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Economic impact of raw milk classification based on microbiological quality in small-scale dairy farms in Kosovo

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Abstract. This study evaluated the economic implications of microbiological quality-based milk classification in small-scale dairy farms in Kosovo. A total of 1,334 raw milk samples were collected from 66 farms over one year. Two samples obtained from each farm during each month of milk delivery were averaged, resulting in 667 farm-month observations used for microbiological classification and economic evaluation. Milk was classified as Extra Class, Class I, Class II, Class III, or Out-of-Class according to national standards based on total bacterial count (CFU mL^{-1}). Monthly CFU mL^{-1} values differed significantly (Kruskal–Wallis $H = 43.70$, $df = 11$, $p < 0.001$), whereas the overall difference among seasons was not statistically significant ($H = 2.875$, $df = 3$, $p = 0.411$). Under a standardized production scenario of 3,000 L per farm per month and a reference fat content of 3.75%, Extra Class milk generated the highest gross revenue at a price of 0.393 € L^{-1}. Relative to Extra Class milk, annual gross revenue was approximately 23% lower for Class II and 43% lower for Class III milk, while Out-of-Class milk generated no milk-sale revenue because it was rejected. These findings demonstrate that microbiological milk quality and the associated classification-based pricing and subsidy system can substantially influence gross revenue from milk sales. Improving hygiene, milk handling, and cooling practices may help producers achieve higher quality classifications and strengthen the economic sustainability of small-scale dairy production.

Key words: milk classification, economic impact, raw milk quality, total bacterial count.

INTRODUCTION

Milk production represents a critical component of the agricultural economy in many countries, particularly in small-scale dairy systems where farm income is highly dependent on milk sales (Fiorillo & Amico, 2024). In such systems, the price received by farmers is increasingly determined by milk quality parameters, including microbiological characteristics, which are incorporated into classification-based payment schemes (Popescu & Angel, 2019). Microbiological quality of raw milk, commonly expressed as total bacterial count (CFU mL^{-1}), is a key indicator of hygienic conditions during milking, storage, and transport (Murphy et al., 2016). Elevated bacterial levels negatively affect both food safety and processing quality, but they also

have direct economic consequences for farmers, as milk with higher microbial loads is assigned to lower quality classes and receives reduced prices or may even be rejected (Aliyo et al., 2022; Martin et al., 2023). This means that strengthening hygiene and handling practices across the dairy value chain is essential for improving milk safety, enhancing product quality, and increasing the economic sustainability of smallholder dairy production in the region (Andrew et al., 2021).

Milk pricing systems in the dairy sector are commonly based on quality-related parameters, including microbiological criteria, that directly influence the prices producers receive. Incorporating milk quality into sustainability efforts contributes to economic, environmental, and social benefits, thereby strengthening resilience in dairy production systems (Priyashantha, 2025). The growing competition within the dairy industry further emphasizes the importance of maintaining high-quality milk production standards, particularly in small-scale farming systems where profitability is closely linked to product quality (MacDonald et al., 2007).

In addition to market-based price adjustments, government support mechanisms also play an important role in stabilizing farm income and encouraging quality-oriented milk production. Similar approaches have been reported in other dairy systems where economic rewards are linked to milk quality and production performance (Hietala et al., 2014; Jongeneel et al., 2023).

Milk classification systems based on microbiological criteria are widely applied in many countries, including Kosovo. The regulatory norms have set the limit for number of microorganisms so that the total plate count of raw milk intended for processing is 100,000 CFU mL^{-1} before commingling, and no more than 300,000 CFU mL^{-1} after commingling for Grade 'A' in the United States (USDA, 2011); 100,000 CFU mL^{-1} in Europe (EU, 2021), while in Canada, 50,000 CFU mL^{-1} total aerobic mesophilic bacteria (GC, 2024). In Kosovo, microorganisms in fresh milk are in line with the broader standards of the European Union, and the Law on Food (RK, 2022), which sets the general framework for food safety in Kosovo, as well as implementing the national pricing and subsidy schemes (MAFRD, 2017), and including standards for the microbiological quality of food products such as fresh milk. Specifically, the number of microorganisms in fresh milk in Kosovo is regulated through Administrative Instruction 13/2011 on Quality Standards and Categorization of Fresh Milk (MAFRD, 2011). Based on this Administrative Instruction, cow's milk as a raw material is subject to Categorization into classes, depending on the number of microorganisms per mL and that into: Extra Class $\leq$ 80,000 CFU mL^{-1}; Class I $\leq$ 100,000 CFU mL^{-1}; Class II $\leq$ 300,000 CFU mL^{-1} and Class III $\leq$ 500,000 CFU mL^{-1} and this categorization affect the final price of milk, as the payment is different through adequate correction coefficients.

Previous research has extensively examined the factors influencing microbiological variability in raw milk, including hygiene practices, environmental conditions, and seasonal effects. In particular, studies conducted in small-scale dairy systems have demonstrated that inadequate hygiene, a lack of cooling infrastructure, and fluctuations in ambient temperature significantly affects bacterial counts and milk quality (Hajmohammadi et al., 2021; Deddefo et al., 2023). Seasonal variation, particularly higher summer temperatures, has consistently been associated with increased microbial growth and reduced milk quality (Gebremichael et al., 2024). Recent research conducted

in the Istog region of Kosovo further confirmed substantial monthly, seasonal, and farm-level variation in CFU mL^{-1} associated with differences in hygiene practices and production conditions (Bytyçi et al., 2026).

However, despite the well-documented variability in microbiological quality, the economic implications of milk classification based on microbial load remain insufficiently quantified under real farm conditions. In particular, there is limited evidence on how differences in milk classification translate into variation in gross revenue from milk sales for farmers operating in small-scale dairy systems. Therefore, this study aimed to evaluvenueate the economic impact of raw milk classification based on microbiological quality in small-scale dairy farms in Kosovo. By linking microbiological data with classification-based pricing and subsidy systems, this study provides an assessment of how microbiological milk quality influences gross revenue from milk sales and identifies opportunities for improving both economic performance and production practices.

MATERIALS AND METHODS

Study area and farm characteristics

The study was conducted over one year using milk samples collected from 66 small-scale dairy farms in Kosovo. The farms included in the study-maintained herd sizes ranging from 5 to 20 cows and operated under typical local management conditions. None of the farms were equipped with on-farm milk cooling systems; therefore, milk was transported in containers to collection points within approximately two hours after milking, twice daily (morning and evening). The average daily milk delivery per farm ranged from 50 to 200 liters. A total of 1,334 individual milk samples were collected and analyzed, corresponding to 667 farm-month observations. Two samples were obtained from each participating farm during each month in which milk was delivered and were averaged to obtain one monthly CFU mL^{-1} value. Farms contributed data for different numbers of months because milk delivery was not continuous throughout the year; only farms that delivered milk for at least six months during the study period were included in the economic analysis. Consequently, the study did not comprise a complete 66 farms × 12 months sampling matrix.

The primary focus of this study was the economic consequence of microbiological milk classification rather than an extensive investigation of farm-level determinants of microbial variability.

Milk sampling procedure

Milk sampling was performed twice per month for each farm over one calendar year. Before microbiological analysis, samples were subjected to an alcohol stability test by mixing 2 mL of milk with 2 mL of 75% ethanol. Only samples that tested negative were included in further analysis. Following homogenization, approximately 20 mL of milk was collected in sterile sampling containers and transported under refrigerated conditions (4 °C). All samples were analyzed on the same day of collection.

Microbiological analysis

The total aerobic bacterial count (CFU mL^{-1}) was determined using 3M™ Petrifilm™ Aerobic Count Plates. A volume of 1 mL of milk was inoculated onto each

Petrifilm plate and incubated at 37 °C for 48 h. After incubation, colonies were enumerated using a 3M™ Petrifilm™ Plate Reader. The Petrifilm Aerobic Count Plate is a validated dry-film method for aerobic bacterial enumeration in foods, and its application for enumeration of mesophilic aerobic bacteria in raw milk has also been evaluated under different official incubation protocols (Vianna et al., 2009; AOAC International, 2023). Results were expressed as colony-forming units per milliliter (CFU mL^{-1}). For each farm-month in which milk was delivered, two samples were analyzed, and their mean CFU mL^{-1} value was calculated. The resulting monthly mean represented one farm-month observation and was used for microbiological classification, temporal statistical analysis, and subsequent economic evaluation.

Milk classification system

Milk samples were classified according to national regulatory standards established by the Ministry of Agriculture, Forestry, and Rural Development (MAFRD), based on the number of microorganisms per milliliter. The classification categories were defined as follows: Extra Class: ≤ 80,000 CFU mL^{-1}; Class I: ≤ 100,000 CFU mL^{-1}; Class II: ≤ 300,000 CFU mL^{-1}; Class III: ≤ 500,000 CFU mL^{-1}; Out-of-Class: > 500,000 CFU mL^{-1}.

Each classification category is associated with specific price adjustments applied by milk processing industries and supported by government subsidy schemes.

Economic analysis

The economic evaluation was based on the relationship between milk classification and the price received per liter of milk. In Kosovo, the base price of milk is determined according to milk fat content, with a reference value of 0.075 € per 1% fat. For the economic calculations, a reference milk fat content of 3.75% was used, resulting in a base price of 0.281 € L^{-1}. This value was not selected arbitrarily; it represents the annual mean milk fat content obtained from 1,616 raw milk samples in a previous study conducted at the same milk collection point, involving the same local dairy-farm population during the preceding year (Bytyçi et al., 2025). The use of this empirically derived reference value was considered representative of the production conditions of the study area. A fixed fat content was applied throughout the economic analysis to standardize the base milk price and thereby isolate the effect of microbiological classification, price-correction coefficients, and government subsidies on gross milk revenue. Accordingly,the calculated gross revenue values represent standardized economic scenarios rather than farm-specific revenues based on actual monthly variations in milk fat content.

Table 1. Milk classification based on microbial load and price correction coefficient

Milk class	Microorganisms (CFU mL^{-1})	Correction coefficient
Extra Class	≤ 80,000	1.15
Class I	≤ 100,000	1.05
Class II	≤ 300,000	1
Class III	≤ 500,000	0.8
Out-of-Class	> 500,000	Not accepted

Milk is classified into quality categories according to the number of microorganisms per milliliter. Each classification category is associated with a correction coefficient applied to the base price (Table 1).

The final price per liter of milk was calculated by multiplying the base price by the corresponding correction coefficient. In addition, government subsidies were applied, providing 0.07 € L^{-1} for Extra Class, 0.04 € L^{-1} for Class I, and 0.02 € L^{-1} for Class II milk. No subsidy is provided for Class III or Out-of-Class milk. For example, based on a base price of 0.281 € L^{-1} (3.75% fat), the final prices were calculated as follows (Table 2).

Table 2. Milk pricing based on microbial load and price correction coefficient

Milk class	Calculation	Final price (€ L^{-1})
Extra Class	0.281 × 1.15 + 0.07	0.393
Class I	0.281 × 1.05 + 0.04	0.335
Class II	0.281 × 1.00 + 0.02	0.301
Class III	0.281 × 0.80	0.224
Out-of-Class	Not accepted	0

Monthly and annual gross revenues were calculated based on an average monthly milk production of 3,000 L per farm, corresponding to approximately 100 L day^{-1}, which falls within the reported production range of 50–200 L day^{-1} observed among participating farms. Gross revenue differences were calculated relative to Extra Class milk, which represented the highest quality-based payment category.

All monetary outcomes calculated in this study represent gross revenue from milk sales, including applicable quality-based price adjustments and government subsidies. Production costs, including feed, labor, electricity, hygiene measures, cooling equipment, and other operating or investment costs, were not included; therefore, the calculated values should not be interpreted as net income or farm profitability.

Statistical analysis

Statistical analyses were performed using Microsoft Excel and JASP (Version 0.19.3). For each farm-month in which milk was delivered, the two CFU mL^{-1} measurements were averaged to obtain a single monthly mean value, resulting in 667 farm-month observations. The distribution of monthly mean CFU mL^{-1} values was assessed using the Shapiro–Wilk test. Because the data deviated significantly from a normal distribution, differences in CFU mL^{-1} among months and seasons were evaluated using the Kruskal–Wallis test. When the overall Kruskal–Wallis test was statistically significant, Dunn's post-hoc pairwise comparisons with Bonferroni adjustment for multiple comparisons were performed. Statistical significance was set at $p < 0.05$. The monthly mean CFU mL^{-1} values were subsequently assigned to the regulatory milk quality classes and used as the basis for the economic analysis.

RESULTS

Statistical analysis of monthly and seasonal variation in CFU mL^{-1}

The distribution of the 667 farm-month mean CFU mL^{-1} observations deviated significantly from normality (Shapiro–Wilk $W = 0.7824$, $p < 0.001$); therefore, non-parametric statistical methods were applied. Differences in CFU mL^{-1} among months and seasons were evaluated using the Kruskal–Wallis test. The results of these analyses are presented in Table 3.

The Kruskal–Wallis test showed a statistically significant difference in CFU mL^{-1} among months ($H = 43.70$, $df = 11$, $p < 0.001$), whereas the difference among seasons was not statistically significant ($H = 2.875$, $df = 3$, $p = 0.411$). These results indicate significant monthly variation in microbiological milk quality, while the observed seasonal variation should be interpreted descriptively.

Table 3. Kruskal–Wallis test results for differences in CFU mL^{-1} among months and seasons

Factor	Kruskal–Wallis H	df	*p*
Month	43.7	11	< 0.001
Season	2.875	3	0.411

Note: Statistical significance was set at $p < 0.05$.

Because the overall Kruskal–Wallis test revealed a significant difference among months, Dunn's post-hoc pairwise comparisons with Bonferroni adjustment were performed to identify which months differed significantly. Seven pairwise comparisons remained statistically significant after adjustment (Table 4).

Table 4. Significant Dunn's post-hoc pairwise comparisons of monthly CFU mL^{-1} values with Bonferroni adjustment

Monthly comparison	z	Bonferroni-adjusted *p*
April–December	3.389	0.046
April–March	4.699	< 0.001
December–January	−3.782	0.01
January–March	5.064	< 0.001
June–March	3.453	0.037
March–November	−3.632	0.019
March–October	−3.935	0.005

Note: Only pairwise comparisons that remained statistically significant after Bonferroni adjustment (adjusted $p < 0.05$) are presented.

The post-hoc analysis indicated that the significant overall monthly variation was attributable to specific differences involving primarily March and, to a lesser extent, April, December, January, June, November, and October. No additional pairwise comparisons remained significant after Bonferroni adjustment.

Monthly distribution of milk classification

The distribution of milk samples by microbiological classification across months is presented in Table 5.

Table 5. Monthly distribution of farm-month observations by microbiological milk quality class (%)

Month	n	Extra Class (%)	Class I (%)	Class II (%)	Class III (%)	Out-of-Class (%)
January	58	27.59	5.17	31.03	20.69	15.52
February	55	45.45	9.09	30.91	9.09	5.45
March	54	62.96	3.7	14.81	11.11	7.41
April	62	25.81	3.23	40.32	22.58	8.06
May	62	45.16	11.29	27.42	8.06	8.06
June	59	37.29	10.17	27.12	11.86	13.56
July	57	45.61	7.02	31.58	8.77	7.02
August	50	44	8	36	6	6
September	51	49.02	9.8	23.53	5.88	11.76
October	50	30	12	30	16	12
November	50	36	12	22	16	14
December	59	50.85	6.78	37.29	5.08	0

The proportion of Extra Class observations varied throughout the year, ranging from 25.81% in April to 62.96% in March. Relatively high proportions were also recorded in December (50.85%) and September (49.02%), whereas January (27.59%) and April (25.81%) showed the lowest proportions. In contrast, Class II milk accounted for a substantial share of farm-month observations, particularly in April (40.32%), July (31.58%), October (30%) and December (37.29%). Class III and Out-of-Class milk, representing lower microbiological quality, were more prevalent in January, April, June, and November.

Seasonal variation in milk classification

Seasonal distribution of milk classification is illustrated in Fig. 1.

The highest proportion of Extra Class observations was recorded in spring (43.82%), followed by summer (42.17%), winter (41.28%), and autumn (38.41%). Class II observations were most frequent in winter (33.14%) and summer (31.33%), whereas Out-of-Class observations were most frequent in autumn (12.58%). Although these descriptive distributions indicate some seasonal variation in milk classification, the overall difference in CFU mL^{-1} among seasons was not statistically significant (Kruskal–Wallis H = 2.875, df = 3, p = 0.411).

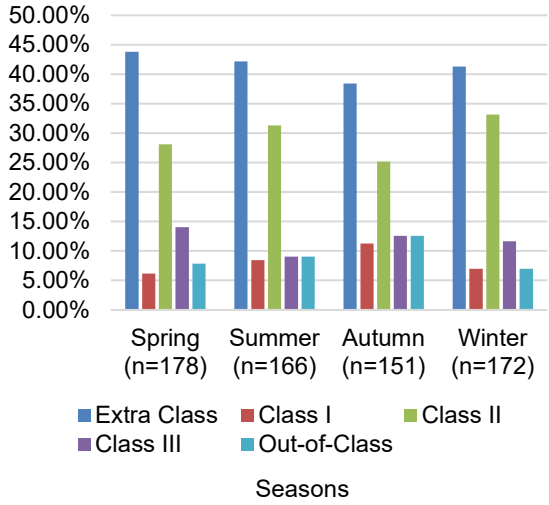

Figure 1. Seasonal distribution of milk classification (%).

Economic outcomes by milk classification

The relationship between milk classification and monthly and annual gross revenue per farm is presented in Table 6.

Under the standardized production scenario, Extra Class milk generated the highest gross revenue, amounting to €1,179 per month and €14,148 per year. Progressively lower milk quality classifications resulted in lower gross revenue. Class I milk generated €1,005 per month, while Class II and Class III milk generated €903 and €672 per month, respectively. Out-of-Class milk generated no gross milk-sale revenue because it was rejected under the applied classification and payment system.

Table 6. Monthly and annual gross revenue per farm under the standardized production scenario, by milk quality class

Milk class	Price (€ L^{-1})	Monthly gross revenue (€)	Annual gross revenue (€)
Extra Class	0.393	1,179	14,148
Class I	0.335	1,005	12,060
Class II	0.301	903	10,836
Class III	0.224	672	8,064
Out of Class	0	0	0

Annual distribution and economic impact

The overall distribution of milk classification and its economic implications are summarized in Table 7.

Table 7. Distribution of farm-month observations and annual gross revenue differences by milk quality class

Milk class	% of farm-month observations	Annual gross revenue (€)	Gross revenue difference vs. Extra Class (€)	Gross revenue difference (%)
Extra Class	41.53	14,148	0	0
Class I	8.1	12,060	2,088	14.76
Class II	29.54	10,836	3,312	23.41
Class III	11.84	8,064	6,084	43
Out-of-Class	9	0	14,148	100

Across all farm-month observations, approximately 49.63% were classified as Extra Class or Class I, representing the two highest microbiological quality categories. The remaining observations were distributed among Class II, Class III, and Out-of-Class milk. Under the standardized production scenario used for the economic analysis (3,000 L month^{-1} per farm), lower classification categories resulted in progressively lower gross revenue. Relative to Extra Class milk, annual gross revenue was reduced by 14.76% for Class I, 23.41% for Class II, and 43% for Class III. Out-of-Class milk generated no gross milk-sale revenue because it was rejected under the applied classification and payment system.

The observed differences in gross revenue across milk classification categories reflect the structure of the quality-based payment system, in which both processor price adjustments and government subsidies linked to milk quality contribute to the final payment received by farmers. Such combined mechanisms are designed to incentivize higher-quality production and improve the economic stability of dairy farms as reported in other dairy systems where economic rewards are directly linked to milk quality parameters (Botaro et al., 2013). Similar quality-based pricing frameworks have been implemented in various countries, emphasizing the economic importance of maintaining high microbiological standards in raw milk.

The economic consequences of microbiological milk classification were evaluated as differences in gross revenue from milk sales under the standardized production scenario of 3,000 L per farm per month. Because the final milk price varied according to microbiological class through quality-based price correction coefficients and government subsidies, progressively lower milk quality resulted in lower gross revenue. These calculations represent standardized gross-revenue scenarios and do not account for farm-specific production costs.

DISCUSSION

The findings of this study demonstrate that milk classification based on microbiological quality is not only a technical or hygienic indicator but also a key economic determinant for small-scale dairy farms. The observed variation in milk

classification across months and seasons reflects underlying differences in microbial load, which directly influence the price farmers receive through quality-based payment systems.

Although descriptive differences in milk classification were observed across seasons, the overall seasonal difference in CFU mL^{-1} was not statistically significant. Seasonal and environmental conditions may nevertheless influence raw milk microbiological quality through their effects on bacterial growth, milk handling, and storage conditions. As noted by the Codex Alimentarius Commission (FAO, 2004), the quality and safety of raw milk are strongly influenced by handling, storage, and transport conditions, while inadequate temperature control can promote microbial growth and reduce product stability. Similarly, Elmoslemany et al. (2010) identified seasonal conditions and inadequate milking hygiene practices as important factors associated with bacterial contamination of bulk tank milk. Thus, the seasonal distributions observed in the present study should be regarded as descriptive patterns rather than evidence of a statistically significant seasonal effect.

However, unlike studies that focus primarily on microbiological variability, the present study highlights how these variations translate into measurable economic consequences. The results clearly show that even moderate increases in microbial load, leading to classification into lower-quality categories, result in substantial reductions in gross revenue from milk sales. This finding is in line with previous research indicating that high milk quality is an important factor influencing market competitiveness, product acceptance, and economic returns within dairy supply chains (Can & Engindeniz, 2025).

The substantial proportion of farm-month observations classified as Class II (29.54%) indicates that a considerable share of milk deliveries met regulatory acceptance criteria but did not achieve the higher quality classifications associated with maximum gross revenue. This reflects structural constraints typical of small-scale dairy systems, including limited access to technology, insufficient training, and inadequate infrastructure. As highlighted by Średzińska (2021), the economic performance of dairy farms is strongly associated with productivity, production efficiency, and milk quality-related factors, emphasizing that improvements in milk quality can directly enhance farm profitability.

The economic analysis conducted in this study demonstrates that the difference between classification categories is substantial. These gross-revenue differences illustrate the economic relevance of quality-based payment systems and are consistent with previous studies emphasizing the importance of production efficiency and quality-related performance indicators for the economic sustainability of dairy farms (Bórawski et al., 2020). The observed differences in gross revenue across milk classification reflect the structure of quality-based payment systems, where both industry price adjustments and government subsidies linked to milk quality play a complementary role in determining final payment received by farmers. Such mechanisms are intended to encourage higher-quality milk production and contribute to greater economic stability for dairy farms (D'Antoni & Mishra, 2012).

The absence of milk-sale revenue for Out-of-Class milk further highlights the economic risk associated with poor microbiological quality. Under the applied regulatory and payment framework, milk exceeding the acceptance threshold is rejected and therefore generates no revenue from sale through the collection channel considered

in this study. This situation may be particularly important for small-scale dairy farmers whose household and farm cash flow depends substantially on regular milk. As reported by Shanta et al. (2020), improving hygienic milking practices and milk handling conditions can contribute substantially to reducing microbial contamination and improving the quality and market acceptance of raw milk, suggesting that relatively simple interventions may yield substantial economic benefits. Improvements in milk handling, hygienic milking practices, and storage conditions can reduce microbial contamination and enhance the marketability and economic value of raw milk (FAO, 2010).

Seasonal economic variation identified in this study reinforces the importance of targeted management strategies. Although descriptive differences in milk classification and associated gross revenue were observed across seasons, the overall seasonal difference in CFU mL^{-1} was not statistically significant (Kruskal–Wallis $H = 2.875$, $df = 3$, $p = 0.411$). Therefore, the observed seasonal patterns should be interpreted as descriptive trends rather than evidence of a statistically significant seasonal effect. Nevertheless, increased attention to hygiene, cooling, and milk handling during warmer periods remains biologically plausible and is supported by previous studies reporting associations between environmental conditions, farm management, and seasonal variation in milk quality (Nateghi et al., 2014; Zaman et al., 2016; Guzmán et al., 2024).

In addition to farm-level practices, institutional support mechanisms such as subsidies and price incentives play a crucial role in shaping economic outcomes. The classification-based approach applied in Kosovo provides a clear financial motivation for improving milk quality. According to Saenger et al. (2013), incentive-oriented dairy systems can encourage farmers to improve milk quality and production practices to achieve better market opportunities and economic returns, which aligns with the findings of the present study.

Overall, the results indicate that improving microbiological quality represents a key strategy for enhancing both the technical and economic performance of dairy farms. Investments in hygiene practices, milk cooling infrastructure, and farmer training programs are essential to enable producers to achieve higher quality classifications and improve the stability of their milk-sale revenue.

For small-scale farms without on-farm cooling systems, immediate improvements do not necessarily require major capital investment. Practical measures include reducing the interval between milking and delivery, using thoroughly cleaned and sanitized milk containers, minimizing exposure of milk to ambient temperature, improving udder and equipment hygiene, and coordinating more frequent collection during warmer periods. Where financially feasible, shared or cooperative cooling facilities at village or collection-point level may provide a more accessible alternative to individual bulk-tank investment. These measures may help reduce microbial growth before collection and increase the likelihood of achieving higher microbiological quality classes and associated gross-revenue premiums.

CONCLUSIONS

The results of this study demonstrate that microbiological classification of raw milk has direct economic implications for small-scale dairy farms through its effect on quality-based milk prices and government subsidies. Differences in total bacterial count

(CFU mL^{-1}) determine the milk quality class and, consequently, the gross revenue obtainable from milk sales under the applied payment system.

Across the 667 farm-month observations, milk quality varied considerably among classification categories. Under the standardized production scenario of 3,000 L per farm per month, Extra Class milk generated the highest gross revenue. Relative to Extra Class milk, annual gross revenue was approximately 23% lower for Class II milk and 43% lower for Class III milk, while Out-of-Class milk generated no milk-sale revenue because it was rejected under the applied classification and payment system.

Significant differences in CFU mL^{-1} were detected among months (Kruskal–Wallis $H = 43.70$, $df = 11$, $p < 0.001$), indicating meaningful short-term temporal variation in microbiological milk quality. In contrast, the overall difference among seasons was not statistically significant ($H = 2.875$, $df = 3$, $p = 0.411$). Consequently, the observed seasonal patterns in milk classification and associated gross revenue should be interpreted as descriptive trends rather than evidence of a statistically significant seasonal effect.

Overall, the findings demonstrate that improving microbiological milk quality can increase the gross revenue obtainable from milk sales by enabling farmers to achieve higher quality classifications and associated price premiums and subsidies. Improved milking hygiene, appropriate milk handling and cooling, farmer training, and effective quality-based incentive mechanisms may therefore contribute to improved milk quality and strengthen the economic sustainability of small-scale dairy production.

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