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A case study of hygiene interventions on small-scale dairy farms to reduce bacterial and somatic cell counts in Sheqeras, Albania

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Ethics approval and consent to participate: participation was voluntary after farmers were informed about the aims of the study, which align with their interests in improving hygiene status on their farms.

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Abstract

Bovine raw milk with high bacterial and somatic cell counts (SCC) may affect food safety and market competitiveness in the dairy sector. This study investigated how a structured hygiene intervention protocol affects milk quality and safety on Albanian dairy farms. From August 2024 to March 2025, five dairy farms of an average herd size of 22.6±2.25 (standard error) were visited bimonthly. Before and after a thorough hygiene intervention, bulk tank milk was tested for total plate count (TPC), SCC, antibiotic residues, *Clostridium* spp. spore count, and California Mastitis Test (CMT) screening test.

The intervention resulted in substantial decreases in microbial load on the majority of farms ($p<0.05$). The average $\log_{10}$ reduction in TPC varied from -0.89 to 2.40, with 80% of farms exhibiting improved hygienic conditions. As a result of monthly CMT monitoring, SCC levels consistently adhered to European Union regulatory limits (<5.6 $\log_{10}$ cfu/mL) across all farms during the study period. A robust positive correlation was identified between $\log_{10}$ SCC and $\log_{10}$ TPC ($r=0.66$, $p<0.05$). Analysis of variance established that CMT sum scores were a highly significant predictor of both $\log_{10}$SCC ($F=31.45$, $p<0.05$) and $\log_{10}$ TPC ($F=9.82$, $p<0.05$). β-lactams were identified in only one farm (1 out of 35 milk samples in total, 2.9%).

Implementing targeted on-farm ten-step hygiene protocols can significantly diminish microbial contamination in raw milk. A significant correlation was observed between SCC and TPC, highlighting the importance of good hygiene practices. This study provides a scalable model for improving milk quality in small-scale dairy production systems.

Introduction

Milk quality is a central determinant of both consumer safety and dairy sector competitiveness in Europe. Within the European Union (EU), Regulation (EC) No. 853/2004 sets stringent hygiene criteria for raw milk, including thresholds of ≤100,000 cfu/mL for total plate count (TPC) and ≤400,000 cells/mL for somatic cell count (SCC) (European Parliament and Council of the European Union, 2004a, 2004b).

In Albania, however, due to the lack of monitoring data in central level, values of TPC and SCC levels in bulk tank milk often exceed these thresholds (Beli *et al*., 2016), creating significant barriers for both export competitiveness and domestic processing (Biçoku, 2023). Benchmarking Albanian production against EU standards is therefore critical for identifying gaps and designing targeted interventions.

Elevated SCC and bacterial loads not only affect regulatory compliance but also carry substantial economic costs for farms and processors. High SCC levels are strongly associated with reduced curd firmness, lower cheese yield, and higher defect rates during ripening (Marth, 1963; More *et al*., 2013; Geary *et al*., 2014; Korena *et al*., 2023; Kaushik and Anand, 2025). Likewise, excessive microbial loads delay maturation, compromise texture, and increases spoilage risks. Evidence from Italy, Ireland, and the Netherlands demonstrates that reducing SCC and TPC translates into measurable yield gains and reduced losses at the processor level (Marth, 1963; More *et al*., 2013). In this context, interventions that lower bacterial and SCC are not only a food safety measure but also a pathway to improved profitability for Albanian farms.

Several EU member states have successfully implemented payment-by-quality systems, linking farm-gate prices to milk hygiene indicators such as SCC and TPC (Draaiyer *et al.*, 2009; Botaro *et al*., 2013). These systems have incentivized farms to adopt better hygiene and udder health practices, leading to national-scale reductions in microbial and somatic cell loads. However, Albania's milk pricing has historically been based only on fat, protein, and non-fat solids, offering little incentive for improved hygiene. Aligning farm–processor contracts with EU-style quality payment systems could thus foster improvements in both milk quality and farm incomes. Furthermore, monitoring and verification protocols—already in place for EU exports—demonstrate that transparent, auditable systems are feasible and effective for ensuring compliance with microbiological standards (Bojnec and Fertő, 2014).

Regional comparisons also underscore Albania's competitive disadvantage along the counties like Serbia, North Macedonia, Bosnia and Herzegovina where no progress was made in Albania on developing a roadmap to improve milk quality (European Commission, 2024).

Without similar improvements, Albanian processors risk being undercut on both domestic and regional markets. Lowering TPC and SCC also reduces public health risks, since these parameters are linked not only to product spoilage but also to the prevalence of pathogens and toxins in dairy products (Korena *etal*., 2023; Ritschard and Schuppler, 2024). Strengthening hygiene at farm and processor levels therefore has dual benefits: safeguarding consumer health and supporting market integration.

Consumer expectations and awareness further reinforce the need for intervention. European studies indicate that lower SCC levels and improved hygiene directly influence sensory attributes and consumer perceptions of milk and dairy products (Gülzari *et al*., 2020; do Carmo *et al*., 2023). At the same time, stakeholder coalitions—linking farms, processors, and regulators—have proven effective in implementing farm-level hygiene programs, reducing microbial contamination and strengthening governance systems (Draaiyer *et al*., 2009; Lemma *et al*., 2018). In the Albanian context, fostering multi-stakeholder collaboration through well-designed pilot projects could serve as a feasible and effective model for strengthening governance within the dairy sector.

Finally, the success of hygiene interventions requires robust monitoring and transparent performance indicators. Longitudinal analyses in EU cooperative systems show that SCC and TPC reductions are achievable at scale when interventions are paired with clear key performance indicators (KPIs) and independent auditing (Berry *et al*., 2006; Innocente and Biasutti, 2013). Against this backdrop, the present study reports on a six-month hygiene intervention pilot conducted in Sheqeras, Albania, designed to reduce TPC and SCC at the farm level, evaluate farm compliance with EU-aligned quality parameters.

This study aimed to evaluate the quality of raw milk by examining SCC (SCC/mL) and bacterial count (cfu/mL) as principal indicators, employing geometric mean calculations on a 6-month hygiene intervention pilot conducted in Sheqeras, located in Korca County, Albania. Moreover, additional assessment encompassed physico-chemical characteristics, clostridial spores (cfu/mL), antibiotic residues, and impurities present in the raw milk. The analysis was performed at the farm level to compare the results against national and EU standards.

Materials and Methods

Study area, farm selection and sample collection

The pilot study at farm level was conducted in Sheqeras village (Lat: 40.7446 Long: 20.7708) located in the Korça County of southeastern Albania. The population of Sheqeras was estimated to be around 2500-3000 and the economy of Sheqeras is primarily based on agriculture and livestock dairy farming.

A volume of 250 mL of raw cow's milk was collected aseptically from the bulk tank refrigerator of each farm from August 2024 to March 2025. In compliance with ISO 707 (2008) protocol, samples were transported under strict refrigerated conditions (3°C) using a mobile refrigeration unit and analyzed on the same day. Temperature was monitored and confirmed upon reception at ADAMA Laboratory. Analytical procedures followed validated alternative methods and cultural method according to ISO, with result interpretation adhering to the stipulations of EU legislation. The average sampling time was 14.3±0.15 (standard error) hours. A monthly collection of fresh milk samples (n=40) was performed at five selected small-scale dairy farms in Sheqeras Village, Albania, from August 2024 to March 2025. Five samples (n=1 sample per farm) were collected prior to the implementation of hygiene interventions, whereas the subsequent thirty-five samples were obtained

afterward (n=7 samples per farm). Additionally, monthly field data on California Mastitis Test (CMT) for each individual animal and farm concerning subclinical mastitis were collected (data not shown).
The samples were examined in duplicate for TPC, SCC, *Clostridium* spp., screening tests antibacterial residues (β-lactams, tetracyclines and cefalexins).

Laboratory examinations

Total plate count

TPCs in milk samples were determined using CompactDry™ TC plates (Shimadzu Diagnostics, 75002 Paris, France) following manufacturer instructions and method validation against AOAC Official Method 966.23. Samples were diluted (1:10) in buffered peptone water to achieve less than 300 cfu per plate and 1 mL of each diluted sample was applied to the center of the dehydrated which rehydrated into a gel within seconds. Medium that contains the redox indicator 3,3,5-Triphenyl Tetrazolium Chloride (TTC), producing red-colored colonies for most organisms, while carved gridlines (1 cm^2 and 0.5 cm^2) facilitated estimation of colony density in plates with higher counts. To cover the quantification between 4 and 6 log plates were labeled (-4; -5; -6) then inverted, and incubated 30±1°C (Thelco Scientific Instruments, Ohio, USA) with up to six plates stacked during incubation. Following incubation, colonies were enumerated from the reverse side of the plate, using a white background to facilitate visualization, and both colored and colorless colonies were counted as total viable bacteria within 48 hours. Regarding the accuracy of the results, analysis per sample was conducted in duplicates.

Somatic cell count

Raw milk samples from bovines, freshly collected without preservatives, were allowed to reach room temperature (15-25°C) and analyzed within minutes using the Lactoscan SCC, SOFIA GREEN dye as a marker, and the LACTOCHIP x4 system (Milkotronic Ltd., Nova Zagora, Bulgaria). For each test, 100 μL of raw milk was transferred into a microtube containing lyophilized SOFIA GREEN dye, thoroughly mixed using a mini vortex (Milkotronic Ltd., Nova Zagora Bulgaria) for several brief cycles, and permitted to interact with the dye for one minute (±15 seconds). After multiple vortexing sessions, 8 μL of the prepared sample was transferred in duplicates into the microfluidic chambers of the LACTOCHIP x4, ensuring sterile handling and accurate pipetting. The loaded LACTOCHIP was meticulously positioned within the LACTOSCAN SCC device, and analysis commenced via the associated software (LSCC-Lactoscan Somatic Cell Counting v 1.5.0.25). This software enabled the identification of cell sizes ranging from 5 to 20 micrometers in diameter and then perform the calculation in line with the formula IDF/ISO 13366 . LACTOSCAN SCC compared with a standard method. Validation of SCC using LACTOSCAN was conducted from the manufacture, with further verification by Prof. Asen Zlatarov (Operational Manual, Milkotronic Ltd, 2017), against the standard method, exhibiting a coefficient of variation between 4% and 7%.

Screening test for antimicrobials

Antibiotic residues in raw bovine milk were analyzed utilizing the Quantum BT-Cef lateral flow test kit (ProGnosis Biotech S.A., Larissa, Greece; Cat. No. W1030/W1060), which supports a 200 μL sample load for the simultaneous detection of β-lactams, tetracyclines, and cefalexin. The assay employs a competitive immunoassay principle, utilizing specific receptors and antibodies conjugated to gold nanoparticles that generate visible test lines in the absence of antibiotics. Bovine milk samples were utilized directly without prior treatment, yielding results within 5 minutes. Results were visually validated by comparing the intensities of the test and control lines.

Sulfite-reducing Clostridium spp.

The enumeration of Clostridial spores in raw milk was conducted using TSC agar enriched with D-cycloserine (BioloifeS.r.l., Milan, Italy) in accordance with ISO/DIS 15213-2. One mL of the milk test sample, or decimal dilutions (1:10), was transferred into sterile Petri dishes, combined with 12–15 mL of rehydrated TSC agar, and subsequently overlaid with 5 mL of the same medium following solidification. Plates were incubated anaerobically at 44±1°C for 21±3 hours, and typical black colonies, indicative of sulfite-reducing Clostridia, were enumerated on plates with fewer than 150 colonies (90 mm dishes). The colony forming unit calculation for each test results was conducted in accordance with ISO 7218:2024.

Statistical analysis

Statistical analysis was conducted utilizing R Studio version 2025.05.0 Build 496. A logarithmic transformation was utilized for TPC and SCC. The geometric mean was used for SCC and TPC as statutory parameter. The CMT cumulative score was determined by summing the CMT index from each individual quarter (Maçi *et al.*, 2025). Additionally, Pearson correlation and statistical significance were conducted among the physicochemical parameters (Fat, SN, Protein, Lactose), CMT Score, TPC and SCC). The cumulative scores of CMT, TPC, SCC were evaluated using one-way analysis of variance for continuous variables.

Results

Hygienic statutory indicator in bulk tank milk (total plate count and somatic cell count)

In this study, milk quality was primarily evaluated through microbiological and somatic indicators, with TPC and SCC being the most relevant parameters. High TPC values indicate poor hygiene during milking or storage, while elevated SCC values are commonly linked to mastitis and reduced milk quality. In this study, data were collected from five dairy farms (indexed as farm 1-5) between August 2024 and March 2025 to assess fluctuations in TPC and SCC over time.

Table 1 summarizes the milk quality analysis for five distinct farms in Sheqeras Village. It employs two principal microbiological indicators to evaluate the hygiene and safety of the produced raw milk as well as other parameters antibiotics and clostridium spores: the geometric mean results provide a solid statistical analysis that determines if the farm's outcomes fall within acceptable criteria as recommended by the legislation.

Other statutory parameters laid down in Albanian legislation are related with physico-chemical analysis such as: fat in bovine milk 3.5% (STASH 1563-87); solids-not-fat (SNF) in bovine milk 8.5 % (STASH 1563-87); e. density in bovine milk (29-34). Moreover no pathogens should be present (STASH 1563-87) as well as no antibiotics should be present or quantified above maximum residue limit (MRL).

The geometric mean findings as mentioned in Table 1 provide a solid calculation assessment of whether the farm's outcomes fall within acceptable limit. In that regards all five farms (100%) was found to have an SCC status categorized as "below 400.000 cel/mL" as an exceptionally advantageous finding. It indicates that the farms in Sheqeras have successfully implemented intervention measures.

Regarding bacterial hygiene (TPC status) was demonstrated that 80% of farms exceed the acceptable EU threshold level for TPC. Five out of five farms was found below 500.000 cfu/mL in geomean (5.69 log). One farm (Farm 5) was categorized as "below threshold of 100.000 cfu/mL".

Temporal description for each farm

Figure 1A shows the temporal changes in TPC (log cfu/mL) and SCC (log cells/mL) in bulk tank milk from Farm 1 between August 2024 and February 2025.

The first measurement in August 2024 (TPC=7.1 log, SCC=5.6 log) represents the baseline condition before intervention. This result indicates a critical hygiene problem with bacterial counts far exceeding the recommended 5.0 log threshold.

Following the implementation of intervention measures, TPC levels showed a progressive decline, reaching 5.59 log by February 2025. Although values remained slightly above the hygienic limit, the clear downward trend demonstrates the effectiveness of improved handling and sanitation practices.

SCC values, by contrast, were relatively stable, fluctuating between 5.3-5.9 log. Most post-intervention results remained around or slightly above the threshold of 5.6 log, suggesting that udder health issues persisted to some degree despite the improvements in bacterial load.

In summary, the figure highlights that the intervention had a notable positive impact on reducing TPC, whereas SCC required further herd health management to achieve consistent compliance with regulatory standards.

Figure 1B presents the time course of TPC (log cfu/mL) and SCC (log cells/mL) in bulk tank milk from Farm 2 between August 2024 and March 2025. The first measurement in August 2024 (TPC=9.18 log cfu/mL; SCC=5.36 log cells/mL) was taken under baseline conditions without any treatment or intervention. This value represents a peak contamination level, well above the hygienic threshold of 5.0 log cfu/mL and reflects poor pre-intervention hygiene.

Following the implementation of corrective measures subsequent TPC values showed a marked decline, reaching as low as 4.00 log cfu/mL in March 2025. Although occasional fluctuations above the recommended limit persisted, the overall trend indicates a substantial improvement in hygienic conditions compared to the baseline (zero treatment).

SCC values, in contrast, remained relatively stable throughout the monitoring period, ranging mostly between 5.0-5.3 log cells/mL, with a notable drop to 4.0 log cells/mL in March 2025.

In the Figure 1C, TPC values fluctuated throughout the sampling period, with a peak of 7.5 log cfu/mL on October 8, 2024. Significant decreases were observed, with a low of 4.8 log cfu/mL on September 14, 2024. Values remained above the lower limit of 5.0 log cfu/mL for the majority of the observations, with some exceptions in October 2024 and March 2025. SCC showed more variability, peaking at 5.7 cells/mL on 21/02/2025. The data points fell below the 5.6 log cells/mL threshold on several occasions.

SCC in Figure 1D shows a fairly stable trend, with values staying between 4.0 and 5.7 cells/mL during the whole time. On March 7, 2025, the SCC reached its highest point, 5.7 cells/mL. The TPC values often fall below the acceptable limit of 5.0 log cfu/mL, but the SCC values stay above the lower limit of 5.6 log cells/mL for most of the time they are reported.

The TPC values found in Figure 1E exhibit a consistent decrease over time, commencing at 6.4 cfu/mL on 21/08/2024 and culminating at a minimum of 3.7 cfu/mL by 13/03/2025. The TPC exhibited consistent fluctuations while predominantly staying above the lower threshold of 5.0 log. The SCC commenced above the lower threshold of 5.6 log, reaching a maximum of 5.7 cells/mL. Nonetheless, it exhibited a declining trend, ultimately arriving at 5.2 cells/mL by the final measurement. During the sampled period, TPC values consistently exceeded SCC values, signifying superior milk quality regarding microbial load relative to somatic cell presence. Both parameters were evaluated to determine milk quality, indicating a trend of enhancement over time, especially in TPC. Overall, these findings highlight a notable improvement in microbial quality, as evidenced by the decrease in TPC and maintained SCC levels, indicating evident improvement in milk quality due to low SCM prevalence as a results of hygiene interventions.

Comparison between total plate count and somatic cell count. Results ofpre- and post-treatment

In Figure 2, TPC log reduction varied across farms, with Farm 3 (2.40 log cfu/mL) improving the most, followed by Farm 5 (1.50 log), Farm 4 (1.03 log), and Farm 2. Farm 1had a 0.89 log cfu/mL increase, indicating a milk hygiene decline. The results showed that most farms reduced bacterial loads, but the intervention had different effects.

A favorable log reduction in log SCC, signifying enhancement, was noted on two farms, with Farm 5 attaining the most significant reduction (0.65 log). Conversely, three farms exhibited minimal (0.00 log) or negative log reductions, the latter signifying a net rise in SCC following the intervention. Farm 4 exhibited the least favorable performance, recording a -0.26 log reduction.

Statistical analysis

Correlation with log_{10}-transformed variables

The positive correlation between SCC and bacterial count (TPC) (0.66***) confirms that high somatic cells are associated with higher bacterial levels, a classic sign of SCM (Table 2). More significantly, both microbial load [$\log_{10}$(TPC)] and SCC [$\log_{10}$(SCC)], key indicators of subclinical mastitis and bacterial contamination, show strong positive correlations with each other(0.66). Crucially, they are also positively correlated with the SCC and SNF at 0.54.

Analysis of variance

The analysis of variance results in Table 3 demonstrates that the CMT score is a highly significant predictor of both microbial load [$\log_{10}$(TPC)] and SCC [$\log_{10}$(SCC)] in milk. For $\log_{10}$(TPC), the model accounted for a significant portion of the variance [F(3, 2016)=9.82, p=2e-06], indicating that the severity of mastitis, as indicated by the CMT score, is strongly associated with higher bacterial counts. Similarly, for $\log_{10}$(SCC), the CMT score was an even more powerful predictor [F(3, 2016)=31.45, $p<0.05$], explaining a substantial amount of the variation in SCC. These findings statistically confirm that as the visual CMT score increases, signifying a more severe intramammary infection, there is a corresponding and significant increase in both the primary cellular indicator of infection (SCC) and the level of bacterial contamination (TPC).

The considerable difference in the sum of squares between the model and the residual for both models confirms that the grouping by CMT score explains meaningful variation in the data. The much larger F-value for the $\log_{10}$(SCC) model compared to the $\log_{10}$(TPC) model indicates that the relationship between the CMT score and SCC is stronger and more defined than its relationship with total bacterial count. The confirmed relationship validates the continued use of the CMT as a reliable, on-farm diagnostic tool for identifying subclinical mastitis and predicting milk quality parameters.

Discussion

This study assesses the TPC, and SCC levels as well as investigates the impact of hygiene interventions through a systematic implementation of farm-level hygiene protocols, including stable management(cleaning berths with lime-treated straw) and milking hygiene standards (use of gloves, teat cleaning, post-milking teat dipping, and CMT). Other steps include following the right milking order, cleaning the machines on a regular basis, and buying stainless steel (inox) equipment for storing and moving milk.

The pilot intervention in Sheqeras locality offered a model for decreasing TPC and SCC, determining geometric mean results for SCC and TPC to conform to acceptable standards, specifically the maximum limits of 400.000 cells/mL and 100.000 cfu/mL of milk as mandated by EU legislation (European Parliament, Council of the European Union, 2004a, 2004b). Additionally, examining the correlations between milk composition and microbial quality indicators utilizing $\log_{10}$-transformed data (Bogdanovičová *et al*., 2016).

CMT scores showed a clear response relationship with $\log_{10}$(SCC) values confirmed with the analysis of variance in which results indicated significant differences in $\log_{10}$(TPC) and $\log_{10}$(SCC) across different CMT score categories ($p<0.05$) (Hoque *et al*., 2015).

The farms that were a part of the study all had a comparable number of animals and utilized milking machines that had the same capacity. These machines were all provided by the project and shared the same technical specifications. All of the farmers were provided with standardized training in milk hygiene and udder cleaning, and the milk from all of the farms was delivered on the same day of collection. This eliminated the variability that was associated with the handling and transportation of the milk. Despite the fact that these controls were implemented, it is possible that the results were influenced by other factors that were not measured. It is for this reason that the authors acknowledge the possibility that environmental and farm management factors could still act as confounding factors. Nevertheless, the fact that there was a consistent downward trend in both TPC and SCC across all farms after the intervention strongly suggests that the hygiene measures that were implemented were the primary drivers of the improvements that were observed.

Conclusions

This intervention is important not only because it shows that milk quality can be improved in measurable ways, but also because it could change the dairy industry's economic perspective. It is very important to improve the quality of raw milk in Albania because high bacterial count (TPC) and high SCC are still problems that make processing less efficient and food less safe for the industry.

This study is of particular importance because it is the first attempt to evaluate hygiene interventions in Albania's dairy sector, which is a critical component of the country's agricultural and economic development.

The results, despite limitations in assessing seasonal fluctuation, offer valuable evidence that can assist policymakers and stakeholders in the development of targeted strategies, while also demonstrating a model that could be scaled up to strengthen the sector more broadly.

References

Beli E, Uruci M, Borova N, 2016. Evaluation of Albanian raw milk quality situation by using somatic cell counts. Evaluation 3:5971-4.

Berry D, O’Brien B, O’Callaghan E, Sullivan K, Meaney W, 2006. Temporal trends in bulk tank somatic cell count and total bacterial count in Irish dairy herds during the past decade. J Dairy Sci 89:4083-93.

Biçoku Y, 2023. Milk sector trends: the case of Albania. Int J Agric Environ Res 9:963-88.

Bogdanovičová K, Vyletělová-Klimešová M, Babák V, Kalhotka L, Koláčková I, Karpíšková R, 2016. Microbiological quality of raw milk in the Czech Republic. Czech J Food Sci 34:189-96.

Bojnec Š, Fertő I, 2014. Export competitiveness of dairy products on global markets: the case of the European Union countries. J Dairy Sci 97:6151-63.

Botaro BG, Gameiro AH, dosSantos MV, 2013. Quality based payment program and milk quality in dairy cooperatives of Southern Brazil: An econometric analysis. Sci Agric 70:21-6.

do Carmo RM, do Nascimento LEC, Leão PVT, de Paula GH, de Castro Dias MB, Fernandes PB, Mesquita AA, Nicolau ES, Rezende MMR, de Sousa WA, Neves Medeiros de Silva EC, Pereira de Silva MA, 2023. Influence of somatic cell removal on milk quality and yield. Beverages 10:5.

Draaiyer J, Dugdill B, Bennett A, Mounsey J, 2009. Milk testing and payment systems. Resource book: a practical guide to assist milk producer groups. Available from: https://www.fao.org/4/i0980e/i0980e00.pdf.

European Commission, 2024. Albania 2024 Report. Brussels, 30.10.2024 SWD(2024) 690 final. Available from: https://enlargement.ec.europa.eu/document/download/a8eec3f9-b2ec-4cb1-8748-9058854dbc68_en?filename=Albania%20Report%202024.pdf

European Parliament, Council of the European Union, 2004a. Regulation(EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin. In: Official Journal, L139/55, 30/04/2004.

European Parliament, Council of the European Union, 2004b. Regulation(EC) No 854/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption. In: Official Journal, L139/206, 30/04/2004.

Geary U, Lopez-Villalobos N, O'Brien B, Garrick DJ, Shalloo L, 2014. Estimating the impact of somatic cell count on the value of milk utilising parameters obtained from the published literature. J Dairy Res 81:223-32.

Gülzari ŞÖ, Owade JO, Ndambi OA, 2020. A review of interventions and parameters used to address milk quality in eastern and southern Africa. Food Control 116:107300.

Hoque MN, Das ZC, Talukder AK, Alam MS, Rahman AN, 2015. Different screening tests and milk somatic cell count for the prevalence of subclinical bovine mastitis in Bangladesh. Trop Anim Health Prod 47:79-86.

Innocente N, Biasutti M, 2013. Automatic milking systems in the Protected Designation of Origin Montasio cheese production chain: effects on milk and cheese quality. J Dairy Sci 96:740-51.

ISO, 2008. Milk and milk products – guidance on sampling. ISO Norm 707:2008. International Standardization Organization ed., Geneva, Switzerland.

ISO, 2024. Microbiology of the food chain — General requirements and guidance for microbiological examinations. ISO Norm 7218:2024. International Standardization Organization ed., Geneva, Switzerland.

Kaushik R, Anand S, 2025. Studying the population dynamics of NSLAB and their influence on spores during cheese ripening. Appl Microbiol 5:65.

Korena K, Krzyzankova M, Florianova M, Karasova D, Babak V, Strakova N, Juricova H, 2023. Microbial succession in the cheese ripening process—competition of the starter cultures and the microbiota of the cheese plant environment. Microorganisms 11:1735.

Lemma DH, Mengistu A, Kuma T, Kuma B, 2018. Improving milk safety at farm-level in an intensive dairy production system: Relevance to smallholder dairy producers. Food Qual Saf 2:135-43.

Maçi R, Meçaj R, Sulçe M, Plaku F, Xhafa A, Sallaku E, Koleci X, Tafaj M, 2025. The relationship between the occurrence of subclinical mastitis and milk quality in medium-sized Holstein cow farms in Albania. Ital J Food Saf 14:13748.

Marth E, 1963. Microbiological and chemical aspects of cheddar cheese ripening. A review. J Dairy Sci 46:869-90.

More SJ, Clegg TA, Lynch PJ, O'Grady L, 2013. The effect of somatic cell count data adjustment and interpretation, as outlined in European Union legislation, on herd eligibility to supply raw milk for processing of dairy products. J Dairy Sci 96:3671-81.

Ritschard JS, Schuppler M, 2024. The microbial diversity on the surface of smear-ripened cheeses and its impact on cheese quality and safety. Foods 13:214.

Table 1.Hygiene and safety of bovine milk tested for total plate count, somatic cell count, antibiotic residues, and *Clostridium* spp. load across tested farms before and after intervention.

Farm ID	Pre-treatment raw milk quality (log$_{10}$cfu/mL)			Post-treatment milk quality (log$_{10}$cfu/mL)		Antibiotic residues screening[4]	Quantification of *Clostridium* spp. spores (>10 cfu/mL)[5]
	TPC[1]	SCC[2]	*Clostridium spp.* spores[3]	Geometric mean of TPC	Geometric mean of SCC		
Farmer 1	6.11	5.6	2.23	7	5.6	β-lactams (1/7)	0/7 samples positive
Farmer 2	6.23	5.32	4.3	5.3	4.9	Not detected (0/7)	0/7 samples positive
Farmer 3	7.9	5.04	2.04	5.5	5.1	Not detected (0/7)	2/7 samples positive (40 cfu/mL)
Farmer 4	6.43	5.04	3.6	5.4	5.3	Not detected (0/7)	1/7 samples positive (610 cfu/mL)
Farmer 5	6.4	5.65	2.3	4.9	5.0	Not detected (0/7)	0/7 samples positive

TPC, total plate count; SCC, somatic cell count. [1]TPC status: all pre-treatment TPC values were above common regulatory thresholds (*e.g.*, >5.0 log$_{10}$ cfu/mL), except Farm 5 during post-treatment. [2]SCC status: all SCC values were within acceptable limits for raw milk (*e.g.*, <5.80 log$_{10}$ cells/mL for European Union standards). [3]*Clostridium* spores: spore count before any treatment. [4]Screening: targeted β-lactams, tetracyclines, and cefalexins. "Not detected" indicates no residues found above the detection limit. [5]Prevalence: the number of samples (out of 7 samples per farm) where *Clostridium* spp. spores were quantified at levels >10 cfu/mL. The maximum quantified concentration is indicated in parentheses for positive results. In this table results geometric mean during post treatment was calculated by excluding non – comply milk. Thus milk with presence of antibiotics, spoiled milk and milk with added water were not taken in consideration.

Table 2.Pearson correlation coefficients among milk composition, hygiene indicators and California Mastitis Testscore.

Variable	Fat	SNF	Density	Protein	Lactose	log$_{10}$(TPC)	log$_{10}$(SCC)	Sum CMT Score
Fat	—							
SNF	.66***	—						
Density	.54***	.99***	—					
Protein	.66***	1.00***	.99***	—				
Lactose	.66***	1.00***	.99***	1.00***	—			
log$_{10}$(TPC)	-.05*	.42***	.48***	.43***	.42***	—		
log$_{10}$(SCC)	.27***	.54***	.55***	.54***	.54***	.66***	—	
Sum CMT Score	-.08***	-.09***	-.08***	-.09***	-.09***	-.09***	-.13***	—

TPC, total plate count; SCC, somatic cell count; CMT, California Mastitis Test. ***$p<0.001$; **$p<0.01$; $p<0.05$. Only the lower triangle of the symmetric matrix is shown for clarity.

Table 3. Analysis of variance for log$_{10}$(total plate count) and log$_{10}$(somatic cell count) by California Mastitis Test score.

Dependent Variable	Source	Degrees of Freedom (Df)	Sum of Squares (Sum Sq)	Mean Square (Mean Sq)	F. value	p
log$_{10}$**(TPC)**	Factor (Sum_CMT_Score)	3	21.680	7.227	9.816	< 0.05
	Residuals	2016	1484.189	0.736	—	—
log$_{10}$**(SCC)**	Factor (Sum_CMT_Score)	3	11.132	3.711	31.454	< 0.05
	Residuals	2016	237.816	0.118	—	—

TPC, total plate count; SCC, somatic cell count; CMT, California Mastitis Test. p-values are reported at a significance level of $\alpha = 0.05$. Sum of squares and mean square values are rounded to three decimal places for clarity. The original p-value for log$_{10}$(SCC) was "0" and is reported here as <0.05.

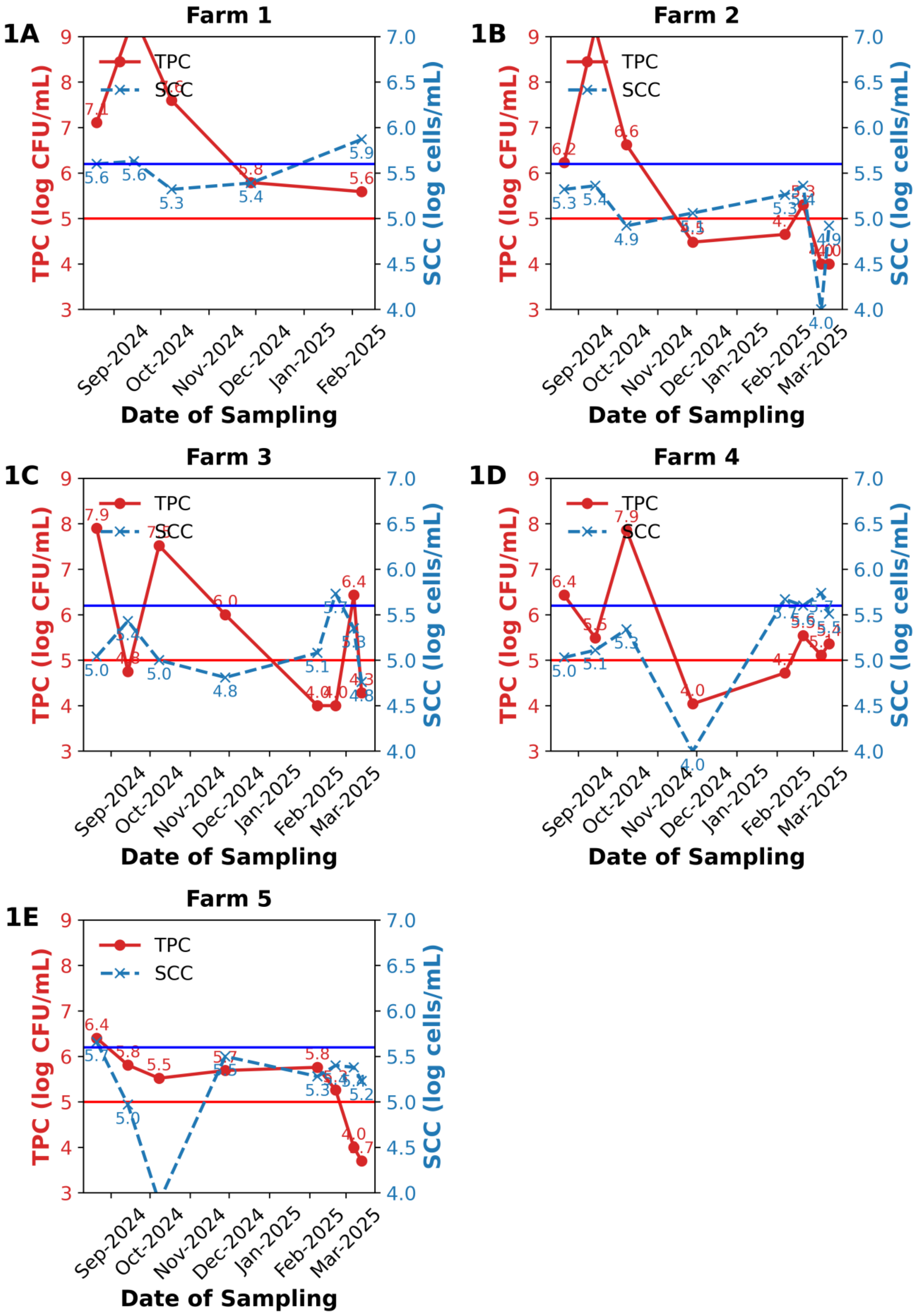

Figure 1. (A-E) Monitoring changes in total plate count (TPC) and somatic cell count (SCC) in bulk tank milk following hygiene interventions in five farms from August 2024 till March 2025 (first result in the plot indicate day zero or "no treatment").

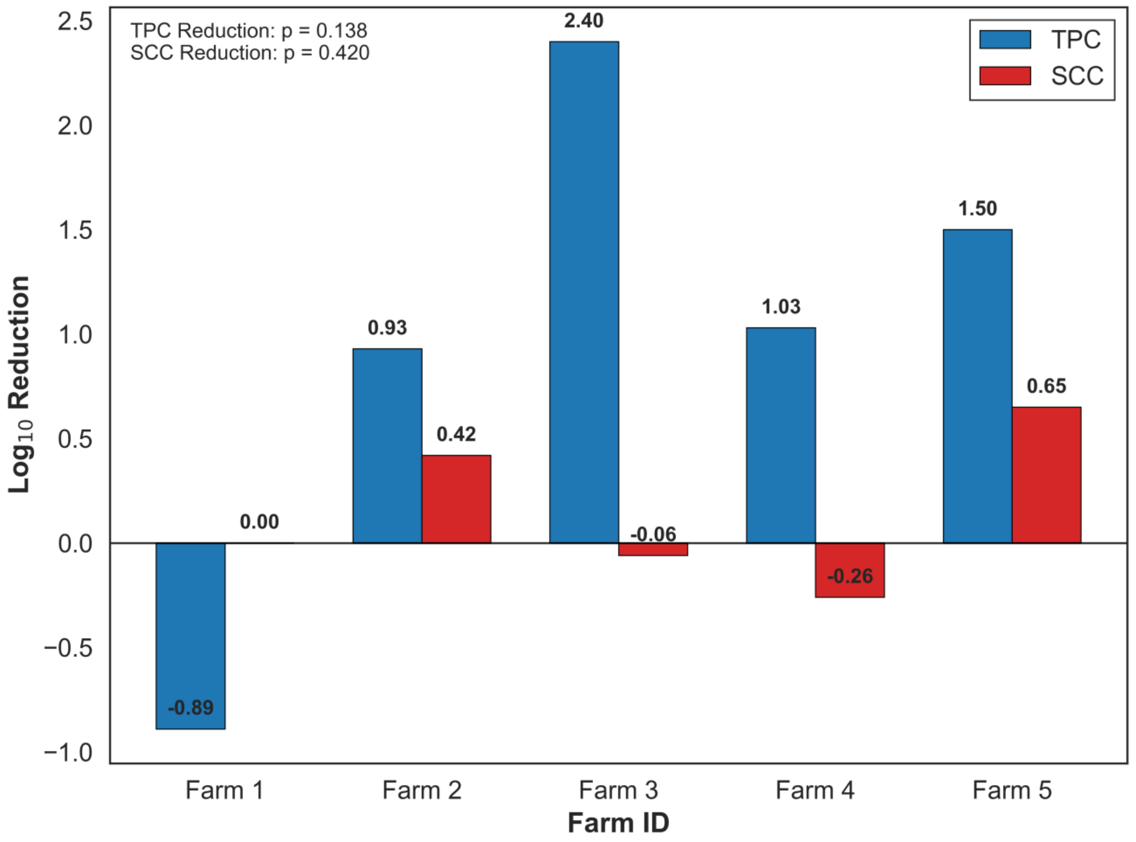

Figure 2. Bar plot showing treatment efficacy reduction of total plate count (TPC) $\log_{10}$cfu/mL and somatic cell count (SCC) $\log_{10}$ cell/mL (positive values indicate effective reduction).