

## Full Length Research Paper

# Risk factors associated with the post-harvest loss of milk along camel milk value chain in Isiolo County, Kenya

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Camel milk is an important commodity in the arid and semi-arid lands where it forms their basic diet, a major source of income and serves significant cultural function to the pastoralists. However, camel milk production is faced with challenges that contributes to the camel milk post-harvest losses due to poor quality and safety. This study aimed at determining the risk factors that may contribute to camel milk quality losses along the Isiolo camel milk value chain. The survey data was collected through structured questionnaire and key informant interview while the microbiological counts data were determined using ISO methods. There was poor hygiene at the herd level where high *Staphylococcus aureus* count was found on the camel udder swab, milkers' hand swab, and milking container which recorded counts of  $1.4 \times 10^4$  cfu/cm<sup>2</sup>,  $1.5 \times 10^4$  cfu/cm<sup>2</sup>, and  $5.9 \times 10^3$  cfu/ml, respectively. In the other chain nodes, the hygiene was significantly ( $p < 0.05$ ) different with milk hands of retailers around Isiolo town, at the cooling hub/bulking milk and milk retailers in Nairobi Eastleigh area recording *S. aureus* counts of  $4.9 \times 10^3$ ,  $1.3 \times 10^4$ , and  $3.7 \times 10^3$  cfu/cm<sup>2</sup>, respectively. There was problem accessing adequate potable water at the herd level than at the other chain nodes. The plastic milk containers were not disinfected with any chemical sanitizers after washing, however the smoke fumigated them. Camel disease management was poor. Both sick and health camels were milked and the milk bulked together. This therefore indicates that hygiene could be one of the most important contributor to milk deterioration along the chain. Improvement of hygiene along the Isiolo camel milk value chain can help reduce milk post-harvest losses.

**Key words:** Camel milk, handling practices, safety, risk factors, post-harvest losses, Isiolo.

## INTRODUCTION

Camel (*Camelus dromedarius*) husbandry is mainly practiced in the arid and semi-arid land (ASAL) by the

pastoral communities who keep the one humped camel (Farah et al., 2007). One humped camel (*C. dromedarius*)

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plays an important role in the livelihood and culture of pastoralists in the ASALs of Northern Kenya; which are characterized with persistent draught and limit production browse and water limit production (Guliye et al., 2007; MoLD, 2007; Mehari et al., 2007a, b; Mahmoud, 2010).

The world's camel population is estimated to be about 27 million (FAOSTAT, 2015) of which about 82.5% are found in Africa; with about 60% of these are found in Eastern Africa region countries of Somalia, Sudan, Ethiopia, and Kenya (FAOSTAT, 2015). Kenya camel population is estimated to be 3 million (KNBS, 2010; FAOSTAT, 2015); the third largest population in Africa after Somalia and Sudan. In pastoral Northern Kenya, camels are mainly kept for milk production. During the dry season when milk from other livestock is scarce, camel produce more milk and for a longer period of time than other livestock (Kaufmann, 1998). In 2008, the annual camel milk production in Kenya was estimated at 338 million tonnes, valued at USD 107 million, representing 12% of the national milk production and 20% of commercially marketable milk (Musinga et al., 2008), however this increased to 937 million tonnes in 2013 (FAOSTAT, 2015), indicating that camel dairy sub-sector can offer a huge potential for improving the livelihoods of ASAL communities.

Camel milk is a major source of food security and income and also serves as a significant cultural function to the pastoral communities (Guliye et al., 2007; MoLD, 2007; Mehari et al., 2007a, 2007b; Mahmoud, 2010). It forms basic diet for the pastoral communities, where it contributes up to 50% of the total nutrient intake and 30% of their annual caloric intake (Farah and Fischer, 2004). Surplus camel milk is usually sold in urban centres and the raised money contributes to the household cash income.

Despite the major contribution of camel milk to pastoral communities livelihoods, camel milk production is still faced high post-harvest quality deterioration and quantity losses. The risk factors contributing to these high post-harvest losses have not been determined quantitatively and qualitatively at different stages along the camel milk value chain. The objective of this study was therefore to determine the risk factors along the camel milk value chain that lead to the postharvest losses of camel milk at different stages along the camel milk value chain.

## MATERIALS AND METHODS

### Study area

The study was conducted in Isiolo County, a typical ASAL area in North-Eastern Kenya with both peri-urban and pastoral camel production systems and a thriving camel milk trade and Nairobi (Eastleigh estate) the terminal market for the Isiolo camel milk value chain. Isiolo County is a semi-arid area that experiences recurring droughts with devastating losses of livestock. Most parts of the county have mean annual temperature of between 24 and 30°C (Herlocker et al., 1993).

The camel milk production in Isiolo County is done by Somali tribesmen who form the majority of the camel owners in both peri-urban (80%) and pastoral (90%) systems. The Borana tribesmen who traditionally keep cattle until recurrent prolonged drought threat spells in ASAL areas, awakened their interest in camel keeping. The Borana tribesmen form 18.3% of peri-urban camel and 10% of pastoral system (Noor et al., 2013). About 87.5% of the produced camel milk is consumed either at the local trading centres or for subsistence at the household level (Musinga et al., 2008). Isiolo County has about 39,084 camels and a human population of about 143,294 (KNBS, 2010).

### Data collection

#### Cross-sectional survey

Survey data was collected using structured questionnaires, focused group discussions (FGDs), key informant interviews, and personal observations. Purposive sampling was used to select the respondents. The respondents were 75 herdsman (who take care of the camels and milk the camel), 75 women at the collection/bulking centre in Isiolo town and 85 women retailing camel milk within Isiolo town and its environs. The structured questionnaires aimed at determining the risk factors associated with post-harvest quality and quantity losses along the camel milk value chain. The questionnaire comprised three sections which included sanitation and hygiene, camel milk handling, and disease management in camels. Three focused group discussions were held separately with the herdsman, women at retailing site and women at the collection/bulking centres met.

#### Sampling framework

The sampling framework used was as described by Bonfoh et al., (2003). The sampling points/stages along the Isiolo camel milk value chain were herd milking level, collection level within the herd area (primary collection points), collection/bulking centre at Isiolo town (secondary collection point) where milk is cooled waiting transportation the next day to Nairobi, retailing point at Isiolo town and its environs, and finally terminal market point (tertiary point) at Eastleigh estate, Nairobi. At camel herd level, the samples collected from 10 purposively sampled camel herds were: 22 udder swabs from camels before milking and 20 hand swabs from herders doing milking, 8 swabs from milking containers.

Personnel hand swabs were 16, 10, and 12 at collection/bulking centre at Isiolo town (secondary collection point), retailing point at Isiolo town, and terminal market point (tertiary point) at Eastleigh estate, Nairobi, respectively. The time of delivering the milk taken from one level of the market chain to another was also determined.

Swabs samples were preserved in cool boxes containing ice packs and transported on a daily basis to nearby Isiolo County Referral and Teaching hospital laboratory within 2 to 3 h after sampling for microbiological analysis.

#### Microbiological analysis of swab samples

The swab samples were analysed for total viable counts, total coliform count and *Staphylococcus aureus* counts.

Total viable counts (TVC) were determined using plate count agar according to ISO 4833:2003 method (ISO, 2003a). The plates were incubated at 30±1°C for 48 ±2 hours. Total coliform counts were determined according to ISO 4832:2006 method (ISO, 2006) using MacConkey agar and incubating the plate at 300°C for 48±2

h. *S. aureus* counts were determined according to ISO 6888-1:1999/Amd 1:2003 method (ISO, 2003b). The swab samples were surface plated onto the surface of Baird Parker agar. The plates were incubated at 37°C for 24 ±2 hours then re-incubated for a further 24 ±2 hours. Typical *S. aureus* colonies black or grey, shining and convex and surrounded by a clear zone which were partially opaque were counted. The TVC, coliform counts and *S. aureus* counts were expressed as colony forming units (cfu) per square centimeter of swabbed area.

#### Data analysis

Data from questionnaires were analyzed using SPSS Statistics Version 20.0 for descriptive statistics (frequencies, means, and percentages). Qualitative data from the focused group discussion and the key informant interview were transformed into thematic components and written into descriptive prose.

The microbiological data was entered into Microsoft Excel 2013 to generate graphs and table presentation of the results. GENSTAT statistical packages 15th Edition was used to determine if there was significant differences in the counts along the Isiolo camel milk value chain.

## RESULTS AND DISCUSSION

### Containers used for milking and milk transportation

The containers used both for milking and transportation were exclusively plastic. The herdsmen milking reported that they use plastic containers for milking, because they are light (47%) and cheap to buy (36.3%). Camel milk traders reported that they use plastic containers for transportation because they are cheap to buy (41.7%) and easier to transport (23.7%). Some herdsmen (9.7%) and traders (17.3%) reported that they use plastic container for milking to prevent spoilage. This indicates poor knowledge among the pastoralists on the causes of spoilage. The convenience of the containers in terms of use and transportation accounted for 2.4 and 3.2% by traders and herdsmen, respectively (Figure 1).

The milking was done while the milkers were standing due to the high level of the udder that demands that the milking container has to be lifted up during milking to prevent spillage. Wayua et al. (2012) reported similar result that milking is done with one leg raised to support the milking container.

### Hygiene and sanitation along the camel milk value chain

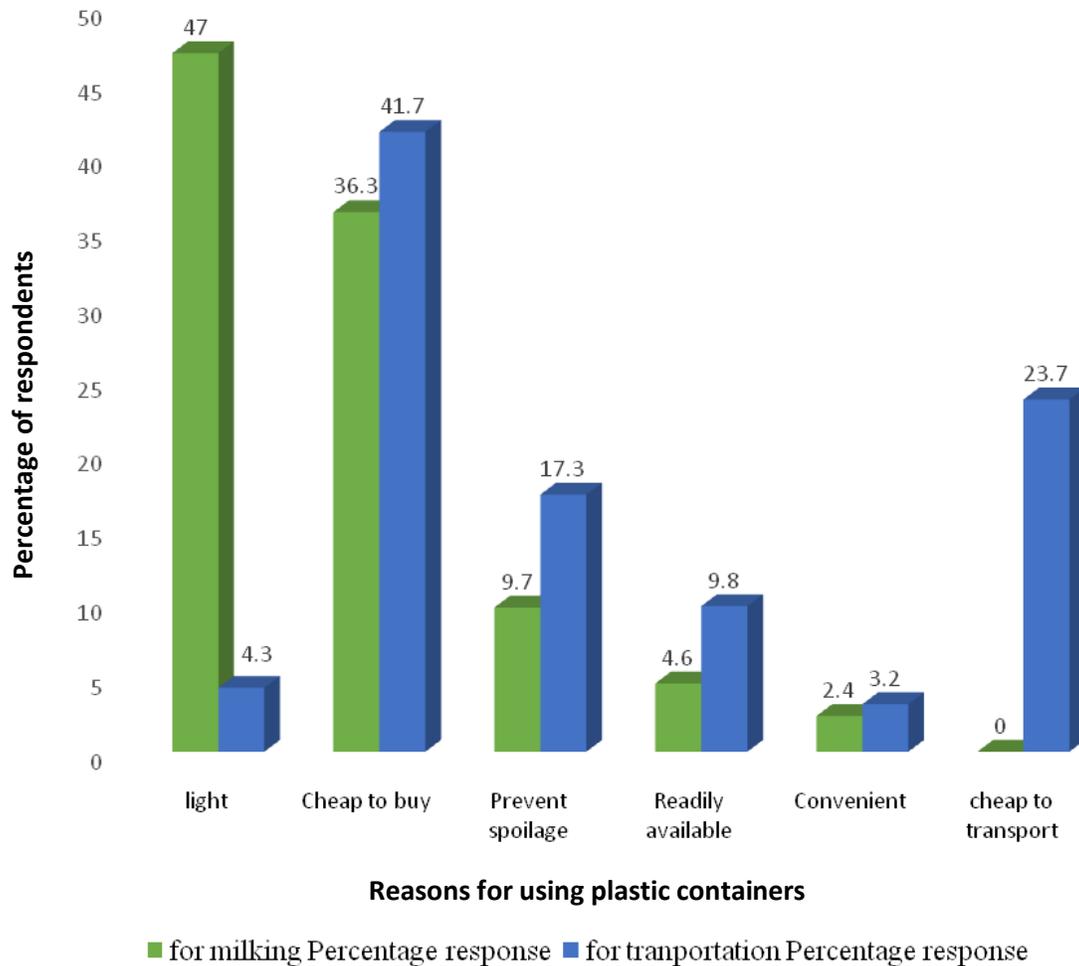
Table 1 shows the microbial counts, as indicated by total viable counts (TVC), coliforms counts, and *S. aureus* counts of swabs from milkers' hands, camel udder, and milking containers at the herd level. There was no significant difference ( $p < 0.05$ ) in TVC and *S. aureus* counts of swabs from milkers' hands and the camel udder. However, milking container showed significantly ( $p < 0.05$ ) lower count for TVC ( $1.1 \times 10^5$  cfu/cm<sup>2</sup>) and *S.*

*aureus* counts ( $5.9 \times 10^3$  cfu/cm<sup>2</sup>). There were significant differences ( $p < 0.05$ ) between coliforms counts of swabs from milkers' hands, camel udder, and milking containers. The udder swabs showed significantly ( $p < 0.05$ ) lower coliform count ( $4.6 \times 10^2$  cfu/cm<sup>2</sup>), while the milkers' hands showed significantly higher coliform count ( $7.2 \times 10^2$  cfu/cm<sup>2</sup>). The high *S. aureus* counts in milking personnel hand swabs was not significantly ( $p < 0.05$ ) different from camel udder swabs. The counts in swabs from milkers' hands for all the three indicator organisms were higher, indicating that milkers' demonstrate poor hygiene during milking, hence could be the main source of microbial contamination of camel milk. Although udders are also not washed before milking and the camel udder swab showed significantly lower swab counts than the milkers' hand swabs. This could be due to the calf suckling before milking. The suckling cleans the udder by removing dirt and microorganisms on the teat. The camel morphology is such that the udder is in direct contact with the soil during resting periods which could result in contamination of the udder with microbes on the ground. The calf may compromise the udder hygiene since after suckling no cleaning of the udder is done before milking. The calf may therefore introduce some microbes to the udder before milking (Noor et al., 2013).

The camel's udder was not washed because the pastoralist believed that the camel udder is always clean. However, our study found that camel's udder was highly contaminated (Table 1). About 37% of the milkers' wet their hands directly with milk in the milking container to lubricate the teat during milking. This act could result into introduction of microbial and dirt contaminants into the milk from the unhygienic milkers' hand, as shown by the microbial load of their hand swabs (Table 1). This results in the milk having higher microbial load, hence facilitating microbial deterioration of the milk leading to post-harvest losses of the milk. This poor hygiene could be due to the fact that the herdsmen do not wash their hands regularly due to lack of water.

Milking container had significantly ( $p < 0.05$ ) low TVC and *S. aureus* counts compared to milkers' hand and camel udder, indicating that washing of the milking containers was not effective as the containers still had high counts. The most important risk factor for possible milk contamination is therefore the herdsmen who milk the camel and handle the camel at the same time.

As indicated by the wide count range in all indicator organisms count, different herds showed significance differences ( $p < 0.05$ ) in hygiene status of the milking personnel, udder, and milking container. The differences in hygiene status in different herds shows that mixing/pooling or bulking of milk from different herds is a risk factor as herds higher microbial counts could compromise the camel milk quality; thus, supporting findings of study by Younan and Abdurahman (2004) among South Somali milk producers/traders. Milk from different herds are usually brought to a central point along



**Figure 1.** Reasons for use of plastic containers at the herd level and during transportation of camel milk.

the road or designated place in area where transporters on either motorbikes or pickup trucks or donkey pick the milk and transport it to bulking centre at Isiolo town.

Table 2 shows microbial counts, as indicated by total viable counts, coliforms counts, and *S. aureus* counts of hands swabs of women at the camel milk cooling hub and those retailing camel milk at Isiolo town and Eastleigh, Nairobi. The results showed that there was no significant difference ( $p > 0.05$ ) in TVC of hand swabs of women retailing camel milk around Isiolo town ( $1.5 \times 10^5$  cfu/cm<sup>2</sup>), women at the bulking/cooling hub at Isiolo town ( $1.3 \times 10^5$ ) and women retailers at Eastleigh, Nairobi ( $9.6 \times 10^4$  cfu/cm<sup>2</sup>). However, there was significant difference ( $p > 0.05$ ) in *S. aureus* counts of hand swabs of women retailing camel milk around Isiolo town ( $4.9 \times 10^3$  cfu/cm<sup>2</sup>), women at the bulking/cooling hub at Isiolo town ( $1.3 \times 10^4$ ), and women retailers at Eastleigh, Nairobi ( $3.7 \times 10^3$ ). As demonstrated by *S. aureus* counts, an indicator organism of personnel hygiene, the women at the bulking/cooling hub in Isiolo town showed poor

personnel hygiene, while the women in Eastleigh, Nairobi showed the best personnel hygiene. There was also significant difference ( $p < 0.05$ ) in coliform counts of hand swabs of women at the bulking/cooling hub at Isiolo town ( $1.5 \times 10^2$ ), women retailing camel milk around Isiolo town ( $1.1 \times 10^2$  cfu/cm<sup>2</sup>) and women retailers at Eastleigh, Nairobi ( $1.4 \times 10^2$  cfu/cm<sup>2</sup>). The women at the bulking/cooling hub at Isiolo town showed significantly poor personnel hygiene ( $1.5 \times 10^2$  coliform cfu/cm<sup>2</sup>), compared to women retailing camel milk around Isiolo town who demonstrated significantly better personnel hygiene ( $1.1 \times 10^2$  coliforms cfu/cm<sup>2</sup>). As shown in the wide range of count (Table 2), there was significant differences ( $p < 0.05$ ) among the women at the bulking/cooling hub at Isiolo town, with some showing better personnel hygiene, while other showing poor personnel hygiene.

The cooling hubs, where different herds milk are bulked into group bulking and cooling tank or into private individual freezers, could therefore be one of the major risk points along the camel milk value chain for camel

**Table 1.** Microbial load of milkers', camel udder and milking containers at milk harvesting at herd level.

Type of organism	Hand swabs for milkers (n*= 20)		Camel udder swab (n=22)		Milking container swab (n=8)	
	Counts (cfu/ cm <sup>2</sup> )					
	Geometric mean	Range	Geometric mean	Range	Geometric mean	Range
Total viable counts (TVC)	6.5×10 <sup>5b</sup>	1.5×10 <sup>4</sup> – 3.5×10 <sup>6</sup>	5.8×10 <sup>5b</sup>	1.4×10 <sup>4</sup> – 2.4×10 <sup>6</sup>	1.1×10 <sup>5a</sup>	1.9×10 <sup>3</sup> – 2.0×10 <sup>5</sup>
Coliforms	7.2×10 <sup>2c</sup>	1.8×10 <sup>1</sup> – 3.3×10 <sup>3</sup>	4.6×10 <sup>1a</sup>	0 – 2.0×10 <sup>2</sup>	4.5×10 <sup>2b</sup>	3.6×10 <sup>1</sup> – 1.2×10 <sup>3</sup>
<i>Staphylococcus aureus</i>	1.5×10 <sup>4b</sup>	2.0×10 <sup>3</sup> – 4.2×10 <sup>4</sup>	1.4×10 <sup>4b</sup>	2.0×10 <sup>1</sup> – 5.1×10 <sup>4</sup>	5.9×10 <sup>3a</sup>	3.8×10 <sup>2</sup> – 2.1×10 <sup>4</sup>

\*n= Number of samples. \*\*The generic mean values with similar letters in the same row are not significantly different at 5%.

**Table 2.** Microbial Counts of hand swabs of women at camel milk retailing and cooling hub at Isiolo town, and women retailing milk in Eastleigh, Nairobi.

Type of microorganism	Women retailers around Isiolo (n=10)		Women at the cooling hubs (n=16)		Women retailer in Nairobi-Eastleigh (n=12)	
	Counts (cfu/cm <sup>2</sup> )					
	Geometric mean	Range of counts	Geometric mean	Range of counts	Geometric mean	Range of counts
Total viable counts (TVC)	1.5×10 <sup>5a</sup>	1.0×10 <sup>4</sup> – 6.4×10 <sup>5</sup>	1.3×10 <sup>5a</sup>	1.8×10 <sup>4</sup> – 4.6 ×10 <sup>5</sup>	9.6×10 <sup>4a</sup>	8.0×10 <sup>3</sup> – 6.4×10 <sup>5</sup>
Coliforms	1.1×10 <sup>2a</sup>	10 – 7.9×10 <sup>2</sup>	1.5×10 <sup>2c</sup>	10 – 1×10 <sup>3</sup>	1.4×10 <sup>2b</sup>	12 – 9.7×10 <sup>2</sup>
<i>Staphylococcus aureus</i>	4.9×10 <sup>3b</sup>	2.4×10 <sup>2</sup> – 2.3×10 <sup>4</sup>	1.3×10 <sup>4c</sup>	6.8×10 <sup>2</sup> – 8.1×10 <sup>4</sup>	3.7×10 <sup>3a</sup>	2.6×10 <sup>2</sup> – 1.2× 10 <sup>4</sup>

The generic mean values with similar letters in the same row are not significantly different at 5%. n= number of samples

milk contamination. Ninety three (93) percent of women at bulking/cooling centre and 73% of women retailing milk at Isiolo town were accessible to potable water provided by county government. However, at herd level water sources were reported to be either river or borehole, or dam or in plastic containers delivered to them when empty milk containers are returned to the herds. This shows that most important risk factor at the camel milk production level water hygiene and sanitation which is more difficult and expensive to control. Therefore, herders have no choice, but to use the water that is available for cleaning milking container. The source of water for use at the herd level therefore presented one of the most important risk factor of camel milk

contamination. Other studies also reported that water in the ASALs is grossly contaminated and its availability in the camel milk production areas is either scarce or unavailable (Kaindi et al., 2011). The water source for cleaning milk containers should be potable (Musinga et al., 2008; Lore et al., 2006). To prevent milk contamination, hygiene and sanitation of personnel, and milking and milk handling containers and water quality are extremely important (Gran et al., 2002). These are hardly exercised at the herd level making camel milk contamination highly likely.

Table 3 shows the duration of time milk takes from milking to various stages along the camel milk value chain.

The results show that camel milk is held for 25 to 30 h before it reaches the terminal market at Eastleigh, Nairobi County.

Milk takes about 11 h at high ambient temperatures (28 to 30°C) before it is cooled at the bulking/cooling centre at Isiolo town. This coupled with poor milk handling hygiene practices contributes a lot to the deterioration of milk quality.

Therefore, holding milk at high ambient temperature for long time is other risk factor associated with final milk quality. Holding of camel milk at low temperatures for 18 to 30 h can allow for growth of psychrophilic spoilage and pathogenic bacteria, which are mostly associated poor hygiene practices. Therefore, holding of poor quality raw milk at low temperature is also a risk

**Table 3.** Time milk takes from milking to reach various stages along the camel milk value chain.

Parameter	Stage along the chain				
	Individual camel milk	Primary collection within the herd areas	Delivered to bulking/cooling hubs in Isiolo	Milk at retailing point in Isiolo	Bulked in in Nairobi Eastleigh
Cumulative time (h) elapsed after milking	< 1	4 - 7	4-11	5-13	25-30

factor to quality and safety of camel milk.

### Cleaning of plastic milk handling containers

The milking containers at the herd level were cleaned exclusively by the herdsman (100%) the following morning, about 20 h after use, by rinsing the container only with water, which may not be effective to remove the accumulated dirt and microorganisms. The rinse water may not be potable thereby increasing the chances of contamination of container and hence by extension contamination of milk. The water used at the herd level also was inadequate for proper cleaning. Containers used to transport milk from the herds to bulking/cooling centre at Isiolo town were cleaned exclusively by the women (94.8%) who receive the milk at bulking/cooling centre or by hired women who clean the containers for a pay (5.2%). Hot water, detergents, and sanitizers are not used during cleaning. This leads to ineffective cleaning of the milk containers with likelihood of residual microorganisms remaining in the containers which contaminates added milk hence leading to poor quality milk, and post-harvest loss of the milk. The containers used to transport the milk to Eastleigh, Nairobi are brought back to Isiolo town uncleaned where they are cleaned more than 12 h after the milk had been drained from the containers.

Delay in cleaning milk handling containers is a risk factor as it presents adequate time for

microorganisms to multiply and increase to microbial load microbial load to levels that are difficult to reduce to acceptable level during cleaning. This could result into high microbial counts in milk handled in these containers and hence accelerated microbial spoilage leading to post-harvest losses of the milk.

### Smoke fumigation of plastic milk handling containers

After cleaning, the milk handling plastic containers are normally smoke fumigated using special trees/shrubs. Other studies have also reported on the use of smoke fumigation in the pastoral system (Wayua et al., 2009; Kipsang, 2011).

Our study found that there are eight tree/shrub varieties commonly used for smoke fumigation of milk handling containers along the chain (Table 4). The most commonly used tree/shrub variety was *Acacia nilotica* known as “*Bil-ill*” by the Somali community and “*Sabans*” by Borana community. While the second most used tree/shrub variety was *Cardia quercifolia* (*C. sinensis*) known as “*Marer*” by the Somali community and “*Madeer*” by Borana community. Seifu et al., (2007) in Ethiopia reported three main tree varieties which included *Olea Africana*, *Balanites galabra*, and *Acacia ethaica*. Wayua et al. (2012) also reported four tree varieties used in Isiolo which included *Olea africana*, *Acacia nilotica*, *Balanities aegyptica*, and *Combretum*

species. The usage is dependent on the effectiveness of the tree/shrub variety and its availability in the area of use.

According to the respondents, the herders use the best tree/shrub varieties for smoke fumigation, because they are accessible to them during grazing of the camels. Some of the women at bulking/cooling and retailing points sent to their cleaned containers to the herders for smoking (8.8%). This was because the herders are more accessible to the tree/shrubs species as they graze camels. The smoking is done by lighting the tree/shrub until it flames for sometimes, then the fire is extinguished and smoke is directed into the container. This is repeated several times depending on the container size until the container gets hot. The container is then closed to enclose the smoke inside it for about 15 min. Some respondents rinse the excess smoke out after some time (32.1%), while others (67.9) do not rinse. During smoking, some particles of the burning tree/shrub drop into the container, some pastoralists’ remove them, while others do not.

This usually changes the colour of the milk. This could lead to post-harvest loss of the milk if the targeted consumers or customers do not prefer smoke flavour and taste in the milk, a case typical to most non-pastoral communities. The foreign taste and flavour further makes the milk unacceptable by processors leading to rejection of milk by processors, hence leading to post-harvest losses.

Several studies have recommended that

**Table 4.** Tree/shrub varieties commonly used for smoke fumigation of milk handling containers at various points along the value chain.

Vernacular name Somali/Borana	Scientific name of tree/shrub varieties	Herdsmen N=74 (%)	Retailing women around Isiolo N=82 (%)	Women at collection point N = 72 (%)
Bil-ill/Sabans	<i>Acacia nilotica</i>	81.2	74.8	76.4
Marer/Madeer	<i>Cardia quercifolia</i> ( <i>C. sinensis</i> )	71.8	41.8	57.0
Qualangal/Qualqulch	<i>Maerua denhardtiorum</i>	55.7	61.5	35.8
Degayera/Ilqabachi	<i>Cadaba ruspolii</i>	42.6	12.4	26.4
Kulan/Bedan	<i>Balanites pedicillaris</i> ( <i>B. rotundifolia</i> )	33.8	23.4	19.4
Fulay /Wachu	<i>Acacia zanzibarica</i>	-	17.2	15.3
Qote	<i>Cardia ovalis</i>	-	5.8	12.5
Da'ar/Bires	<i>Terminalia kilimandscharicum</i>	-	13.6	11.4

N= number of samples.

containers for milking, transporting, and storing milk should be adequately cleaned using good quality water and disinfected to avoid microbial contamination and improve the microbiological quality of milk (Bonfoh et al., 2006; Lore et al., 2006; Musinga et al., 2008).

### Camel health

About 78% of herdsmen reported that camels had painful and swollen teats an indication of early stage of mastitis and 9% reported milk discoloration an indication of advanced mastitis. Just like using uncleaned milking machine for several cows, the herdsmen usually milks both infected and uninfected camels at same time, a milking practices that has been reported to increase spread of mastitis. Our other study, which screened the same camels for mastitis using California Mastitic Test (CMT), also showed high prevalence of mastitis in the herds examined (Lamuka et al – manuscript submitted).

Prevalence of mastitis in camel milk production

system has been reported in Kenya (Younan and Abdurahman, 2004; Kaindi et al., 2011) and Ethiopia (Abera et al., 2010). Milk from camels showing sign of mastitis were mixed with the rest of the milk from healthy camels. This poses health risk as pathogenic microorganisms are likely to be present in the mastitic milk (Tesfaye et al., 2011); hence, mastitic milk should not be consumed resulting to post-harvest losses.

About 97% of the herders indicated that they self-medicate camels. Therefore, the milk is likely to have high levels of veterinary drug residues than levels acceptable for consumption leading to its being rejection.

The herdsmen do not segregate milk from sick camels instead they mix it with milk from healthy camels, a practice that is likely to pose a food safety public health risk due to the likely presence of zoonotic organisms. This increases food safety risk to the population who consume the raw milk without even boiling, a practice common among pastoralists (Wayua et al., 2012).

About 95% of the herdsmen responded that there is no health risk in drinking milk from sick

camels and that there is no need to observe the withdrawal period as this will be milk wastage. Several studies have shown that foodborne pathogens in the camel milk can be associated with unhealthy camels (Meile, 2010; Wanjohi et al., 2010; Megersa et al., 2011; Tesfaye et al., 2011).

Unlike a study by Younan and Abdurahman (2004) who listed several factors as contributors to the poor hygiene; this study has used quantitative and qualitative data to extensively demonstrate that poor sanitation and hygiene practices along the camel milk value chain are as a result of interaction of many risk factors which may lead to the post-harvest losses of milk and/or make milk unacceptable for consumption and processing.

### Conclusion

The Isiolo camel milk value chain is associated with a number of risk factors which results to the spoilage of camel milk or the camel milk being

unfit for processing and unsafe for consumption. Among the risk factors include poor personnel hygiene, inadequate cleaning and sanitation of milk handling containers, lack of potable water for cleaning of milking containers, poor camel health management, unfavorable high ambient temperatures, longer time taken for milk to be cooled at cooling facilities. Sanitation and hygienic practices at various stages along the Isiolo camel milk value chain were found to be significantly different. Strategies to improve pastoralists' income and livelihoods from camel milk should therefore focus on innovative ways of reducing camel milk contamination, spoilage and post-harvest losses along the camel milk value chain. This can be achieved through well-tailored hygiene and food safety education aimed at improving pastoralists' knowledge on food hygiene and sanitation and hence improved quality and safety of marketed milk.

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## Conflict of interests

The authors have not declared any conflict of interests.

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