village was between 0% and 42.9% and in Lushoto between
356 14.3% and 68.8%. A significantly higher number of households in Lushoto district had a small number of cattle
357 with a median of one cow ($n=34$, $\text{min}=1$, $\text{max}=4$, $\text{IQR}=1$), compared to Mvomero, where the herds appeared
358 to be larger with a median of 8 cows ($n=12$, $\text{min}=1$, $\text{max}=55$, $\text{IQR}=37$).

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

363 A total of 126 households (%) answered the dietary consumption questions. Of the index individuals, 63%
364 were females and 37% were males, the median age was 11.5 years ($\text{min}=0.25$, $\text{max}=72$, $\text{IQR}=35.25$). The FCS
365 was found to be above the threshold for undernutrition of 35 for all households. Differences were non-
366 significant by district, but significant differences in the FCS of the index cases were found between Mlandizi
367 (FCS=96), Manolo and Wami Dakawa (FCS=150-145), (p -value<0.05) (Table 5). There was a significant
368 difference (p -value=0.000) in FCS between dairy cattle and non-dairy cattle owning HHs: The median FCS-HH
369 for cattle owners was 139 ($\text{min}=72$, $\text{max}=217$, $\text{SD}=34.22$) and for non-cattle owners 112 ($\text{min}=38$, $\text{max}=207$,
370 $\text{SD}=39.39$); the median FCS-Index was 141 ($\text{min}=56$, $\text{max}=217$, $\text{SD}=33.98$) for cattle owners and 113 ($\text{min}=14$,
371 $\text{max}=207$, $\text{SD}=39.91$) for non-cattle owners.

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

375 18% in Lushoto indicated taste as an important criterion when purchasing milk. Hygiene or safety aspects
376 were generally regarded as a factor of minor importance in both districts.

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

379 Boiled milk was the product reported to be consumed most frequently (85%), followed by chai, i.e. tea with
380 raw milk (63%), and fermented milk. All villages reported at least occasional consumption of raw and
381 fermented milk; 25.5% of consumers reported to consume raw milk “usually” or “sometimes” and 53.5% of
382 consumers reported to drink fermented milk “usually” or “sometimes” (Fig. 6). A total of 85% of consumers
383 (83% in Lushoto and 87% in Mvomero) reported to consume boiled milk “usually” or “sometimes”.

384 Most of the consumers (89%, n=124) reported to transport the milk in their own container. The most
385 common material was plastic (92%), only 6% used traditional clay pots. The median transportation time was
386 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,
387 max=53, IQR=1.8). The most reported occasions of hand washing were before eating (84%), after going to
388 the toilet (60%) and after cooking (60%). Some of the respondents stated to clean their hands after other
389 dirty activities (20%) or before feeding the children (28%).

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

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

399 **4. Discussion**

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

402 ***Food security***

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

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

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

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

436 ***Food safety***

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

450 Another important challenging aspect identified in this study were limited levels of biosecurity and hygiene
451 as well as regular use of antimicrobials without observation of withdrawal periods. While antimicrobials have
452 an important therapeutic function and contribute to animal health, welfare and productivity (Bengtsson and
453 Greko, 2014), resistance can develop if they are not used prudently (Ungemach et al., 2006). This includes
454 consumption of milk or selling milk for human consumption during or after antimicrobial therapy as reported
455 by producers in this study. Such practice can lead to development of antimicrobial resistant bacteria with the
456 potential to affect consumers, other animal populations and contaminating the environment (Aidara-Kane,
457 2012; Chantziaras et al., 2014) including the possibility for resistant pathogens to be found in species that
458 were not treated with the relevant drugs (Dulo et al., 2015). Antimicrobial resistance and prudent use
459 guidelines become particularly pressing topics when considering the use of less disease-resistant dairy cattle
460 breeds to promote increases in productivity, as disease susceptibility may lead to an increase the use of
461 antimicrobial drugs. In food and income scarce settings, farmers will be reluctant to discard milk due to
462 antibiotic residues and thereby reduce food security. This is likely to be of particular importance for
463 pastoralist populations with high milk intake (Iannotti and Lesorogol, 2014). The use of oxytetracyclin was
464 common among Maasai producers. Private veterinarians were reported to be the main source of antibiotics,
465 but the understanding of the term veterinarian was not verified and it may well be that this category included
466 also other related professions such as drug sellers or technicians. Furthermore, a lack of training about food
467 safety and hygienic handling of milk was found. Producers using risky practices, such as the sale of milk from
468 sick animals or milking when the udder presents infection as well as producers using informal supply and sale
469 channels were less aware of the risk that cows under treatment can pose to the consumers' health. While
470 biological sampling was not used in this study, related studies in the same regions documented
471 contamination of milk samples with foodborne bacteria in the dairy value chains including in boiled milk
472 samples thereby demonstrating that the foodborne disease risks were not negligible (Hyera, 2015; Joseph,
473 2013; Msalya, 2017). Cooking patterns can be a crucial factor in food safety, but consumers interviewed did
474 not seem to be aware of that, as they gave the same importance to the two statements "one can get sick
475 from drinking milk" and "one can get sick from drinking boiled milk". Future studies should look in detail at

476 cooking practices and investigate them in conjunction with biological sampling and data on foodborne
477 disease.

478 ***Potential trade-offs food security and food safety***

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

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

499 ***Limitations***

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

510 ***Conclusions***

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

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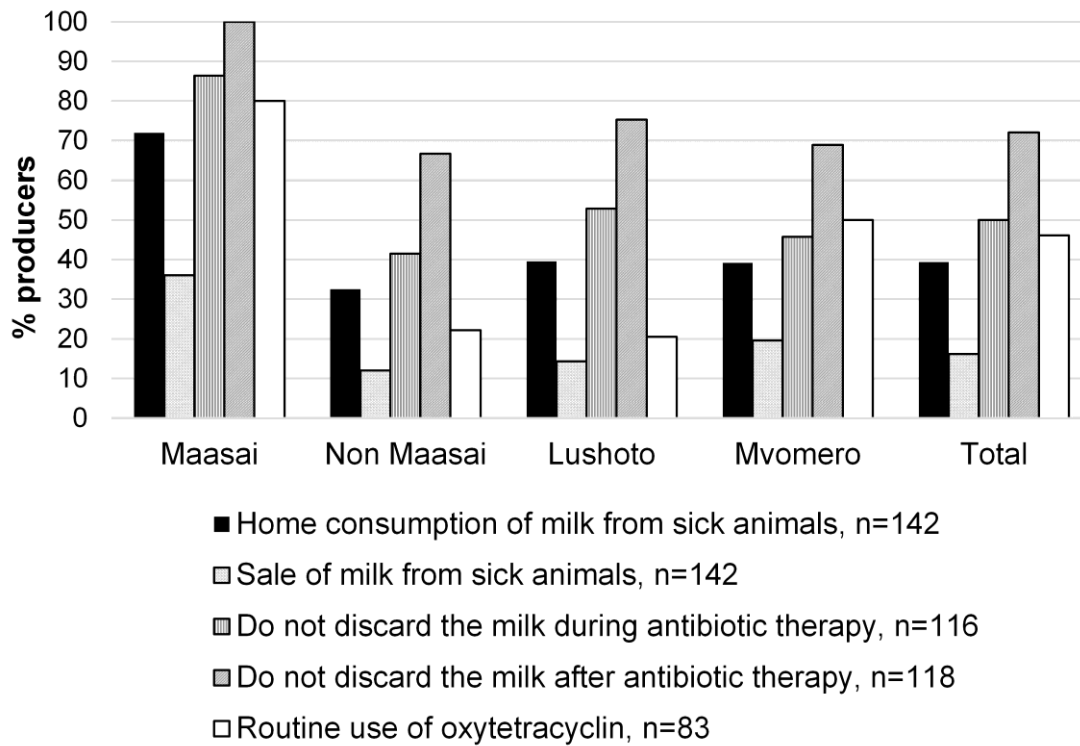
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710 **FIGURE CAPTIONS**

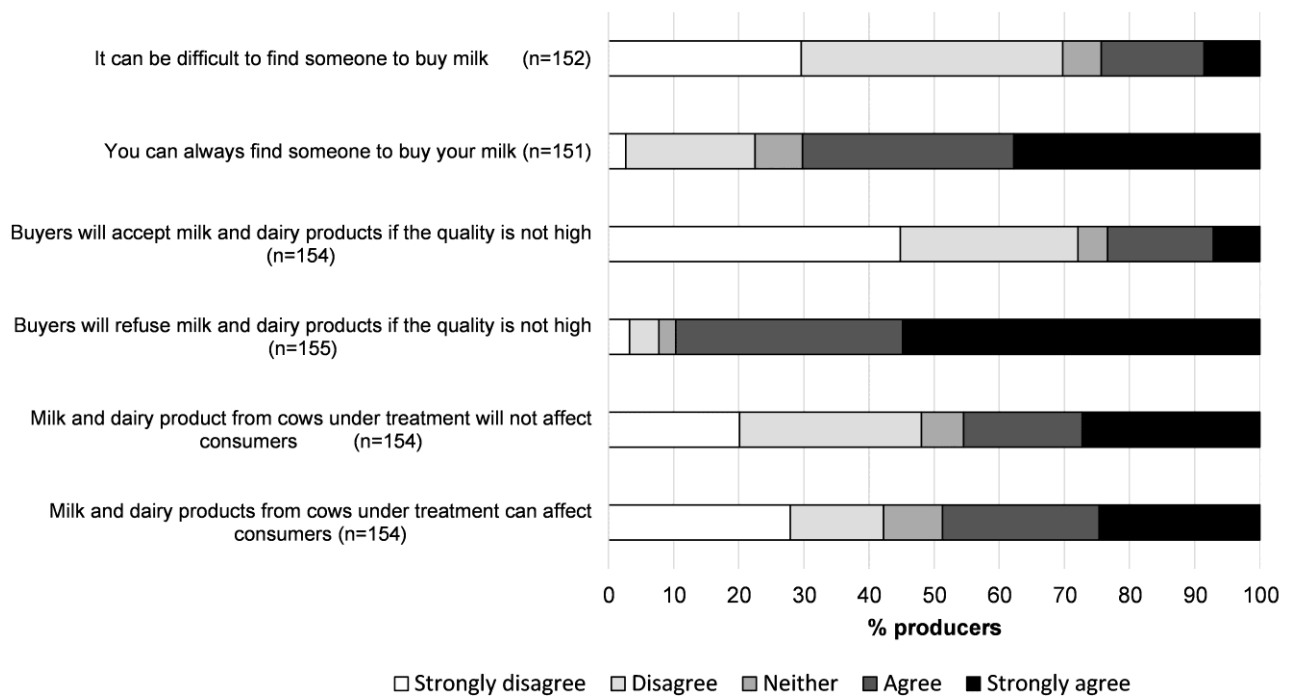
711 **Fig. 1** Reported hazardous consumption practices of producers related to animal disease, antimicrobial
 712 usage and use of milk by district and ethnicity



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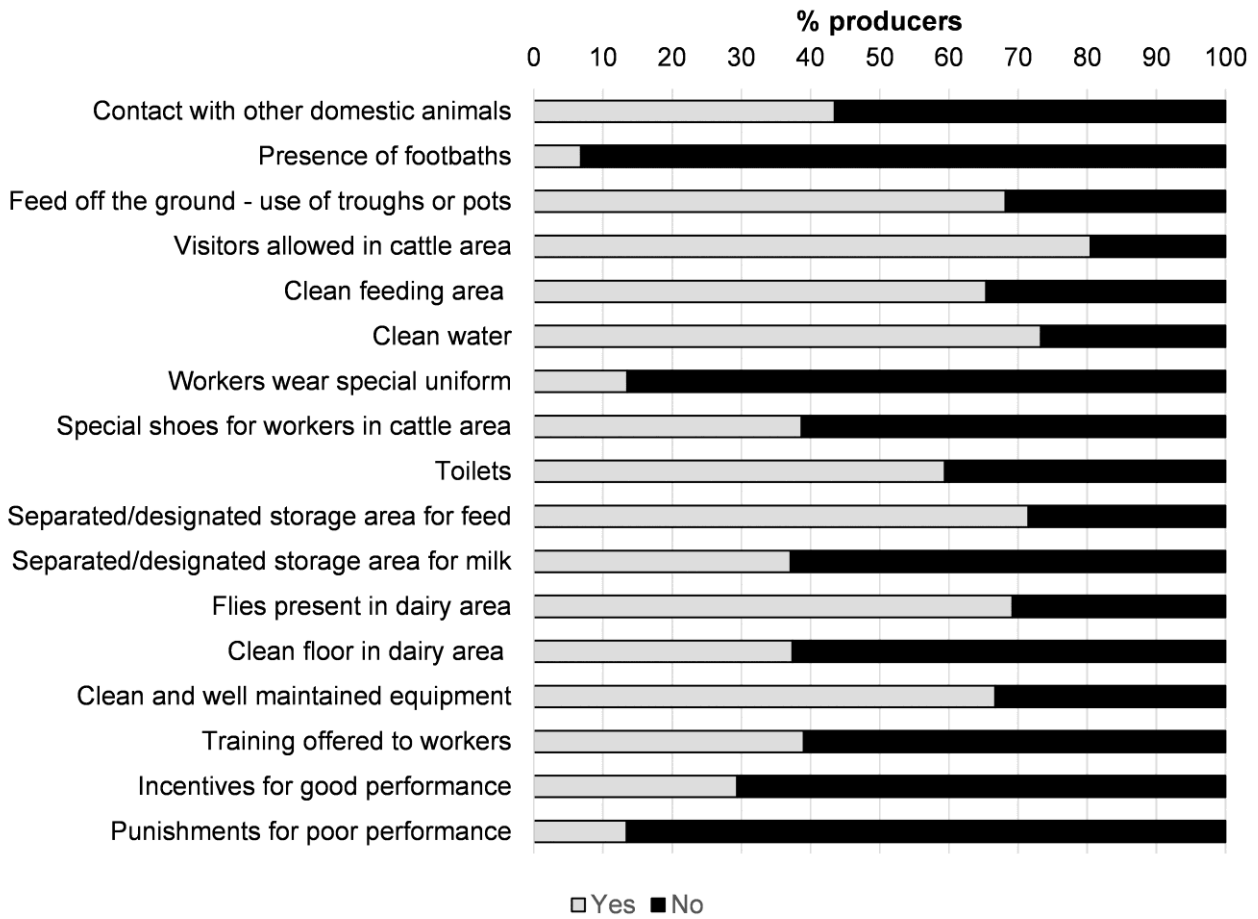
715 **Fig. 2** Knowledge and perceptions among producers about food safety, dairy product acceptance, demand
 716 and accessibility of customers



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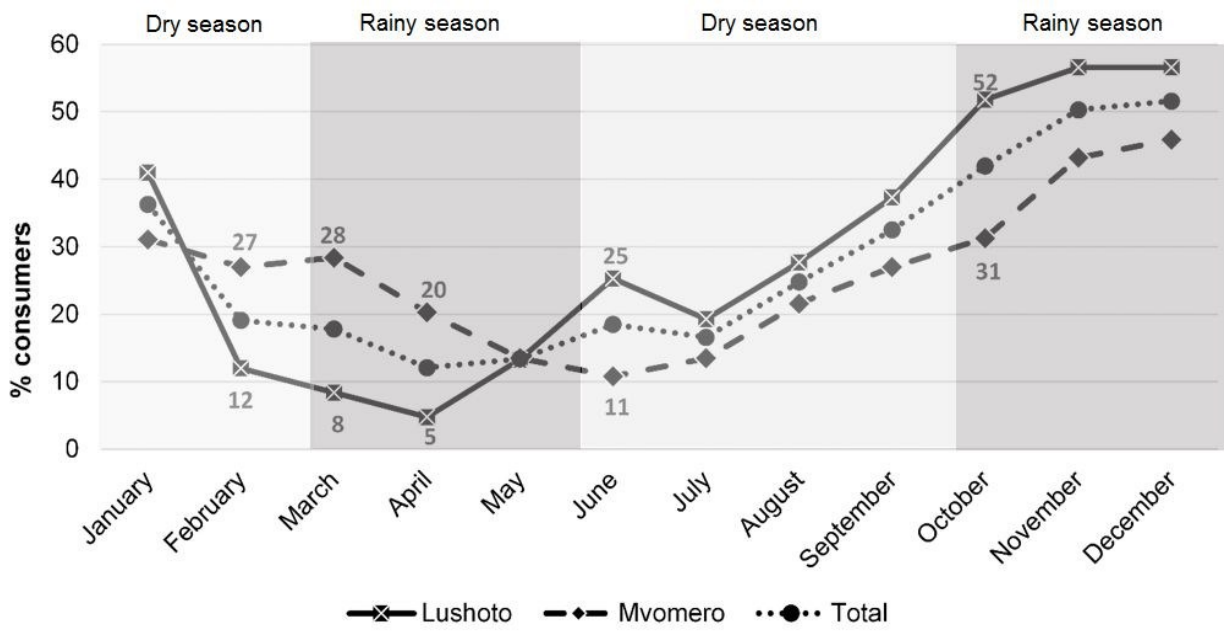
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719 **Fig. 3** Observed conditions on dairy farms related to biosecurity, cleanliness, storage, and management
 720 protocols



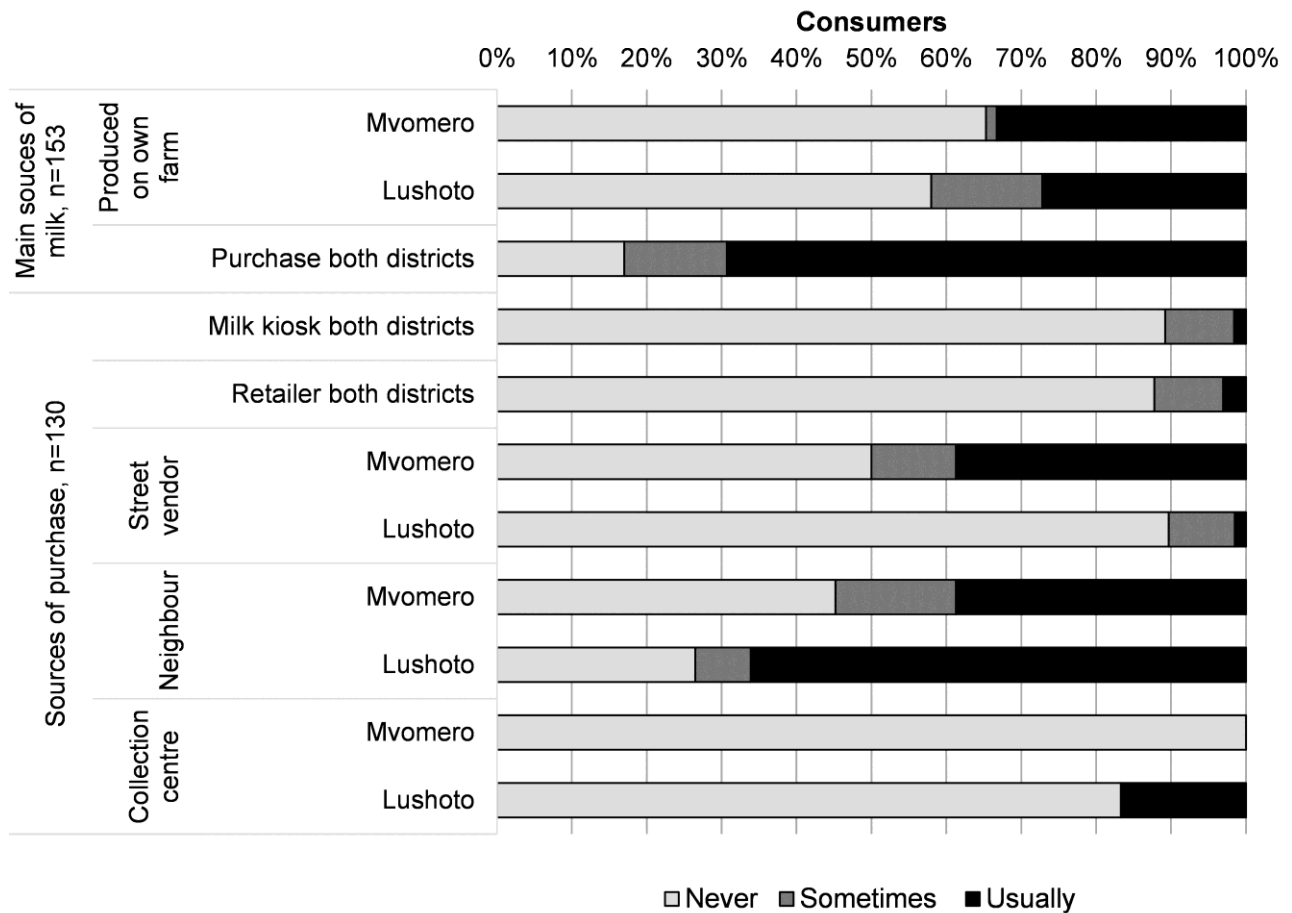
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722 **Fig. 4** Food insecurity reported by consumers for the previous year by district and total (n=157). The
 723 numbers indicate significant differences between districts



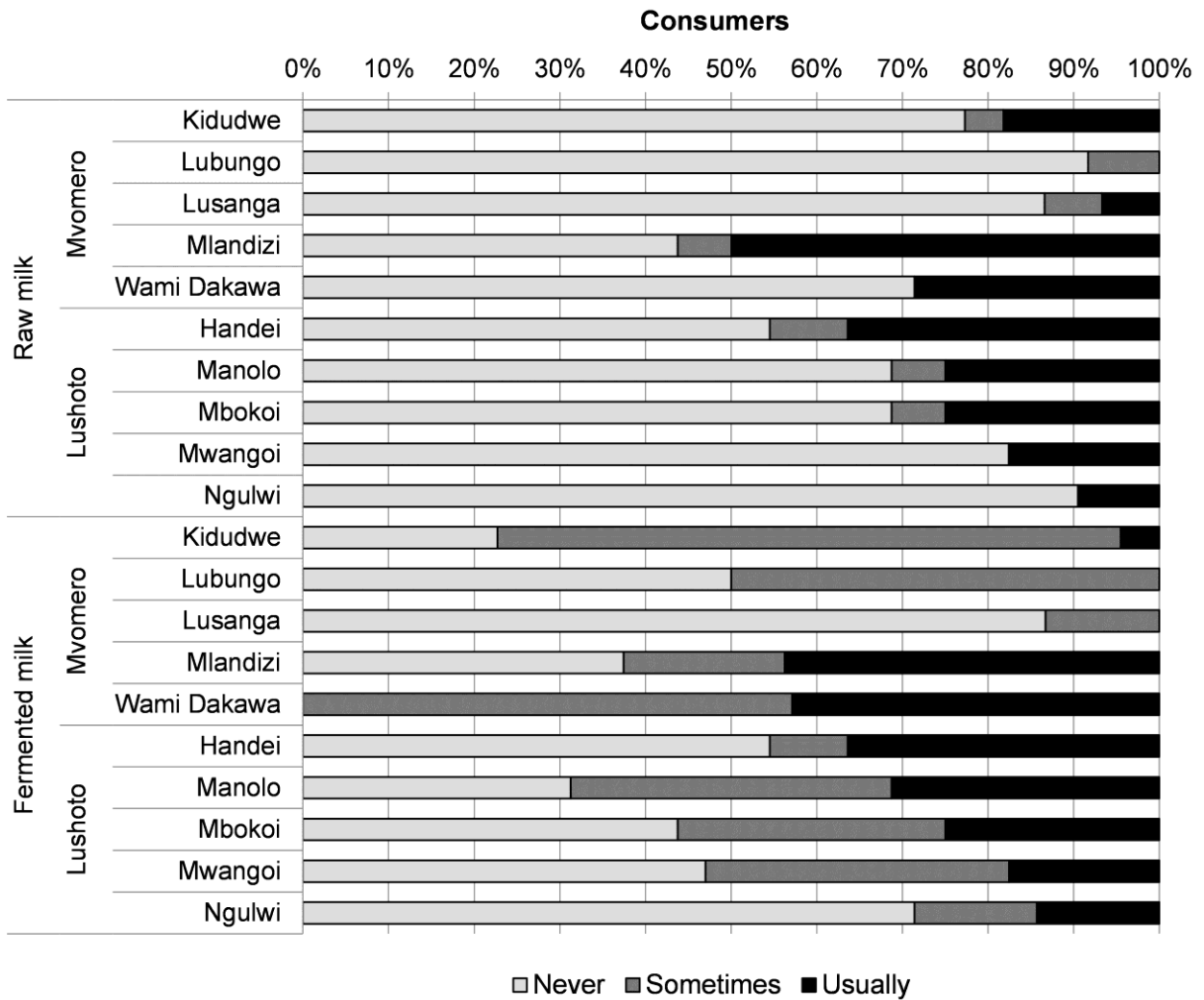
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725 **Fig. 5** Frequency of consumption of raw and fermented milk among consumers in ten villages in Mvomero
 726 and Lushoto districts in Tanzania, n=153. Information by district is presented when the difference is
 727 significant.



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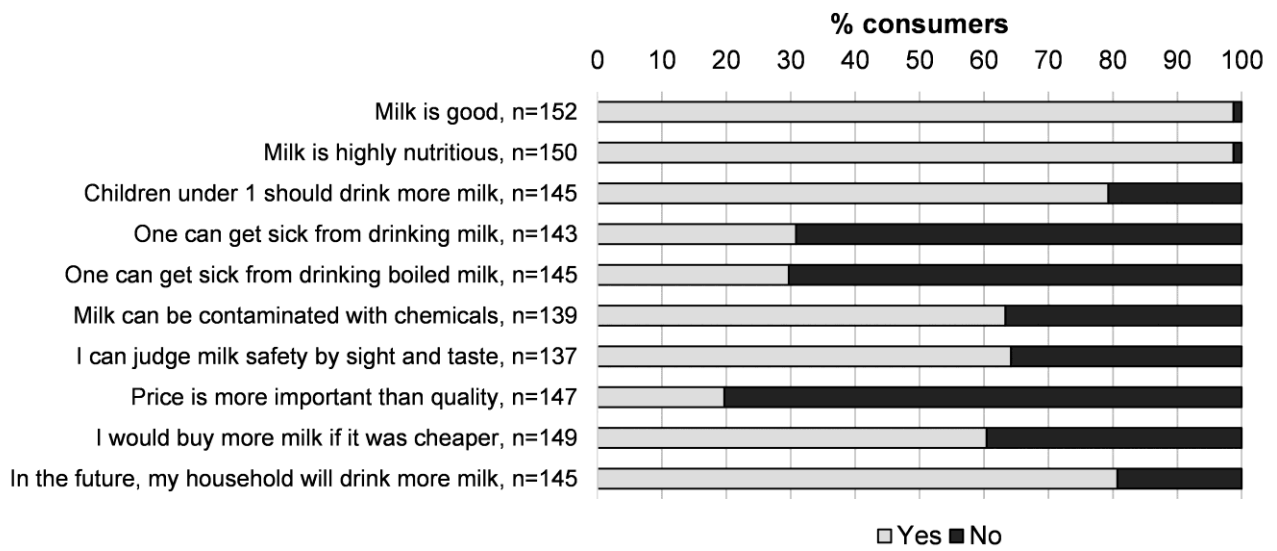
729 **Fig. 6** Frequency of main routes (n=153) and sources of purchasing milk and products (n=130). The values
 730 are indicated for the population (total) and per district (Mvomero, Lushoto) when the differences are
 731 significant



732

733

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



735

736 TABLES

 737 **Table 1:** Summary of demographic information for producers and consumers interviewed on dairy

738 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	-	-

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

 741 ² 1=no education, 2=primary education, 3=secondary education, 4=tertiary education

742

743 **Table 2:** Number of cattle owned, average daily milk yield and best cow milk yield by producer ethnicity and
 744 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	

745

746 **Table 3:** Frequency of using different milk sale channels and associated predictors from the multivariate
 747 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		
Yes	60.9	8.7	30.4	1				

748

749

750 **Table 4:** Knowledge and perceptions among producers about food safety, dairy products acceptance,
 751 demand and accessibility of customers and associated predictors from the multivariate analysis.
 752 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	0.000
		Non-Maasai	129	23.3	11.6	9.3	27.9	27.9	11.21 (3.37-37.3)	
	Source of drugs	Private vet	59	52.2	6.8	8.5	18.6	13.6	1	0.000
		others	77	9.1	19.5	9.1	31.2	31.2	6.53 (2.54 – 16.75)	
	Stop milking when quarter is infected	Yes	33	75.8	6.1	9.1	3.0	6.1	1	0.015
		No	79	20.3	12.7	8.9	20.3	38.0	10.18 (3.19- 32.53)	
	Sale directly to the consumer	Yes	104	20.2	14.4	9.6	28.8	27.9	1	0.000
No		35	48.6	17.1	5.7	11.4	17.1	0.28 (0.10-0.78)		
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	0.002
		No	119	25.2	25.2	7.6	16.0	26.1	0.199(0.071-0.56)	
	Stop milking when quarter is infected	Yes	33	9.1	3.0	6.1	9.1	72.2	1	0.000
		No	79	29.1	27.8	6.3	16.5	20.3	0.101 (0.04-0.25)	
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	0.002
		No	90	2.1	7.4	3.2	41.5	45.7	0.29 (0.13-0.63)	
	Pre storage treatment	Filtration	63	1.5	1.5	3.0	23.9	70.1	1	0.001
		Other	77	5.0	7.5	2.5	41.3	43.8	0.29 (0.14- 0.59)	
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	0.011
		Non-Maasai	88	47.3	29.5	3.9	13.2	6.2	0.30 (0.12- 0.75)	
	Stop milking if a quarter is infected	Yes	33	75.8	6.1	3.0	6.1	9.1	1	0.001
		No	76	45.6	22.8	6.3	17.7	7.6	4.84 (1.81-12.96)	
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	0.004
		Non-Maasai	127	0.8	18.9	7.1	30.7	42.5	3.33 (1.46-7.61)	
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	0.032
		Non-Maasai	128	32.0	40.6	7.0	12.5	7.8	0.417 (0.19 – 0.93)	
	Total			152	29.6	40.1	5.9	15.8	8.6	

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754

Food safety and nutrition in dairy value chain in Tanzania

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	0.000
		Non-Maasai	129	23.3	11.6	9.3	27.9	27.9	11.21 (3.37-37.3)	
	Source of drugs	Private vet	59	52.2	6.8	8.5	18.6	13.6	1	0.000
		others	77	9.1	19.5	9.1	31.2	31.2	6.53 (2.54 – 16.75)	
	Stop milking when quarter is infected	Yes	33	75.8	6.1	9.1	3.0	6.1	1	0.015
		No	79	20.3	12.7	8.9	20.3	38.0	10.18 (3.19- 32.53)	
Sale directly to the consumer	Yes	104	20.2	14.4	9.6	28.8	27.9	1	0.000	
	No	35	48.6	17.1	5.7	11.4	17.1	0.28 (0.10-0.78)		
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	0.002
		No	119	25.2	25.2	7.6	16.0	26.1	0.199(0.071-0.56)	
	Stop milking when quarter is infected	Yes	33	9.1	3.0	6.1	9.1	72.2	1	0.000
		No	79	29.1	27.8	6.3	16.5	20.3	0.101 (0.04-0.25)	
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	0.002
		No	90	2.1	7.4	3.2	41.5	45.7	0.29 (0.13-0.63)	
	Pre storage treatment	Filtration	63	1.5	1.5	3.0	23.9	70.1	1	0.001
Other		77	5.0	7.5	2.5	41.3	43.8	0.29 (0.14- 0.59)		
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	0.011
		Non-Maasai	88	47.3	29.5	3.9	13.2	6.2	0.30 (0.12- 0.75)	
	Stop milking if a quarter is infected	Yes	33	75.8	6.1	3.0	6.1	9.1	1	0.001
		No	76	45.6	22.8	6.3	17.7	7.6	4.84 (1.81-12.96)	
You can always find someone to buy your milk	Ethnicity	Maasai	24	12.5	25.0	8.3	41.7	12.5	1	0.004
		Non-Maasai	127	0.8	18.9	7.1	30.7	42.5	3.33 (1.46-7.61)	
It can be difficult to find someone to buy milk	Ethnicity	Maasai	24	16.7	37.6	0	33.3	12.5	1	0.032
		Non-Maasai	128	32.0	40.6	7.0	12.5	7.8	0.417 (0.19 – 0.93)	

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757 **Table 5:** Food consumption score of the household respondent (FCS HH) and the index case (FCS Index) in
 758 ten villages in Mvomero and Lushoto districts. Only details of significant differences between villages in the
 759 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

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762 Supplementary materials 1 – Location of the study villages

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

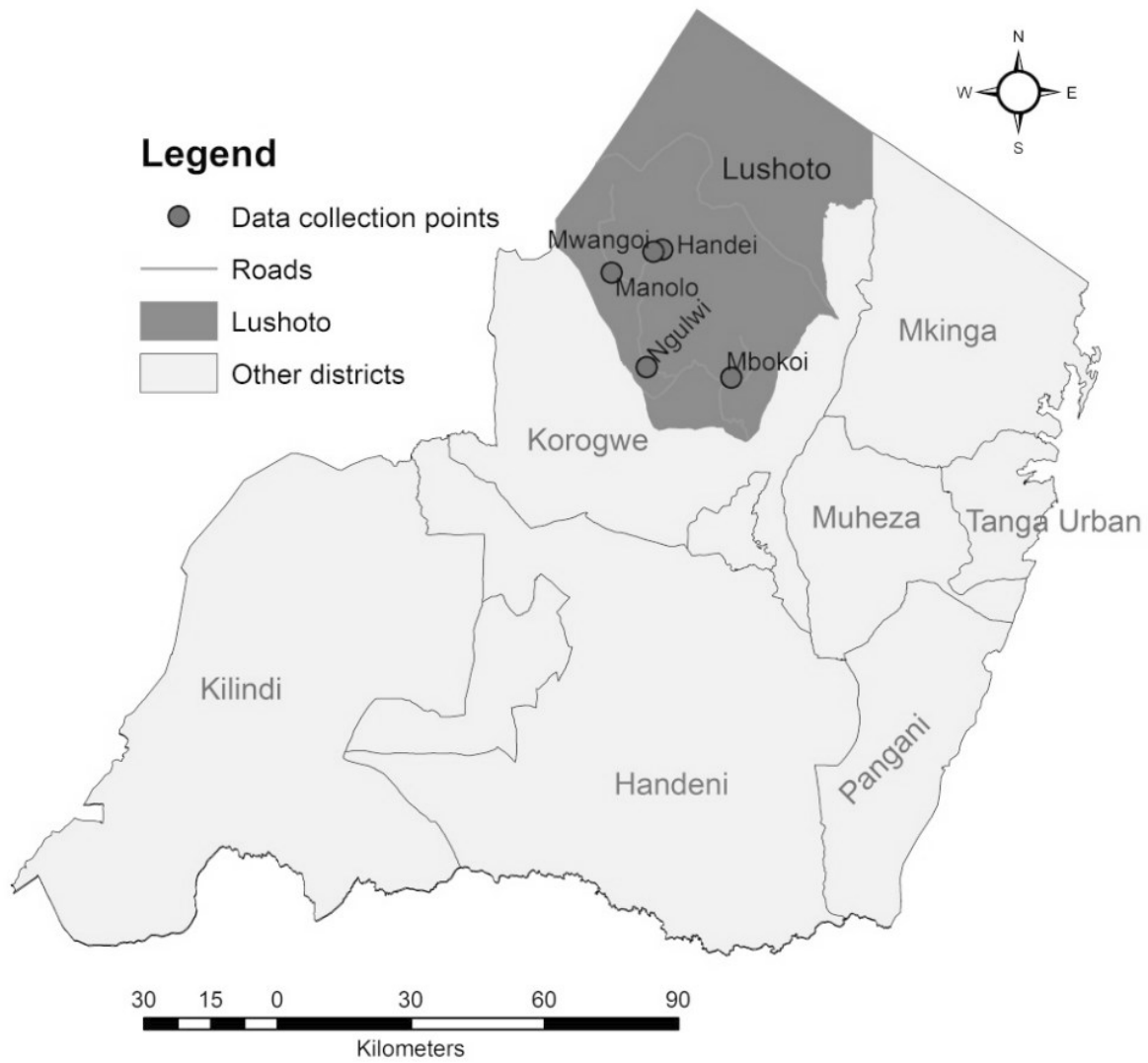
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772 **Fig. 2** Location of the study villages visited in Mvomero district

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775 **Electronic supplementary material 2**

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

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

779 **Electronic supplementary material 2, Table 1: Food groups and their weights used to calculate the food**
780 **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

781

782 **Reference**

783 World Food Programme. (2008). Food consumption analysis - calculation and use of the food consumption
784 score in food security analysis. *Technical Guidance Sheet*.

785 http://home.wfp.org/stellent/groups/public/documents/manual_guide_proced/wfp197216.pdf

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