Research Article

Milk Quality Improvement Program for Small-Scale Dairy Farmers in Angochagua, Ecuador

Elena Balarezo*, Jose Luis Flores and Miguel Angel Toro-Jarrin

School of Agricultural and Agro-industrial Sciences, Yachay Tech, Urcuqui, Ecuador.

Abstract | Almost 5.7 million liters of milk are produced annually in Ecuador, and around 60% of production comes from small-scale producers with unregulated production processes and distribution systems. This lack of regulation encourages the development of pathogens in milk and lowers the final sales price. The aim of this study was to implement and test a milk quality program to improve product quality and sales prices. We carried out an initial diagnosis of management practices and bacteriological quality of milk, followed by program implementation directed to project promoters and community members. We checked the bacteriological quality of milk and industry price on a monthly basis before and after implementation. After the introduction of the Milk Quality Program, the quality of milk from small-scale producers improved, allowing producers to receive $0.08 more for each liter of milk produced. This increase means approximately $17,000 more annually for community producers. These results show that training on hygienic milk production is an effective intervention for improving the bacteriological quality of milk.

Received | June 27, 2024; **Accepted** | October 16, 2024; **Published** | November 22, 2024
***Correspondence** | Elena Balarezo, School of Agricultural and Agro-industrial Sciences, Yachay Tech, Urcuqui, Ecuador; **Email:** ebalarezo@yachaytech.edu.ec
Citation | Balarezo, E., J.L. Flores and M.A. Toro-Jarrin. 2024. Milk quality improvement program for small-scale dairy farmers in Angochagua, Ecuador. *Sarhad Journal of Agriculture,* 40(4): 1491-1500.
DOI | https://dx.doi.org/10.17582/journal.sja/2024/40.4.1491.1500
Keywords | Food safety, Milking, Milk quality

Introduction

About 5.7 million liters of milk are produced daily in Ecuador (Orbe and Cuichán, 2022). The base price on dairy farms in Ecuador is 52.4% of the current public retail price per liter of UHT milk , which at the time of the study was $ 0.42 at the farm or collection point (Ministerio de Agricultura, Ganadería, Acuicultura y Pesca, 2013). The Organic Law came into force in August 2022, when the price of milk at the farm was updated (Asamblea Nacional República del Ecuador, 2022). The price of milk varies depending on the composition quality and is based on fat content of 3% and a protein content of 2.9%. For every tenth of a percent of fat it can be increased by $0.0024 per litter and for every tenth of a percent of protein in can be increased by $0.0045. The price decreases when the milk quality is below base. The baseline value for the bacteriological quality of the milk is 300,000 colony-forming units per milliliter (CFU/ml). The base price of $0.42 per liter varied by $0.003 per liter for each unit change of 10,000 CFU/ml. In addition, producers receive bonuses in exchange for certificates of brucellosis and tuberculosis-free products (bonus of $0.01 per liter) and certificates of good agricultural practices (bonus of $ 0.02 per liter) as health quality measures of the system (Ministerio de Agricultura, Ganadería, Acuicultura y Pesca, 2013).

In Ecuador, small-scale producers gather around 60% of the milk. Producers are considered small if they own fewer than five cows (Orbe and Cuichán, 2022). One of the biggest challenges for small-scale producers is their lack of access to formal trading markets. One of the reasons for this is that they have inadequate educational resources, infrastructure, and technology (Dhillon and Moncur, 2023). Milk from small-scale producers has a higher bacterial count than is legally permitted in Ecuador (Guevara-Freire *et al*., 2019). This fact restricts the sale of milk to only collection points, where frequent checks are carried out to ensure product safety. The lower bacteriological quality of milk produced by small-scale producers may be due to their low purchasing power and limited access to equipment that allows adequate monitoring, handling, and storage of the milk. This situation can be exacerbated by the lack of direct technical supervision by the trader. 93.2% of agricultural producers in Ecuador do not receive technical assistance (Orbe and Cuichán, 2022). The remaining producers receive this support from trading houses, foundations, individuals, the Ministry of Agriculture and Livestock (MAG) and other institutions. Therefore, it can be hypothesized that the quality of milk produced is influenced by systemic factors combined with a lack of direct technical support to the producer.

Under these conditions, small-scale producers are forced to sell their milk to collection points or join production associations in order to gain access to the official market. These centers typically have transport, cooling, and storage systems for raw milk. In addition, producers within these groups have access to feedback, technical services, and credit (Alemu and Adesina, 2015). Producers who participate in the official market with stricter quality standards increase the network supporting advice-seeking behavior (Nyokabi *et al*., 2021). However, Ecuador's geographical distribution makes access to collective support through distribution centers difficult. In addition, there is a smuggled milk market and the presence of unregulated middlemen. Finally, producers are not used to associations and tend to run their farms independently and without advice, making it difficult to organize to improve quality (Ministerio de Agricultura y Ganadería del Ecuador, 2020).

The aim of this study was to determine the relationship between training in hygienic milk production processes and milk quality and benefits. This work was carried out from January to Jun 2022 at the Cochas La Merced agricultural production association, a producer organization in the high Andean sector of Imbabura, Ecuador. Before the implementation of the milk quality program, the Cochas La Merced agricultural production association. Association produced around 600 liters of milk per day and received an average compensation of $ 0.4152 per liter. This price reflects that the association's milk barely met the minimum milk hygiene quality parameters set by MAG Ecuador. This study diagnosed the current situation of small-scale producers and established a milk quality program to improve the bacteriological quality of milk and thereby increase producers' income.

Materials and Methods

Description of the study location

The Association of Agricultural Producers Cochas La Merced is based in Ibarra, Imbabura (Secretaria Técnica del Comité Nacional de Límites Internos, 2015). The temperature in the area is between 10°C and 12°C. This area is a semi-humid mesothermal equatorial climate zone in some parts and a high mountain equatorial climate zone in others. The average rainfall is between 1250 and 1500 mm/year (INAMHI, 2015). Figure 1 shows the location of the area where the intervention took place.

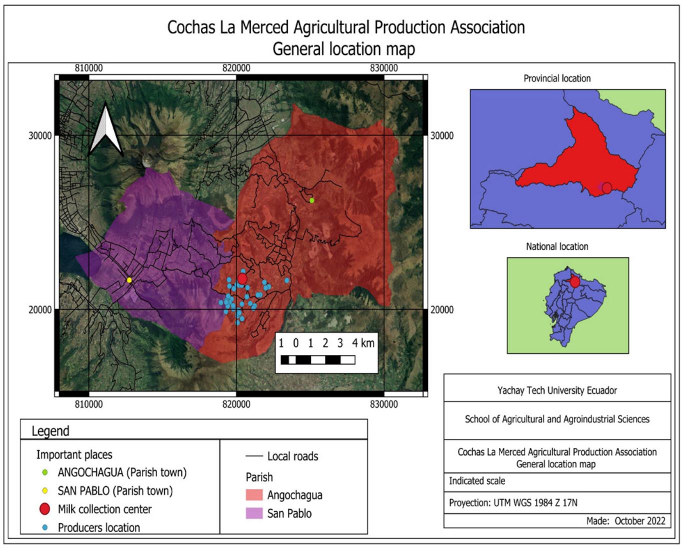

Figure 1: *General location map of Cochas La Merced agricultural production association.*

Demographics

The research team collected age, gender, education and milking experience from producers in the region. 76.3% were women. The role of women in milk production is fundamental. Women in rural communities generally milked and fed livestock while men engage in other paid activities (Franco *et al*., 2019). 33.3% of producers do not have a primary school education, are on average 54 years old, and have more than 20 years of milking experience. A study conducted with small-scale producers in Mexico showed that younger producers with better levels of education were more willing to try new ideas, and valued technical assistance (Espinoza-Ortega *et al*., 2007). This suggests that the overall low level of education combined with old age makes training more difficult. Given this complex context, the milk program in this study was carried out in an integrative way, encouraging the active participation of members (Rivera, 2020), recognizing the prior knowledge of the members of the association (López, 2009) and recognizing the importance of the role of women in milk production (Pautassi, 2011).

Producers' infrastructure and production

Most association members lack sufficient infrastructure for primary milk production. 97.6% of producers milk manually, 92.9% on unpaved ground, and 92.9% do not have a roof for milking. 64.3% of producers usually milk between 5 and 6 am. 85.7% of producers milk twice daily and 14.3% milk once. The average milking time is 27.5 minutes, and the average daily production is 17.8 liters. The producers sell the entire production. Overall, producers have low production and poor milk quality, as shown by studies linking poor hygienic quality of milk to non-compliance with the requirements of good practices on farms (Martínez-Vasallo *et al*., 2017).

On average, producers wait 43.93 minutes for their milk to be transported. The maximum waiting time is approximately 120 minutes. The association collects the milk from the producers. The average pick-up time is 75 minutes. Bacterial growth in milk occurs during transportation because manufacturers do not have mechanisms to maintain an appropriate temperature during transportation. High temperatures have a significant impact on bacterial growth. Raw milk should be cooled to 4°C for the first 4 hours after milking. During transport, the temperature must be below 5 °C to reduce the proliferation of mesophilic microorganisms (Celestino *et al*., 1997). Mesophilic aerobic microorganisms grow at temperatures between 20 °C and 45 °C. Transporting milk in this temperature range for more than an hour increases microbiological contamination and bacterial counts (Magariños, 2000).

Description before the intervention

The association's producer members lack good milking practices, such as washing hands before milking, using disinfectants to pre-seal animals before milking and using disposable towels. 73.8% of producers wash udders before starting milking, 45.2% wash their hands before starting milking, and only 11.9% wash and disinfect their hands before milking another animal. Hand washing is important as it prevents contamination between animals and contamination of the final product. 97.6% of producers do not use gloves when milking. 95.2% of producers do not have disposable towels for milking. 76.2% of producers have cows with long and dirty tails. 92.9% of producers tie the cows' legs with a rope for milking. 61.9% of producers have the calf with the mother during milking. The calves feed on the cow after milking, a common practice in small farms as they use the calf to stimulate milking (Carrera and León, 2018). 85.17% of producers ultimately do not milk the infected animals. All producers used metal barrels. 57.1% of manufacturers wash milk jugs with dish soap.

Producers (100%) do not have a strip cup to detect clinical mastitis and do not use a disinfectant substance to pre-seal animals before milking. Only one producer has a disinfectant to seal the animals with iodine after milking. Disinfecting the nipples with sealants reduces the bacterial load on the surface of the nipple skin (Pankey, 1989). It reduces the infection rate of mastitis pathogens (Kumar *et al*., 2012). By not using sealants to disinfect teats, small-scale producers are not preventing the proliferation of bacteria that could impact mastitis and milk quality problems. Similar results were found in other studies (Bonifaz and Requelme, 2011; Carrera and León, 2018), where almost 100% of producers who performed manual milking did not use a disinfectant substance to pre-seal the animals before milking

Implementation of the milk quality program based on milk hygiene

First, a preliminary assessment of the producers socio-demographic situation, infrastructure and milking practices was carried out. After the preliminary assessment, the implementation goals and the action plan were discussed with the members of the association and the Ministry of Agriculture (MAG). The action plan was then implemented in four different phases. (1) The research team trained community promoters on good milking practices and how to manage a milk quality control program. The project promoters monitor good milking practices on each producer farm. Promoters strengthen community engagement (Rong *et al*, 2023). (2) The research team trained community members on good milking practices. The training material was based on the Farmer Field Schools (FFS) concept developed by FAO (1995) and Holt and Giménez (2006). The training began with integration activities that made learning more dynamic, strengthened the group, and helped the research team get to know all members (Simkin and Becerra, 2013). The training included concepts and practical activities on good milking practices. (3) After the training, the association members purchased milking hygiene products to improve milk quality. Specifically, the association members purchased disposable towels for milking, solutions for teat disinfection and cups for teat disinfection. No changes were made to the infrastructure of the producers' properties. (4) The promoter visits each producer monthly for six months to monitor training and use of milking hygiene products. In addition, the promoter visits the producers with the lowest bacteriological milk quality to train them in good milk practices. Finally, the implementation was assessed by collecting data on each producer's management practices, teats, nipples and udders hygiene, and milk microbiological quality before and after the intervention.

Data collection

The dairy management practices procedures (National Mastitis Council, 2013) and a hygiene scale (Schreiner and Ruegg, 2003) was administered. Data were collected before and after the intervention. 42 valid responses were collected. The survey consisted of two sections: 20 closed-ended questions addressed directly to the producer and 20 closed-ended questions answered by the research team. The hygiene scale records the degree of contamination of the teats and udders as well as the hygiene of the cows. We administered the instruments during morning (4:00 a.m. – 6:00 a.m.) and afternoon (4:00 p.m. – 6:00 p.m.) milking sessions. We administered the instruments via a mobile phone application (Kobo Toolbox, 2022). We pre-tested the survey with 20 producers who were not involved in the study to test the survey flow and ensure that the questions were clearly worded.

We collected cleanliness data for nipples (n) and udders (u) before and after the intervention. The cleaner the cows, the fewer problems with mastitis and milk quality occur. The cleanliness of the teat tip indicates good milk practices (Cook and Reinemann, 2007). To record the level of cleanliness, we used the Teat Cleanliness Scorecard developed by Westfalia surge (Cook and Reinemann, 2007). For the udders, we used the udder hygiene rating table (Schreiner and Ruegg, 2003). All items were rated from 1 to 4, with 1 indicating clean and 4 indicating dirty.

In addition, we collected milk samples from each producer before and after the intervention to conduct a microbiological analysis of total aerobic bacterial count. We collected samples following prescribed instructions (Flores, 2018). We collected 100 ml samples from each producer's drums and transported them to the collection site in sterile containers on an alcohol-disinfected pallet. The samples were transported refrigerated for three hours until they arrived at the laboratory.

Data analysis

Milking hygiene

Five items from the quality assessment survey were considered good indicators of hygiene practices according to the recommendations of the National Mastitis Council Milking Procedures (NMC, 2013). The items were: (a) wearing gloves when milking (G), (b) disposable towels for the cows (Tow), (c) washing hands before milking (HW), (d) using a disinfectant before immersion (DesiPrior) and (d) Using a disinfectant after immersion (DesiPost). All items were scored in binary form (0: no, 1: yes). A composite score were created from these items before and after the intervention. Normality for both scores was inspected using a Shapiro normality test (Mishra *et al*., 2019). Both values were non-normal ($W_{before} = 0.698$; p-value < 0.01; $W_{after} = 0.913$; p-value < 0.05). Since the results were non-normal, a Mann-Whitney U test was conducted to examine the difference between before and after the intervention. This nonparametric test applies to unpaired samples (Nachar, 2008). This test was chosen because not all participants were the same between data points.

Udder, nipples and teats cleanliness

Points 1 and 4 were compared between subjects. A significant increase in the number of points 1 and a decrease in the number of 4 indicated an overall positive effect of the intervention. A Shapiro test to check the normality of udder and nipple cleanliness values was done. Values were non-normal (wbefore = 0.699, $p < 0.05$; wafter = 0.724, $p < 0.05$). A Mann-Whitney U test was implemented to compare the results. This test is suitable for non-normal independent samples (Nachar, 2008).

Microbiological analysis

Each producer's milk's bacteriologic count was examined before and after the intervention. The sampling protocol consisted of a microbiological analysis of the total aerobic bacterial count of each sample using serial dilutions, following Erkmen (2021). Once the microbiological dilution process was carried out, seeding was done on a Compac Dry™ TC plate. The plates used have redox indicators and chromogenic substrates that give the colonies a red color (Nissui Pharmaceutical, 2024). We added a 1 ml aliquot to the culture medium, then placed it face up and allowed it to incubate at 37 °C for 48 h. Once the incubation process was completed, counting was carried out using a manual counter. Given the non-normality of the scores, a Mann-Whitney U test was done to compare them.

Results and Discussion

Milking hygiene

A significant ($w = 96.5$; $p < 0.01$) improvement in the hygiene composite score was found. Figure 2 shows the community average for good milking practice ratings before and after the intervention. Community averages for good milking practices improved after the intervention, demonstrating the positive impact of training and follow-up.

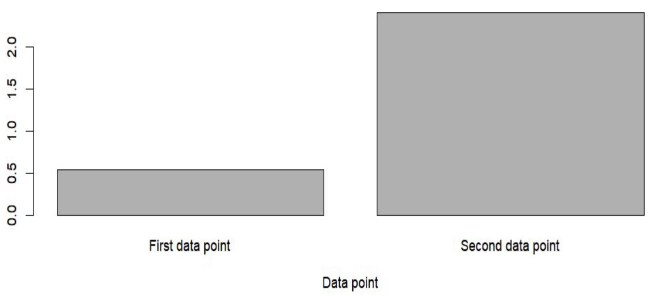

Figure 2: *Community average good milking practices score before and after the intervention.*

Udder, nipples and teats cleanliness

The number of 4 (dirty) for nipple cleanliness decreased significantly ($w = 475.5$; $p < 0.05$) after the intervention (Figure 3). Overall udder cleanliness also improved (Figure 4). The increase in score 1 was significant ($w = 452.5$; $p < 0.1$), while the number in score 4 decreased ($w = 669$; $p < 0.1$) (Figure 5).

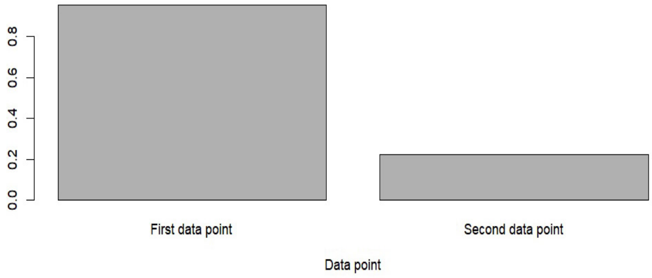

Figure 3: *Overall number of nipples cleanliness scores 4 in the community before and after the intervention.*

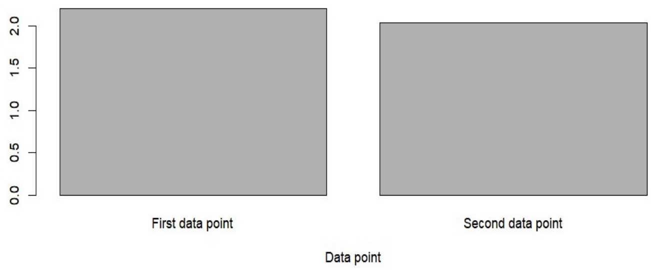

Figure 4: *Overall number of nipple cleanliness scores 1 in the community before and after the intervention..*

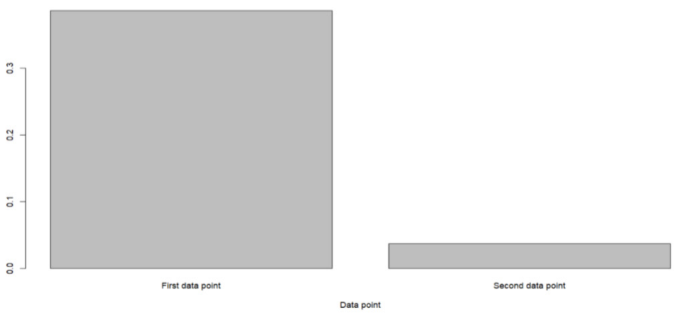

Figure 5: *Overall number of udder cleanliness scores 4 in the community before and after the intervention.*

Milk's bacterial count

The bacteriologic count did not decrease after the intervention. A possible reason for this is that the bacterial count was taken one day before the intervention and one day after the intervention. This data does not reflect the development of the bacterial count of individual producer's milk producer. Furthermore, milk quality parameters are influenced by seasonal conditions (Botaro *et al*., 2013). The bacteria count obtained from the 42 milk samples from the producers before the intervention showed that three producers had bacteria counts of more than 30,000 CFU/ml. These three producers have milk of poorer microbiological quality than the other producers. The producers whose microbiological quality was not sufficient were notified and the promoter visited their farms to improve their milk practices.

Monthly Microbiological quality of the community's milk during project development

Figure 6 shows the microbiological quality of community's milk during program development. The data suggests an improvement in milk quality following the implementation of the program. The bacterial count fell from 516,000 CFU/ml to 240,000 CFU/ml.

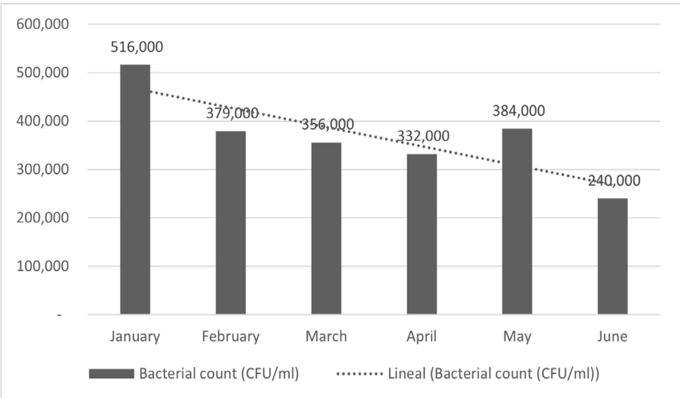

Figure 6: *Bacterial count (CFU/ml) of the milk produced by the Association.*

Variation in milk price during the study

Figure 7 shows milk prices from the beginning to the end of the study. Initially, the community received \$0.415 per liter of milk and increased the price to \$0.49. Due to the cost of collecting milk in the community, each producer initially received \$0.365 per liter of milk and increased the price to \$0.42. Since the community supplies approximately 600 liters per day to the industry and receives an incentive of \$0.08 per liter for improving milk quality, the community receives an additional \$48 per day, equivalent to \$1,440 per month and \$17,280 per year.

Community averages for good milking practices improved after the intervention. As shown in other studies, training is one of the most effective methods to change the producer's knowledge, skills and management practices (Makokha *et al*., 2019). The hygiene of udders, nipples and teats improved after the intervention. Udders and nipples hygiene is a parameter that influences milk quality (Cook and Reinemann, 2007). There is a significant association between poor udder hygiene and the prevalence of environmental mastitis (Schreiner and Ruegg, 2003). Cows with udders moderately or mostly covered with dirt are 1.5 times more likely to be infected than cows with udders are lightly covered with dirt or free of dirt (Schreiner and Ruegg, 2003). Furthermore, poor udder hygiene is associated with high somatic cell counts (Reneau *et al*., 2005). Some producers have milk of poorer microbiological quality than the other producers, which affects the final quality of the milk tank at the collection point. Similar results exist at the country level (Buñay-Barahona and Peralta Vásquez, 2015; Contero and Cachipuendo, 2021; De la Cruz *et al*., 2018). Milk with a high bacterial count has a lower value for cheese, yogurt, and other derivative manufacturing industries. This is because milk from cows with mastitis contains less fat and protein and therefore has a lower cheese yield also influencing the organoleptic parameters of other productions (Bedolla and Ponce de León, 2008).

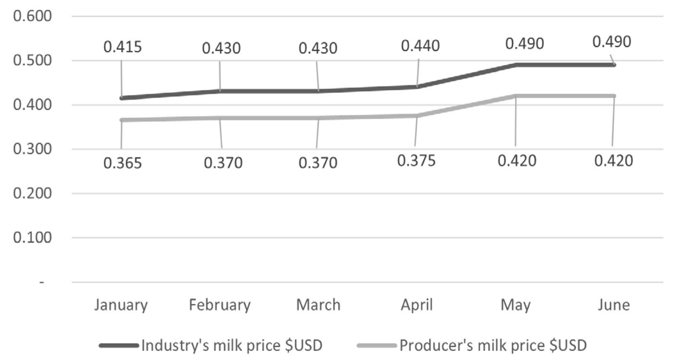

Figure 7: *Milk price variation that the dairy industry pays to the collection center and that the collection center pays to the producer (Dollars/liters of milk).*

The improvement in the bacteriological quality of the milk resulted in a more favorable income for the community. In addition, thanks to the better milk price, the community also receives a higher price per liter of milk paid to each producer. These measures have been shown to be effective in similar studies in the country (Bonifaz and Requelme, 2011). Implementing training and monitoring programs improves dairy practices and, thereby increases the value of their milk in the market (Contero *et al*., 2021).

Improving milk quality has health and economic benefits (Barrera *et al*., 2004). In this study, it was found that intervening in milk quality practices has a positive economic impact of approximately \$17,000 to the community. The study results are consistent with similar studies that have found that milk quality is directly related to its market value (Yanes and De la Cruz, 2021). At the same time, payment incentives based on milk quality encourage producers to improve milk hygiene (Busanello *et al*., 2020). In dairy cooperatives in southern Brazil, the implementation of payment programs based on milk quality improves milk quality hygiene (Botaro *et al*., 2013). Implementing quality-based milk payment policy in Ecuador improves milk quality parameters (Contero *et al*., 2021).

Conclusions and Recommendations

Low education, advanced age, poor milking practices, and lack of infrastructure are limiting factors for small producers. This brings poor bacteriological milk quality to the market and reduces the price per liter of milk. In addition, some producers who supply lower quality milk compromise the overall quality of the milk in the collection points.

After the introduction of the milk quality milk program, the quality of milk from small producers was improved, allowing producers to receive $0.08 more for each liter of milk produced. This increase means approximately $17,000 more annually for community producers. The quality of the community's milk has improved thanks to the community's commitment led by the project promoter.

Based on the results obtained, this study highlights the importance of training of the local promoter, which becomes a focus to be strengthened in future interventions. It is obvious that a support system is necessary for the organic and social strengthening of the organization. Based on what has been described, it was assumed that the connection between the bacteriological quality of milk and training in hygienic milk production processes is effective and constantly necessary.

Despite the significant improvement in the bacteriological quality of the milk, it is necessary that studies of this type be extended over a longer period, covering more than one year of follow-up to clarify the influence of the season on hygienic milk production.

Other studies confirmed the findings in this study developed with Cochas La Merced agricultural production association. This proposes the establishment of a permanent training program for small-scale dairy producers at regional level. This program should include the supervision of a local promoter. The results of this study can be serve as a starting point to motivate milk collection companies to train producers to achieve quality in raw materials.

Acknowledgments

Thanks to the members of Cochas La Merced agricultural production association, especially to the promoter Carmen Sandoval. Her daily work contributed to improving the quality of life of the members of her community. Thanks to the Imbabura District Directorate of the Ministry of Agriculture and Livestock for their assistant in data collection. Thanks to our students for working on the project. Also thanks to the MAG District Director of Imbabura for supporting the project.

Novelty Statement

This study highlights the importance of training and follow-up to improve milk quality among small dairy farmers. Furthermore, the pre-intervention description of the community highlights the reality of dairy production in Ecuador and emphasizes the need to adopt new technologies to improve benefits for local milk producers.

Author's Contribution

Elena Balarezo: Carried out the experiment and drafted the manuscript.
Miguel Angel Toro-Jarrin: Contributed to the data analysis, results interpretations, and manuscript structure and edition.
Elena Balarezo, Jose Luis Flores and Miguel Angel Toro-Jarrin: Collect additional data and edited the manuscript.
All authors read and approved of the final manuscript.

Conflict of interest
The authors have declared no conflict of interest.

References

Alemu, A.E. and J. Adesina. 2015. Effects of cooperatives and contracts on rural income and production in the dairy supply chains: Evidence from Northern Ethiopia. Afr. J. Agric. Resour.

Econ., 10: 312–327.

Asamblea Nacional República del Ecuador, 2022. Ley Orgánica para Fomentar la Producción Comercialización, Industrialización, Consumo y Fijación del Precio de la Leche y sus Derivados. Retrieved from: https://www.asambleanacional.gob.ec/es/leyes-aprobadas?leyes-aprobadas=All andtitle=lecheandfecha=

Bedolla, C. and M. Ponce de León. 2008. Pérdidas económicas ocasionadas por la mastitis bovina en la industria lechera. Rev. Electrón. Vet., 10(4): 1–26. https://www.redalyc.org/pdf/636/63611952010.pdf

Bonifaz, N., and N. de J. Requelme. 2011. Buenas prácticas de ordeño y la calidad higiénica de la leche en el Ecuador. La Granja, 14(2): 45–57. https://doi.org/10.17163/lgr.n14.2011.04

Botaro, B., A. Gameiro and M. Santos. 2013. Quality based payment program and milk quality in dairy cooperatives of Southern Brazil: An econometric analysis. Sci. Agricola, 70: 21-26. https://doi.org/10.1590/S0103-90162013000100004

Buñay-Barahona, N.C. and F. K. Peralta-Vásquez. 2015. Determinación del recuento de aerobios mesófilos en leche cruda que ingresa a Industrias Lacto Ochoa Fernández Cia. Ltda. (Bachelor's thesis). Retrieved from https://dspace.ucuenca.edu.ec/handle/123456789/21584.

Busanello, M., I.M.P. Haygert-Velho, M.A. Piuco, V.I. Heck, Stürmer, L.C. Cosmam and J.P. Velho. 2020. Relationship between seasonal variation in the composition of bulk tank milk and payment based on milk quality, Slovak J. Anim. Sci., 53: 132-144.

Carrera, M.J. and G.J. León. 2018. Mejoramiento de la calidad de leche de pequeños productores del cantón Biblián. Bachelor's tesis, Universidad del Azuay, Cuenca.

Celestino, E.L., M. Iyer and H. Roginski. 1997. The effects of refrigerated storage of raw milk on the quality of whole milk powder stored for different periods. Int. Dairy J., 7(2-3): 119–127. https://doi.org/10.1016/S0958-6946(96)00041-6

Contero, R. and C. Cachipuendo. 2021. Calidad del agua y de la leche en sistemas de ordeño manual de la Sierra Norte del Ecuador. Rev. Inv. Vet. Perú, 32: 20937. https://doi.org/10.15381/rivep.v32i4.20937

Contero, R., N. Requelme, C. Cachipuendo and D. Acurio. 2021. Calidad de la leche cruda y sistema de pago por calidad en el Ecuador. La granja. Rev. Ciencias Vida, 33(1): 31-43. https://doi.org/10.17163/lgr.n33.2021.03

Cook, N. and D. Reinemann. 2007. A tool box for assessing cow, udder, and teat hygiene biomechanics of milk extraction and lactation physiology view project farm animal responses to the electrical environment view project. NMC Ann. Meet. Paper, pp. 21-24.

De la Cruz, E., P. Simbaña and N. Bonifaz. 2018. Gestión de calidad de leche de pequeños y medianos ganaderos de centros de acopio y queserías artesanales, para la mejora continua. Caso de estudio: Carchi, Ecuador. La Granja, 27(1): 124–136. https://doi.org/10.17163/lgr.n27.2018.10

Dhillon, R. and Q. Moncur. 2023. Small-scale farming: A review of challenges and potential opportunities offered by technological advancements. Sustainability, 15(21): 15478. https://doi.org/10.3390/su152115478

Erkmen, O., 2021. Laboratory practices in microbiology. Academic Press.

Espinoza-Ortega, A., E. Espinosa-Ayala, J. Bastidas-López, T. Castañeda-Martínez and C.M. Arriaga-Jordán. 2007. Small-scale dairy farming in the highlands of central Mexico: technical, economic and social aspects and their impact on poverty. Exp. Agric., 43(2): 241–256 https://doi.org/10.1017/S0014479706004613.

FAO, 1995. Desarrollo Agropecuario: de la dependencia al protagonismo del agricultor. Serie de desarrollo rural N9. Ed4. Santiago de Chile. https://www.fao.org/3/aI006s/aI006s00.pdf

Flores, J., 2018. Instructivo para "Toma de Muestras de Leche Cruda y Suero de Leche". https://www.agrocalidad.gob.ec/wp-content/uploads/2020/05/calech3.pdf

Franco, C., L. Morales, N. Lascano and A. Cuesta. 2019. Dinámica de los Pequeños Productores de Leche en la Sierra Centro de Ecuador. La Granja, 30(2): 103–120. https://doi.org/10.17163/lgr.n30.2019.09

Guevara-Freire, D., M. Montero-Recalde, A. Rodríguez, L. Valle, and D. Avilés-Esquivel. 2019. Quality of milk collected in small farms of Cotopaxi, Ecuador. Rev. Inv. Vet. Perú, 30(1): 247–255. https://doi.org/10.15381/rivep.v30i1.15679

Holt-Giménez, E., 2006. Campesino a campesino:

Voices from Latin America's farmer to farmer movement for sustainable agriculture. Food First Books.

INAMHI, 2015. Información meteorológica. Visor geográfico GAD Imbabura. https://www.imbabura.gob.ec/index.php/componente-territorial/visor-geografico.

Kobo Toolbox, 2022. KoboCollect V2022.2.3. https://play.google.com/store/apps/details?id=org.koboc.collect.androidandhl=enandgl=USandpli=1.

Kumar, A.V., L.V. Rao, M.K. Kumar, B. Srinu and T.M. Rao. 2012. Efficacy of udder disinfectants on reduction of bacterial load and certain pathogens of public health significance. J. Microbiol. Biotechnol. Res., 2(1): 147-151.

López, J., 2009. La importancia de los conocimientos previos para el aprendizaje de nuevos contenidos. https://archivos.csif.es/archivos/andalucia/ensenanza/revistas/csicsif/revista/pdf/Numero_16/JOSE%20ANTONIO_LOPEZ_1.pdf.

Magariños, H., 2000. Producción higiénica de la leche cruda: una guía para la pequeña y mediana empresa. Guatemala, Organización de Estados Americanos -OEA- http://portal.oas.org/LinkClick.aspx?fileticket=wlyuTwR3IEc%3D

Makokha, S.N., D. Yongo, M. Mwirigi and M. Nyongesa. 2019. Smallholder group dynamics and capacity building: A case study of dairy groups in Kenya. East Afr. Agric. For. J., 83(4): 281-288. https://doi.org/10.1080/00128325.2018.1549967

Martínez-Vasallo, A., A. Ribot-Enríquez, A. Villoch-Cambas, N. Montes de Oca, D. Remón-Díaz and P. Ponce-Ceballo. 2017. Calidad e inocuidad de la leche cruda en las condiciones actuales de Cuba. Rev. Salud Anim. 39(1): 51–61. http://scielo.sld.cu/scielo.php?pid=S0253-570X2017000100007andscript=sci_arttext

Mishra P., C.M. Pandey, U. Singh, A. Gupta, C. Sahu and A. Keshri. 2019. Descriptive statistics and normality tests for statistical data. Ann. Card Anaesth., 22(1): 67-72. https://doi.org/10.4103/aca.ACA_157_18

Nachar, N., 2008. The mann-whitney U: A test for assessing whether two independent samples come from the same distribution. Tutor. Quant. Methods Psychol., 4(1): 13-20. https://doi.org/10.20982/tqmp.04.1.p013

National Mastitis Council, 2013. Recommended milking procedures, retrieved from http://www.nmconline.org/wp-content/uploads/2016/09/Recommended-Milking-Procedures.pdf

Nissui Pharmaceutical, 2024. Compact dry TC. https://compact-dry.com/productos/compact-dry-tc-total-count/

Nyokabi, S., P.A. Luning, I.J.M. de Boer, L. Korir, E. Muunda, B.O. Bebe, J. Lindahl, B. Bett and S.J. Oosting. 2021. Milk quality and hygiene: Knowledge, attitudes, and practices of smallholder dairy farmers in central Kenya. Food Contr., 130: 108303. https://doi.org/10.1016/j.foodcont.2021.108303

Orbe, D., and M. Cuichán. 2022. Encuesta de Superficie y Producción Agropecuaria Continua (ESPAC) 2021. Quito.

Pankey, J.W., 1989. Premilking udder hygiene. J. Dairy Sci., 72(5): 1308–1312. https://doi.org/10.3168/jds.S0022-0302(89)79238-9

Pautassi, L.C., 2011. La igualdad en espera: el enfoque de género; Universidad de Buenos Aires. Facultad de Derecho; Lecciones y Ensayos; 89; 11: 279-298. http://hdl.handle.net/11336/193737

Ministerio de Agricultura, Ganadería, Acuicultura y Pesca. 2013. Acuerdo Ministerial 394. 4 de septiembre (Ecuador).

Ministerio de Agricultura y Ganadería del Ecuador. 2020. Programa Nacional de Reconversión de la Ganadería Sostenible (PNRSG). Quito, Ecuador.

Reneau, J.K., A.J. Seykora, B.J. Heins, M.I. Endres, R.J. Farnsworth, and R.F. Bey. 2005. Association between hygiene scores and somatic cell scores in dairy cattle. J Am Vet Med Assoc, 227(8): 1297–1301. https://doi.org/10.2460/javma.2005.227.1297

Rivera, R., 2020. Comunicación con personas de comunidades rurales: Resultados de la encuesta inicial. SmartFish A.C. México, 1-13.

Rong, T., E. Ristevski and M. Carroll. 2023. Exploring community engagement in place-based approaches in areas of poor health and disadvantage: A scoping review. Health Place, 81: 103026. https://doi.org/10.1016/j.healthplace.2023.103026

Secretaria Técnica del Comité Nacional de Límites Internos (2015). División política de Imbabura. https://www.imbabura.gob.ec/index.php/descargas/componente-territorial/shape-files/file/800-division-politica-de-la-provincia-de-imbabura-conali

Schreiner, D.A. and P.L. Ruegg. 2003. Relationship between udder and leg hygiene scores and subclinical mastitis. J. Dairy Sci., 86(11): 3460–3465. https://doi.org/10.3168/jds.S0022-0302(03)73950-2

Simkin, H. and G. Becerra. 2013. El proceso de socialización. Apuntes para su exploración en el campo psicosocial. Humanidades y Ciencias Sociales: Comunicaciones.

Yanes, G.C. and A.S. De la Cruz. 2021. Dinámica del precio de la leche en las regiones de Colombia: un análisis de series de tiempo. Clío Am., 15(29): 598-608. https://doi.org/10.21676/23897848.4254