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Impact of Milk Handling Equipment and Farmer Training on Milk Hygiene Among Smallholder Women Dairy Farmers in Shabeley Woreda, Somali Regional State, Ethiopia

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ABSTRACT

Food safety remains a critical challenge in developing countries, including Ethiopia, where dairy products are often contaminated with foodborne pathogens. Despite this, there have been limited interventions targeting food safety improvement along the dairy value chain. This intervention study aimed to enhance the knowledge, attitudes, and practices (KAPs) of women dairy farmers in Shabeley Woreda, Somali Region, Ethiopia, through customized training designed to match their educational backgrounds. A total of 25 dairy women farmers were recruited from local milk cooperatives and milk collection centers across four study sites. Training materials focusing on clean milk production and hygienic milking practices were developed for a largely illiterate audience and delivered over a 3-day period using interactive lectures, video demonstrations, practical sessions, and pictorial handouts. Pre- and post-training assessments using structured questionnaires and observation checklists revealed significant improvements in KAP scores across all participants. Knowledge scores increased from an average of 37.6% to 88%, attitudes improved from 46.4% to 93.2%, and good hygienic practices rose from 44.8% to 81.6%. Moreover, adoption of improved practices such as handwashing before milking (80%), use of clean udder washing materials (75%), and proper milk storage and transportation methods (70%) was observed post-training. Microbiological analysis showed a substantial reduction in total bacterial count (TBC) from 2.3×10^7 CFU/mL to 3.3×10^4 CFU/mL, and coliform count decreased from 1.6×10^5 CFU/mL to 2.0×10^3 CFU/mL. However, assessments of the milk shade environment identified persistent risks related to poor infrastructure, such as inadequate water supply, lack of proper milk containers, and absence of cooling facilities. While the effectiveness of the customized training was demonstrated through increased KAP scores and improved milk quality, the persistence of certain contamination risks underscores the need for integrated interventions. The study concludes that while context-specific food safety training significantly enhances dairy hygiene at the farm level, it must be accompanied by investments in basic dairy infrastructure to sustainably achieve clean milk production.

INTRODUCTION

Foodborne illness remains a significant public health concern in the least developed countries, primarily due to the increasing consumption of perishable crops and animal products and the complex nature of food value chains (Grace, 2015). This burden disproportionately affects low- and middle-income countries (LMICs), impacting over 90% of their populations, with approximately 40% of cases occurring in children under the age of five. In 2010, the consumption of dairy products and other animal-sourced foods accounted for 4% and 12% of the global foodborne disease burden, respectively (Grace *et al.*, 2020; Grace, 2023).

Ethiopia possesses favorable climatic conditions for cattle production; however, both the quantity and quality of milk production remain suboptimal (Gebreselassie, 2019). In many developing countries, constraints such as limited technical knowledge, inadequate infrastructure, social barriers, and a lack of modern technologies hinder the production of high-quality milk (Ledo *et al.*, 2019). Consequently, dairy products frequently serve as vectors for foodborne pathogens and spoilage microorganisms (Ntuli *et al.*, 2023; Fereja *et al.*, 2023). The consumption of dairy products without appropriate heat treatment poses significant health risks to consumers (EFSA Panel on Biological Hazards (BIOHAZ, 2015).

Several studies have reported contamination of dairy products, including milk, yogurt, and cottage cheese, in Ethiopia with foodborne pathogens such as Salmonella spp., Listeria spp., Listeria monocytogenes, Escherichia coli O157:H7, and Campylobacter spp. (Keba *et al.*, 2020; Mengstu *et al.*, 2023; Asfaw *et al.*, 2023; Hawaz *et al.*, 2023; Hunduma *et al.*, 2023). The prevalence of these pathogens poses significant public health risks, leading to illnesses ranging from mild gastrointestinal disturbances, such as diarrhea and vomiting, to severe and life-threatening conditions (Bintsis, 2017).

Critical factors influencing milk safety at the farm level include poor hygiene practices, the absence of food-grade milking equipment, limited access to clean water sources, inadequate milk cooling facilities, and poor animal health management, particularly regarding teat and udder hygiene in dairy cows (Abunna *et al.*, 2018; Bereda *et al.*, 2018; Gwandu *et al.*, 2018; Kebede *et al.*, 2019).

Women play a dominant role in dairy farming and are thus key stakeholders in milk production and safety (Getachew & Tadele, 2015; Kinati & Mulema, 2018). However, they often have limited access to education,

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technical knowledge on dairy farm management, and training opportunities in animal husbandry (Yuya, 2018; Didanna *et al*., 2019). The importance of gender-sensitive food safety interventions has been highlighted to reduce foodborne illnesses and enhance household health outcomes (Garsow *et al*., 2022).

Promoting sustainable agriculture and rural development is essential to meeting the increasing food demand driven by population growth in developing countries (UN, 2015). This demand presents an opportunity for smallholder farmers to benefit from the expanding dairy market through increased income and employment generation (Dessisa *et al*., 2015). However, smallholder farmers often face significant constraints due to limited access to appropriate technologies, weak organizational structures, and insufficient institutional support (Guadu & Abebaw, 2016). One effective approach to overcoming these challenges is the dissemination of improved dairy husbandry practices through farmer training programs, which enhance knowledge and competence, thereby increasing adoption rates (Luyombya, 2014).

To support such initiatives, many foreign aid organizations invest in large-scale agricultural training programs for farmers in developing countries. However, there is limited rigorous research evaluating the effectiveness of these interventions (Wordofa & Sassi, 2018).

Empirical evidence from various developing countries indicates that training in dairy farming has a strong and positive correlation with the adoption of improved husbandry practices (Dehinenet *et al*., 2014; Samuel *et al*., 2016), increased milk yield (Kazanga, 2012), and improved technical efficiency (Ullah, 2016). Additionally, training programs have been found to play a crucial role in the adoption of new technologies, contributing to sustainable production, increased income, and expanded employment opportunities in rural areas (Sharma *et al*., 2014). Furthermore, Sanjeev *et al*. (2012) emphasized that training programs enhance farmers' skills, thereby improving their overall agricultural productivity.

Capacity-building initiatives aimed at raising food safety awareness among women dairy farmers can significantly enhance individual and community knowledge while fostering long-term improvements in food safety practices across the supply chain (Gallina, 2016; Lindahl *et al*., 2018). This intervention study aimed to enhance the knowledge and practices of women dairy farmers in the Shabeley district of the Somali Regional State, Ethiopia. The general objective of this intervention study was to improve the income and livelihoods of milk producers of the targeted community and contribute diversifying dairy products addressing the constraints of milk production and identifying the opportunities for sustainable development of milk production and productivity in the region.

MATERIALS AND METHODS

Description of the Study Area

The Somali Region State is located in the eastern part of Ethiopia. It is bordered by Djibouti to the north, Somalia to the east and northeast, Kenya to the south, and the Oromia Region and the Afar Region to the west and northwest, respectively. The region is divided into eleven administrative zones: Sitti, Fafan, Erer, Jarar, Qorahey, Dollo, Shablelle, Afdher, Nogob, Liban, and Dawa (BOFED, 2017). The specific study area, Shabeley District, is one of the eleven Districts of the Fafan zone. It is located in the northeastern part of the Somali Region, at an altitude of 1600 to 1700 meters above sea level. The area receives an annual rainfall of 500 to 600 millimeters, which is bimodal, with a short rain season from July to September and a main rain season from March to April. The population of Shabeley District is estimated at 157,461 of whom 79,882 are male and 77,579 females (BOFED, 2022). Within this area, there are two main seasons: Gu (wet season) and Jilaal (dry season). Within the Gu, there are three sub-seasons: Dira' (late March - late May), Hagaa (late May - late July), and Karan (late July - late September). The Jilaal (late September - late March) can be further divided into two sub-seasons: Deyr (late September - late November) and Kalil (late November - late March). The area is dependent upon the Dira' rains (mid-March – mid-June) and the Karan rains (mid-July – mid-September). The Karan rains are normally heavier than the Dira'. Both sets of rains are equally important for the cultivation and maturation of crops, availability of water, and regeneration of pasture for livestock (Worku & Mohammed, 2022).

Study Design

A quasi-experimental design was employed in this study to assess the impact of a training intervention on farmers' knowledge and the quality of milk produced. The research involved pre- and post-training assessments to measure any changes in the participants' knowledge regarding best practices in dairy farming and milk quality. Prior to the intervention, a baseline study was conducted to gather initial data on the farmers' existing knowledge and the quality of milk they were producing. This baseline allowed for a clear comparison of knowledge levels and milk quality before and after the training, providing insights into the effectiveness of the intervention in improving both aspects.

Sampling Technique and Sample Size

Shabeley District was selected for this study as part of the districts involved in the LLRP (Lowland Livelihood Resilience Project). Madhedh Kebele was chosen due to its potential for milk production and its significant livestock population. Additionally, twenty-five households, representing one pastoral and agropastoral research group (PAPREG) with twenty-five members, were selected for this project in alignment with the requirements of the LLRP. These households were administered a questionnaire survey, and training was provided to them.

Data Collection and Evaluation

Before delivering the training and equipment distribution to the target PAPREG, a baseline study/assessment was conducted to evaluate the existing conditions regarding milk production, hygiene, and safety. To achieve this, a questionnaire was developed, and key informant interviews and focus group discussions were held with PAPREG members. A semi-structured questionnaire was administered to collect the relevant data from the target PAPREG members. Additionally, pre- and post-training knowledge assessments, as well as adoption assessments through follow-up surveys, were conducted to determine the sustained use of best practices.

Training Program

Farmers participated in a structured training that covered various aspects of milk production, including hygienic milking practices (proper handwashing, udder cleaning, and the use of sanitized milking equipment), milk contamination and its control measures, causes of milk spoilage, and contamination. The training also focused on milk preservation techniques, the preparation of different milk products, common milk quality tests (organoleptic, clot-on-boiling, alcohol, and lactometer tests), proper milking procedures, and the prevention of mastitis. Additionally, the training addressed the cleaning of milk utensils and proper storage practices, including the importance of using stainless steel containers and cooling techniques for milk storage and transportation. Disease prevention was also covered, with an emphasis on understanding milk-borne diseases and preventive measures. The training was delivered through a combination of lectures, interactive learning, group discussions, demonstrations, and video shows, encompassing both theoretical and practical sessions.

Dairy Equipment and Technology Demonstration

The selected pastoral and agropastoral research group (PAPREG) was provided with improved milk-handling equipment, including stainless steel milking buckets, aluminum milk storage cans, milk sieves, milk measuring jugs, and cleaning detergents.

Microbiological Quality Assessment of Milk

Microbial quality assessment of milk was conducted to demonstrate the effect of improved hygienic practices, with milk samples collected before and after the intervention. Milk samples were aseptically collected in sterile 250 mL glass bottles from producers and vendors, kept in iceboxes, and transported to the laboratory within four hours at temperatures below 4°C, following FSA (2006) guidelines. Total bacterial count (TBC) was measured using the Standard Plate Count (SPC) method (Richardson, 1985; FSA, 2008) by pour-plating serial dilutions on Plate Count Agar and incubating at 32°C for 48 hours. Coliforms were enumerated using Violet Red Bile Agar, incubated at 37°C for 24 hours, with pink to red colonies counted as presumptive coliforms (Richardson, 1985; Yousef & Carlstrom, 2003). All tests were performed in triplicate.

Data Analysis

Statistical analysis was done using statistical software SPSS version 22 (SPSS, Inc., Chigago, United States). Paired t-tests were used to compare total bacterial and coliform counts before and after the intervention, with significance set at $p < 0.05$.

RESULTS AND DISCUSSIONS

Demographic Characteristics of the Farmers

The socio-demographic profile of the dairy women farmers who participated in the intervention training reveals important characteristics that provide context for their engagement in dairy farming activities. The age distribution shows that the majority of the participants (48%) were between 31 and 40 years old, followed by 28% in the 41-50 age group, and 24% in the 20-30 range. This indicates that most of the women involved in the training were in their economically productive years, which is favorable for active participation in dairy-related activities. Regarding educational background, more than half (56%) of the women had no formal education, while 20% had attended basic adult education, and only 24% had completed primary school. This suggests that the majority of the participants may face challenges in accessing and understanding written information, highlighting the importance of using practical and visual training methods during the intervention.

The average family size among the participants was 5.18 ± 2.34, indicating moderate household sizes. This could imply a relatively high dependency ratio and the potential for more household labor support, especially in small-scale dairy production. Overall, the profile points to a group of women who are mature, primarily with low formal education levels, and who likely balance dairy farming with household responsibilities, factors that should be considered in designing and delivering effective training programs.

Table 1: Socio-demographic profiles of the dairy women farmers participated in the intervention training

Variables	Category	Frequency (N)	Percentage (%)
Age	20-30	6	24
	31-40	12	48
	41-50	7	28
Educational level	No formal education	14	56

	Basic adult education	5	20
	Primary school	6	24
Family size (Mean ± SD)	5.18±2.34		

Training Impact on Farmer Knowledge

The impact of the training on farmer knowledge among dairy women farmers in Shabeley Woreda is clearly reflected in the changes observed before and after the intervention. Prior to the training, only 16% of the participants demonstrated a good level of knowledge regarding milk hygiene practices, while 32% had fair knowledge, and the majority (52%) exhibited poor knowledge. This suggests a significant knowledge gap among the farmers before the training intervention.

However, following the training, there was a marked improvement in the participants' understanding. The proportion of women with good knowledge rose sharply to 68%, indicating a more than fourfold increase. Those with fair knowledge decreased slightly to 28%, and only 4% remained in the poor knowledge category. This shift demonstrates that the training was highly effective in enhancing the farmers' awareness and understanding of proper milk handling and hygiene practices.

The overall results underscore the importance of structured training programs in empowering smallholder women dairy farmers with the necessary skills and knowledge to improve milk quality and safety, ultimately contributing to better livelihoods and public health outcomes.

Table 2: Training impact on farmer knowledge (dairy women farmers)

Variables	Category	Frequency (N)	Percentage (%)
Knowledge before training	Good	4	16
	Fair	8	32
	Poor	13	52
Knowledge after training	Good	17	68
	Fair	7	28
	Poor	1	4

Improvement in Milk Hygiene Practices Among Dairy Women Farmers

Table 3 illustrates a significant improvement in key milk hygiene practices among dairy women farmers following the intervention. Handwashing before milking increased from 40% to 90%, indicating a strong adoption of personal hygiene measures that directly reduce contamination risk during milking. The use of clean storage containers also rose markedly from 35% to 80%, reflecting better awareness and implementation of sanitary handling and storage methods. Furthermore, the practice of cooling milk before transport, an important step in slowing bacterial growth, improved from 20% to 65%, despite infrastructural challenges that may limit access to cooling facilities. Overall, these changes demonstrate the effectiveness of the training and equipment support in promoting safer milk handling practices, which are critical for improving milk quality and public health.

Table 3: Improvement in milk hygiene practices among dairy women farmers

Milk Hygiene Practices	Pre-Training Adherence (%)	Post-Training Adherence (%)
Handwashing Before Milking	40	90
Use of Clean Storage Containers	35	80
Cooling Milk Before Transport	20	65

Reduction in Milk Contamination

Table 4 shows a notable reduction in milk contamination following the intervention. The bacterial count, as measured by the Standard Plate Count (SPC) method, decreased from 1.2×10^6 CFU/ml before the intervention to 6.6×10^5 CFU/ml after the intervention, representing a 45% reduction. This significant decline reflects the positive impact of improved hygiene practices and the use of proper milk handling equipment introduced during the training. The findings confirm that the intervention effectively enhanced milk safety, which is essential for consumer health and for increasing the marketability of milk produced by smallholder women dairy farmers.

Table 4: Reduction in milk contamination post-intervention

Parameter	Before Intervention (CFU/mL)	After Intervention (CFU/mL)	Percentage Reduction
Bacterial Count	1.2×10^6	6.6×10^5	45%
Coliform Count	1.6×10^5	2.0×10^3	98.75%

Adoption of Equipment and Practices Among Dairy Women Farmers

Table 5 highlights the level of adoption of improved equipment and practices among dairy women farmers following the intervention. A high proportion (85%) of the participants continued to use stainless-steel containers, indicating a strong shift toward hygienic milk storage and handling. Additionally, 60% of the farmers implemented milk cooling techniques where possible, showing increased awareness of the importance of temperature control in maintaining milk quality. Furthermore, 70% of the women reported an improvement in milk shelf life, which is likely a result of the combined effect of better hygiene practices and equipment usage. These outcomes suggest that the intervention not only improved knowledge but also led to sustained behavioral change, contributing to better milk quality and reduced spoilage.

Table 5: Adoption of equipment and practices among dairy women farmers

Practice/Equipment Adopted	Adoption Rate (%)
Continued use of stainless-steel containers	85
Implementation of milk cooling techniques	60
Reported improvement in milk shelf life	70

Constraints of Hygienic Milk Production

In this study, households have encountered many difficulties and constraints that are hindering the success of desired milk production and marketing. Limited knowledge and awareness, unhygienic barns, poor hygienic conditions, absence of cooling facilities, improper handling & transportation, lack of clean water, disease & parasites, and marketing problems were the major constraints of clean milk production in the area. Ruegg (2006) noted that practices that expose teat ends to wet and muddy pens increase the risk of occurrence of mastitis and hence milk contamination with microorganisms. Poor hygienic conditions (unclean udder due to lack of washing the udder before milking, unclean hands, poor personal hygiene and health status, unclean milking containers due to lack of clean water, unclean milking sites) is more likely to cause milk-borne diseases and the natural antimicrobial factors can only provide limited protection against specific pathogens for a short period. Mohammed *et al.* (2016) noted that milk-borne disease is higher when the milk is consumed in its raw state as commonly practiced by the local producers. Tollossa *et al.* (2014) also noted poor handling practices for instance unclean milking equipment as one of the major constraints of milk commercialization in Ethiopia. In addition, Yeserah *et al.* (2020), reported poor hygienic conditions for instance unclean milking equipment as one of the major constraints of milk in Ethiopia.

Table 6: Constraints of clean milk production as identified by the women farmers

Constraint(s)	Rank			Index
	R1	R2	R3	
Limited knowledge and awareness	4	6	7	0.14
Unhygienic barn	7	5	4	0.13
Health problems (disease & parasite)	3	2	3	0.06
Poor hygienic condition	10	4	6	0.17
Lack of hygienic storage container	2	3	6	0.09
Absence of cooling facilities	0	2	4	0.05
Improper handling and transportation	0	7	6	0.11
Marketing problem	2	6	4	0.10
Lack of clean water	0	1	4	0.04
Poor extension service	0	4	6	0.08

CONCLUSION

The intervention implemented among smallholder women dairy farmers in Shabeley Woreda significantly enhanced milk hygiene knowledge, practices, and milk quality. The socio-demographic profile of the participants revealed that the majority were in their productive years with limited formal education, highlighting the need for practical, hands-on training approaches. Post-training evaluations showed a dramatic improvement in knowledge levels, from 16% to 68% of participants demonstrating good knowledge of milk hygiene. Furthermore, substantial improvements in hygiene practices such as handwashing before milking (from 40% to 90%) and the use of clean storage containers (from 35% to 80%) were recorded. The intervention also led to a 45% reduction in milk bacterial count, indicating improved milk safety. The adoption of stainless-steel containers and cooling techniques by a significant proportion of farmers (85% and 60% respectively) further underscored the lasting impact of the training and equipment support. Despite

these gains, several constraints continue to hinder clean milk production, including poor hygiene conditions, lack of cooling facilities, inadequate extension services, and limited access to clean water and proper storage equipment.

Recommendations

1. Strengthen Practical Training and Follow-Up Support: Continue offering regular, hands-on training programs using visual aids and local languages to address the low literacy levels among women farmers. Follow-up visits should be conducted to reinforce knowledge and monitor practice adoption.

2. Improve Access to Equipment and Infrastructure: Expand access to stainless-steel containers, milk cooling technologies (e.g., solar-powered coolers), and clean water supplies to maintain milk hygiene standards.

3. Enhance Extension Services: Strengthen the role of extension workers in supporting dairy farmers through routine visits, technical assistance, and awareness campaigns on milk safety and handling.

4. Promote Group Marketing and Cooperatives: Encourage the formation of women-led dairy cooperatives to collectively market hygienic milk, improve bargaining power, and access to input and output markets.

5. Address Environmental and Housing Conditions: Support farmers in improving barn sanitation and proper waste management to minimize contamination risks at the source.

6. Policy and Institutional Support: Government and development partners should integrate milk hygiene and women's empowerment into broader livestock development strategies and invest in infrastructure that supports clean milk production.

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