

DATA ARTICLE

Open Access



Hygienic assessment of spontaneously fermented raw camel milk (*suusa*) along the informal value chain in Kenya

Linnet Wanjiru Mwangi^{1*}, Joseph Wafula Matofari¹, Patrick Simiyu Muliro¹ and Bockline Omedo Bebe²

Abstract

Background: *Suusa* is a spontaneously fermented milk product from raw camel milk used by the pastoral communities of Northern and Eastern Kenya. The product can be as a result of intentional fermentation at ambient temperature for 3 days where it is prepared by women specifically for home consumption. The product can also result from unintentional fermentation where raw camel milk intended for sale, undergoes coagulation at any node of the informal value chain. Since no heat treatment is involved in preparation, microbial safety and quality of *suusa* is completely dependent on the raw milk inherent flora and handling practices. Therefore, the aim of this study was to determine the microbiological quality and safety of *suusa* along the informal value chain in relation to the raw camel milk handling practices. The study was carried out in Isiolo County where production, bulking and cooling of raw camel milk is done and in Nairobi County where there is biggest market for that milk. A total of 59 milk samples were obtained from the production, bulking, cooling and marketing nodes and analysed for, Titratable Acidity (TA), Total Viable Count (TVC), Coliform Count (CC), Spore Count (SC) and Yeast and Moulds Count (YM). The microbial load of TVC, CC and YM, increased significantly ($P < 0.05$) by 1 log increase, while SC increased by 3 log increase from production to market. The lactic acid increased from 0.07 % to 0.23 % for the unintended *suusa*. The microbial load comprised of 67 % Gram Negative Rods (GNR), 62 % Gram Positive Cocci (GPC) and 28 % YM from production, processing and marketing. Hygienic practices in raw camel milk and *suusa* production potentially expose the product to microbial contamination associated with reduced shelf life and public health concern.

Results: A total of 59 milk samples were obtained from the production, bulking, cooling and marketing nodes and analysed for, Titratable Acidity (TA), Total Viable Count (TVC), Coliform Count (CC), Spore Count (SC) and Yeast and Moulds Count (YM). The microbial load of TVC, CC and YM, increased significantly ($P < 0.05$) by 1 log increase, while SC increased by 3 log increase from production to market. The lactic acid increased from 0.07 % to 0.23 % for the unintended *suusa*. The microbial load comprised of 67 % Gram Negative Rods (GNR), 62 % Gram Positive Cocci (GPC) and 28 % YM from production, processing and marketing.

Conclusion: Hygienic practices in raw camel milk and *suusa* production potentially expose the product to microbial contamination associated with reduced shelf life and public health concern.

Keywords: Camel milk, Microbial quality, *Suusa*, Contamination, Value chain, Isiolo

* Correspondence: lymwng@gmail.com

¹Department of Dairy and Food Science and Technology, Egerton University, P.O. Box 536-20115, Egerton, Kenya

Full list of author information is available at the end of the article

Background

In Kenya, the camel population is approximated to be 3.1 million (Corman et al. 2014). They are all one-humped (*Camelus dromedarius*), found mainly in the low lands of Northern Kenya. The camel lives in areas not suitable for crop production and where other livestock species can hardly thrive (Noor et al., 2012). Due to its outstanding performance in arid and semi arid areas (ASAL) of northern Kenya, camels play a central role to the livelihoods and culture of nomadic pastoralists (Guliye et al. 2007). They provide milk, meat and means of transport. The camel milk production in Kenya is estimated at 937 thousand tonnes in 2013 (FAOSTAT, 2015) which translates to about US\$ 107.1 million. This quantity of milk represents about 12 % of the total national Kenyan milk production (Musinga et al. 2008). During prolonged droughts, camel milk may contribute up to 50 % of total nutrient intake by pastoral groups (Wayua et al., 2012). The most popular camel milk product among the pastoral groups is *suusa*. *Suusa* is spontaneously fermented raw camel milk. The fermentation is carried out at room temperature ranging from 26–29 °C, for 1–2 days in a gourd (Lore et al., 2005). The product is a white, low-viscosity product with a distinct smoky flavour and astringent taste (Lore et al., 2005). However, due to demand, the gourds have become small to produce the amount needed and the women pastoralists have turned to recycled plastic oil containers. *Suusa* is prepared by the Borana and Somali communities of North and Eastern Kenya, by storing milk in plastic containers which is allowed to slowly coagulate over a period of 1–3 days.

Spontaneous fermentation of raw milk takes advantage of the action of naturally occurring mixed microflora inherent in the milk in the plastic containers as well as factors such as temperature and pH provide the necessary selective factors for evolution of lactic acid bacteria (LAB) that impart desirable attributes to the product (Lore et al., 2005). However, *suusa* production process faces several handicaps; these include unpredictable production environment, unknown microbiology in processing, lack of process control and, unknown toxicological status (Chinyere and Onyekwere, 1996). Under pastoral production of *suusa*, factors such as unknown udder health, plastic milking and storage containers, milking personnel practices like tying the quarters to prevent suckling by the calf and dusty milking environment, and lack of water may act as points of contamination (Mulwa et al., 2011). During transportation, either by walking, on donkeys or occasionally on open pickups, long distance from milking point to collection or storage point, poor roads and lack of cooling facilities affects the microbial load by providing conditions for rapid

multiplication in the milk (Mulwa et al., 2011). At the collection centres, milk from different suppliers is pooled without prior quality control tests and this acts as a source of contamination and affects the safety and quality of the milk (Momanyi and Jenet 2010; Noor et al., 2013). The only test carried out is organoleptic (taste, sight and smell) (Noor et al., 2013) which is insufficient to detect for other detrimental quality and safety issues related to milk. The variables involved the fermentation include lack of heat treatment of the milk, storage at ambient temperature, lack of known culture composition and hence lack of process control which results in a product of variable quality (Eyassu, 2007). The final product is sold in open air markets and this has an effect on the quality of the product. *Suusa* produced under pastoral environment faces these challenges along the value chain from production to consumption.

This practice of spontaneously fermenting raw camel milk into *suusa* is highly valued by the pastoral communities for nutritional and cultural reasons. Earlier studies on *suusa* product have majorly focused on the handling practices (Wayua et al., 2012) and Lactic Acid Bacteria (LABs) responsible for the fermentation (Lore et al., 2005). However, there exists no information on the microbial quality and safety of *suusa* along the value chain. The aim of this study was to determine the microbiological quality of *suusa* along the informal value chain with the aim of enhancing food and income security among the pastoral communities.

Methods

Study site

The study was carried out in Isiolo County which is camel milk producing area and in Eastleigh, Nairobi County which is a major urban consumption centre for camel milk. Isiolo County is located in Eastern Kenya, approximately 285 km North of Nairobi. The County is located at coordinates are 0° 21' 0" North and 37° 35' 0" East and an altitude ranging from 200 to 300 meters above sea level (ASL) although there are some areas in the county that go up to 1000 ASL. Its annual average temperature ranges between 12 and 28 °C and receives low rainfall ranging between 300 and 500 mm per year.

Milk handling practices survey

Semi structured questionnaires were administered to 90 respondents. At production, 30 respondents were purposively selected who comprised of herders, herd owners and transporters. At collection/bulking centres 30 respondents were selected who comprised of cooling hub attendants, traders and consumers. At Nairobi, Eastleigh market 30 respondents were selected who comprised of

consumers and traders. Focus Group Discussions (FGD) held with women group of 15 members who were randomly selected to represent camel milk producers, herders, milk traders, and consumers at Isiolo and Eastleigh, Nairobi. This was done to identify handling practices along the value chain.

Milk sampling

Samples of raw camel milk and *suusa* were collected in triplicates at each representative point of the value chain for microbiological analysis. At production, pooled milk samples from the herds. Milk samples were collected from each container at the herd level and later pooled to make a representative sample of 20. At bulking centres, a total of 12 random samples were collected from each cooling hub. A total of 7 unintended *suusa* samples were collected at the time of the study while a total of 10 intended *suusa* were collected. Intended *suusa* was collected from pastoral women who were requested to prepare it since the commodity is rare. A total of 10 *suusa* samples were collected from Eastleigh, Nairobi market from 10 traders. Pooled *suusa* sample was made by pooling milk from as many containers as each woman trader had to obtain a representative sample. At each sampling point, 50 ml of milk sample was taken and transferred into sterile screw-capped sampling bottles, securely capped, clearly labelled and immediately transported to the laboratory for analysis under ice (4 °C). A total of 59 samples were obtained for titratable acidity and microbial analysis.

Sample analysis

The raw camel milk and *suusa* samples analysis was done at Egerton University, Food microbiology laboratory. Serial dilution of up to 10^{-6} was done using peptone water and 1 ml of homogenate of sample was aseptically transferred into a sterile petri dish. Total Viable Counts (TVC) was enumerated on Plate Count Agar (PCA) (Oxoid, UK) using pour plating method and the plates incubated at 37 °C for 48 hours. The Coliforms counts (CC) were enumerated on Violet Red Bile Agar (VRBA) (Oxoid, UK) using pour plating technique and plates incubated at 37 °C for 24 hours (AOAC, 1995). The Spore Counts (SC) were enumerated by heat treating milk samples in a water bath at 80 °C for 10 - minutes and 1 ml of appropriate dilution pour plated on (PCA) (Oxoid, UK) and the plates incubated at 37 °C for 24 hours (AOAC, 1995). While the yeast and mould were determined on Potato Dextrose Agar (PDA) (Oxoid, UK) by spread plating technique and the plates incubated at 25 °C for 5 days (AOAC, 1995).

Discrete colonies grown on plates after incubation were selected randomly and purified by repeated plating on the same agar according to Lore et al. (2005). The

colonies were then subjected to morphological (cell shape, motility, cell grouping and endospores), biochemical (catalase, oxidase, carbohydrate utilization, indole, and Methyl red-Voges-Proskauer) and physiological tests and identified to genus level (AOAC, 1995).

Developed acidity in the samples was determined according to the method described by the International Dairy Federation (I.D.F.) (1990). 9 ml of the milk samples were measured into the conical flasks, and 1 ml 0.5 % alcoholic phenolphthalein indicator added then titrating with 0.1 N sodium hydroxide (NaOH) until a faint pink colour appears. The results were then expressed as % lactic acid where 1/10 ml NaOH is equal to 0.09 % w/v lactic acid.

Statistical analysis of data

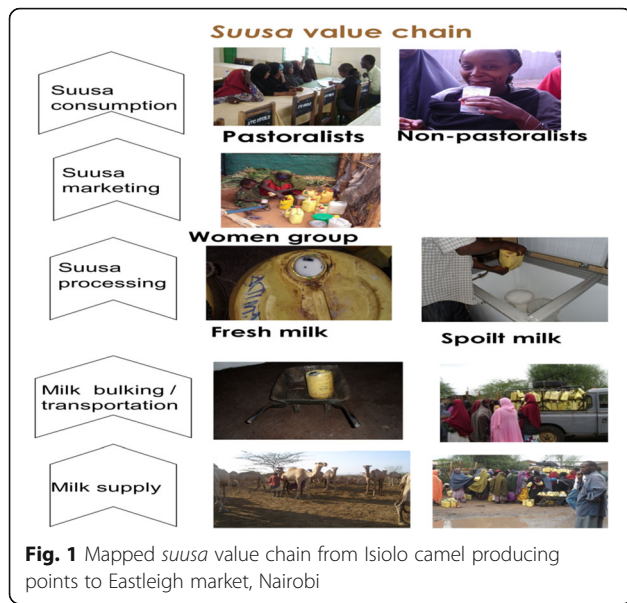
The microbial counts for the total viable count (TVC), coliform count (CC), spore count (SC), yeast and mould count (YM) were transformed to base-10 logarithm of colony forming units (cfus) per millilitre (ml) of the milk samples (\log_{10} cfu/ml). The transformed data was tested for normality using PROC NPAR1WAY procedure of Komolgorov–Smirnov's test and also tested for homogeneity of variances using Levene's test before assumption of analysis of variance (ANOVA) was done using the General Linear Model (GLM) procedure of SAS version 9.1 (SAS Institute, Inc., Cary, NC). The independent variable was the milk quality and value chain points (production, bulking, processing and marketing). The significance of the means was determined using Tukey's Honestly Significance Difference (HSD) test at $P < 0.05$.

Results

Mapping the *suusa* value chain

The value chain for *suusa* mapped from surveys and FGD is represented in Fig. 1, revealing the handling practices along the value chain. Camels are milked at "boma" (similar to a kraal) by herders. Fresh milk is bought by women groups or individuals to make *suusa* or sell in open air market. Soured milk is downgraded and sold as unintended *suusa*. Fresh camel milk and *suusa* is consumed by both pastoralists and non-pastoralists.

The common camel milk handling practices that influence the contamination levels in milk is shown in Table 1. It was found that all herders neither wash their hands nor wash the camel udder before milking and all camel milk handling containers were plastic. After milking and bulking at the herd level, all milk was found to be transported by the either motorbikes when the herd was near Isiolo town or trucks when the herds were far from the town e.g. from Kulamawe which was about 100 KM from Isiolo town. Isiolo town is the main collection center for raw camel milk where there are cooling facilities for the milk. At Isiolo, milk



was either transported to Nairobi using Buses or sold in the town through open air vending or milk bars. Of interest was that *suusa* was made through 2 identified processes. One process is that raw camel milk that gets sour/coagulates on transit to collection or market centres from the production area- *Boma* would be sold as *suusa* referred to as unintended *suusa* by the authors. The fermentation in this case would take from 4-24hours. The other process is intentional spontaneous fermentation of raw camel milk for a period of 3 days mostly done by pastoral women for home consumption referred as intended

Table 1 The common handling practices for the camel milk

Practice	N	Frequency (%)
Hand washing	30	0
Udder washing	30	0
Plastic milk storage containers	30	100
Means of transport to cooling centres:		
Truck	30	20
Motorbike		70
Donkeys		10
Means of transport to the market-Nairobi:		
Truck	30	0
Buses		100
Non-performance of quality control tests before bulking	30	100
Boiling milk before making <i>suusa</i>	30	0
Sale area of <i>suusa</i> : Roadside	30	80
Dairy		10
Hotel		10

suusa. However, preparation of *suusa* through the 2 processes involved no heat treatment or quality control tests before fermentation. Unintended *suusa* was found to be vended by the roadside (80 %), sold in the milk bars (10 %) and also sold in hotels (10 %).

Practices associated with handling of camel milk by the pastoralists

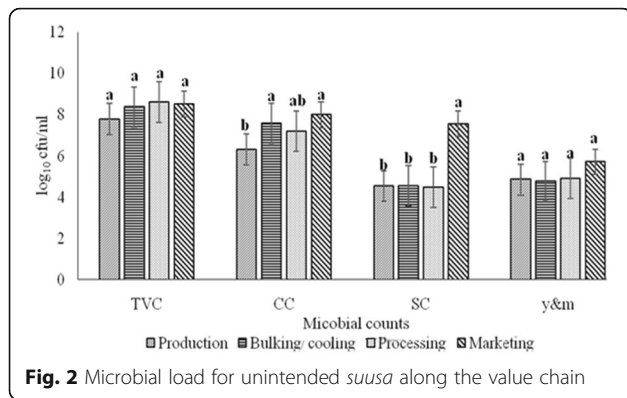
The challenges faced by the actors along the camel informal milk value chain that affect the quality of the milk as identified from the FDGs are shown in Table 2. Sanitation problems were identified as the biggest challenge due to the lack of potable water along the value chain. Lack of milk cooling facilities, interrupted electricity supply where these facilities are available, poor road network to the market, long distance to the market and pooling of milk from different sources were the main challenges identified for the spoilage of milk to unintended *suusa*.

Microbial load and acidity of *suusa* along the value chain

Figure 2 shows the microbial load for unintended *suusa* along the value chain. For unintended *suusa*, the Total Viable Count (TVC) increased from log₁₀ 7.79 at production to log₁₀ 8.51 at the market, Coliform Counts (CC) increased from log₁₀ 6.31 to log₁₀ 7.99, Spore Count (SC) increased from log₁₀ 4.53 to log₁₀ 7.56 and Yeast and Moulds (YM) counts increased from log₁₀ 4.85 to log₁₀ 5.70 cfu/ml. The microbial load of intended *suusa* at the production and market levels is shown in Fig. 2. The TVC increased from log₁₀ 7.79 at production to log₁₀ 8.41 at the market, CC increased

Table 2 The Challenges faced in the camel milk value chain

Value chain node	Challenges
Production	Lack of water
	Lack of cooling facilities
	Personal, equipment and environment hygiene
	Mixing of milk from diseased camels
	Lack of veterinary service due to high mobility
Cooling centres	Spoilage/unexpected fermentation
	Interrupted power supply to coolers
	Pooling milk
	Lack of clean water
	Lack of quality control tests
Transportation	Lack of knowledge on hygiene and quality checks
	Lack of refrigerated tankers for transporting the milk
	Poor state of roads
Marketing	Sale in open air-roadside
	Long distance to market
	Lack of cooling facilities
	Spoilage/unexpected fermentation



from log₁₀ 6.31 to log₁₀ 7.75, SC increased from log₁₀ 4.53 to log₁₀ 7.24 and YM increased from log₁₀ 4.85 to log₁₀ 5.41 cfu/ml. The SC was significantly higher at $P < 0.05$ for the *suusa* at the market level than at the production level. Also, the microbial load for the TVC, CC and YM were significantly high in *suusa* at the market than at the production.

Figure 4 shows the change in developed lactic acid in unintended *suusa*. Lactic acid increased significantly ($P < 0.05$) along the value chain from 0.07 to 0.23 %. The lactic acid (% LA) for the intended *suusa* increased from 0.07 % to 0.60 % from production to the market as shown in figure.

Main types of organisms in *suusa* along the value chain

Table 3 shows the main type of microorganisms that were isolated from unintended *suusa*. There was high incidence of Gram negative rods of 67 % from production to the market followed by Gram positive cocci with an incidence of 62 %. YM had the least incidence at 28 %.

Table 4 shows the main type of microorganisms that were isolated from intended *suusa*. The incidence of Gram negative rods and gram positive cocci were highest at 60 % and 50 %, respectively.

Table 5 shows the different types of microorganisms isolated from the two *suusa* value chains. Gram negative rods were identified to be *E. coli*, *Pseudomonas* and

Table 3 Incidence of Main groups of microorganisms isolated from the unintended *suusa*

Chain node	N	G+ rods ^a	G- rods ^a	G+ cocci ^a	Spores ^a	Y&M ^a
Production	10	2	6	7	2	2
Cooling/bulking	12	6	8	7	3	2
Processed product	7	4	4	4	3	4
Market	10	8	8	6	5	3
Total	39	20	26	24	13	11
Incidence (%)		51	67	62	33	28

Key: N is the number of samples; G+: Gram positive, G-: Gram negative, Y&M: yeast and moulds; ^ais the number of positive observed for a specific group of organisms.

Table 4 Incidence of main groups of microorganisms isolated from the intended *suusa*

Value chain node	N	G+ rods	G- rods	G+ cocci	Spores	YM
Production	10	2	5	6	2	2
Processing/marketing	10	3	7	4	3	3
Total	20	5	12	10	5	5
Incidence		25 %	60 %	50 %	25 %	25 %

Enterobacter. Gram positive rods included *Bacillus* and *Lactobacillus* species while the gram positive cocci included *Micrococcus*, *Streptococcus* and *Staphylococcus* species.

Discussion

Microbial load and acidity along the *suusa* value chain

Kenya Bureau of Standards (KEBS) regards raw whole camel milk as good when the total viable counts (TVC) are between $0-5 \times 10^5$ cfu/ml for grade I and II (KEBS, 2007). The raw camel milk at production was above the recommended range and therefore, the milk can be regarded as of poor quality. High TVC at production can be attributed to handling practices like not washing hands before milking, no washing of the camel’s udder before milking, use of plastic containers for milking and storage of milk in plastic containers which are not easy to clean. Use of recycled plastic containers which are not easy to clean harbours spoilage microorganisms, unrefrigerated transportation, long distance, poor roads to cooling centres and pooling of milk from different suppliers at the cooling centres are risk factors to the growth and multiplication of the indigenous microflora, resulting in reduction of milk quality and safety (Wayua et al., 2012). There was significant increase ($P < 0.05$) in TVC from production to marketing which is attributed to absence of heat treatment of milk prior to fermentation coupled with spontaneous fermentation. Results agree with those reported by Odongo et al. (2016) and Matofari et al. (2013). The GNR were the most prevalent types of microorganisms for both the intended and unintended *suusa* while the YM were the least prevalent for both.

Lactic acid increased significantly ($P < 0.05$) from production to the market with no effect on microbial load reduction as shown in Figs. 4 and 5. With fermentation, lactic acid bacteria break down lactose into lactic acid. Presence of GNR which are fermentative organisms had an influence on increased acid content. Intended *suusa* is fermented over a period of 3 days (72 hrs) and this further explains why the percentage lactic acid was higher than unintended *suusa* which takes less than 24 hours.

Coliforms increased significantly ($P < 0.05$) from production to the market by 1 log increase as shown in

Table 5 Types of microorganisms isolated from the *suusa* value chain

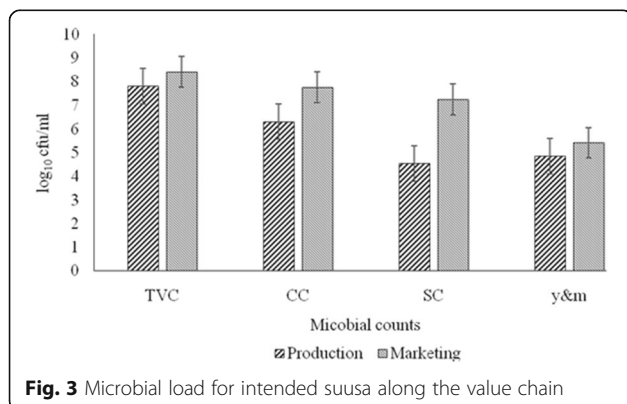
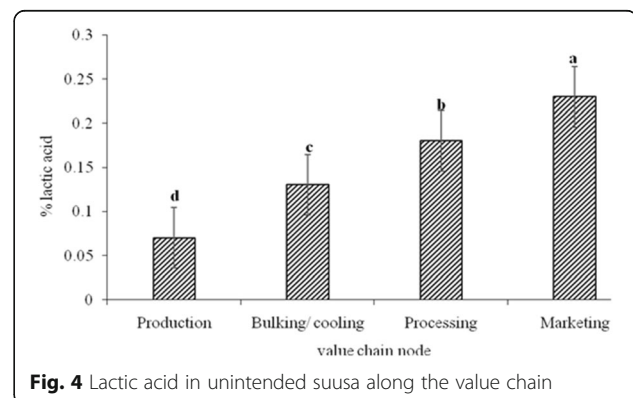
Chain node	N	<i>E. coli</i>	<i>Enterobacter</i>	<i>Pseudomonas</i>	<i>Micrococcus</i>	<i>Staphylococcus</i>	<i>Streptococcus</i>	<i>Bacillus</i>	Yeast and molds
Production	10	5	6	-	5	2	3	2	2
Bulking/cooling	12	4	4	8	3	2	4	3	2
Processing	7	4	4	-	2	2	3	3	4
Marketing	10	4	3	2	6	2	2	5	3
Total	39	17	17	10	16	8	12	13	11
Incidence (%)		44	44	27	41	21	31	33	28

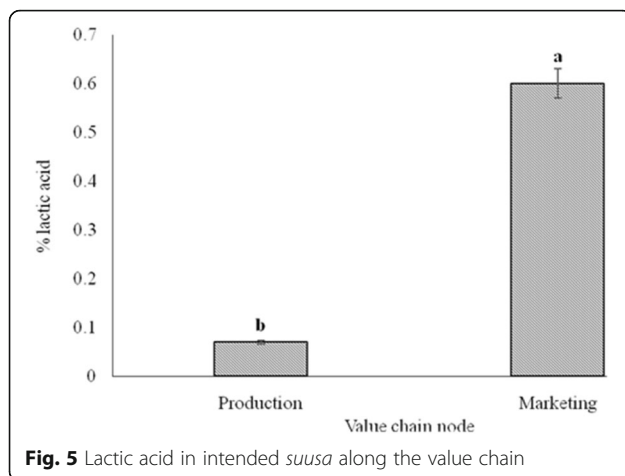
Key: N is the number of samples analysed

Figs. 2 and 3. Coliforms are found in the soil, mud, dust, plant materials and can be dispersed into the atmosphere by dust into the product. With natural fermentation, the coliforms will multiply and cause problems in the final product because lactic acid bacteria will initially be very low Gadaga et al. (2004). Coliforms also have adaptation strategies that range from temperature evasions, acid tolerance and production of probiotics like colicins that inhibit growth of other microorganisms (Abee et al. 1995; Gadaga et al., 2004). Occurrence of coliforms more so *E. coli* in the final product despite high lactic acid (Figs. 4 and 5) is probably due to induced acid tolerance by the organism through production of acid shock proteins which enhance its survival through neutralization of the external environment, adjusting catabolism to the new environment, performing DNA repair and membrane biogenesis and contribute to microbial pathogenesis (Bearson et al., 1997). Karagözlü et al. (2007) found that stationary phase cells of *E. coli* strains were able to survive and multiply in *kefir* (Caucasian fermented camel milk). It has also been found to survive in fermented goat milk, *amasi* (Bearson et al., 1997). Isolation of coliform bacteria along the *suusa* value chain is an indication of presence of enteric pathogens in the *suusa* value chain as shown in Table 5. This shows hygienic conditions during handling and processing of camel milk into *suusa* are low. *Suusa* therefore has public health risk potential for spread of foodborne illnesses such as *Escherichia coli* O157:H7 illnesses.

There was a significant ($p < 0.05$) increase in spore counts from production to market samples by 3 log increase as shown in Figs. 2 and 3. Spore forming bacteria are environmental microorganisms such as *Bacillus* and *Clostridium* species. At production, they may originate from water used to wash the milking equipment and dust from the milking area. Spore formers like *Bacillus cereus* display a mechanism of acid tolerance response (ATR) and can survive below pH 4.0 favourable for spore formation (Gadaga et al., 2004). This explains the existence of increased spore forming bacteria in *suusa* at the market level. Gram positive spore forming rods were identified as *Bacilli*. High incidence at the market could be attributed to the marketing environment characterised by sale in the open with heaps of waste material, dust and mud close to where the product is sold. Spores are carried by wind into the atmosphere and into the product. *Bacilli* are aerobic whose typical habitat is soil although they are widely distributed in nature and gain access to milk and *suusa* through air, water, fodder and feed. Spore-forming bacteria are known to cause food spoilage and food-poisoning by producing heat labile enterotoxins. Therefore, their presence in *suusa* poses a risk of food poisoning by the enterotoxins to the consumers of the milk product.

Yeast and moulds increased by 1 log increase from production to the market as shown in Figs. 2 and 3. High contamination by yeasts and moulds may be due to poor

**Fig. 3** Microbial load for intended *suusa* along the value chain**Fig. 4** Lactic acid in unintended *suusa* along the value chain



processing and marketing conditions and uncontrolled fermentation which led to contamination. During spontaneous fermentation of *suusa*, organic acids such as lactic, acetic and propionic acids are produced which lower the pH. The lower pH is favourable for growth of yeast and mould species which causes these species to become competitive in the immediate medium (*suusa*) hence the significant increase ($P < 0.05$) in yeast and mould count in marketed *suusa* (Lefoka, 2009).

Results in Tables 3 and 4 display the main type of microorganisms that were isolated from intended and un-intended *suusa* along the value chain. Gram negative rods had the highest incidence of 88 % from production to the market followed by Gram positive cocci with an incidence of 84 %. *Micrococci* were isolated and could account for the high count of Gram positive cocci which is mostly found in water, soil and dust. Yeast and moulds had the least incidence at 28 %. Gram negative rods were identified to be *E. coli*, *Pseudomonas* and *Enterobacter*. Presence of *E.coli* is an indication of faecal contamination by handling from production to the market Rochelle-Newall et al. (2015). This indicates possibility of presence of other enteric pathogens. Gram positive spore forming rods were identified as *Bacillus* and the high incidence at the market could be attributed to the environment in which the product is produced and sold. The environment was characterised by heaps of waste material, dust and mud and this could be the source of the spores which are carried into the atmosphere and into the product.

Gram positive cocci isolated from camel milk and *suusa* included *Streptococcus* and *Micrococcus* species. *Streptococcus* species especially the *Streptococcus lactis* group originate from equipment that is contaminated due to insufficient sanitation. Organisms like *Micrococci*, coliforms and enteric pathogens originate from hand milking and milk handling that might contaminate the milk via the skin, nose and mouth (Cui et al., 2016). Risk

factors identified in the field of study that have contributed to the specific organisms associated with *suusa* were: not washing hands or camels' udder before milking, dusty milking environment, use of organoleptic tests for quality assessment of milk, bulking milk from different suppliers, use of not easy to clean plastic containers, delayed milk delivery, lack of refrigeration during transport and sale of *suusa* in open air markets (Noor et al., 2013). Other authors (Akweya et al. 2012; Wanjohi et al. 2010) have also detected *Staphylococcus aureus*, in camel milk.

Spores of *Bacillus* species as well as the organism were also detected. The genus *Bacillus* are typical habitats of the soil and are widely distributed in nature and may gain access to milk and dairy products through the air, water, fodder and feed thereby present on the skin and hair of cattle (Loralyn and Robert, 2009). *Bacillus* species produce heat stable protease and lipase which may eventually cause spoilage to camel milk and milk products (Samaržija et al. 2012). Other species such as *Bacillus cereus* produce toxins which lead to food intoxication from ingestion of contaminated food. Presence of the *Bacillus* species in camel milk makes the food a potential risk to consumers. Spores increased significantly ($P < 0.05$) along the value chain in Fig. 2. This is attributed to handling practices observed along the value chain that have led to contamination of both raw and fermented product. Risk factors identified include: dusty milking environment, use of plastic milking and storage containers and unrefrigerated transport of raw milk from production to cooling centres. These factors most probably led to the growth and multiplication of spore forming bacteria hence high counts.

Among the major isolates of the microorganisms was the *Pseudomonas* species. *Pseudomonas* species produce heat stable proteases and lipases keeping their activity even after pasteurization thereby producing off-flavours in milk as well sweet curdling of pasteurized milk (Perko, 2011). *Pseudomonas* species are the main psychrotrophic bacteria isolated from refrigerated raw milk, being among the major spoilage agents in the dairy industry (Paula Ana et al. 2011). Presence of the genus *Pseudomonas* indicates improper cooling and refrigeration of camel milk.

Conclusions

Handling practices along the *suusa* value chain influences microbial load and consequently, contributes to spoilage of camel milk and *suusa*. Extension, training and regular monitoring to improve handling practices along the *suusa* value chain is essential. Statutory (legal) institutions like Kenya Bureau of Standards need to address handling practices of camel milk and milk products along the chain to improve safety, quality and acceptability hence better

market. As a consequence of lack of process control in *suusa* fermentation, the microbial diversity in the product is uncontrolled. *Suusa* has presence of high loads of microorganisms of safety concern. More in depth studies on *suusa* are needed to quantify and identify organisms of safety concern to the species level using molecular techniques.

Abbreviations

ANOVA: Analysis of Variance; CC: Coliform Count; FGD: Focus Group Discussions; GLM: General Linear Model; GNR: Gram Negative Rods; GPC: Gram Positive cocci; HSD: Honest Significant Difference; KEBS: Kenya Bureau of Standards; LAB: Lactic Acid Bacteria; LSD: Least Significant Difference; NC: North Carolina; PCA: Plate Count Agar; PDA: Potato Dextrose Agar; RUFORUM: Regional Universities Forum for capacity building in Agriculture; SAS: Statistical analysis software; SC: Spore count; TA: Titratable acidity; TVC: Total viable count; UK: United Kingdom; VRBA: Violet red bile agar; YM: Yeast and Molds

Acknowledgements

The authors acknowledge the women group of Isiolo County for availing samples and participating in the study. Acknowledgement also goes to Steven Wakoli and Pauline Madete for their assistance in sample collection. We also acknowledge Dr. Olivier Kashongwe for assistance in data analysis as well Mr. Nobert Wafula for the invaluable assistance in the editing of the manuscript.

Funding

This research work was financially supported by Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) under research grant number RU2011GRG11 titled: Consumer and regulator concerns about pastoral indigenous knowledge food processing: participatory analysis for producers' and consumers' benefits in Kenya.

Authors' contributions

This research work was part of LM Thesis research for the award of MSc. Food Science degree of Egerton University and supervised by JM, PM and BB. LM was in-charge of FGDs and questionnaire administration, samples collection and analysis under the guidance and supervision of the three supervisors. All the authors were involved in the designing of the experiment, data analysis, interpretation of the results and manuscript drafting. All authors read and approved the final manuscript.

Authors' information

Ms. Linnet Mwangi was a graduate Student in the Department of Dairy and Food Science and Technology in Egerton University, Kenya, undertaking MSc. Food Science. Ms. Mwangi has a BSc. Food Science and Technology and MSc in Food Science from the same university. She has several years of working experience in the dairy and food manufacturing industries in Kenya. Prof. Joseph Matofari is an associate professor and Dr. Patrick Muliro is a senior lecturer in the Department of Dairy and Food Science and Technology in Egerton University while Prof. Bockline Bebe is a professor at the of Department of Animal Science, Egerton University, Kenya.

Competing interests

Authors of this research article declare that they don't have any financial or non-financial competing interests.

Author details

¹Department of Dairy and Food Science and Technology, Egerton University, P.O. Box 536-20115, Egerton, Kenya. ²Department of Animal Sciences, Egerton University, P.O. Box 536-20115, Egerton, Kenya.

Received: 5 August 2016 Accepted: 11 October 2016

Published online: 18 October 2016

References

Abee TL, Krokkel L, Hill C. Bacteriocins: Modes of action and potentials in food preservation and control of food poisoning. *Int J Food Microbiol.* 1995;28:169–85.

- Akweya BA, Gitao CG, Okoth MW. The acceptability of camel milk and milk products from north eastern province in some urban areas of Kenya. *Afr J Food Sci.* 2012;6(19):465–73.
- Bearson S, Bearson B, Foster JW. Acid stress responses in enterobacteria. *FEMS Microbiol Lett.* 1997;147:173–80.
- Chinyere II, Onyekwere SE. Nigerian indigenous fermented foods: their traditional process operation, inherent problems, improvements and current status. *Food Res Int.* 1996;29:527–40.
- Corman VM, Jores J, Myer B, Younan M, Liljander A, Said MY. Antibodies against MERS Coronavirus in dromedary camels, Kenya, 1992–2013. *Emerg Infect Dis.* 2014;20:1319–22.
- Cui H, Zhou H, Lin L. The specific antibacterial effect of the Salvia oil nanoliposomes against *Staphylococcus aureus* biofilms on milk container. *Food Control.* 2016;61:92–8.
- Eyassu S. 2007. Handling, preservation and utilization of camel milk and camel milk products in Shinile and Jijiga Zones, eastern Ethiopia. *Livest. Res. Rural Dev.* 2016;19(6). from <http://www.lrrd.org/lrrd19/6/seif19086.htm>.
- FAO STAT 2015. World camel population. At <http://faostat3.fao.org/browse/Q/QA/E>. Accessed 12 Feb 2016.
- Gadaga TH, Nyanga LK, Mutukumira AN. The occurrence, growth and control of pathogens in african fermented foods. *Afr J Food Agric Nutr Dev.* 2004;4:1.
- Guliyeh AY, Noor IM, Bebe BO, Koskey IS. Role of camels (*Camelus dromedarius*) in the traditional lifestyle of Somali pastoralists in northern Kenya. *Outlook Agric.* 2007;36(1):29–34.
- International Dairy Federation (I.D.F.). 1990. Handbook on milk collection in warm developing countries. IDF Bulletin special issue 9002
- Karagözü N, Karagözü C, Ergönül B. Survival characteristics of *E. coli* O157:H7, *S. typhimurium* and *S. aureus* during kefir fermentation. *Czech J Food Sci.* 2007; 25:202–7.
- KEBS. 2007. Raw whole camel milk — Specification, KS 2061:2007 (confirmed 2013). Kenya
- Lefoka Mamajoro. 2009. Survival of microbial pathogens in dairy products. Msc dissertation, University of the Free State. scholar.ufs.ac.za:8080/xmlui/bitstream/handle/.../LefokaM.pdf. Accessed 14 Oct 2016.
- Loralyn H. Ledenbach and Robert T. Marshall. 2009. Microbiological spoilage of dairy products. *Compendium of the microbiological spoilage of foods and beverages*, p.27.
- Lore TA, Samuel KM, John W. Enumeration and identification of microflora in *Suusa*, a Kenyan traditional fermented camel milk product. *Lebensm-Wissu-Technol.* 2005;38:125–30. marketing practices in an emerging peri-urban production system in Isiolo County, Kenya. *Pastoralism: Research, Policy and Practice*, 3:28.
- Matofari JW, Shalo PL, Younan M, Nanua NJ, Adongo A, Qabale A, Misiko BN. Analysis of microbial quality and safety of camel (*Camelus dromedarius*) milk chain and implications in Kenya. *J Agric Ext Rural Dev.* 2013;5(3):50–4.
- Momanyi S. and Jenet A. 2010. Study on hygiene practices and market chain of milk and milk products in Somalia. <http://fex.enonline.net/39/study.aspx>. Accessed 14 Oct 2016.
- Mulwa WD, Schelling E, Wangoh J, Imungi KJ, Farah Z, Meile L. Microbiological quality of raw camel milk across the Kenyan market chain. *Global Sci Book.* 2011;5(1):79–83.
- Musinga M., Kimenyi D. and Kivolonzi P. 2008. The Camel Milk Industry in Kenya <http://www.ebpdn.org/download/download.php?table>. Accessed 14 Oct 2016.
- Noor IM, Bebe OB, Abdi YG. Analysis of an emerging peri-urban camel production in Isiolo County, Northern Kenya. *J Camelid Sci.* 2012;5:41–61.
- Noor IM., Gulye A.Y., Tariq M. And Bebe B.O. 2013. Assessment of camel and camel milk
- Odongo N. O, Lamuka P. O, Abong G. O, Matofari J. W, Abey K. A. 2016. Physicochemical and Microbiological Post-Harvest Losses of Camel Milk Due Deterioration Along the Camel Milk Value Chain in Isiolo, Kenya. *Current Research in Nutrition and Food Science*; 4(2)
- Patricia Curiff. 1995. Official Methods of Analysis of AOAC International 16th Edition. Virginia, USA: AOAC International; p 108–110.
- Paula Ana FC, Daniel JD, Renata VV, Adriano B. Hydrolytic potential of a psychrotrophic *Pseudomonas* isolated from refrigerated raw milk. *Braz J Microbiol.* 2011;42:1479–84.
- Perko B. Effect of prolonged storage on microbiological quality of raw milk. *Mljekarstvo.* 2011;61(2):114–24.
- Rochelle-Newall E, Nguyen TMH, Le TPQ, Sengtaheuanghoung O, Ribolzi O. A short review of fecal indicator bacteria in tropical aquatic ecosystems: knowledge gaps and future directions. *Front Microbiol.* 2015;6:308.

- Samaržija D, Šimun Z, Tomislav P. Psychrotrophic bacteria and milk and dairy products quality. *Mljekarstvo*. 2012;62(2):77–95.
- Wanjohi, GM, CG Gitao, and LC Bebor. 2010. The hygienic quality of camel milk marketed from North Eastern Province of Kenya and how it can be improved. Garissa: A paper presented at International Camel Symposium
- Wayua FO, Okoth MW, Wangoh J. Survey of post-harvest handling, preservation and processing practices along camel milk chain In Isiolo District, Kenya. *Afr J Food Agric NutrDev*. 2012;12(7):6897–912.

Submit your manuscript to a SpringerOpen[®] journal and benefit from:

- ▶ Convenient online submission
- ▶ Rigorous peer review
- ▶ Immediate publication on acceptance
- ▶ Open access: articles freely available online
- ▶ High visibility within the field
- ▶ Retaining the copyright to your article

Submit your next manuscript at ▶ springeropen.com
