Food Control 130 (2021) 108303

Contents lists available at ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont

Milk quality and hygiene: Knowledge, attitudes and practices of smallholder dairy farmers in central Kenya

Simon Nyokabi[a,*], Pieternel A. Luning[b], Imke J.M. de Boer[a], Luke Korir[d], Emmanuel Muunda[d], Bockline O. Bebe[c], Johanna Lindahl[e,f,g], Bernard Bett[d], Simon J. Oosting[a]

[a] Animal Production Systems Group, Wageningen University & Research, PO Box 338, 6700 AH, Wageningen, the Netherlands
[b] Food Quality and Design Group, Wageningen University and Research, P.O. Box 17, 6700 AA, Wageningen, the Netherlands
[c] Department of Animal Science, Egerton University, PO Box 536, 20115, Egerton, Kenya
[d] International Livestock Research Institute, (ILRI), P.O BOX 30709, Nairobi, 00100, Kenya
[e] International Livestock Research Institute, 298 Kim Ma Street, Ba Dinh District, Hanoi, Viet Nam
[f] Department of Medical Biochemistry and Microbiology, Uppsala University, P.O. Box 582, 75123, Uppsala, Sweden
[g] Department of Clinical Sciences, Swedish University of Agricultural Sciences, P.O. Box 7054, 75007, Uppsala, Sweden

ARTICLE INFO

Keywords:
Dairy
Fresh milk
Food safety
Food security
Value chains
Good agricultural practices (GAPs)

ABSTRACT

Milk production is an important livelihood source for smallholder dairy farmers in low-to-middle-income countries (LMICs) such as Kenya. However, milk quality and safety are a challenge due to unhygienic handling and non-adherence to food safety standards. The objective of this study was to investigate the knowledge, attitudes and adoption of milk quality and food safety practices by smallholder farmers in Kenya. Ten Focus Group Discussions (FGDs), involving 71 smallholder farmers, were held to collect qualitative data on knowledge, attitudes and practices (KAPs) of smallholder dairy farmers in Laikipia, Nakuru, and Nyandarua counties. Additionally, data were collected through a cross-sectional administered to 652 smallholder farming households.

The results of the study revealed low knowledge level and negative attitudes towards respecting antibiotics treatment withdrawal periods, milk quality standards and food safety regulations. Farmers stated they had received low levels of training on milk quality and safety standards. The majority of farmers adopted animal health measures and hygienic measures such as hand washing and udder cleaning. However, unhygienic milking environments, the use of plastic containers, the use of untreated water, and lack of teat dipping compromised milk quality and safety. Currently, milk production, handling and consumption could expose actors along the dairy value chain to health risks. The adoption of milk quality and food safety practices was influenced by farmers' knowledge, socioeconomic characteristics, and choice of marketing channel.

There is a need to improve farmers' knowledge and attitudes and implement hygienic control, disease control and antibiotic residue control practices in the milk production process to meet required milk quality and food safety standards. Awareness campaigns and training programmes for smallholder dairy farmers could foster behavioural change and lead to an improvement in milk quality in Kenya.

1. Introduction

Milk plays an important role in diets globally (Kamana et al., 2014). Milk is a complex mixture of macro and micro-nutrients and a rich source of fats, proteins, carbohydrates, minerals and vitamins such as calcium, vitamin B12 and riboflavin (Dugum & Janssens, 2015). Milk and dairy products are the most affordable animal source foods in low-to-middle-income countries (LMICs) (Alonso et al., 2018; Muunda et al., 2021).

Milk production is an important source of livelihood for smallholder dairy farmers (Kamana et al., 2014; Msalya, 2017). Demand for dairy products in LMICs is growing, driven by population growth, rising incomes and changing lifestyles. There is an imperative for smallholder farmers to produce milk that meets food safety standards to take advantage of this growing demand for milk and dairy products (Lemma et al., 2018).

* Corresponding author.
E-mail address: ndungukabi@gmail.com (S. Nyokabi).

https://doi.org/10.1016/j.foodcont.2021.108303
Received 19 January 2021; Received in revised form 11 May 2021; Accepted 1 June 2021
Available online 5 June 2021

Milk contamination results from improper handling, and poor hygiene and sanitation conditions in the milking environment (Olivier et al., 2005). Contaminated milk could be a conduit for pathogens such as bacteria, viruses, parasitic agents and chemical residues responsible for foodborne diseases which negatively affect consumers' health and nutrition status (Amenu et al., 2019). Milk is a highly perishable product, and its safety and quality deteriorate quickly if not handled under hygienic conditions (Kamana et al., 2014). Poor milk quality and food safety risks are a major challenge in the dairy sector in LMICs with weak food safety management systems and low compliance with food safety standards (Amenu et al., 2019; Kussaga et al., 2014). There is a need for an integrated approach to milk quality and safety that guarantees its integrity from '*farm to glass*' (Grace et al., 2007).

Smallholder dairy farmers' low knowledge levels and poor attitudes influence their behavioural practices regarding compliance with milk quality standards and food safety regulations (Brown et al., 2019; Ledo et al., 2019). Empirical evidence has linked improved knowledge, training and positive attitudes to improved hygienic milk handling practices at the farm-level (Lindahl et al., 2018). Improved knowledge and compliance with milk quality standards and food safety regulations are crucial for the mitigation of milk-borne diseases (Dongol et al., 2017; Kumar et al., 2017). Farmers adopt milk quality and safety practices that are economically viable, technically feasible, and socio-culturally acceptable (Hermans et al., 2017).

Only a few studies have assessed knowledge, attitudes and practices (KAPs) regarding milk quality and safety of smallholder dairy farmers, namely in India and Nepal (Dongol et al., 2017; Kumar et al., 2017). There is a need to understand drivers of KAPs regarding milk quality to improve milk quality in LMICs, particularly in Africa (Dongol et al., 2017; Kumar et al., 2017).

The current study focuses on Kenya, which has one of the highest levels of milk production in Africa (Alonso et al., 2018). Over 4 million tonnes of milk were produced in 2016, primarily by smallholder dairy farmers (Alonso et al., 2018). Kenya has a per capita milk consumption of 50–150 L per year (Bosire et al., 2017). The current state of milk quality and safety is a public health concern (Nyokabi et al., 2021) (Muunda et al., 2021). Zoonoses such as brucellosis and pathogens such as cryptosporidium and *E. coli* have repeatedly been reported in milk (Grace et al., 2008; Wanjala et al., 2017). Antibiotic residues levels exceeding the maximum residue limits (MRLs) have also been found frequently in milk (Ahlberg et al., 2016; Ondieki et al., 2017).

To date, research in Kenya has focused on post-farm-gate milk handling practices in dairy value chains (Alonso et al., 2018; Grace et al., 2008; Nato et al., 2018; Orregård, 2013). To our knowledge, this is the first study to document smallholder farmers' KAPs regarding microbial contamination, zoonoses and antibiotics residues at the farm-level.

2. Materials and methods

2.1. Study location

The study was conducted in Laikipia, Nakuru and Nyandarua counties in Kenya (Fig. 1) due to a large number of smallholder dairy farmers and well-established dairy sector (Migose et al., 2018; Muia et al., 2011; Staal et al., 2003). The counties were stratified to capture farming system and agroclimatic diversity using a farming systems spatial framework, explained by Nyokabi et al. (2021). The framework characterises farms based on their market quality and intensification of their dairy systems. These systems were classified as intensive dairy systems in urban and peri-urban locations (UL), semi-intensive dairy systems in mid-rural locations (MRL) and extensive dairy systems in extreme-rural locations (ERL).

In Nakuru, we purposively selected Nakuru town and Rongai as UL, Njoro and Subukia as MRL, and Molo Elburgon, Keringet, Maili-sita and Kampi ya moto as ERL. In Nyandarua, we considered Olkalau, Oljoro-orok and Engineer as UL, Njabini and Miharati as MRL and Ndaragwa and Olbolosat as ERL. In Laikipia, Nyahururu town and Nanyuki were selected as UL, Marmanet and Ngarua as MRL and Rumuruti and Kinamba as ERL.

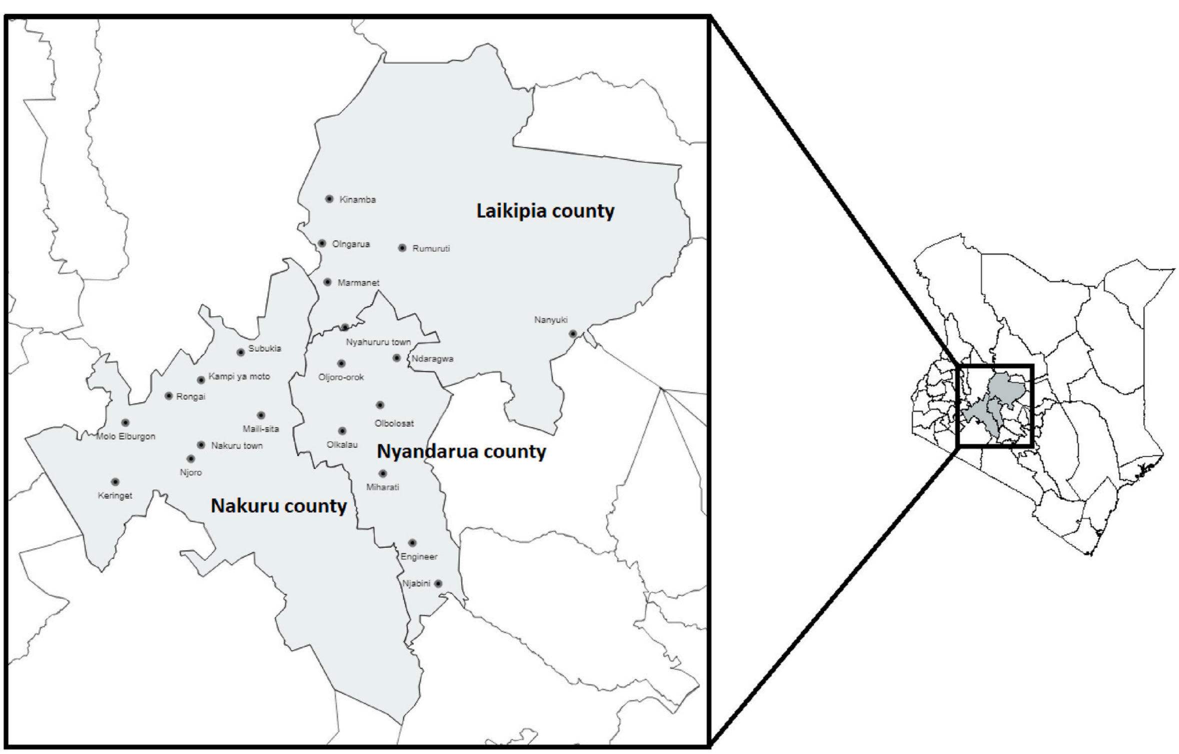

Fig. 1. The study area (source: Authors own).

2.2. Research design

This study used focus group discussions (FGDs) and individual interviews to investigate smallholder dairy farmers' KAPs regarding milk quality and safety.

2.3. Focus group discussions (FGD)

FGDs were used to collect qualitative data before the collection of quantitative data. Smallholder dairy farmers were purposively selected to participate in FGDs with the help of county livestock production and veterinary officials. The inclusion criteria for FGDs discussants were: (1) above 25 years old, (2) experience in smallholder dairy farming, and (3) resided in the community for over 3 years. The inclusion criteria were meant to include farmers with experience, made farm decisions and participating in milk production. Each FGDs consisted of between 6 and 9 participants conducted as either male or female and mixed groups. FGDs were held in the villages in one of the smallholder farmers' homesteads and lasted between 60 and 75 min and were recorded using digital recorders with the consent of the discussants. FGDs were conducted using a semi-structured interview guide with open-ended questions and were facilitated by a moderator, with a note-taker in the local languages and the national languages Kiswahili and English. In total 10 FGDs (4 men only, 4 women only, and 2 mixed groups) were held with 71 smallholder farmers, i.e. 37 males and 34 female discussants, respectively.

FGDs explored farmers' knowledge regarding milk quality standards and food safety regulations, animal diseases, zoonoses, microbial contamination, and antibiotics residues risks. FGD participants were asked general questions such as *"what makes milk bad?"* or/and *"what qualifies as good milk?"* to assess knowledge and perceptions of milk quality and safety due to the difficulties of directly translating scientifically understood terms of microbiological quality or safety, as also explained by Amenu et al. (2019). FGDs participants were asked to explain and elaborate on practices adopted at the farm to prevent milk microbial contamination during milking and storage; animal health and zoonoses; and antibiotics prevention. The practices included milking parlour cleanliness, hand and udder cleaning, milking and storage containers, cleaning of milk containers, cow's vaccination and treatment and discarding milk from sick or treated cows.

2.4. Questionnaire survey

2.4.1. Identified KAPs and indicators related to milk quality and safety

We explored milk quality, food safety and good agricultural practices (GAPs), as recommended by Kumar et al. (2011), (2017) and FAO (2004), to identify good milk quality hygiene and safety practices. A milk hygiene index was developed using four indicators: (i) washing of udder before milking (ii) washing hands before milking (iii) cleaning of milking area, and (iv) containers used for milking and storage (aluminium/metal or plastic). Vaccination was used as an indicator to analyse animal health practices that could prevent zoonoses such as brucellosis. Farmers' observation of withdrawal period for milk from sick and treated cows was identified as an indicator for prevention of antibiotics residues (FAO, 2004; Kumar et al., 2017, 2011; Orregård, 2013; Yobouet et al., 2014). These indicators were used as proxies for the adoption of milk quality and safety practices at the farm-level.

The survey questionnaire had open and closed-ended questions and was based on the FGD's findings and good agricultural practices (GAPs) recommended by FAO (2004). The first part of the questionnaire captured respondents' general information, e.g. county of residence, the gender of household head, education level, farming experience, gender and age of milker, farmer groups membership, herd size, choice of milk marketing channel, milk price, amount of milk sold, amount of milk consumed at home, access to water and access animal health.

The second part captured farmers' knowledge and attitudes including knowledge of milk quality standards and regulations, milk quality parameters, animal diseases and milk-borne diseases, milk quality tests, antibiotic residues risk, access to milk quality information and training on milk quality handling and hygiene, animal health-seeking behaviour and drug withdrawal period. Questions regarding attitudes towards milk quality and food safety regulations explored whether farmers were complying or willing to comply with milk quality standards and regulations; whether they placed importance on animal health advice-seeking behaviour, control of milk-borne disease, compliance with withdrawal period for treated cows, use of treated water; and their views towards milk quality-based payment systems.

The third part captured farm-level adoption of practices aimed at preventing milk contamination, zoonoses and antibiotic residues including milking and storage practices, milk quality testing, deworming, vaccination, self-treatment of cows with purchased drugs, mastitis tests, teat disinfection, udders and hand cleaning and drying, use of treated water, use of milking cream, milking and storage container (aluminium or plastic), discarding milk from treated cows, cleaning of milking parlour and cowshed, control flies and other vectors.

2.4.2. Sample size and respondent selection

Sample size calculation was undertaken using a single proportion estimation for a finite population as explained by Pham-Duc et al. (2019). The sample size was determined with the assumption that 50% of the population of smallholder farmers implemented good milk quality and handling practices. The study considered a 5% precision and 15% added to cover for non-response, which resulted in a sample size of 460 households. To increase the external validity of the survey findings and due to the availability of resources, we proportionately increased the sample in each county leading to a total sample of 652 households, as explained by Mutua et al. (2017). Survey respondents were identified through purposive sampling in the UL, MRL and ERL farming systems (section 2.1). First, the study counties were stratified using the framework explained in section 2.1. A list of farmers was compiled with the help of livestock and extension officers in the farming systems in each county. Farmers were selected from the list using random numbers generated using an online software. The selected farmers were interviewed based on their willingness to participate. In cases of non-consenting farmers, a similar farm in close proximity was selected as a replacement. The questionnaire was administered to the household head or, in cases where that was not possible, to an informed member of the household, i.e. male or female, aged 18 years or above.

2.4.3. Data collection

Smallholder farmers' data were gathered using a structured quantitative questionnaire. The questionnaire was pre-tested with 25 respondents in areas with similar characteristics to study sites and revisions made before data was collected. The questionnaire was administered by trained enumerators who could speak Swahili, Kalenjin and Kikuyuand lasted approximately 45–60 min.

The interviews were conducted between May and July 2018. Ethical approval for the study was granted by the Institutional Research Ethics Committee (IREC) of the International Livestock Research Institute (ILRI) (REF: ILRI-IREC2017-09). Participants were informed about the project and that they could withdraw from the study at any time, and those who chose to proceed were asked to review and sign a consent form.

2.5. Data management and analysis

2.5.1. Qualitative data analysis

The audio recordings of the FGDs were transcribed verbatim. Transcription of the data into English was undertaken by a trained research assistant with a good command of the local languages, English and Swahili. The transcripts were compared against the original recordings and notes taken during the interviews to ensure consistency and minimise the loss of ideas or concepts during translation.

The data analysis process was as described by Green et al. (2007), and involved reading and re-reading of the transcripts for familiarisation with the data. Themes were identified and grouped according to the questions guide. Emerging themes were identified and added as appropriate, for example, information regarding sick animals and milk from sick and treated animals. Verbatim quotes of the FGDs participants were identified and used to support the important findings.

2.5.2. Quantitative data analysis

Descriptive statistics were calculated for farmers' demographic characteristics, knowledge, attitudes and adopted practices. To compare KAPs between counties, analysis of variance (ANOVA) was calculated for continuous variables and Chi-square test for frequencies and categorical variables.

Farm-level indicators, i.e. milk hygiene index, vaccination and observation of withdrawal period, were used in the linear and logit regression models to identify the determinants of adoption. The hygiene index comprised: (i) wash udder before milking (yes = 1/no = 0), (ii) wash hands before milking (yes = 1/no = 0), (iii) clean milking area (yes = 1/no = 0), and (iv) milking and storage containers (aluminium/metal = 1/plastic = 0). The hygiene index was the sum of the scores of these indicators, i.e. a maximum score of 4 and a minimum score of 0.

The milk hygiene index was used in an Ordinary Least Squares (OLS) model to test farmers' adoption of milk quality and safety practices as explained in Model 1.

$$y_i = \alpha + \beta_i x_i \ldots . \beta_n x_n + \varepsilon_i \qquad \text{(Model 1)}$$

Where y_i is the farm-level indicator for household i, α is the intercept, β_i …. β_n are coefficients to be estimated, Xi … Xn is a vector of farm characteristics, and εi is the error term.

Logistic regression was used to evaluate the effect of smallholder dairy farmers' demographic characteristics on adoption of vaccination (yes = 1/no = 0; model 2), discarding of poor-quality milk (yes = 1/no = 0; model 3) and influence of milk market channel on farmers' KAP. Logit regression predicting the binary dependent outcome was specified by the following equation:

$$\log[p/p\text{-}1] = \beta 0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + e \qquad \text{(Models 2, 3 and 4)}$$

Where: p = predicted probability that a farmer adopts zoonoses or antibiotics residues prevention practices, β0 … βn = estimated parameters; X_1 … Xn = independent predictor variables (farm characteristics); e = the random error term.

The predictors evaluated in all three models were county; milk marketing channel; knowledge of hygiene regulations; training on milk quality; the age of milker; experience of farming; gender of milker; access to water; access animal health; pay to access water; the amount of milk sold; average milk price; herd size; the number of milking cows; the amount of milk consumed; cow breed; awareness of milk-borne zoonoses; gender of household head; membership of cooperative; animal health advice-seeking behaviour; and knowledge of milk quality standards parameters. Multicollinearity tests were performed on the predictor variables and only those with values below 5 were kept in the final models.

All statistical analyses were conducted using R statistical software version 3.6.2 (R Core Team, 2019). OLS and logit regressions were undertaken using lm, bayes glm and polr functions in R, respectively.

3. Results

3.1. Smallholder dairy farmers' socio-economic and demographic characteristics

The characteristics of smallholder farmers in the three counties are presented in Table 1. The majority of farmers were aged between 30 and 60 years and practised mixed crop-livestock farming. Farmers primarily kept Holstein-Friesian crosses due to their high milk production potential. However, local breeds were preferred in arid and semi-arid locations due to their adaptability to the harsh environment.

Table 1
Smallholder dairy farmers' socioeconomic demographic characteristics (in percentage).

Demographic characteristics		Laikipia [a] (n= 211)	Nakuru [b] (n=220)	Nyandarua [c] (n=221)
Proportion of farmers using different Milk marketing channels	Subsistence	17.1	24.1[c]	11.8
	IVC	60.2[c]	55.5[c]	31.7
	FVC	20.4	16.4	55.7[a,b]
	IVC &FVC	2.4	4.1	0.9
Milker gender	Male	45.0	43.6	51.6
	Female	55.0	56.4	48.4
School levels	No formal education	14.2	8.2	8.1
	Primary level education	42.7	36.4	42.1
	Secondary level education	32.2	43.2	38.5
	Post-secondary level education	10.9	12.3	11.3
Percentage of who were members of a cooperative		27.5	23.6	38.5[a,b]
Experience in farming (years)	<10	13.7	22.3	23.5[a]
	10–20	28.9	28.6	33.0
	21–30	19.0	19.0	17.7
	>30	38.4[c]	30.0	25.8
Percentage with access to a source of water		73.0	89.1[a]	82.8[a]
Percentage with access to animal health services		98.6	95.5	99.6[b]
	X¯ (se)		X¯ (se)	X¯ (se)
Amount of milk sold (litres/farm/day)	8.11 (0.67)		9.56 (1.07)	15.04 (2.55)[a]
Milker age (years.)	47.91 (1.23)[a]		41.76 (0.96)[b]	42.55 (0.93)[b]
Total number of cows (heads of cow/farm)	3.76 (0.22)		5.53 (0.45)[a,c]	4.32 (0.30)
Milking cows (heads of cow/farm)	2.16 (0.13)		2.80 (0.22)[a]	2.30 (0.15)
Average milk price (Ksh/litre)	33.50 (0.48)		37.49 (0.50)[a,c]	33.25(0.23)[a]
Amount of milk consumed (litres/farm/day)	2.46 (0.15)		2.22 (0.12)	2.92 (0.19)[b]

IVC-Informal value chains, FVC- Formal value chains.
Means or percentages in the same row with different superscript (a, b, c) are significantly different (P < 0.05).

Most of the milk produced in urban and peri-urban locations was sold through the informal value chain. Farmers in rural locations sold their milk collectively through farmer groups and cooperatives to processors. However, a significant share of the milk was also sold in the informal value chain through small-scale traders and middlemen.

3.2. Focus group discussion results

Table 2 summarises FGD results regarding milk quality knowledge and attitudes. FGD participants knew the existence of milk quality standards and milk quality parameters and tests used by milk buyers

Table 2
Focus groups' results of knowledge and attitudes relating to milk quality.

		Finding	Respondents' explanation/ comments
Knowledge	Milk quality	•Knowledge of milk quality regulations, parameters and tests used by milk buyers	•*Sure, you're told not to drink it for 72 h*" FGD Oljororok
	Animal diseases and zoonoses	•There was knowledge of animal diseases and milk-borne zoonoses	•Animal diseases e.g. pneumonia, mastitis, foot and mouth, black quarter, anaplasmosis diarrhoea and east coast fever, parasitic worms and anthrax outbreaks. Milk borne zoonoses e.g. brucellosis, diarrhoea and vomiting
	Antibiotics residues	•Low knowledge of antibiotic residues risks. Some farmers knew that some drugs could be detected by organoleptic tests, i.e. smell test	•"*Trodax (used to treat flukes) when administered, don't drink the milk because it changes the look of the milk*" FGD Oljororok
			•"*We sell it there is no need to lie to you […] I think there's is no harm, the milk will be mixed with other milk and it will neutralize the antibiotics, and also the processing will take care of it with boiling, pasteurisation and whatever else they do in the processing plants*" FGD Nakuru
Attitudes	Milk quality	•Farmers had negative attitudes towards milk quality requirements	•"*cleaning [..] is too much work. Even the wood for warming that water is not here […] farmers are very stubborn and even when we know the benefits or the dangers […] we'll still ignore opting for shortcuts.*" FGD Engineer
		•Increased knowledge leads to a positive attitude and compliance with milk quality standards.	•"*The plastics are cheaper […] cost for the metal containers is too high […] 5 thousand and the same in plastic is one hundred, definitely I will opt for the cheaper one due to the economic issues […] aluminium ones are good […] but also the prices of the same milk … is not allowing it.*" FGD Mutarakwa
	Animal diseases and zoonoses	•Farmers had a positive attitude towards the control of animal diseases because of their impact on milk production and quality	•"*We don't treat all the cows simultaneously […] I don't treat all of them I leave some for home consumption and after the withdrawal period I treat those that I hadn't been treated*" FGD Oljororok •"*The loss is felt by the farmer […] the milk should not be consumed for 72 h […] you can imagine for three days that's a lot of money you'll lose*" FGD Nakuru
	Antibiotics residues	•Farmers had negative attitudes regarding antibiotic residue risks	•"*I'm the only person who knows I had given the antibiotics […] they don't-test antibiotics, or even return the milk that had antibiotics […] It's not like farmers don't know that it's wrong […] and as they say when you go to Rome you do as they do, you won't pour your milk while you know everyone else is selling their milk with antibiotics*" FGD Engineer
		•Farmers deriving most of their income from milk production found it difficult to discard poor quality milk	

such as density, smell, alcohol and organoleptic tests to determine milk quality. They knew animal diseases and milk-borne zoonoses such as brucellosis and symptoms such as diarrhoea and vomiting. Tick-borne diseases were common in extensive grazing systems practised in Nyandarua and Laikipia counties. FGD participants reported that mastitis was common in zero-grazing systems compared to open-grazing systems. FGD participants knew the negative impacts of animal diseases on milk quality, i.e. clots and blood in milk. There was, however, little knowledge of risks from antibiotic residues and a misconception that these were diluted during bulking or degraded by boiling at home or by pasteurisation and heat treatment during processing. The majority of the FGD participants had acquired knowledge from training, and from milk buyers, NGOs and media i.e. television, radio, and social networks including fellow farmers, cooperatives and farmer groups.

Farmers had varying attitudes toward animal diseases and milk-borne zoonoses. FGD participants reported positive attitudes towards milk standards and quality parameters used by buyers. The majority of the FGD participants reported good animal health-seeking behaviour and looked to minimise zoonoses risks, i.e. they looked to improve animal health through deworming and vaccination for East coast fever (ECF) and foot and mouth disease (FMD). However, there were negative attitudes towards antibiotic residues risk, expressed by farmers' reluctance to discard milk from treated cows to avoid economic losses. The mandatory withdrawal period was not observed by farmers, partly due to the knowledge that milk was rarely tested for antibiotic residues and was unlikely to be rejected.

FGD participants' adoption of milk quality practices at the farm-level is summarised in Table 3. The majority of FGD participants had adopted some hygienic milking and storage practices, animal diseases and zoonoses prevention practices and antibiotic risk reduction practices. However, farmers used plastic containers because aluminium containers were too expensive to purchase. Moreover, they did not discard milk from sick animals or treated cows and reported that poor farmers disregard laws to avoid economic losses. Some FGD participant opined that greed and ignorance were the main reasons why farmers sold rather than discarded poor quality milk. The adoption of milk quality practices at the farm level was influenced by the market channel requirements, availability of economic resources and labour availability. Farmers selling to cooperatives and dairy companies faced strict milk quality requirements. However, they received information, training and

Table 3
Focus groups' results of adopted practices relating to milk quality.

	Finding	Observation and explanations
Milk quality	•Farmers practised hand milking and just a handful of big farmers with big herds used machine milking.	•Famers avoided mixing evening and morning milk to minimise milk spoilage.
	•Farmers used warm water to wash udders, hands and milk utensils	•Plastic containers were cheap and easily available, while aluminium containers were expensive.
	•The majority of farmers used the same water and towel to clean all cows' udders.	•In the Oljoro-orok area in Nyandarua county, farmers depended on water from a water pan which they reported had liver flukes (*Fasciola hepatica*).
	•Milking containers and hand towels were washed with soap or detergent.	•There were also reports of sub-standard aluminium containers that rusted being traded in the markets.
	•The majority of farmers did not sieve their milk to remove dirt	•Farmers without piped water did not treat their water due to a lack of knowledge, or resources to buy water treatment agent.
	•Evening milk was cooled in a cold-water bath to preserve it.	
	•The majority of farmers used plastic containers for milking and storage.	
	•Farmers had access to water such as wells, rivers or piped water although, in some areas, availability was seasonal	
Animal diseases and zoonoses	•Teat dipping was not widely adopted in all the counties.	•Animal health services were easily accessible through the subsidised public extension, private veterinary practitioners and self-treatment with purchased drugs
	•Farmers vaccinated cows and boiled milk to prevent zoonoses.	•Government-subsidised services focused on high economic impacts contagious diseases but were inefficient to respond to farmers needs due to understaffing and underfunding
	•There was a lack of monitoring of purchased drug and likely misuse by untrained farmers who administered them	
	•Private practitioners were driven by money and did not strictly emphasis the observation of the withdrawal period.	
Antibiotic residues	•The majority of farmers did not strictly comply with the mandatory withdrawal period for drug residues, such as discarding milk from sick or treated cows.	•Farmers opined that poverty and economic loses made them disobey or disregard food safety standards.
	•Only a handful reported feeding such milk to calves or dogs.	•There was also no insurance mechanism in place to compensate for the loss of income or motivate farmers to obey rules
	•Some farmers with large herds treated their cows in batches (several cows are treated, and their milk discarded, while some are left untreated for milking).	

incentives such as bonuses which could have influenced their milk hygiene behaviour.

3.3. Survey results

The overall results of the survey evaluating farmers' knowledge and attitudes regarding milk quality are presented in Table 4. Farmers knew the milk quality regulations and believed it was important to observe and comply with standards. Farmers were aware of milk parameters used by buyers to judge milk. However, approximately half of the farmers did not know of drug withdrawal periods, milk quality parameters and milk-borne diseases. The majority of farmers were not trained on milk quality and hygienic handling. Furthermore, the majority of farmers thought it was important to have a quality-based payment system.

Table 4
Smallholder farmers' knowledge and attitudes regarding milk quality (percentage of farmers).

	Laikipia [a] **n=211**	**Nakuru** [b] **n=220**	**Nyandarua** [c] **n=224**
Smallholder farmers' knowledge of milk quality			
Said they know about hygiene milk regulations	91.5	90.9	$98.2^{a,b}$
Said they know how to self-treat cows with purchased drugs	62.1^{b}	46.8	72.4^{b}
Said they know about the drug withdrawal period	61.1^{b}	44.5	70.1^{b}
Said they know milk quality parameters	50.2	59.1	54.3
Said they know milk-borne diseases	52.6	42.5	59.1^{b}
Said they had training on milk quality handling and hygiene	26.1	22.7	34.8^{b}
Smallholder farmers' attitudes regarding milk quality			
Think it is important to comply with milk regulations	96.2	91.4	98.2^{b}
Think it is important to control milk-borne disease	64.9	85.9^{ac}	63.3
Think it is important to have a quality-based payment system	64.0	74.1^{C}	55.2
Think it is important to observe the withdrawal period	61.1^{b}	42.7	63.8^{b}
Think it is important to seek animal health advice	50.7	52.7	43.3
Think it is important to use treated water or treat water	20.9	22.3	23.1

Means in the same rows with different superscript (a, b, c) are significantly different ($P < 0.05$).

3.4. Milk quality practices adopted by smallholder farmers

Table 5 presents the adoption of milk quality and safety practices by smallholder farmers. Farmers widely adopted animal health practices such as deworming, vaccination and self-treating cows with purchased drugs. Results in Table 7 (supplementary material) show that majority of farmers, 72.1%, had not received training related to milk quality and hygienic handling and only 12.3% of the respondents had received training in the last six months. Moreover, only 21.2% of farmers kept farm records i.e. animal health and production records, while 46.9% did not keep any records.

Although the majority of farmers had access to water sources (Table 1), 33% of farmers paid to access treated water for farm and household use (Table 7, supplementary material). Table 7 shows that a majority of farmers, 85%, cleaned cow udders with water only, and only 9% used water with soap or disinfectant. The majority of farmers washed cow udders and used a reusable cloth or towel to dry cow udder. 87% of farmers cleaned the a reusable cloth or towel daily.

Nearly half of the farmers used plastic containers for milking and storage. The majority of farmers, 91%, used water and soap to clean milking and storage containers, and 61% of farmers dried these containers in the open. Hand washing was common, with 93% of the farmers practicing it. After washing their hands before milking, 53% used a reusable towel to dry their hands, 24% used the towel used to dry udders, and 23% did not dry their hands. Some farmers, 6%, used calf suckling to stimulate milk release during milking.

The self-reported milk-borne zoonoses awareness was low in all three counties, with only 51.6% knowing milk-borne zoonoses. Farmers who knew zoonoses mentioned brucellosis (44.2%), diarrhoea (2.9%), tuberculosis (2.8%) and vomiting (1.8%). Milk quality testing was low with only 26.8% of farmers having their milk tested which led to low milk rejection due to poor quality. The most common milk tests included clot on boiling (11.8%) and density using a lactometer (7.8%).

Table 5
Milk quality practices adopted by smallholder farmers (percentages of farmers).

	Laikipia [a] n=211	Nakuru [b] n=220	Nyandarua [c] n=224
Animal health practices			
Farmer regularly deworms cows	87.7	86.8	90.5
Farmer has vaccinated cows	$91.0^{b,c}$	76.8	81.9
Farmer self-treat cows with purchased drugs	62.1^{b}	46.8	72.4
Farmer performs mastitis test	47.4	52.7	50.7
Farmer performs teat disinfection before milking	30.3	21.4	25.3
Farmer performs teat disinfection after milking	$33.2^{b,c}$	17.3	21.3
Farmer uses treated or treats water used for household	20.9	22.3	23.3
Hygienic milking and handling practices			
Milker washes udders before milking	94.3	88.6	97.3^{b}
Milker washes their hand before milking	93.8	89.5	96.8^{b}
Milker dries udders after washing & before milking	93.8^{b}	79.1	96.4^{b}
Milker uses milking cream during milking	87.2	79.1	$95.9^{a,b}$
Milker dries hands before milking	84.4^{b}	67.3	84.6^{b}
Milking and storage container Aluminium	43.1	46.8	56.1^{a}
Plastic	56.9^{c}	53.2	43.9
Milker uses different towels for cleaning and drying each cow	33.6^{b}	23.2	34.8^{b}
Farmer discards milk from treated cows	4.7	5.0	10.4
General hygienic practices			
Farmer cleans milk area before milking	56.9	50.5	46.2
Farmer regularly cleans cow shed	44.1	34.1	23.5
Farmer controls flies and other vectors	26.5	37.7	20.8

Means in the same rows with different superscript (a, b, c) are significantly different ($P < 0.05$).

3.5. Determinants of farm-level adoption of practices regarding milk quality

The regression analysis results are presented in Table 6. In the regression models, Laikipia was used as the base county, while subsistence consumption was used as a base milk marketing channel. The results indicate the important determinants of the adoption of milk quality practices. Adoption of milk quality hygiene practices was significantly lower in Nakuru and Nyandarua counties ($p < 0.001$ and $p = 0.001$, respectively) when compared to Laikipia. Farmers with knowledge of hygiene regulations and knowledge of milk quality standards and quality parameters adopted more measures compared to counterparts with little knowledge. Similarly, access to water increased the adoption of milk quality hygiene practices. However, there was low adoption of milk hygiene measures by farmers with animal health-seeking behaviour, access to animal health and those with high on-farm consumption (i.e. high proportion consumed at home).

Adoption of vaccination as a practice for preventing zoonoses and animal diseases was significantly lower in Nakuru and Nyandarua counties ($p < 0.000$ and $p = 0.008$, respectively) when compared to Laikipia. Adoption of vaccination increased with larger herd sizes. However, the results also show that farmers with knowledge of milk quality standards and parameters were less likely to vaccinate their cows.

The adoption of antibiotic residues prevention by discarding milk from sick and treated cows was widely adopted in farms that sold to formal value chains (processors and cooperatives), and farms with access to water. High milk prices also led to increased discarding of milk from sick and treated animals.

The choice of milk market channel (Table 8) varied significantly between the counties ($P < 0.00$). Farmers' choice to participate in the formal milk market channel significantly influenced their knowledge of hygiene regulations ($P < 0.00$), increased their likelihood of being a member of a cooperative ($P < 0.00$), and their inclination advice-seeking behaviour ($P = 0.00$).

4. Discussion

The main objective of this study was to investigate the smallholder dairy farmers' knowledge, attitudes and adoption of milk quality practices in central Kenya.

4.1. Smallholder dairy farmers' milk quality knowledge and attitudes

The results of this study reveal that the majority of smallholder dairy farmers knew milk quality regulations and standards due to their interaction with buyers, e.g. cooperatives and processors, who had high milk quality demands and used milk quality tests to measure quality aspects, i.e. density and alcohol tests as reported by Ndambi et al. (2020). Farmers had limited knowledge of animal diseases and milk-borne zoonoses, which likely limited compliance with hygienic milk handling practices, as also noted by Dongol et al. (2017), Kumar et al. (2017) and Lindahl et al. (2018). Limited knowledge of zoonoses and milk safety risks is of particular importance because *Salmonella* spp., *Escherichia coli O157:* H7 and brucellosis have been reported repeatedly in Kenya (Kang'ethe et al., 2012; Mutua et al., 2017; Ng'ang'a et al., 2016; Njeru et al., 2016; Nyokabi et al., 2018). On the other hand, farmers had a positive attitude towards milk quality regulations and standards and milk quality testing as well as disease prevention, which could reduce zoonoses risks (Lindahl et al., 2018). Furthermore, the results (Table 7) reveal low levels of training crucial for improving farmers' knowledge and understanding regarding milk quality. Alonso

Table 6
Determinants of farm-level adoption of practices regarding milk quality at farm-level.

Explanatory variables	Milk hygiene (Model 1)		Vaccination (Model 2)		Discarding poor quality milk (Model 3)	
	Coefficients (Std. Error)	P-value	Coefficients (Std. Error)	P-value	Coefficients (Std. Error)	P-value
Intercept	1.68 (0.28)	<0.001***	1.13 (1.00)	0.257	−6.39 (1.78)	0.000 ***
County Nakuru	−0.24 (0.07)	0.001**	−1.07 (0.30)	0.000***	0.03 (0.47)	0.948
County Nyandarua	−0.32 (0.08)	<0.001***	−0.85 (0.32)	0.008 **	0.55 (0.42)	0.193
Sell to informal value chain	0.11 (0.08)	0.176	0.53 (0.30)	0.082	1.53 (0.85)	0.073
Sell to formal value chain	0.11 (0.10)	0.264	0.02 (0.37)	0.950	2.30 (0.88)	0.009 **
Sell to informal& formal value chain	−0.08 (0.20)	0.700	0.77 (0.75)	0.306	1.48 (1.26)	0.240
Know hygiene regulations	1.99 (0.12)	<0.001***	0.05 (0.44)	0.913	−0.23 (0.96)	0.810
Training milk quality	−0.10 (0.07)	0.130	0.18 (0.27)	0.512	0.05 (0.36)	0.895
Gender of milker	−0.10 (0.06)	0.085	0.10 (0.23)	0.677	0.06 (0.35)	0.873
Have access to water	0.16 (0.08)	0.034 *	−0.03 (0.32)	0.931	−0.79 (0.38)	0.038 *
Have access to animal health	−0.53 (0.20)	0.007 **	1.01 (0.59)	0.086	−0.15 (0.97)	0.880
Amount of milk sold	−0.00 (0.00)	0.541	−0.00 (0.00)	0.672	0.01 (0.01)	0.063
Average milk price	−0.00 (0.00)	0.382	−0.01 (0.02)	0.508	0.05 (0.03)	0.049 *
Total number of cattle	−0.01 (0.01)	0.113	0.16 (0.06)	0.007 **	−0.04 (0.05)	0.473
Number of milking cows	0.01 (0.02)	0.747	−0.03 (0.10)	0.798	0.04 (0.09)	0.691
Amount of milk consumed	−0.4 (0.01)	0.006 **	0.13 (0.07)	0.060	0.09 (0.05)	0.079
Zoonoses knowledge	0.08 (0.06)	0.197	−0.44 (0.23)	0.057	0.59 (0.36)	0.099
Member of cooperative	−0.03 (0.07)	0.715	0.23 (0.29)	0.417	−0.02 (0.39)	0.962
Sought animal health advice	−0.12 (0.06)	0.046 *	−0.33 (0.23)	0.149	0.36 (0.34)	0.288
Knowledge of milk quality standards & parameters	0.25(0.06)	<0.001 ***	−0.49 (0.23)	0.036 *	−0.03(0.36)	0.943

p-value: <0.001.
Adjusted R-squared: 0.3654.
Laikipia is the base county, subsistence production and consumption is the base marketing channel.
Significance codes: '***' 0.001 '**' 0.01 '*' 0.05.

et al. (2018) and Lindahl et al. (2018) have reported that training increases the adoption of hygienic milk handling practices. The results in Tables 3 and 4 also revealed that training farmers could increase the adoption of milk quality practices as knowledge was disseminated through farmers' social networks, diffusing from trained farmers to untrained peers (Muange & Schwarze, 2014).

4.2. Adoption practices related to milk quality at farm level

The findings in Table 5 demonstrated a high adoption of animal health practices that could prevent milk-borne zoonoses. Given that other research has reported endemic zoonoses in Kenya, e.g. Q-fever and brucellosis (Kang'ethe et al., 2012; Njeru et al., 2016), the findings of high adoption of animal health practices observed in this study is thus paradoxical. The practice of treating cows in batches (Table 2) violates animal welfare standards, may lead to disease transmission by sick asymptomatic untreated cows and could lead to diseases transmission within herds (FAO, 2004). Reports of mastitis in smallholder dairy farming systems could be due to poor hygiene in zero-grazing housing units as also suggested by Shitandi (2004).

The results in Table 5 reveal a compliance gap in the adoption of hygienic milking and milk handling practices which is similar to findings reported in India (Kumar et al, 2011, 2017; Lindahl et al., 2018), Nepal (Dongol et al., 2017) and Tanzania (Ledo et al., 2019, 2020). Table 5 results revealed that nearly half of the farmers contravened milk quality standards and food safety regulations by using non-food grade plastic containers for milking and storage which is similar to the findings of Muloi et al. (2018) and Orregård (2013). The low adoption of the recommended steel and aluminium containers by farmers could be due to their high price as also reported by Wanjala et al. (2017).

Results in Table 5 show the urgent need to increase compliance with good agricultural practices and hygienic practices to reduce milk contamination. Low compliance with hygienic practices is associated with contamination with *Salmonella* spp., *Escherichia coli O157:* H7, and *Staphylococcus aureus* (Lindahl et al., 2018). Improvements in milk microbiological quality will hinge on improving the hygienic conditions of cow housing (Abera et al., 2012), and increasing access to refrigerators or cold storage facility by farmers (Lindahl et al., 2018; Mwangi et al., 2016). Additionally, there is a need for improved hygiene of utensils, hygienic milk handling and storage and increases access to clean water which could reduce the risk of milk contamination with bacteria (Lindahl et al., 2018; Muloi et al., 2018).

The results in Tables 2–4 show limited knowledge and misconception regarding antibiotics residues risks, they assume that antibiotics residues are diluted by bulking or degraded by pasteurisation which is in agreement with the findings of Ondieki et al. (2017) and Shitandi and Sternesjö (2004). This could suggest that the risks were not widely understood or even acknowledged as also reported by Shitandi and Sternesjö (2004). The majority of farmers did not discard milk from sick and treated animals (Table 2), which could explain the antibiotic residues above the maximum residue limits as reported by Ondieki et al. (2017) and Shitandi and Sternesjö (2004) in milk sampled at farm and value chains. Milk boiling as reported by the farmers in this study does not make it completely safe, and there is still a risk of recontamination due to unhygienic handling (Lindahl et al., 2018; Muunda et al., 2021). Moreover, boiling and pasteurisation does not eliminate contaminants such as aflatoxins, antibiotics residues, pesticide residues and bacterial enzymes, which can lead to spoilage of the packaged milk and pose a public health risk to consumers (Ahlberg et al., 2016; Lindahl et al., 2018).

4.3. Determinants of adoption of practices related to milk quality at farm level

Regression models results (Tables 6 and 8) suggest that improving knowledge of milk quality and safety standards could lead to increased adoption of milk quality hygiene practices. Increasing milk quality standards compliance requires the provision of information and training of smallholder farmers who often lack managerial skills such as hygienic milk handling and record-keeping (Handschuch et al., 2013). Additionally, stricter enforcement of milk quality regulations, such as that observed in the formal value chain could lead to improved farmers' knowledge through increased advice-seeking behaviour and the formation of cooperatives and farmer groups which are a source of information, training and other benefits.

This study shows that the adoption of milk quality and hygiene practices at the farm level entails recurrent and non-recurrent costs (Table 5). Non-recurrent costs are usually fixed costs involving one-time initial investments, i.e. purchase of milking equipment. In contrast, recurrent costs are incurred regularly and vary depending on farm size i.e. water payment and extra labour costs. These costs may be beyond the resources available to smallholder dairy farmers in LMICs (Handschuch et al., 2013). Farmers' socio-economic factors, such as access to resources and milk prices, also influence the adoption of hygienic milk practices and compliance with milk quality and food safety standards. Similar observations have been reported for smallholder farmers in India, by Lindahl et al. (2018). Compliance with milk quality and food safety standards is a challenge for smallholder farmers due to high transaction costs associated with low production (Kumar et al., 2011). Smallholder farmers are often reluctant to make high-risk investments due to the lack of necessary resources needed to implement such milk quality practices (Handschuch et al., 2013). The results reveal that smallholder farmers preferred accessible and easy to implement milk quality practices, which is similar to observations made by Nyokabi et al. (2018).

The results show, in the three counties, smallholder farmers differ in their knowledge and attitudes towards milk quality and their choice of milk marketing channels (Tables 6 and 8). Nakuru and Nyandarua have well-established dairy sectors. Farmer cooperatives and groups and processing plants playing an important role in exposing smallholder farmers to training, information and knowledge regarding milk quality management compared to their peers in Laikipia, a county which prioritises tourism and pastoralism (Nyokabi et al., 2021; van de Steeg et al., 2010). The quality of infrastructure such as road networks and access to water and animal health services could affect farmers' behaviour regarding the implementation of hygiene and animal health practices (Migose et al., 2018; Nyokabi et al., 2021).

5. Conclusion

This research on smallholder dairy farmers' KAPs regarding milk quality in Low and Middle-Income Countries (LMICs) provides practical, empirical and theoretical contributions to the literature on milk quality. The findings of this study indicate that farmers in Kenya have low knowledge and negative attitudes regarding zoonoses and antibiotics residues as reflected by their disregard for milk regulations and standards. Low adoption of important milk quality practices can lead to milk contamination and exposes milk consumers to health risk. As the first step in ensuring farm to fork milk quality and safety is producing quality milk under hygienic conditions from healthy animals, there is an imperative for downstream actors such as non-governmental, governmental institutions and supply chain actors, such as processors, to help smallholder dairy farmers comply with milk quality standards and improve their milk handling practices. Training and provision of incentives, e.g. a milk quality-based payment system, could result in behavioural change and ensure that consumers have access to clean, safe milk and dairy products.

Statement of ethics

This work had ethical approval from the International Livestock Research Institute's (ILRI) Institutional Research Ethics Committee (ILRI IREC) (REF: ILRI-IREC2017-09). IREC is accredited in Kenya by the National Commission for Science, Technology and Innovation (NACOSTI).

Statement funding

This work was funded by a PhD scholarship as part of the project "Local and International business collaboration for productivity and QUality Improvement in Dairy chains in SE Asia and East Africa (LIQUID)". This project is supported by the Netherlands Organisation for Scientific Research's (NWO) Science for Global Development department (WOTRO) through the Food and Business Global Challenges Programme (GCP) (NOW-WOTRO project number W.08.250.204).

Declaration of competing interest

The authors would like to state that there was no conflict of interest resulting from funding or otherwise.

Appendix A. Supplementary data

Supplementary data to this article can be found online at 10.1016/j.foodcont.2021.108303.

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