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Adoption of milk safety practices: evidence from dairy farmers in Ethiopia

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Abstract

Background Foodborne zoonotic diseases caused by inadequate on-farm controls are a major global public health concern, despite dairy products' nutritional value and role in food security. To improve dairy safety on farms, it is critical to understand the factors that influence the adoption of safe milk production practices. The objective of this paper was to assess milk safety practices implemented on smallholder dairy farms and to identify factors associated with farm-level adoption of these practices by dairy farmers in Ethiopia.

Methods A semi-structured questionnaire was used to collect primary data from 424 randomly selected dairy farmers across five districts in Ethiopia, with 410 of them being used in the analysis. The level of milk safety practices was developed based on the reported adoption of 45 recommended milk safety measures, which were grouped under animal health, milking hygiene, milk storage, and general hygienic practices. Descriptive and inferential statistics were used to describe and compare key variables, while factors associated with the adoption of milk safety practices under each group and the overall level of milk safety practices adopted were identified using truncated Poisson and ordinary least squares, respectively.

Results Smallholder dairy farmers adopted 59% of the milk safety practices, with considerable variation across dairy farmers. Although the level of milk safety practices adoption does not significantly differ between the two zones, our finding uncovered that most of the factors associated with the adoption of milk safety practices significantly differ between zones. This demonstrates that there is a need for location-specific policy recommendations and strategies to improve the adoption of milk safety practices by dairy producers in Ethiopia. Households with more education, dairy farming experience, dairy production training, access to milk safety information, access to credit, and experience with milk safety inspections adopted significantly more milk safety measures. On the other hand, the number of lactating cows, distance from water and proportion of milk consumed at home were found to be negatively associated with milk safety practices adopted.

Conclusions The findings of the study suggest that strengthening food safety inspections at the farm and improving regulatory enforcement, disseminating food safety information through different outlets and location-specific interventions are important to improve the adoption of milk safety practices in Ethiopia.

Keywords Milk safety practices, Food safety measures, Milk quality, Adoption, Dairy farmers, Ethiopia

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Introduction

Despite the fact that dairy products are nutritionally dense and play a significant role in ensuring household food and nutrition security, foodborne zoonotic diseases caused by inadequate on-farm controls remain a major global public health concern [26, 44, 48]. Every year, 1 in 10 people suffers from foodborne diseases globally

[50]. According to the 2010 global burden of foodborne diseases estimate, diarrheal disease is the most serious in terms of the annual number of deaths and illnesses caused by pathogens associated with it [22].

Developing countries like Ethiopia are disproportionately affected by foodborne diseases for several reasons [26, 27, 41]. On one hand, Animal Sourced Foods (ASFs) are naturally perishable and easily contaminated if not handled properly [39], and producers and consumers in these countries often practice unsafe food handling and consumption practices [2]. In addition, the majority of ASFs are produced by smallholder farmers and mostly sold in informal markets where the safety standards and regulatory action regarding compliance with food safety measures are lacking [7, 18, 42, 43, 48]. On top of these, consumers' preference for raw dairy products over pasteurized and processed ones coupled with a culture of eating raw dairy products, put Ethiopia at a higher risk of being affected by dairy-borne diseases.

Consequently, there have been shifts in consumers' preference for safer and quality dairy products, which in turn, posed significant market restrictions for smallholder dairy farmers [15, 24]. Hence, the adoption of milk safety practices at dairy farms is important to ensure safe and quality milk production, which meets consumers' demand [33, 44]. Dairy farmers could benefit from adopting milk safety practices both as producers and consumers because smallholder farmers in the study areas produce dairy for both home consumption and the market. A growing body of literature suggests that the adoption of higher milk safety practices leads to higher milk acceptance, higher milk prices, and better profit [12, 32, 33]. These practices can also improve milk productivity [36], which in turn, increases production, market surplus, and income of dairy farmers [15]. Finally, safer milk plays a vital role in reducing child micronutrient deficiencies, and improving household food availability and diet diversity [39].

Though there has been strong attention regarding the drivers of the adoption of these milk safety practices in developed countries, relatively it is a recent phenomenon in developing countries [29, 31, 32, 33, 37–39, 51]. In Ethiopia, few studies have investigated the drivers of the adoption of improved dairy technologies and milk safety practices [2, 17, 20, 36, 38]. However, the focus of the majority of these studies is limited to a single or couple of dairy technologies such as improved breeds, improved feeds, and hygienic milking practices [2, 17, 20, 36]. As a consequence, assessing the adoption of the recommended milk safety practices and investigating factors associated with the use of these practices at smallholder dairy farms is crucial to inform policymakers on strategies that may improve milk safety.

Overall, the study is important for the following reasons: First, previous empirical studies on the adoption of milk safety practices are either in developed countries (e.g., [5]) or rapidly growing countries such as China and India [31, 51], therefore, dearth of information is available in developing countries like Ethiopia. Second, there is no premium pricing system for milk safety compliance in developing countries, including Ethiopia [26, 38, 39], which makes adopting milk safety practices voluntary. Therefore, our study contributes to the existing limited literature on dairy farmers' voluntary adoption of milk safety practices. Third, we specifically focused on smallholder dairy farmers because smallholder dairy farmers differ from medium and commercial dairy farms in terms of farm size, profit orientation, financial liquidity, and dairy housing types, among others [32, 38, 51]. Hence, understanding the factors associated with the adoption of milk safety practices by smallholder dairy farmers helps formulate evidence-based dairy intervention and policy that could improve the milk safety practices adopted by smallholder farmers in Ethiopia and other countries with similar socioeconomic settings.

The remaining parts of the paper are organized as follows: The second section presents the research methodology and the data. In the third section, results and discussion are presented by also disaggregating by location of the dairy farmers to shed some light on location-specific factors associated with the adoption of milk safety practices. The last section presents the conclusion and policy implications by also acknowledging the limitations of the study and options for further research.

Research methodology

Study areas

The study was conducted in two zones, namely Oromia Special Zone Surrounding Finfinne[1] and East Hararghe, which are located in the Oromia National Regional State (hereafter; Oromia Region) of Ethiopia. Out of the estimated 70 million cattle population of Ethiopia, the region accounts for the highest number of cattle populations with an estimated 25 million cattle, followed by Amhara and Southern Nations, Nationalities and Peoples' Regions with estimated 17 and 11 million cattle population, respectively [11]. The same source further shows that the region represents about 36.19% of the country's dairy cows and 38.23% of the country's annual milk production. The mentioned facts clearly demonstrate that the region is vitally important in Ethiopia's dairy sub-sector. Hence, assessing the adoption of milk safety practices

[1] Parts of the Oromia Special Zone Surrounding Finfinne have recently structured under the newly established city in Oromia region, Shaggar City.

by smallholder dairy farmers in the region could provide important inputs for the country's dairy sub-sector development.

Oromia Special Zone Surrounding Finfinne is one of the zones of the Oromia region, and it surrounds the capital of Ethiopia, Addis Ababa (also known as Finfinne). The zone was established in 2008 to ease the coordination and development cooperation between Addis Ababa and the surroundings, and to control the illegal expansion of Addis Ababa to the surrounding communities farm land. The zone is characterized by bimodal rainfall and gets rainfall during a short rainy season from February to May and a long rainy season from June to September. It is predominantly characterized by urban, pre-urban, and mixed crop-livestock farming rural communities [16]. Livestock rearing and crop production are the main economic activities and sources of livelihood of farmers in the zone. It is known for its livestock production and cattle is the most important one in the zone. It is also suitable for the production of different crops such as teff, wheat, beans, and barley [6, 47, 49].

East Haraghe zone is another zone of the Oromia region. It is located in the eastern part of Ethiopia. It is composed of three agroecological zones, the semiarid, semi-temperate, and temperate tropical highlands. The semiarid is the largest agroecological zone that covers 62.2% of the total area of the zone. The semi-temperate and the temperate tropical highlands cover 26.4% and 11.4%, respectively [45]. These agroecological zones are suitable for growing various crops and livestock rearing. Cereal crops such as sorghum, maize, and wheat,vegetables such as potatoes, onions, shallots, and cabbages; perennial crops such as coffee and *khat*[2] are widely grown in the zone. Moreover, the livestock subsector is an integral part of the livelihoods of farmers in the zone.

Data

Primary data were collected from 424 randomly selected dairy farmers of the Oromia Special Zone Surrounding Finfinne and East Hararghe Zone between February and March in 2021. However, 14 sample households were dropped because of missing information on key variables and only 410 of the sample households were used in the final data analysis.

The survey was used to collect primary data on milk safety practices, farm characteristics, sociodemographic characteristics, and access to institutional services, among others. Before starting data collection, a semi-structured questionnaire was designed, pre-tested, and refined using information from the pilot survey. A highly experienced data collection team was recruited, and training was provided to ensure that they understood the questionnaire properly. During the data collection period, data collected were checked by a primary author of this paper each night to ensure that the data collected met the required quality. Accordingly, the collected data were checked against the questionnaire, and improperly filled questionnaires were discarded, which led to the dropping of 14 households. On top of that, further clarifications and instructions were given to data collectors following the errors observed. This helped us ensure the quality of data.

Another potential problem associated with survey data like ours is potential response biases due to various reasons. We used a semi-structured questionnaire in identifying milk safety practices adopted by dairy farmers. Farmers' self-response to such questions may be biased towards reporting either positive (adoption) or negative (not adopting) due to social desirability bias [30], even when they actually did not or did. To reduce this bias, data collectors explained the purpose of the study to the participants until they fully understood the purpose of the study and assured them that their responses would not be shared with the government or other organizations.

Sampling techniques and sample size determination

To select a representative sample, a multi-stage sampling method was used. Oromia Special Zone Surrounding Finfinne and East Hararghe zone were selected purposively considering the milk production potential, and their proximity to the biggest cities (Addis Ababa, Dire Dawa, and Harar) in Ethiopia, where demand for milk is high. According to information obtained from the respective zones, there are six districts in Oromia Special Zone Surrounding Finfinne while 20 districts are available in East Hararghe zone [13, 40]. While milk is heavily produced in all the districts of the Oromia Special Zone Surrounding Finfinne, we classified only nine districts of the East Hararghe as high milk-producing areas based on the actual milk production data obtained from EHOLFD (2021). In the second stage, two districts (Walmara and Sululta), and three districts (Babile, Kersa and Meta) were selected randomly from Oromia Special Zone Surrounding Finfinne and East Hararghe zone, respectively. In the third stage, fourteen kebeles were selected randomly based on proportionate sampling techniques. Finally, 424 dairy producer households were randomly selected from each sampled kebeles based on the probability proportional to size.

[2] "It is an erect, evergreen, glabrous shrub or tree 2–25 m high with reddish stems, shiny green leaves and white flowers" [19], p. 908), and consumed as a stimulant.

The sample size was determined using a formula developed by Cochran [9], with a 95% confidence interval and a 5% margin of error as follows: $n = \frac{Z^2 * pq}{e^2} \cong 139$ and 246 in Oromia Special Zone Surrounding Finfinnne and East Hararghe Zone, respectively.

where n is the required sample size, z is the confidence level with a t-value of 1.96, p is the proportion of the households assumed to have a desired attribute (dairy cow), q is 1-p, and e is the desired level of precision. The proportion of households who own a dairy cow was assumed to be 90% in the Oromia Special Zone Surrounding Finfinne and 80% in the East Hararghe zone, based on the data obtained from each zone. Although the required sample size was 385, we included 424 households in our survey to account for potential non-responses.

Measurement of adoption of milk safety practices

To assess the adoption status of milk safety practices at the farm level, we followed three steps. First, we identified recommended milk safety practices being used by dairy farmers. In total, we identified 45 milk safety practices adopted in the study areas. These milk safety practices were classified under animal health, milking hygiene, milk storage, and other general hygienic practices following FAO and IDF's (2011) good dairy farming practices guideline and recent empirical studies on the adoption of food safety, elsewhere (e.g., [31, 33, 51]). The intuition behind this classification is that the adoption of a given milk safety practice enhances either animal health, milking hygiene, milk storage or have a more general effect on milk safety.

Secondly, we counted the number of milk safety practices adopted under each group, and this helped us know the proportion of milk safety practices adopted from a list of milk safety practices under each category. On top of this, it is useful to identify the factors associated with the number of milk safety practices adopted under each major milk safety category. In the third stage, we constructed the overall level of milk safety practices adopted, which shows the percentage of milk safety practices adopted by each dairy farm. It has been argued that adding the number of milk safety practices adopted under the major milk safety categories to obtain the overall level of adoption is not a plausible way because the contributions of different milk safety categories to milk safety are not equal [32, 33, 39]. Hence, the weighting framework developed by Kumar et al. [33][3] was used to obtain the weighted score of milk safety adoption of each household. As such, weights of 0.25, 0.35, 0.20, and 0.20 were used for animal health, milking hygiene, milking storage, and other general hygienic practices, respectively. The overall milk safety index was then determined as:

$$Y_i = \sum_{j=1}^{4} w_j P_j \quad (1)$$

where Y_i is the percentage of milk safety practices adopted by the i^{th} dairy farmer (its value lies between 0 and 100), w_j is the weight attached to j^{th} milk safety group, and P_j is the proportion of milk safety practices adopted in j category.

Estimation strategy

A farmer adopts a given agricultural technology to maximize his/her expected profit or utility (see [1, 28, 31]). Like many developing countries, the food safety regulatory system in Ethiopia is very weak and dysfunctional [18]. In addition, dairy farmers do not receive a premium price for adopting higher levels of milk safety practices [38], and the adoption of milk safety practices is completely voluntary. Hence, we adopted an expected utility maximization theory following previous empirical studies [1, 4, 28, 45]. Hence, a dairy farmer adopts milk safety practices only if the adoption of a given milk safety practice has a positive expected utility.

Regarding the empirical estimations, we are interested in identifying the factors associated with the overall (percentage) and the number of milk safety practices adopted under each major milk safety component (animal health, milking hygiene, milk storage and other general hygienic practices). Therefore, our dependent variables are truncated from below, but it takes a continuous value and is bounded at 100 in the former case while it takes positive integers (count number) in the latter case. The econometric model can be specified as follows:

$$Y_i = \beta X_i + \mu_i \quad (2)$$

where Y_i is the percentage (number) of milk safety practices adopted by farmer i,X_i is vector of independent variables, β is the parameters to be estimated, and μ_i is the error term.

We employed OLS to estimate the parameters of interest of the overall level of milk safety practices adopted. On the other hand, our survey indicates that the mean number of milk safety practices adopted under each major milk safety category is relatively small, with less than 10 under four of them (Table 5). As a consequence, the application of OLS in estimating the parameters of interest would provide biased and inefficient estimates [10]. In such cases, Poisson regressions have been

[3] Kumar et al. [33] noted that they developed these weights by consulting milk safety experts for the relative importance of different milk safety groups in ensuring safe milk production. Kumar et al. [32] and Mwambi et al. [39] also employed a similar framework to account for differences in the contribution of each milk safety practices to safe milk production. Interested readers may read Kumar et al. [33] and Mwambi et al. [39] for more detail information as to how each weight was developed.

thought of as a plausible alternative [8, 21], and several studies have applied Poisson regression in empirical studies of the adoption of food safety measures, elsewhere (for instance, [31, 51]). Our dependent variables, here the number of milk safety practices are non-negative, count and greater than zero under the four major milk safety categories. Hence, we estimated the relationship between dependent and independent variables under each component using a truncated Poisson regression model.

Variables definition and hypotheses

We selected household demographics, socioeconomics, farm, and institutional characteristics based on previous empirical studies conducted on agricultural technology adoption in general and food safety adoption in particular [5, 17, 29, 31–33, 38, 51].

Demographic characteristics such as sex, level of education, and dairy production experience of the household heads have been reported to have an association with food safety adoption. Male headed households are urged to have better access to resources, information, and knowledge about the importance of food safety. The education level of the household head has also been argued to have a positive association with the adoption of food safety measures [33, 51]. Moreover, experienced households would be more aware and knowledgeable about the milk safety practices needed to produce safe and quality milk and more likely to adopt milk safety practices. A study conducted by Yang et al. [51] found a positive association between dairy farmers' experience with milk safety practices adopted in China.

The number of working-age family members (active labor force) is important for implementing different milk safety practices. We expect that it could be positively associated with the level of milk safety practices adopted. Previous studies have also argued that the active labor force has a crucial importance in increasing the adoption of food safety measures [32]. Similarly, having a child under the age of five is also expected to be associated with the level of milk safety practices adopted positively. This is because, households who have children under the age of five are more likely to adopt stringent milk safety practices given that children consume milk more often than other members of the households in rural Ethiopia as reported by Hoddinot et al. [25]. The potential health hazards of unsafe milk consumption have been increasingly recognized by dairy producers [2], and dairy farmers are becoming more aware of this fact. Hence, we expected that the proportion of milk consumed at home would have a positive association with the level of milk safety practices adopted.

Regarding the size of dairy farms, large dairy farms have more resources at their disposal and more likely to adopt higher milk safety practices [31, 38]. Hence, we expected a positive association between dairy farm size and the adoption of milk safety practices. Further, different institutional services such as dairy training, membership in dairy cooperatives, and access to credit could be positively correlated with the adoption of milk safety practices [12, 29, 39]. Finally, milk safety inspection is also expected to be positively correlated with the adoption of milk safety practices [32, 51].

Results and discussion

Description of milk safety practices identified in the study areas

A full list of the milk safety practices identified is provided in Table 1. We categorized different milk safety practices adopted under four major milk safety categories [14, 33, 51] for more information regarding the classification of milk safety practices). Accordingly, these milk safety practices are listed under animal health, milking hygiene, milk storage or other general hygienic practices (Table 1). These practices could ensure milk safety via different channels. For instance, animal health practices contribute to the health of animals, thereby enhancing safe milk production. Hygienic milking practices, modern storage practices, and other general hygienic practices help eradicate milk contamination by different physical, biological, and chemical contaminants [2, 14, 29].

Regarding animal health, 17 milk safety practices have been identified. The majority of the dairy producers (93%) reported that they have selected dairy cows suitable to the local environment. However, only 18% of the households believe that the herd size is balanced with the available resources such as feed, labor requirements, and other resources. About 75% of the households reported that they vaccinate all animals at least once every year.

On the other hand, we observed mixed results regarding the purchase of animals of known health status and treatments of sick animals. About half of the sample respondents reported that they buy animals of known health status and immediately quarantine if observe signs of diseases on the purchased animals. Interestingly, about 87% of the sample households reported that they regularly check animals for signs of diseases, and diseased animals are treated by veterinarians immediately.

However, adoption of some of the milk safety practices related to animal health is not encouraging. For instance, only 61% of dairy producers keep sick animals isolated from other animals and only a few (7%) of the dairy producers keep written records of animal treatment and follow treated animals accordingly. Furthermore, only 57% and about 74% of dairy producers carefully manage animal diseases that could affect the public and store veterinary medicines securely so as to contain

Table 1 Summary of milk safety practices adopted in the study areas

Animal Health	% of adopters	Milking hygiene	% of adopters	Milk storage	% of adopters	Other general hygienic practices	% of adopters
Selected dairy cows well suited to the local environment	93.17	Washing hands before milking	98.78	Milk storage area is clean	99.27	Plan ahead to ensure the herd's feeds and water requirements are met	72.68
Herd size is balanced with available feed, labor and other resources	17.80	Drying hands before milking	53.90	Milk storage area is separate from milking area	96.83	Buy inputs from known sources for quality inputs	33.90
Vaccinate all animals at least yearly	74.88	Washing udder of cows before milking	52.93	Milk storage area is lockable and free from birds, cats, dogs, etc	95.12	Prepare food mix as directed by feed experts to meet nutritional needs of dairy cows	11.22
Buy only animals of known health status	50.49	Udders of dairy cows dried before milking	29.76	Store milk in refrigerator	0.49	Discard/ avoid feeding spoiled and contaminated feed by chemical, biological or physical contaminants	73.66
Quarantine immediately if observe sign of diseases on bought animals	49.51	Use disposable tissue for drying breasts of each dairy cows after washing	18.05	Fresh milk collection equipment is kept clean when vacant	95.85	Get awareness about disease that affects feed (aflatoxin)	7.07
Regularly check animals for sign of disease	86.59	Drying hands before milking	53.90	Equipment washed before bulking	100	Drain (dry) urine immediately after excretion	10.49
Sick animals treated immediately by veterinarians	85.85	Washing milking utensils before milking	100	Bulking equipment dried before used for bulking	97.80	Nails of milking person is trimmed regularly	90.73
Keep sick animals isolated	61.22	Milking done in separate place from feeding areas	68.29	Use stainless steel or aluminum milk storage equipment	3.66	Awareness about gap in milking after treatment	55.61
Keep written record of all treatments and identify treated animals appropriately	7.32	Wearing clean and suitable clothes during milking	46.59			Floor of milking and stall-feeding area is concrete	3.41
Carefully manage animal disease that can affect the public (zoonosis)	57.32	Ensure a sufficient supply of clean water during milking	92.93				
Only use veterinary medicine as prescribed by veterinarians	81.95	Ensure milking area is kept clean	96.59				
Store veterinary medicines securely and dispose them responsibly	73.90						
Calf dehorning	8.05						
Veterinarians routinely check animals every year	45.12						

Table 1 (continued)

Animal Health	% of adopters	Milking hygiene	% of adopters	Milk storage	% of adopters	Other general hygienic practices	% of adopters
Group feeding for horn cows and hornless cows	53.41						
No feces seen on the dairy cows	42.44						
Washing of dairy cows frequently	21.95						

Source: Authors

transmissions of animal diseases to other animals and humans.

Moreover, about 8% of the dairy producers reported calf dehorning, which helps to decrease the harm by dairy cow/cattle on other dairy cows/cattle and ensure safe herd management [46], thereby contributing to safe milk production. We also observed that about half of the dairy producers feed horn and hornless cows by group. Furthermore, 45% of the sample households reported that veterinarians regularly check animals every year. We also found that feces can be seen on the bodies of lactating cows including udder (see Fig. 1), and washing animal body is not a common practice in the study areas. Only 42% of the sample households reported that feces do not appear on the body of animals while 22% of the sample households reported that they wash animals frequently.

Regarding milking hygiene, 11 milk safety practices related to hygienic milking have been identified and presented (Table 1). The result indicates that almost all (99%) of the sample households reported washing hands before milking. However, we found that only 54% of the sample dairy producers dry their hands before milking. We also asked whether dairy producers wash and dry udders of the dairy cows before milking. About 53% and 30% of the sample dairy producers wash and dry udders of the cows before milking, respectively. Similarly, only 18% of dairy producers reported the use of clean and disposable tissues for drying udders of dairy cows after washing cows' udders.

Moreover, one hundred percent of the sample households have reported that they wash milking equipment before milking. Regarding the milking area, 97% of the respondents reported that the milking area is clean and more than 93% of the respondents reported a sufficient supply of clean water during milking. About 68% of the dairy producers reported that milking is done in a separate place from feeding areas. However, only 47% of the sample respondents reported wearing clean and suitable clothes during milking.

The third milk safety group is milk storage. We identified eight milk safety practices related to milk storage (see Table 1). Generally, we observed that overall milk storage practices are widely adopted by dairy farmers. Almost all of the dairy producers reported milk storage area is clean, separate from milking areas, lockable, and free from birds, dogs and cats. Cleaning and drying fresh milk collection and storage equipment are also widely practiced. However, we are highly concerned regarding milk storage practices because modern milk storage practices such as refrigerator, stainless steel and aluminum are almost absent.

Lastly, milk safety practices related to general hygienic practices are also presented in Table 1. Accordingly, about 73% and 34% of the households plan ahead to ensure sufficient and quality feed is available throughout the year and buy feed and other inputs from known sources for quality, respectively. Moreover, only 11% of dairy producers prepare feed mix according to the direction of feed experts. We also observed that there is a gap in discarding contaminated feed as only 74% of the households reported discarding feed contaminated by different contaminants. Moreover, only 7% of dairy producers are aware about diseases that can affect feeds (e.g., aflatoxin). This indicates that there is a knowledge gap regarding the contamination of milk by contaminated feeds.

Similarly, we observed that only 10% of the sample respondents reported cleaning urine immediately after excretion. In addition, more than 90% of dairy producers reported that a person who milk cows trim his/her nails regularly. We also observe that only 56% of the dairy producers are aware about the required gap in milking treated cows and practice recommended gap in milking of treated cows. Furthermore, the overall housing of the dairy producers is not encouraging. We observe that some dairy producers do not have separate houses for animals and they share the living house with animals, which could expose the households to different diseases and deteriorate their food and nutrition security [23]. Most of the animal houses are also traditionally constructed and sub-standards (see Fig. 1). Most of the animal houses are constructed from wood and lack sufficient wall and roof. On top of that, the floors of most of the animal houses are either soil or traditionally constructed stone, which is very difficult to clean and could increase the likelihood of milk being contaminated by animal feces.

Description and comparison of sampled dairy producer households' characteristics by zone

Table 2 presents descriptive statistics of the independent variables used in this paper and a comparison of these variables by zone. The comparison of independent variables was made to shed some light on the similarity and variation of dairy producer households' characteristics by location. As shown in Table 2, the majority of the sample dairy producers (90%) were headed by a male. On the other hand, the mean educational level of the sample households was 3.5 years of schooling while the mean dairy production experience was found to be 20 years. The finding reveals that there was a significant difference between the two zones in terms of dairy production experience while no significant

Fig. 1 Some poor milk safety practices. Source: Captured by the primary author during field observations, 2021

Table 2 Descriptive statistics and comparison of independent variables by zone

Variables	East Hararghe		Oromia Special Zone Surrounding Finfinne			Total	
	Mean	SE	Mean	SE	*t*-value	Mean	SE
Education of head (years of schooling)	3.46	0.25	3.69	0.32	−0.56	3.55	0.20
Active labor (number)	3.21	0.10	3.18	0.12	0.19	3.20	0.08
Distance from water (walking minutes)	14.73	1.15	16.97	1.18	−1.30	15.59	0.84
Dairy production experience (years)	19.26	0.66	21.99	0.97	−2.40***	20.30	0.55
Number of lactating cows	1.28	0.04	2.52	0.12	−11.77***	1.75	0.06
Milk consumed at home (%)	57.04	1.74	55.94	3.23	0.33	56.62	1.64
Sex of head (male = 1)	0.92	0.02	0.89	0.03	1.06	0.90	0.01
Children under five (yes = 1)	0.58	0.03	0.41	0.04	3.54***	0.52	0.02
Credit use (yes = 1)	0.21	0.03	0.13	0.03	2.12**	0.18	0.02
Membership to cooperative (yes = 1)	0.24	0.03	0.26	0.04	−0.46	0.25	0.02
Dairy training (yes = 1)	0.09	0.02	0.31	0.04	−5.95***	0.17	0.02
Milk safety information (yes = 1)	0.22	0.03	0.48	0.04	−5.60***	0.32	0.02
Milk safety inspection (yes = 1)	0.22	0.03	0.35	0.04	−2.98***	0.27	0.02

Source: Authors

*** and ** signify statistically significant at 1% and 5% significance levels, respectively. SE means standard error

difference was observed in terms of sex and educational level of the household head.

Concerning the active labor force and children under the age of five, the mean active labor force of the sample dairy households was 3.2, and about 52% of the households have at least one child under the age of five (see Table 2). Furthermore, the mean number of lactating cows owned during the survey year was 1.75. The finding also reveals that about 57% of the milk produced was consumed at home. We find a statistically significant mean difference in

the number of lactating cows owned and children under the age of five, while there was no significant difference in the active labor force and proportion of milk consumed at home between the two zones (Table 2).

The study also assessed access to different services such as distance from water, access to credit, membership in dairy cooperatives, and dairy training (see Table 2). Accordingly, the mean distance from the nearest water source was found to be 15.59 min. Regarding credit utilization, only 18% of the sample households received credit during the survey year and the difference in the proportion of households who have received credit was statistically significant between the two zones. Similarly, about 25% of the sample households reported that they are a member of a dairy cooperative. The result further reveals that only 17% of the sample households have received dairy-related training and there was a statistically significant difference between the two zones at a 1% significance level (Table 2).

Regarding access to milk safety information and milk safety inspection, 32% of the households had access to milk safety information while 27% of the households reported that their milk had been inspected for safety and quality during the survey year (see Table 2). We observed significant differences between the two zones in terms of these variables at a 1% significance level. Generally, the result presented in Table 2 shows that households located in the East Hararghe zone and Oromia Special Zone surrounding Finfinne significantly differ by dairy production experience, number of lactating cows, children under five, credit utilization, access to training, milk safety information and experience of milk inspections.

Comparisons of the independent variables across the level of milk safety practices were also conducted to get insights on variables that vary across the level of adoption, which provided some information for the econometric analysis. To this end, dairy producer households were classified into three groups based on the level of milk safety practices adopted. To categorize households into three equal groups, the 30th and 70th percentile were used as a cut-off value. As such, households whose overall level of adoption fell below the 30th percentile were classified as low adopters ($n=122$), whose adoption was between the 30th and 70th percentile were classified as medium adopters ($n=163$), and households whose level of adoption was higher than the 70th percentile were classified as high adopters ($n=125$).

The test results are provided in Tables 3 and 4 for East Hararghe zone and Oromia Special Zone Surrounding Finfinne, respectively. As shown in Table 3, most of the independent variables are not statistically different across the three adoption groups in the East Hararghe zone. On the other hand, most of the independent variables are significantly different across the level of milk safety practices adopted in the Oromia Special Zone Surrounding Finfinne (Table 4). In general, the descriptive results support the intuition behind disaggregating the households by location of the households.

Description of outcome variables

Table 5 provides the descriptive statistics of the dependent variables. Accordingly, the mean percentage of milk safety practices adopted in the study areas was 59%, ranging from 32 to 82%. This means, on average, dairy farmers in the study areas had adopted 59% of the milk safety practices identified. Out of the 17 milk safety practices identified under animal health, the mean number of milk safety practices adopted was 9.11. Similarly, out of the 11 milk safety practices identified under milking hygiene, the mean number of milk safety practices adopted was 7.54. The result also indicates that the mean number of milk safety practices adopted under milk storage and other general hygienic practices were 5.89 and 3.59, respectively. The level of adoption of milk safety practices in Ethiopia is low compared to other countries like Canada, Nepal, and India [5, 31, 32]). However, the level of adoption of milk safety practices in Ethiopia is comparable to that of developing countries like Siri Lanka [29].

Overall, the results indicate considerable variations in the adoption of milk safety practices across dairy farmers. Nonetheless, the finding shows that the overall level of milk safety practices adopted was not significantly different between the two zones. Similarly, the number of milk safety practices adopted under the four categories, except milk storage, was found to be not significantly different between the two zones (Table 5).

Factors influencing the adoption of milk safety practices

Before fitting the OLS to identify the factors associated with the overall level of milk safety practices, we tested the existence of multicollinearity. Our test result reveals that there was no multicollinearity problem as indicated by low levels of variance inflation factor (VIF) (Appendix Table 8). We have also tested the violation of equidispersion and our data set exhibits equidispersion[4] under all the major milk safety groups. Consequently, we used a truncated Poisson regression model to identify the factors significantly correlated with the number of milk safety practices adopted under each sub-category.

The OLS and truncated Poisson regression estimations are provided in Tables 6 and 7 for the two zones

[4] The test result is available upon a reasonable request.

Table 3 Comparison of independent variables across levels of milk safety practices adopted: East Hararghe zone

Variables	Low		Medium		High		*F*-value
	Mean	SD	Mean	SD	Mean	SD	
Education of head (years of schooling)	2.64	3.47	3.86	4.26	3.89	4.14	2.67*
Active labor (number)	3.26	1.69	3.24	1.62	3.10	1.58	0.22
Distance from water (walking minutes)	15.60	20.04	12.80	15.13	16.41	19.86	0.95
Dairy production experience (years)	20.69	11.48	18.81	10.81	18.19	8.59	1.24
Number of lactating cows	1.31	0.62	1.24	0.57	1.29	0.54	0.31
Milk consumed at home (%)	54.52	27.71	59.17	28.34	57.07	26.77	0.64
Dummy variables	**Percent**		**Percent**		**Percent**		**χ^2-value**
Sex of head (male = 1)	90.48		88.89		97.14		3.92
Children under five (yes = 1)	57.14		56.57		62.86		0.76
Credit use (yes = 1)	17.86		22.22		22.86		0.74
Membership to cooperative (yes = 1)	23.81		19.19		31.43		3.36
Dairy training (yes = 1)	5.95		7.07		14.29		3.88
Milk safety information (yes = 1)	9.52		26.26		31.43		12.24***
Milk safety inspection (yes = 1)	20.24		18.18		28.57		2.77

Source: Authors

*** and * signify statistically significant at 1% and 10% significance levels, respectively. SD means standard deviation

Table 4 Comparison of independent variables across levels of milk safety practices adopted: Oromia Special Zone Surrounding Finfinne

Variables	Low		Medium		High		*F*-value
	Mean	SD	Mean	SD	Mean	SD	
Education of head (years of schooling)	2.18	3.14	3.81	4.00	4.58	4.18	4.35***
Active labor (number)	3.05	1.51	3.14	1.48	3.31	1.49	0.37
Distance from water (walking minutes)	21.68	20.89	15.44	12.65	15.51	11.12	2.60*
Dairy production experience (years)	20.76	13.32	22.16	11.85	22.64	11.88	0.27
Number of lactating cows	2.63	1.60	2.45	1.47	2.51	1.50	0.17
Milk consumed at home (%)	62.79	39.61	61.30	39.31	44.96	40.76	3.22**
Dummy variables	**Percent**		**Percent**		**Percent**		**χ^2-value**
Sex of head (male = 1)	84.21		92.19		87.27		1.63
Children under five (yes = 1)	31.58		42.19		45.45		1.88
Credit use (yes = 1)	7.89		20.31		7.27		5.58*
Membership to cooperative (yes = 1)	15.79		32.81		25.45		3.60
Dairy training (yes = 1)	15.79		35.94		34.55		5.19*
Milk safety information (yes = 1)	28.95		43.75		65.45		12.70***
Milk safety inspection (yes = 1)	21.05		29.69		50.91		10.16***

Source: Authors

***, **, and * signify statistically significant at 1%, 5%, and 10% significance levels, respectively. SD means standard deviation

separately. The model diagnostic tests (*F*-test and Wald Chi-square) indicate that the models fit the data set at 1% significance levels. Overall, eleven of the thirteen independent variables included in the models were found to have a statistically significant association with at least one of the dependent variables. To save space, we report only the incidence rate ratio (IRR) for the truncated Poisson model instead of coefficients because the coefficients cannot be interpreted. According to Ma et al. [35], the IRRs of truncated Poisson models are exponential transformations of the truncated Poisson regression coefficient, and are interpreted directly as

Table 5 Comparison of outcome variables by zone

	East Hararghe		Oromia Special Zone Surrounding Finfinne			Total			
Milk safety categories	**Mean**	**SD**	**Mean**	**SE**	***t*-value**	**Mean**	**SE**	**Minimum**	**Maximum**
Animal health (count)	9.02	0.15	9.27	0.20	−1.01	9.11	0.12	2	15
Milking hygiene (count)	7.46	0.11	7.66	0.14	−1.09	7.54	0.09	3	11
Milk storage (count)	5.86	0.03	5.94	0.03	−1.97*	5.89	0.02	4	7
Other general hygienic practices (count)	3.53	0.08	3.68	0.11	−1.10	3.59	0.06	1	7
Overall milk safety practices adopted (%)	58.03	0.56	59.50	0.76	−1.59	58.59	0.45	32.48	82.32

Source: Authors

* Signifies statistically significant at10% significance level

Table 6 Factors influencing milk safety practices adopted: East Hararghe zone

	Truncated Poisson for each sub-group								Multiple linear regression	
Dependent variables	**Animal health (count)**		**Milking hygiene (count)**		**Milk storage (count)**		**Other general hygienic (count)**		**Overall adoption (%)**	
Independent variables	**IRR**	**R. SE**	**IRR**	**R. SE**	**IRR**	**R. SE**	**IRR**	**R. SE**	**Coefficient**	**SE**
Sex of head (male = 1)	1.034	0.043	1.088	0.066	1.007	0.021	1.059	0.102	2.393	2.088
Education of head (years of schooling)	1.006	0.005	1.004	0.004	0.999	0.001	1.002	0.006	0.185	0.150
Children under 5 (yes = 1)	1.008	0.036	0.974	0.034	1.004	0.010	1.069	0.058	0.190	1.272
Active labor (number)	0.997	0.010	0.985	0.009	0.999	0.005	1.012	0.021	−0.230	0.371
Dairy production experience (years)	1.001	0.002	0.999	0.002	0.999**	0.001	0.999	0.003	−0.036	0.062
Total lactating cows (number)	0.938**	0.029	1.036	0.026	1.001	0.007	0.933	0.043	−0.912	0.987
Milk consumed at home (%)	1.001	0.001	1.000	0.001	1.000	0.000	1.002*	0.001	0.020	0.021
Dairy training (yes = 1)	1.105*	0.061	1.039	0.056	0.952**	0.020	1.167**	0.084	3.076	2.015
Credit use (yes = 1)	1.034	0.044	1.003	0.036	1.034***	0.010	0.974	0.060	0.970	1.454
Cooperative membership (yes = 1)	1.024	0.040	1.009	0.035	0.987	0.012	1.009	0.059	0.496	1.325
Milk safety information (yes = 1)	1.087**	0.042	1.080**	0.038	1.030***	0.011	1.087	0.060	3.940***	1.404
Milk safety inspection (yes = 1)	1.035	0.042	0.990	0.038	0.991	0.011	1.142***	0.061	1.319	1.415
Distance from water (minutes)	1.001	0.001	0.998***	0.001	1.000	0.000	1.002**	0.001	0.001	0.032
Constant	8.340***	0.605	7.138***	0.604	5.951***	0.159	2.784***	0.422	54.743***	3.138
Observations	253									
Wald chi2(13)	29.470		33.780		40.850		35.440		*F*(13, 239)	2.030
Prob > chi2	0.006		0.001		0.000		0.001		Prob > *F*	0.019
Log pseudolikelihood	−580.692		−536.034		−462.920		−433.381		*R*-squared	0.100

Source: Authors

***, **, and * signify statistically significant at 1%, 5%, and 10% significance levels, respectively

follows: If the IRR is less than one, a unit change in the independent variable predicts [(1-IRR)*100] decrease in the dependent variable while it predicts [(IRR-1)*100] increase in the dependent variable should IRR be greater than one, keeping other factors constant. The significant variables are discussed as follows:

We found that the level of education of the household head is positively associated with the number of animal health and other general hygienic practices adopted by dairy producers of the Oromia Special Zone Surrounding Finfinne at a 1% and 5% significance level, respectively. The IRR of educational level under animal health is 1.012 while it is 1.018 under the other general hygienic practices. This indicates that one additional year of schooling is associated with a 1.2% and 1.8% increase in adoption of the number of milk

Table 7 Factors influencing milk safety practices adopted: Oromia Special Zone Surrounding Finfinne

Dependent variables	Truncated Poisson for each sub-group								Multiple linear regression	
	Animal health (count)		Milking hygiene (count)		Milk storage (count)		Other general hygienic (count)		Overall adoption (%)	
Independent variables	IRR	R. SE	IRR	R. SE	IRR	R. SE	IRR	R. SE	Coefficient	SE
Sex of head (male = 1)	0.961	0.082	0.988	0.053	0.986	0.011	0.789***	0.080	−2.868	2.386
Education of head (years of schooling)	1.012***	0.005	1.006	0.004	1.001	0.001	1.018**	0.008	0.476***	0.186
Children under 5 (yes = 1)	1.030	0.050	1.033	0.039	1.013	0.011	1.204***	0.085	2.608	1.691
Active labor (number)	1.002	0.014	1.015	0.012	0.994	0.004	1.022	0.023	0.380	0.549
Dairy production experience (years)	1.004**	0.002	1.000	0.001	1.001*	0.000	1.006**	0.003	0.139**	0.067
Total lactating cows (number)	0.986	0.013	0.983	0.012	1.000	0.004	0.962*	0.020	−0.857	0.525
Milk consumed at home (%)	1.001*	0.001	0.998***	0.000	1.000	0.000	1.000	0.001	-0.012	0.023
Dairy training (yes = 1)	1.013	0.046	1.022	0.042	0.994	0.009	1.063	0.073	0.939	1.838
Credit use (yes = 1)	1.072	0.059	0.878***	0.044	1.004	0.009	1.039	0.090	−0.495	2.167
Cooperative membership (yes = 1)	0.992	0.048	1.033	0.042	0.999	0.008	1.060	0.074	0.827	1.754
Milk safety information (yes = 1)	1.080*	0.047	1.020	0.035	1.023***	0.010	1.133*	0.073	3.053*	1.563
Milk safety inspection (yes = 1)	1.276***	0.063	0.959	0.037	1.017	0.011	1.278***	0.086	6.093***	1.784
Distance from water (minutes)	0.999	0.001	0.998*	0.001	1.000	0.000	0.996*	0.002	−0.077	0.050
Constant	7.035***	0.816	8.620	0.667	5.876***	0.089	2.924***	0.467	55.025***	3.645
Observations	157									
Wald chi2(13)	46.530		45.460		15.880		72.300		*F*(13, 157)	4.010
Prob > chi2	0.000		0.000		0.256		0.000		Prob > *F*	0.000
Log pseudolikelihood	−363.614		−327.500		−287.253		−268.954		*R*-squared	0.267

Source: Authors

***, **, and * signify statistically significant at 1%, 5%, and 10% significance levels, respectively

safety practices under animal health and other general hygienic practices, respectively, keeping other variables constant. The OLS estimation also reveals that the educational level of the household head is positively associated with the overall level of milk safety practices adopted by dairy producers in the Oromia Special Zone Surrounding Finfinne at a 1% significance level (see Table 7). Its coefficient (0.476) shows that one additional year of schooling is associated with a 0.476 increment in the percentage of milk safety practices adopted, keeping other variables constant. The positive and significant association of education with the adoption of milk safety practices was expected because educated households are more knowledgeable and aware about good milk production practices. Our result is consistent with previous studies conducted by Mekonnen et al. [36] and Yang et al. [51]. Nonetheless, the educational level of the household was not significant under any of the outcomes specified for the East Hararghe zone.

On the other hand, the proportion of milk consumed at home is positively associated with the number of general hygienic practices at a 10% significance level in East Hararghe. On the other hand, in the Oromia Special Zone Surrounding Finfinne, it is significantly and positively associated with the number of milk safety practices adopted under animal health and overall level of adoption while negatively and significantly correlated with milking hygiene. A negative correlation between the proportion of milk consumed at home and milking hygiene seems contradicting, but the result is plausible given the fact that smallholder farmers in Ethiopia usually sell quality products and consume less preferred products at home. As a result, smallholder dairy producers might be less concerned about milking hygiene as the proportion of milk consumed at home rises. Yang et al. [51] and Kumar et al. [31] found positive effects of the proportion of milk consumed at home on milk safety practices adopted.

The finding also reveals that having children under-five is positively and significantly associated with the number of general hygienic practices adopted at a 1% significance level, but only for the Oromia Special Zone Surrounding Finfinne. This is intuitively plausible because children often consume milk, and are also at higher risk of milk-borne diseases if the safety and quality of milk is not maintained. Its IRR (1.204) implies that households

who have children under the age of five are 20.4% more likely to invest in stringent milk safety practices, keeping other variables constant (Table 7). This is consistent with Liu and Niyongira [34], who find out that households that have children are more concerned about the safety of food in China.

Concerning dairy production experience, our study reveals that it is positively correlated with milk safety practices adopted in the Oromia Special Zone Surrounding Finfinne. In this contrast, it is negatively associated with the number of milk storage practices adopted in the East Hararghe zone (Tables 6 and 7). The former finding is in line with our expectation since more experienced dairy farmers are assumed to have more knowledge and awareness about safe milk production. Previous studies have also highlighted that dairy production experience positively influences the adoption of milk safety practices [33, 51]. However, a negative correlation observed for East Hararghe might be that experienced dairy farmers are older and reluctant to adopt better storage practices.

Our finding further reveals that the number of lactating cows owned had a negative and significant association with the number of animal health practices adopted in East Hararghe zone, and with the number of other general hygienic practices in the Oromia Special Zone Surrounding Finfinne (see Tables 6 and 7).

Our finding seems contradicting with previous empirical studies in Ethiopia and elsewhere [31, 38, 51]. These studies showed that larger dairy farms implement more milk safety measures due to the economies of scale. However, our study is different from previous studies in two ways. First, our study is limited to smallholder farmers who engage in mixed crop-livestock production. Unlike commercial dairy producers, dairy farmers in the study areas produce milk in small quantity and may not benefit from the economies of scale. Secondly, we observed that households with higher dairy farms lack a number of good dairy farming practices. For instance, feeding practices, housing, and other hygienic practices deteriorate as dairy farm size increases. Therefore, our study is not comparable with studies which have investigated the behavior of commercial dairy firms. A recent study conducted by Feyissa et al. [17] in the central highlands of Ethiopia (partly the same with our study area) also found a negative association between livestock size and adoption of dairy technologies.

Concerning institutional services such as dairy training and credit, we observed a mixed relationship between these variables and the adoption of milk safety practices. Dairy training is found to have a negative association with milk storage practices at a 5% significance level while it is found to have a positive association with animal health and general hygienic practices in the East Hararghe zone at 10% and 5% significance levels, respectively. The results indicate that compared to dairy producers who did not get dairy training during the survey year, dairy producers of East Hararghe zone who obtained dairy-related training adopted less milk storage practices, and more animal health and general hygienic practices (Table 6).

Unlike training, credit use is found to have a positive and statistically significant association with milk storage practices adopted by dairy producers of East Hararghe zone at a 1% significance level. Hence, compared to dairy producers who did not receive credit during the survey year, those who obtained credit have adopted more milk storage practices in East Hararghe zone (Table 6). This is consistent with the previous study of Feyissa et al. [17] who also found a positive association between credit use and adoption of dairy technologies in Ethiopia. Against this, credit utilization is negatively and significantly associated with the number of hygienic milking practices in Oromia Special Zone Surrounding Finfinne at a 1% significance level (Table 7), which seems to suggest that dairy producers invest the credit obtained on other activities.

Further, we observed that access to milk safety information and milk quality inspection are important variables associated with milk safety practices adoption in both zones. Tables 6 and 7 indicate that access to milk safety information is positively correlated with milk safety practices adopted consistently, except under milking hygiene and other hygienic practices in Oromia Special Zone Surrounding Finfinne and East Hararghe zone, respectively. Our finding is in line with our prior expectations and similar studies in the past [3, 32, 51]. Information regarding the importance of safe milk production practices plays a vital role, especially in smallholder farmers where a high knowledge gap exists [3].

The finding further reveals that milk quality inspection is positively and significantly correlated with general hygienic practices in both zones; and also positively correlated with animal health practices and overall level of milk safety practices adopted in Oromia Special Zone Surrounding Finfinne (Tables 6 and 7). Our finding highlights that compared to dairy producers whose milk have not been inspected, dairy producers whose milk have been inspected are more likely to adopt general hygienic practices in both zones. Moreover, dairy producers of the Oromia Special Zone Surrounding Finfinne who experienced milk quality inspections are likely to adopt a higher number of animal health practices and overall level of milk safety practices compared to those who have never experienced milk quality inspections.

Our finding further reveals that distance from water is negatively and significantly associated with the number of milking hygiene adopted in both zones. Similarly,

it is negatively associated with general hygienic practices in Oromia Special Zone, while it is positive for East Hararghe zone. As such, the number of milking hygiene adopted is likely to decrease in both zones as the distance from water increases. This is plausible because proximity to water is very important for maintaining hygienic milking practices. A positive association between distance from water and adoption of general hygienic practices may suggest the substitutability of general hygienic practices and milking practices. Finally, the sex of the household is negatively correlated with general hygienic practices in Oromia Special Zone at a 1% significance level (Table 7). This indicates that male headed households in Oromia Special Zone are less likely to adopt general hygienic practices compared to female headed households.

Conclusion and policy implications

This study assessed milk safety practices and the adoption of these practices by dairy producers in East Hararghe and Oromia Special Zone Surrounding Finfinne in Ethiopia. We identified 45 milk safety practices being adopted by dairy producers, and categorized them under four major groups, namely animal health, milking hygiene, milk storage, and other general hygienic practices. On average dairy farmers in the study areas adopted 59% of the 45 milk safety practices, with no significant difference between the two zones. Nevertheless, the result shows there is considerable variation in the adoption of milk safety practices across dairy producers in general. Although the level of milk safety practices adoption does not significantly differ between the two zones, our finding uncovered that most of the factors associated with the adoption of milk safety practices significantly differ between zones. This demonstrates that there is a need for location-specific policy recommendations and strategies to improve the adoption of milk safety practices by dairy producers in Ethiopia.

Moreover, dairy producers in the study areas do not receive premium prices for adopting higher milk safety practices. Since there is no quality-based pricing system, the adoption of milk safety practices is entirely voluntary, and dairy farmers adopt milk safety practices based on the perceived benefits (utility) of adopting particular milk safety practices. In general, while the importance of financial incentives is widely argued as a driving factor behind milk safety adoption [31, 32], a study conducted in Kenya highlights that "social incentives" are of crucial importance to smallholder farmers [39]. In a rural area, households often sell milk to their neighbor with whom they have strong social networks and are forced to obey safe milk production practices. Our study also contributes to this debate as a handful of empirical evidences is available in low- and middle-income countries, especially at smallholder dairy farmers. We highlight that smallholder dairy farmers adopt milk safety practices in an attempt to maximize overall dairy farm benefits (utility), indirect private gains and social benefits.

The finding further reveals that access to milk safety information and milk quality inspection are positively associated with the level of milk safety practices adopted in both zones. The proportion of milk consumed at home is positively correlated with general hygienic practices adopted in East Hararghe zone. The result also shows that the proportion of milk consumed at home is positively associated with animal health practices while it is negatively associated with the adoption of milking hygiene in Oromia Special zone surrounding Finfinne. Similarly, the number of lactating cows is also negatively correlated with the adoption of animal health, and general hygienic practices in East Hararghe Zone and Oromia Special Zone Surrounding Finfinne, respectively. These findings seem to contradict the findings of previous studies [31, 38, 51], which imply that policies and strategies aimed at improving the adoption of milk safety practices should be designed considering the contexts.

This study also found that the educational level of the household head, dairy production experience, and having children under-five are positively associated with the adoption of milk safety practices in Oromia Special Zone Surrounding Finfinne, while the sex of the household head is negatively correlated with general hygienic practices. Moreover, access to credit is negatively correlated with milking hygiene while the distance from water is negatively associated with milking hygiene and general hygienic practices. In the East Hararghe zone, dairy production experience and training are negatively correlated with the adoption of milk storage practices while access to credit is positively associated with it. The finding also shows that training is positively associated with the adoption of animal health practices and general hygienic practices. Distance from water is found to be negatively associated with milking hygiene and positively associated with general hygienic practices. This might be because the two categories are implemented in a substitute way in East Hararghe zone.

The policy emanating from this study is that strengthening food safety inspections at the farm and improving the regulatory enforcement may improve smallholder dairy farm milk safety adoption in Ethiopia. Further, disseminating food safety information through different outlets such as radio, television, extension workers,

local research institutes, universities, and local development practitioners could enhance the adoption of farm-level milk safety practices by dairy producers. On the other hand, location-specific interventions are important to improve the adoption of milk safety practices in Ethiopia. As such, incorporating food safety issues in education, and educating younger dairy producers and households headed by male may help improve the adoption of milk safety practices in Oromia Special Zone Surrounding Finfinne. Indeed, incorporating dairy training in the existing agricultural extension services could be a cost-effective strategy to improve the adoption of milk safety practices in East Haraghe zone.

Despite the important contributions of this study to the food safety literature in general and milk safety in particular, this study has limitations in the following ways: The study identified milk safety practices adopted by dairy producers based on their self-reports, which may suffer from respondents' bias. Although the study points out the importance of interventions such as milk safety training, milk safety inspections, and milk safety information, further experimental studies aimed at evaluating the causal effects of such interventions are needed.

Table 8 Testing existence of multicollinearity among independent variables

East Hararghe		Oromia Special Zone Surrounding Finfinne	
Variables	**VIF**	**Variables**	**VIF**
Dairy farming experience	1.44	Percent of milk consumed	1.84
Children under five	1.33	Milk safety inspection	1.56
Active labor force	1.23	training	1.54
Education of the head	1.22	Children under five	1.49
Credit use	1.18	Dairy farming experience	1.43
Percent of milk consumed	1.16	Active labor force	1.42
Milk safety inspection	1.15	Total lactating cows	1.33
Milk safety information	1.15	Milk safety information	1.31
Sex of the head	1.12	Cooperative	1.28
Distance from water	1.12	Sex of the head	1.24
Total lactating cows	1.1	Education of the head	1.16
Training	1.09	Distance from water	1.14
Cooperative	1.09	Credit use	1.12
Mean VIF	1.18	Mean VIF	1.37

Source: Authors

Appendix

See Table 8.

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Author contributions

BWF: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; software; supervision; validation; visualization; roles/writing—original draft; writing—review and editing JH: Conceptualization; supervision; writing—review and editing AM: Supervision; Writing—review and editing. All the authors read and approved the final manuscript.

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Availability of data and materials

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