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Milk value chains maps identifying challenges and vulnerabilities in the pastoral and agro-pastoral areas of Narok, Kenya

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Abstract

Milk forms a key dietary component in pastoral areas of Kenya whose dwellers are faced with limited dietary options. The goal of this study was to map milk value chains from pastoral and agro-pastoral areas and identify constraints and existing vulnerabilities that hampers their upgrading in Narok County, Kenya. A cross-sectional study was done between March and July 2019, and data was collected through 9 focus group discussions comprising 134 pastoralists and 4 key informant interviews using a questionnaire guide. Data was collected on chain profiles, governance, existing constraints, and vulnerabilities. The chain analysis revealed that the key actors were input suppliers; pastoral and agropastoral producers; wholesalers; cooperatives; private and public processers; retailers and consumers. Most of the milk was produced by small holder farmers for household consumption and only sold the surplus. Average daily milk yield was 15 liters, 7 liters and 4 liters per cow intensive, semi-intensive and extensive systems respectively. Milk pricing was determined by local brokers and processors who were the dominant buyers of the milk. Value addition to the milk was limited to ghee production, souring. One bulking center produced yoghurt while other bulking centers and retailers sold the milk either raw or boiled. The major constraints reported in the production of milk were water and feed scarcity; low production; poor milk pricing and unreliable veterinary services. The results further revealed existence of both formal and informal milk value chains. The informal chain was dominated by small-scale producers with minimal inputs and low levels of outputs. The producers had no influence on price setting and faced challenges in marketing milk. Interrelationships between the actors, was based on verbal agreements with no binding contracts. This study revealed existing deficiencies in input supply and vulnerabilities which may result in contamination of milk along the chain nodes.

Keywords: *Agro-pastoralists; Chain actors; Dairy value chains; Narok County; pastoralists; vulnerabilities*

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Introduction

About a quarter of the global land area is reportedly used for grazing in the developing countries of Africa, Asia, and South America, (Blench, 2001). In parts of Eastern Africa, pastoralists are reported to survive exclusively on milk because the bimodal rainfall enables milking all year year-round. The main products from pastoralism are meat, milk, blood, wool, hides and skins, manure, and labor. The significance of milk to pastoral survival was first documented by social anthropologists in the 1950s and 1960s (Dupire, 1963). Meat

contrarily, is usually available only sporadically, but milk is available daily during certain seasons therefore providing subsistence for exceedingly more people per unit area than any other production method in arid areas (Suttie, 2001).

In Kenya, arid and semi-arid lands (ASALs) occur in approximately 84% of the total land surface area and are occupied by about 20% of the population (Idris, 2011). Livestock production is the key economic activity in the arid and semi-arid lands (ASALs) of Kenya (Kidake *et al.*, 2016) and it supports more than 14 million people and at least 70% of the country's livestock population (Opiyo *et al.*, 2013). Despite this, high poverty tends to be prevalent within ASALs than in the high potential regions of East Africa (Little *et al.*, 2008). The value of pastoralism in Kenya is however not properly understood, even though it is said to be huge and instrumental in cushioning the pastoralists livelihoods (Nyariki and Amwata, 2019).

Other benefits of pastoralism include being source of prestige, wealth, dowry and being a mode of dispute settlement (Nyariki and Ngugi, 2002). Pastoralism exploits unfavorable environmental conditions for productivity. It endures and remains gainful within the ASALs in spite of environmental stresses such as recurrent droughts and floods, that showcases pastoral resilience (Hesse, 2009). Pastoral household income from livestock and livestock product sales is characterized by seasonal fluctuations, which forces them to diversify their income sources by engaging in activities such selling firewood and charcoal (Sandford, 1983).

Kenya's dairy industry is estimated to account for 4% of gross domestic product (GDP) with an estimated average production of 7-8 liters per day per cow (MoALF) and a total 3.43 billion liters annual national production. Most of Kenya's milk production is sold in raw form with less than 20% being consumed at the farm level. A very low proportion of 12% of the milk produced is processed (Kenya National Bureau of Statistics, 2009).

There are three main dairy production systems in Kenya. These include intensive, semi-intensive and extensive grazing systems. The systems vary widely in feeding and breeds kept intensity of land and labor utilization (Wakhungu, 2001). Majority (70-80%) of dairy producers consist of about 1.8 million smallholder households, intensive and semi-intensive production systems, using exotic cattle and their crosses.

Kenya's milk production calculated from different locations showed that the 305 days lactation yield ranged from 3040 to 3739 liters/year and an average of 3389 liters/year (Ajak *et al.*, 2020). There exists a variation in average milk yield in different areas that was attributed to the high-quality feeds availability, differences in animal breeds and production system which was influenced by agroecological zones (Muia *et al.*, 2011).

The major inputs to dairy production systems include purchased supplemental feed, grown fodder, veterinary and breeding services, vaccination, tick and another vectors control and labor. The inputs for the large-scale dairy and meat systems were costs of antibiotics and acaricides (Wanyoike, 2009). The feeding systems employed by smallholder dairy farmers, range from cut-and-carry for stall feeding supplemented with purchased concentrate feed in areas of high population density where extensive system is not workable, to free grazing on natural pastures in marginal areas.

The major outputs from cattle include draft power, beef, cash, and milk, (Ndathi *et al.*, 2011) are all important and farming households may target any of them as the major output. Live form is the chief livestock-related offtake. However, milk is the primary product of pastoral herds. However, milk production from the pastoral herds however is largely never quantified (Nyariki and Amwata, 2019).

Liberalization of milk marketing led to the increased of sale of raw milk particularly in urban centers. The increase was encouraged by the consumer preference for unprocessed whole milk citing the following reasons: The unprocessed milk is 20 to 50% cheaper due to reduced costs involved, better taste (because of high butterfat content); and poor communities to access milk because it's sold in different quantities.

Some of the constraints of dairy production include poor feed resource quality and scarcity which hinder productivity and holds back

reproduction (Methu *et al.,* 2000). Others include diseases, chiefly East Coast Fever and Anaplasmosis, result in significant morbidity and mortality losses. Additionally, poor access to breeding services leads to inbreeding and slow genetic progress. Poor infrastructure, particularly road networks affect milk delivery and input acquisition increasing costs.

Milk is marketed through two distinct channels, formally and informally. The formal channel is mainly comprised of large-scale processors, while the informal sector that accounts for 86% share of the milk market (Kaitibie *et al.,* 2010) is mainly driven by middlemen. Approximately more than 90% of milk consumed at the household level is raw unpasteurized milk sold by informal small-scale milk traders (Njarui *et al*., 2011). It has also been documented that most of the milk produced and traded, in the informal value chains, does not meet composition, contamination standards (microbial and chemical) stipulated by the Kenya Bureau of Standards (Alonso *et al*., 2018). These chains are characterized by, traditional processing, predominant retail practices and products; limited inputs and infrastructure such as water, electricity, sanitation, and refrigeration; do not undergo health and safety regulation; some operators are not licensed and do not pay statutory fees; and little public sector support (Grace, 2015).

These pose huge sanitary and regulatory challenges putting a high percentage of the population at risk of various public-health related issues associated with the consumption of unprocessed milk. This risk is higher among pastoral communities in which milk hygiene at the farm level is generally poor, there is scarcity of potable water for washing the milking equipment and common use of plastic containers for milk storage and transport to the markets (Kaindi *et al*., 2012). Bacterial contamination of milk commonly occurs when bacteria from the cow's udder, her environment, through unhygienic milking and handling practices. Handling by several chains actors during bulking and transporting, increases the risks of bacterial contamination in such complex systems.

Data of the actual milk production and consumption volumes as well as the supply and value chains in pastoralist systems of Narok County are scanty and identification of safety risks has not been implemented in Narok County. Thus, investigation of the dairy value chains in the pastoral and agro-pastoral areas of Narok County allow for identification of possible entry points for intervention and designing appropriate polices that would enhance the development of the subsector.

This current study was thus aimed at mapping out the dairy value chains by identifying the chain actors, their roles, and linkages in pastoral and agro-pastoral areas of Narok County. It was the goal of this study to identify constraints of dairy/milk production and marketing of the milk as well as the potential risks of contamination.

Materials and methods

Study area

The study w carried out in Narok County. The County lies between latitudes 0° 50´ and 1° 50´ South and longitude 35^{o} 28´ and 36^{o} 25´ East. It borders the Republic of Tanzania to the South, Kisii, Migori, Nyamira and Bomet Counties to the West, Nakuru County to the North and Kajiado County to the East. The county lies in the South-eastern part of Kenya, at an average altitude of 1296 meters above sea level. It covers an area of 17,932 km^2. The temperature ranges between 12 and 28^{o}C. Rainfall increases from 500 mm/year in the dry Southwest plains to 2000 mm/year in the wet northern highlands. The estimated human population of Narok County was 1,157,873 (579,042 males and 578,805 females), with a density of 65 persons per Km^2 (KNBS, 2019). Higher human population density in the county is found in the humid, sub-humid and semi-humid zones characterized with high agricultural activities, while the other portion of the county was characterized by pastoralism. Narok County is divided into six sub-counties namely, Narok North, Narok South, Narok East, Narok West, Emurua Dikirr and Kilgoris. The study area was selected because the predominant economic activity is pastoralism and agro-pastoralism. It is characterized by frequent spells of dry weather conditions. Narok County was reported to have an estimated 1,488,891 heads of cattle, 2,603,542 sheep and 1,015,845 goats (KNBS, 2019).

Study design

A cross-sectional study of Narok County's was implemented between March and July 2019. These areas were purposively selected based on the land tenure systems and sizes; prior knowledge of livestock ownership provided by livestock extension officers; herd sizes and grazing systems. The use of a descriptive study design was useful for expanding the understanding in pastoral and agro-pastoral dairy farming practices in the county. Data was collected from pastoralists and agro-pastoralists in selected locations in sub-counties of Narok that included Narok North, Narok West, Narok South and Narok East Sub-counties out of the six sub-counties (Figure 1) and were purposively selected for being known to have pastoral and agro-pastoral households.

The wards that were sampled were stratified into pastoral and agropastoral zones and these included Kishermoruak, Olmodieni, Esupetai, Maji moto and Ololulunga, Sogoo, Eor Enkitok, Olkurto and Nairagie Enkare respectively. Ololulunga, Sogoo, Eor Enkitok, Olkurto and Nairagie Enkare (9/30), were characterized by a mixture of plantation agriculture as well as intensive and semi intensive dairying. These areas receive higher average annual rainfall owing to their high altitude and proximity to the Mau Forest. The pastoral zones including Kishermoruak, Olmodieni, Esupetai, Maji moto are characterized by low lying altitudes and low annual rainfall that supports grasslands and shrubs suited for nomadic pastoralism and wildlife conservancy.

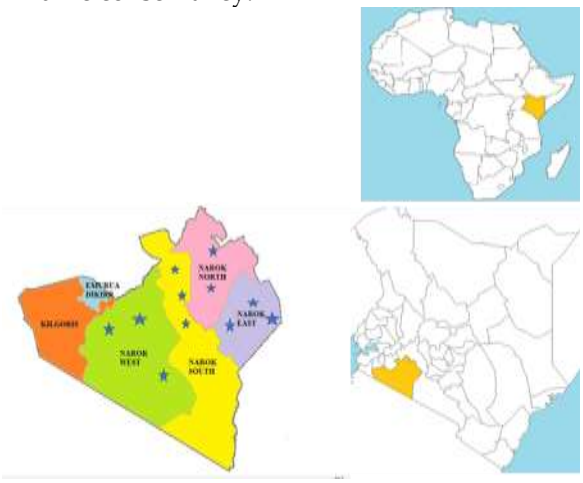

Figure 1. Maps showing administrative regions of Narok County and the blue stars showing areas where the focus group discussions were held with milk value chain actors

Selection of study participants

Records of dairy farmers within the study area was not available, therefore local livestock extension officers and animal health assistants as well as local administration were instrumental in identification and recruitment of dairy farmers for this current study. The criterion for inclusion in the study was based on the fact that one had to be keeping at least one cow, sheep, or goat that they were milking either for household consumption and or for sale and had lived in the study area for at least one year prior to the study date. The selected farmers were invited to attend focus group discussions which were held in homesteads or nearby schools in the selected areas. The group discussions were conducted predominantly in the local Maa language with translation to Swahili which was understood by all participants. The discussions were guided by a member of the research team, who wrote the main points on flip charts so that all participants could discuss and reach consensus on different responses that were provided, while other members of the research team wrote down detailed notes and took audio recordings of the proceedings. Before data collection sessions began, participants were asked for their verbal consent to participate in the study, and data collection only continued after the consent was obtained.

Data collection

Qualitative data was collected through guided focus group discussions and key informant interviews. Data were collected on herd sizes and structures; farmers' perceptions on the types of production systems practiced; types of farm inputs; type of farm outputs, chain actors and governance; challenges faced in; input acquisition, production of milk; and handling of the milk. The participants were also asked to rank the challenges which were identified using simple ranking method. Proceedings of these group discussions were recorded by audio and by photography with prior consent from participants. Livestock production officers from Narok North, Ololulung'a, Nairragie Engare, and Olkurto sub county offices and an officer from the Kenya Dairy Board, were interviewed as key informants to validate findings from dairy farmers.

Data management and analysis

Data that were collected from focus group discussions were recorded on flip charts, notebooks, and audio recordings. The data were transcribed to Microsoft® Word 2007 (Microsoft Corporation, Redmond, WA, USA) documents and written notes were used to complement the audio recordings. Several salient themes were identified and were entered in templates. Thematic analysis enabled identification of governance themes, key challenges, and analysis of their implications on milk production, marketing, and hygiene (Gale, 2013). Value chain profiles were drawn from the interactions between people, inputs, production activities and distribution channels for milk and milk products as reported by farmers. The profiles were created by identifying flow of inputs into dairy farms, types of farms classified by scale of production, feeding system and number of cattle kept in each area and outflow of products from each production system. This approach has been described in a related publication which mapped the beef, sheep, and goat systems in Nairobi (Alarcon *et al.,* 2017). Constraints were identified in the focus groups, the discussant then unanimously through simple ranking they were ordered based on their comparative importance/significance.

Results

Milk value chain profiles

The current study revealed two main milk value chains: Formal and informal value chains with input supply, production, bulking, processing, distribution, wholesaling, and retailing being reported (Figure 2).

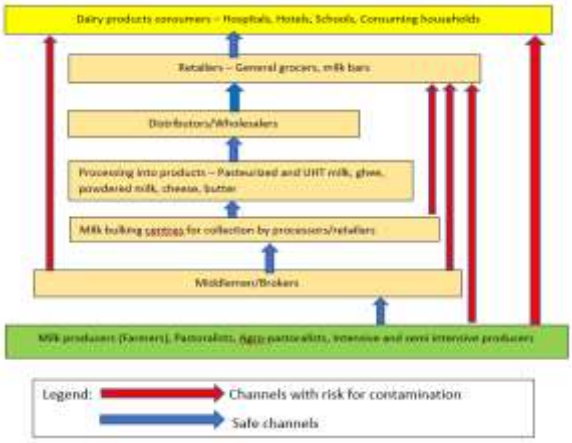

Figure 2. Flow chart showing the milk value chain profiles and the associated contamination risk in Narok County. (Pathways with higher risk for contamination are depicted in red arrows)

The formal milk value chain involved production of milk by pastoralists and Agro pastoralists who used inputs that included cattle of predominantly (70%) indigenous Small East African Zebu breed and few (4%) purely exotic breeds as well as their crosses (26%); grazing on natural pastures (90%); communal land (80%); water from rivers (80%), wells (10%), water pans and dams (10%) and veterinary medicines for self-medication from agrovet shops (100%) (Figure 3).

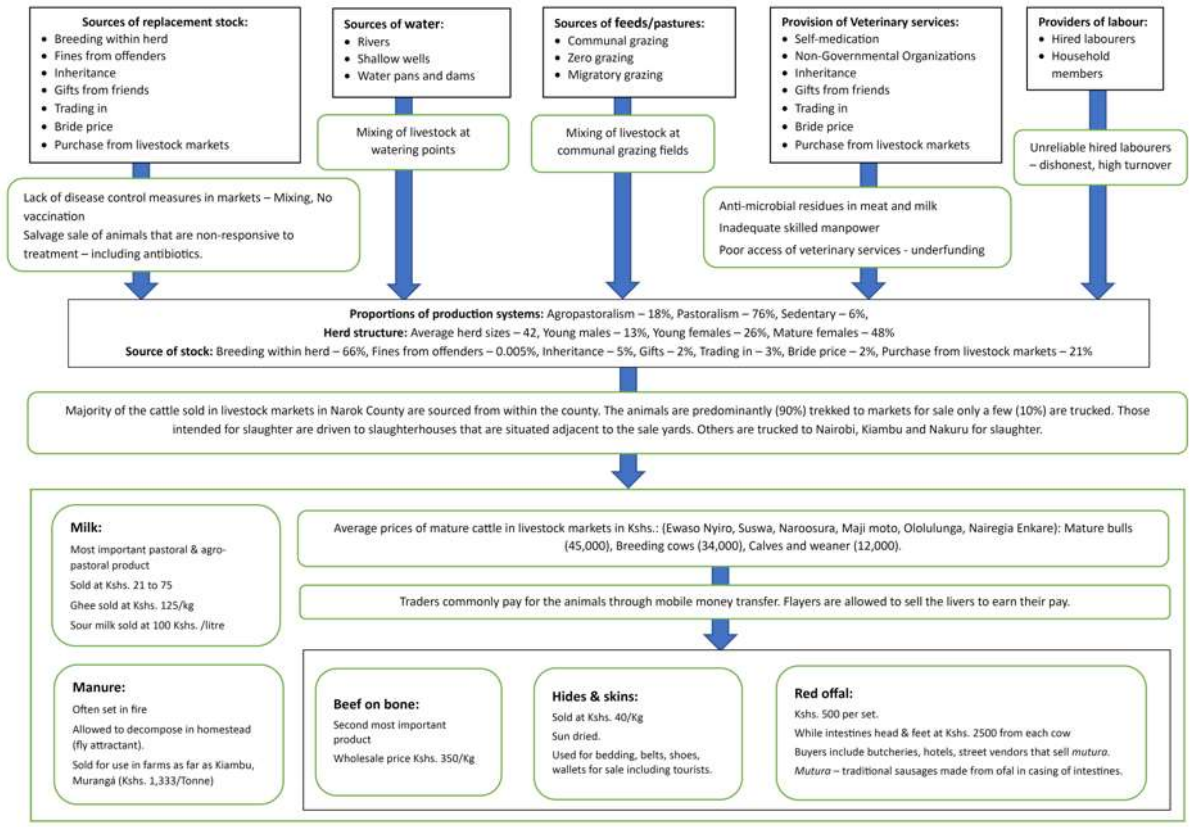

Figure 3. Flow diagram depicting key inputs, challenges encountered in their exploitation, proportions of the production systems, herd structures and dynamics as well as the prices of the main products of the pastoral and agropastoral dairy farms of Narok County

The average herd sizes in the study areas were 3 cows per household in the intensive and semi intensive systems and 56 cows per household in the extensive systems. The average land sizes owned by the households ranged between 5 acres in the highlands where intensive dairy farming is practiced and 86 acres in the southern lowlands with the largest farms measuring up to 170 acres. The average daily milk yield was 15 liters per cow in the intensive and 7 liters per cow in the semi intensive systems and 4 liters per cow in the extensive systems. It was stated that majority (more than 80%) of the milk was sold and less than 20% reserved for household consumption. Value addition and shelf life prolongation involved either boiling, souring either through natural fermentation or in a few areas such as Sogoo and Olkurto it involved traditional souring to produce *Mursik*. Delivery of the milk to buyers that included neighbors, brokers, general grocers, hotels, dairy bars was predominantly carried out once a day. Such purchase and sale of milk arrangements were purely informal with no written/binding contractual agreements. The milk was delivered to bulking centers for collection by national processors predominantly (98%) in plastic containers either by foot (50%) by the farmers, (40%) by bicycles and motorcycles, (8%) by cars, including public transport and (2%) on donkeys. The milk was delivered to the bulking centers raw and was never treated in any way. Most (70%) of the milk is delivered by brokers, who obtain the milk from the farmers at prices dictated by the brokers to be delivered to the bulking centers at a profit. The milk is then picked from the bulking centers by national processors using refrigerated trucks for processing at their plants located in distant places such as Nairobi, or for sale by dairy bars located in Narok town and surrounding shopping centers.

Chain profile for the milk processors/Formal milk distribution

Large processing companies were reported to receive approximately 50,000 and 100,000 liters of milk per day from Narok County. The milk bulking centers were situated in areas that were densely populated with milk producers with higher daily milk yields.

Sourcing of milk by processors

Milk was delivered to the coolers either by the milk producers or by middlemen for collection by trucking agents, who transported the milk in large tanks for processing in dairy processing plants located at least 100 km away. The prices for the milk that was delivered was dictated by the milk processors. However, the prices often fluctuated depending on the abundance or scarcity of milk which was influenced by weather patterns.

The milk was either directly delivered to the milk bulking centers that have refrigerated coolers or sold to middlemen who accumulate little amounts of milk from the farms and then they deliver the milk to the coolers. The relationship between the middlemen and the farmers was largely informal with no written agreements. The coolers were mainly located in areas with higher potential for milk catchment.

Deliveries made by the middlemen accounted for most (65%) of the milk delivered to coolers. Selling milk to the middlemen was preferred by the pastoralists because they received immediate cash payments and did not have to wait for end of month/year payments done by milk processors.

The milk was delivered either on foot, donkey, motor bikes or motor cars depending on the quantities of milk and the distance from the farms to the coolers. The bulked milk was then collected daily using trucks with stainless steel tanks for processing in plants that were in Sotik, Limuru and Nairobi, 80km and 250km from Narok County respectively (Chepkangor, 2019 *personal communication*). Some of the coolers have their own pasteurizers and added value to the milk by producing yoghurt and fermented milk *(mala)* for local distribution.

However, much of the milk in the bulking centers was sold to large processing companies that carry out value addition to produce pasteurized milk; ultra-heat treated (UHT) milk; salted and unsalted butter; ghee; milk powder; flavored and unflavored yoghurt, cheese. Processed products were then distributed either through factory outlets including tracking to wholesalers, supermarkets, and general grocers. Such products were then distributed throughout the country through direct sale to retailers such as supermarkets and general grocers. Some were sold in large quantities to wholesalers who then sell to retailers.

Informal milk distribution channels in Narok County.

The informal milk value chain accounted for the greatest proportion (70%) of milk off take in Narok County. The milk is either sold to neighbors, directly to general grocers/kiosks in the local trading centers, to middlemen or to hotels and restaurants (Figure 2), either raw, soured milk or ghee. Plastic containers used for handling of milk in the informal channel, posed the risk of microbial contamination of the milk owing to the challenge of adequate decontamination. Use of plastic containers is complicated by the widespread inadequacy of potable water for cleaning in most areas of Narok County. The interactions among the major actors were largely informal, mainly relying on mutual trust between the milk sellers and buyers (Chepkangor, 2019 *personal communication*). Only one cooperative society in Narok was identified to be involved in pasteurization of milk and yoghurt making, all the rest did not process their milk.

Ranking of constraints faced by milk producers in Narok County

The value chain constraints in this study were analyzed under 3 groups including 1. Challenges encountered during input acquisition, 2. Challenges faced during production and 3. Challenges experienced in handling of milk and milk products. Constraints associated with input supply most frequently mentioned were feed scarcity characterized by long trekking distances to find pasture and frequent droughts and reliance on natural unimproved pastures; low genetic potential of the cattle breeds; expensive high-yielding exotic breeds which were more susceptible to diseases and require heavy feeding; lack of adequate veterinary/disease/vector control measures and extension services and unreliable (dishonest, unskilled, high replacement rates) employees (Figure 3).

Constraints which were identified by the milk producers in Narok County are explained in Tables 1, 2 and 3 respectively. The resulting ranks for challenges by dairy farmers were Feed and water scarcity were ranked first in all

the sampled areas dairy production systems in Narok County except Olkurto where it was not considered a challenge. Dairy farmers from more than half (5/9) of the areas studied ranked the challenge of acquiring good quality replacement stock second, apart from those from Ololulung'a, Olmodieni and Maji moto where this challenge was ranked third, while in Olkurto it was ranked first.

Dairy farmers from Maji moto, Olmoodieni and Olkurto areas, ranked inaccessibility of veterinary services second. This challenge was ranked third in Nairragie Engare, Kishelmoruak and Sogoo. In Ololulung'a and Morijo it was not mentioned as a challenge, therefore not ranked. The challenge of unreliable herdsmen (dishonest, non-committed, un-skilled) was ranked second in Ololulung'a, third in Morijo and Olkurto areas. It was ranked fourth in Olmoodieni, Nairragie Engare and Kishermoruak, Sogoo, Maji moto areas (Table 1).

Table 1. Table showing ranking of challenges if input acquisition for dairy production in Narok County. The challenges were cited and ranked by the dairy farmers during focus group discussions. For analysis the most commonly occurring constraints were considered.

Challenge	**Area**								
	Ololulung'a	N. Engare	Morijo	Maji moto	Kishelmoruak	Olmodieni	Sogoo	E. Enkitok	Olkurto
Feed and water scarcity	1	1	1	1	1	1	1	1	
Difficulty in acquiring quality replacement stock		2	2	3	2	3	2	2	1
Lack of veterinary services		3		2	3	2	3		2
Unreliable employees	2	4	3		4	4	4		3

The major constraints associated with production of milk and its by-products included: low dairy genetic potential of the indigenous breeds; pests and diseases, long trekking distances to pastures, competition with wild animals for pasture; cost of fencing and inadequate knowhow of livestock husbandry practices.

Low genetic potential was ranked first in majority (6/9) of the areas that were sampled except Olmodieni, Maji moto and Kishelmoruak where this was not considered a challenge. This is because the Small East African Zebu were adapted for the said areas that were characterized by frequent droughts as well as water and feed scarcity. Pests and diseases were ranked first in Olmodieni, Maji moto and Kishelmoruak areas, these were however ranked second in all the other areas that were sampled. Competition for pasture with wild animals was ranked second in Olmodieni, Maji moto and Kishelmoruak areas, it was however not considered a major challenge in the other areas that were sampled and therefore was not ranked.

Inadequate knowledge of proper husbandry practices was ranked third in four of the areas that were sampled in the current study (Table 2).

Table 2. Table showing ranking of challenges faced in production of milk in Narok County. The challenges were cited and ranked by the dairy farmers during focus group discussions. For analysis the most commonly occurring constraints were considered.

Challenge	**Area**								
	Ololulung'a	N. Engare	Morijo	Maji moto	Kishelmoruak	Olmodieni	Sogoo	E. Enkitok	Olkurto
Low genetic potential	1	1	1				1	1	1
Pests and diseases	2	2	2	1	1	1	2	2	2

Competition with wild animals for water and pastures			2	2	2				
Poor livestock husbandry know-how	3	3				3	3		

The major constraints associated with handling dairy products from the highest priority included: low milk prices; market scarcity; lack of cold storage facilities; long distance to the market; poor road network non-compliance in payment for milk delivered; expensive aluminum cans for handling milk and seasonal excess milk production.

Prices, which ranged widely, fluctuated between Kshs. 21 to 75 per liters between low and high seasons and were determined by milk buyers/middlemen, was ranked first by all (9/9) the dairy farmers sampled in the current study. Dairy farmers in less than half (4/9) of the areas in Narok County, ranked second the challenge of lack of market and storage facilities especially during seasons of excess production. This was however not considered a challenge in the other areas that were sampled in this current study including Ololulung'a, Olkurto, Sogoo, Morijo, Olkurto and Nairragie Engare where there are functional coolers.

Poor road networks and distance to the market was ranked third by more than half (5/9) of the areas in Narok county; however, farmers from the four areas with coolers did not consider this a challenge and thus did not rank it. Noncompliance in payment for milk delivered to buyers was ranked fourth in Maji moto, Olmodieni, Morijo, Eor Enkitok and Kishermoruak, this was said to happen because the farmers delivered to buyers who included brokers with no formal/written sale agreement. The farmers in the other areas delivered the milk to coolers owned by cooperatives thus did not face this challenge (Table 3).

Table 3. *Table showing ranking of challenges faced in handling milk and milk products in Narok County. The challenges were cited and ranked by the dairy farmers during focus group discussions. For analysis the most commonly occurring constraints were considered.*

Challenge	**Area**								
	Ololulung'a	N. Engare	Morijo	Maji moto	Kishelmoruak	Olmodieni	Sogoo	E. Enkitok	Olkurto
Poor prices	1	1	1	1	1	1	1	1	1
Lack of market & storage facilities				2	2	2		2	
Poor road network and distance to the market			2	3	3	3			
Noncompliance in payment for milk delivered to buyers		2		4	4	4		3	
Expensive aluminum cans for handling milk	2	3					2		2

Aluminum cans for handling milk being unaffordable was ranked second in Sogoo and Ololulunga; fourth in Eor Enkitok and fifth in Morijo. These areas had potential for high milk production. This was however not ranked in the other areas that were visited in this study.

Governance in the dairy value chain

The milk distribution channels assumed two distinct channels namely, informal chain which was characterized by oral agreements and the formal chain which was guided by fluid contractual agreements. The two profiles are dominated by small scale producers who either

belong to cooperatives or the majority (80%) that did not belong to cooperatives. The only existing important relationships in the mapped chain, was that between the pastoralists and the suppliers of veterinary medicines and supplements (Agrovets). The Agrovets were reported to be the main source of advice on how to manage livestock diseases.

Majority (80%) of the farmers cited ready market for milk was their reason for not forming associations, while most (80%) of the milk collection centers/coolers were owned by farmer associations. From such cooperatives the farmers would benefit from accessing better pricing of the milk, storage of milk before sale and access to market.

The farmers preferred selling milk directly to consumers or middlemen for immediate cash payments in as much as the prices were poorer and there were reports of losses following claims of their milk having gotten spoilt. Furthermore, farmers reported that they didn't have formal contractual agreements with middlemen, retail shops, milk bars and milk collection centers and relied on the delivery records for tabulating payments that were due.

Large processing companies revealed that they distributed of high volumes of processed and value-added products such as yoghurt, butter, cheese, and ghee. The processors had highly competitive processed product delivery arrangements with supermarket chains, wholesale distributors and general grocers.

Discussion

The aim of this study was to map the structures of milk production and distribution in Narok County, showing their linkages, identifying the chain actors, and determining the constraints and vulnerabilities. Mapping of the value chains of pastoral dairy subsector of Narok will help in understanding the complexity of the milk production, identify the existing challenges and vulnerabilities in the milk supply system.

This current study has depicted two distinct chain profiles, showing the flow of inputs to dairy farms and produce to markets. The two chains that were identified are formal and informal value chains. The interrelationships between the chain actors were fluid with no written and legally binding contracts. The informal chain handles the higher quantity of milk produced in pastoralist systems of Narok, this similar to the findings documented by Majalija *et al*., (2020), who reported that the informal chains accounted for 80% of milk distribution in Nakasongola, Uganda.

Regular interaction was common among the people within the two chains; contracts were mainly verbal, including those involved in the formal value chain. The informal value chains were predominantly found in areas that lacked/were distant from coolers while the formal chains were found associated with coolers. This was possible because of the higher daily milk yield and availability of coolers that encouraged milk processors to pick the milk on a daily basis. The milk distribution channels that were described in the current study bears striking similarity to the milk distribution channels of Dar es Salaam region in Tanzania as described by Mdoe *et al.,* (2000) where brokers/middlemen collected milk from villages and delivered it on bicycles to collection depots, each having capacities of up to 1,000 to 20,000 liters per day.

Mutual trust and cultural beliefs played an important role in discouraging bad practices such as defaulting in payments and practices such as milk adulteration in the informal milk chains.

Key inputs to dairy production in the current study included water, feeds, veterinary and breeding services, labor, and replacement stocks (Figure 3). The means of acquisition of these inputs posed biosecurity concerns to the pastoralist herds. For example, the shared communal grazing fields and watering points, some of which are used by wildlife, pose the risk of introduction of infectious organisms such as Brucella and Mycobacterium tuberculosis into the dairy value chains of Narok County (Figure 3).

There also exists documented evidence of shared grazing grounds between domestic livestock and wildlife (Niamir-Fuller *et al*., 2012). Anthrax and salmonellosis are zoonotic diseases that have been reported through participatory epidemiology in different zones of Narok County's livestock wildlife interface (Nthiwa *et al*., 2019). However, the true extent of the existing risk of various zoonosis remains unconfirmed.

This concern is affirmed by the findings of Enstrom *et al*., (2017), who reported occurrence of symptoms consistent with brucellosis in both humans and animals among pastoralists residing in the periphery of the Maasai Mara national park in Narok County. A further study by Gathogo, (2011), confirmed the presence of *Mycobacterium tuberculosis* in a bovine carcass originating from Narok (the current study area) in Kenya Meat Commission and Njiru slaughterhouses.

Accessibility to potable water for maintenance of hygiene along the value chain was reported to be a major challenge, thus milk hygiene practices were poor. This finding is consistent with what has been reported by Ekou, (2014), who stated that milk hygiene practices among pastoralist communities were poor. The poor hygiene practices create an opportunity for contamination of the milk with potentially harmful pathogens such as *E.coli* and *Salmonella* spp. *E.coli* contamination of milk has been reported to be possible due to poor, unhygienic handling other than direct fecal contamination, Arafa and Soliman, (2013).

The main constraints of marketing milk included: poor prices, market scarcity, lack of cold storage facilities, poor road network and long distance to the market, non-compliance in payment for milk delivered, expensive aluminum cans for handling milk and seasonal excess milk production. The quantity of milk supplied was dictated by rainfall pattern that influenced availability of feeds and would in-turn lead to fluctuation in prices and wastage due to lack of storage facilities. The finding of seasonal fluctuation in milk supply agreed with that reported by Njarui *et al.,* (2010) in Mwala and Kangundo areas of Machakos District, Kenya.

The bottlenecks for milk production were reported to include low genetic potential of the cattle breeds; pests and diseases compounded by the fact that veterinary services are difficult to access; long trekking distances to pastures; competition, with wild animals for pastures in the face of fencing costs and inadequate knowhow of livestock husbandry.

Lack of access to veterinary services was reported to result in undocumented morbidity and mortality losses. With the limited access to veterinary services, prudent use of veterinary medicines and particularly antibiotics, is not guaranteed posing a public health risk and concern in terms of medicinal residues in milk and milk by-products. Antibiotic residues was ide in milk are a concern in developing countries, where there is absence of regulation of antibiotic use in animals; negligence in observation of withdrawal periods or lack of antibiotic residue testing, Garcia *et al*., (2019).

This current study revealed that marketing faces infrastructural constraints characterized by poor road networks, lack of chilling and storage facilities. Poor road networks and far distances to the market further impedes delivery of milk to the collection and marketing centers. These challenges are amplified during the rainy seasons that come along with surplus production of milk due to pasture growth. Similar findings have been documented by Wambugu *et al*., (2011).

Use of easily sterilizable aluminum cans was largely not practiced in Narok County with the participants citing the high cost of acquisition as the main hinderance in so far as they understood their comparative advantage over the plastic jerrycans and containers that they currently use. This finding is in contrast to the scenario in Uganda where plastic containers and plastic jerrycans use in handling of milk was banned by the Dairy Development Authority (Tijjani and Yetişemiyen, 2015).

Vulnerabilities that were identified in this study include: lack of disease control measures in the livestock markets and mixing of animals from different herds and wild animals on pastures and at watering points that creates risk for disease transmission between herds and possibly to humans. This finding is similar to in other areas where mixing of herds at pasture presents opportunities for transmission of the infection, particularly in sub-Saharan Africa, where these circumstances are common (Barrios *et al*., 2006; Jones and Tornton, 2009). Njeru *et al.,* (2016) found a high sero-prevalence of *Brucella* antibodies in African buffaloes that shared grazing and watering areas with cattle of Maasai communities in Narok thereby indicating the risk arising from sharing grazing and watering points. Nyaga (2015) also found a high sero-prevalence of *Brucella* antibodies in milk obtained from informal market agents in Narok. Poor access to veterinary services posed the risk of antimicrobial residues in milk since

the pastoralists are forced to administer drugs to their animals without guidance of qualified veterinarians or para-veterinarians. Further, withdrawal of milk was not a common practice. The need to travel long distances to access veterinary services is a common problem in Africa (Schelling *et al.,* 2005).

Laborers were reported to be unreliable and were a risk for adulteration of the milk to accrue more benefits from the little that is produced or mask reduced production, similar findings of milk adulteration by unfaithful workers have been reported elsewhere by Ryoba *et al*., (2005).

Conclusion

This study established that there exist two distinct milk value distribution channels, the formal and informal chains. The chains have different actors with varying decision making capacity and bargaining powers. The middlemen and large processing companies largely dictate the prices of milk, including farm gate prices.

Additionally, the milk production process is traditional with minimal modern additional input such as concentrate supplementation or use of milking machines. The pastures that are provided to the animals are predominantly natural species that are less nutritious and are often not conserved for utilization during the dry seasons which are frequent and usually protracted.

The study has also established that due to scarcity of important resources such as potable water, observation of hygiene measures right from milking to delivery to the consumer was not religiously observed these were likely to reduce the keeping quality of the milk and its shelf life. Additionally, there exists the risk of antibiotic residues in milk as well due to the fact that there were inadequate veterinary service providers and the livestock owners have direct access to antibiotics from agro-veterinary shops with no prescriptions. These two pose a huge public health threat.

From the findings of the current study, we recommend that education of the value chain actors in various aspects such as feed production and conservation, breeding, hygiene, and marketing would improve productivity and profitability of dairy farming in Narok County. We also recommend the strengthening and intensification of extension services as well as injection of resources (milk bulking centers/coolers, roads, breeding centers) so as to harness the full potential of dairy production in Narok County. Further studies to identify and characterize contaminants along the critical nodes of the mapped values chains is prudent.

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