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COMPARATIVE ANALYSIS OF MILK QUALITY PARAMATERS IN DAIRY FARMS FROM TRANSYLVANIA, ROMANIA

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Abstract

Milk quality, including physicochemical and microbiological parameters, is an essential element to increase the value of dairy products. Within the European Union, milk producers are incentivized to enhance these qualitative parameters by establishing solid standards and differentiated compensation systems. This study aims to present a comparative analysis of key milk quality parameters in dairy farms from Transylvania, Romania, between 2023 and 2025. For the scope of the study, four groups of farms, grouped by herd size, were assessed for milk physicochemical and microbiological indicators - fat, protein, density, total dry matter, lactose, somatic cell count, and total germ count. Data analysis included comparisons with Romanian national averages, EU averages, and top-performing EU countries (e.g., France, Germany), considering milk production volumes and predominant cattle breeds. The analysis revealed variations in milk quality parameters across farm groups, with differences influenced by herd size and breed composition. Comparative results highlighted areas where Transylvanian farms close in or diverge from national and EU benchmarks. The findings underscore opportunities for targeted improvements in milk quality among dairy farms in Transylvania. Implementing specific technical measures and adhering to sustainable milk quality standards could enhance raw milk valuation and increase processing yields on long-term, implicitly the farmers revenues.

Key words: *competitiveness, microbiology, measure, milk quality, physicochemical.*

INTRODUCTION

The physicochemical and microbiological quality of cow milk represent essential milk parameters with direct impact in the competitiveness of milk valorisation, especially considering the focus of European Union (EU) farmers to reduce the number of cows and to increase the production level and efficiency of milk production per cow, implicitly the level of revenues vs. costs, the resulting profitability per animal and overall exploitation.

The objective was to obtain representative conclusions concerning the dynamics of milk production level and milk quality parameters performance per group of farms pursuant to a detailed evaluation of the evolution for the period 2023-2025 of the most important technical indicators of cow milk production to the four groups of cow milk farms from Transylvania - Romania, grouped accordingly to the number of animals per farm; the results per group were compared among the evaluated groups and also with the performance level of similar indicators at Romanian (RO) and EU average and vs. top EU cow milk production performers, France (FR), Germany (DE) and Poland (PL). All the conclusions will support, as further steps of doctoral thesis in preparation, the development of specific technical and commercial farms management models per each group of farms and will be focused on the aspects mentioned above. Considering the importance of cow milk production performance, quantity and quality, the topic was addressed also in other countries, with focus on the impact of different factors of influence (e.g. breed, nutrition, physiology) in the milk production performance (Fiorillo & Amico, 2024; Duguma, 2021).

MATERIALS AND METHODS

Locations, period of research, main parameters evaluated

For the complete period 2023-2025 (at monthly and yearly level) the dynamics of core physics-chemical and microbiological milk quality indicators - fat, protein, density, total dry matter, lactose, somatic cells number, total number of germs - for four groups of cow milk farms from Transylvania (RO) was analysed. The evolution of milk quality parameters for all the groups was studied also in the relation to average milk production per cow for each group and in relation with the structure of cattle herds per each group for the same period 2023-2025. The groups were built considering the total number of cattle, out of which cows in lactations, cows in mammary rest and heifers; Group 50 - 100 cattle, Group 100 - 200 cattle, Group 200 - 300 cattle and Group +300 animals. Each group (lot) includes 8 farms. Simultaneously all the analysed indicators were evaluated in comparison with the first four groups for a fifth group which includes all 32 farms (Group Total). Concerning the breeds structure, at Group Total level, the predominant breed is Romanian Spotted Cattle (80% share), Holstein (15% share) and Montbeliard (5% share from total cumulated herd). Split per groups, Romanian Spotted Cattle has a minimal share of 73% (Group +300) and a maximal share of 99% (Group 50 - 100), Holstein with a share between 1% (Group 50 - 100) and 20% (Group +300) and Montbeliard from 0% to 7% (Group +300), with an increasing share for Holstein and Montbeliard as the group size is higher.

The laboratories used for determining all the analysed parameters of milk are the processor's certified factory laboratory and the Milk Quality Control Foundation from Cluj- Napoca.

Processing and statistical analysis of data

The experimental data collected were subjected to statistical analysis using Statistical Package SPSS software, version 20 (2011). To assess the influence of variation factors on milk production and quality parameters, Anova Multifactorial was applied. The main variation factors included in the model were group size and the year.

For the detection of significant differences among group averages, after achieving the overall effects through GLM (Multivariate general linear model), post-hoc multiple comparison tests were performed - Tukey test and LSD (Least Significant Difference) test. The Tukey test was performed for or the assessment of differences between the pairs, reducing the risk of errors. The LSD test allowed to underline more sensitive differences between groups when the main effect was significant. The results were stated as averages ± standard error, statistical differences considered significant at p 0.05. The dependent variables analysed included milk production level per cow per cow and the physics – chemical milk content: percentages of fat, protein, lactose, total dry matter (TDM), milk density.

As mentioned above, the evolution of each farm group focus on each criterion was studied for 2023, 2024, 2025 and as a comparison among the four groups; implicitly, for the fifth group which included the cattle from all 32 farms, the weighted average results per parameter were compared with the results of similar criteria from all 4 groups. For having representative conclusions, the group results were put in the balance with Romanian national average, European Union (28) average also vs. the national averages of the countries with high results on cow milk production (DE, FR, PL).

The main conclusions were presented, split per each evaluated criterion and focused on every group. Together with recommendations, they could consolidate the specific milk production quality performance of all studied 4 groups of cow milk farms from Transylvania. The primary data evaluated from all 32 cow milk farms (grouped in the mentioned 4 groups and Group total) are the results of own doctoral research, while the national and EU averages constitute public data.

The evaluated farms are independent specialised farms, organized as legal entities, with a mix of family farms and farms with permanent and temporary employees; the cow raising technology is based on free-range housing and the milking is carried out in milking parlors (with a higher degree of automation corresponding to a higher farm size). All the farms are sanitary -veterinary authorized and are included in all the national control programs.

RESULTS AND DISCUSSIONS

For each criterion and group of farms, a Grubbs Test was performed to identify eventual outliers that must be taken out from the group structure. The G critical value identified for n=8 (8 farms per group (lot)) and α equal with 0.05 was 2.126. All the G calculated values were below G critical value and implicitly all the farms from all the groups (for all evaluated criteria) were kept in the designed group structure (e.g. examples of G calculated value for the parameter of milk fat for each group and for 2023: 1.9211 for the Group +300 cattle, 1.4297 for the Group 200 - 300, 1.3395 for the Group 100 - 200, 1.4975 for the Group 50 - 100 cattle, all of them below the G critical value of 2.126 already mentioned). The results and conclusions of the statistical tests are presented within the article in relation to each criteria analysed.

2023-2025 average yearly milk production/ cow and dynamics of cattle herds

For 2023-2025 **the yearly average cow milk production** for all 32 farms (Group Total) registered a slow increase of 0.97% (2025 vs 2023) with a relative stagnation in 2024 vs 2023 of -0.07%; the total number of cattle increased with 5.23% in 2025 vs 2023 and with an intermediary increase of 2.82% in 2024 vs 2023. At the same time, analysing the dynamics of herds structure, it could be underlined that the share of total cows in lactation decreased in 2025 vs 2023 to 41% from 43% and the share of cows in lactation plus heifers decreased to 59% from 60% (as shares from total herd). As split per groups, the Group 200 - 300 registered an important increase of 9.38% in 2025 vs 2023, while the rest of the groups registered negative development (2025 vs 2023) of yearly milk production per cow: -0.77% for Group +300, -1.96% for Group 100 - 200 and -5.07% for Group 50 - 100 cattle. For all the groups (except Group 50 - 100 where the share of cows in lactation increased in 2025 to 47% from 45% in 2023) the shares of cows in lactation decreased with ~1 percentage point (pp). The share of cows in lactation plus heifers decreased in 2025 vs 2023 to 53% from 56% for Group +300, while for the rest of the groups the share is increasing with ~1 pp for Group 200 - 300 and Group 100 - 200 (to 63% from 62%) and with 2 pp at Group 50 - 100 (to 71% from 69%). As a preliminary statement, it could be pre-concluded that for Group Total the yearly milk production per cow registered an increase of 1% in 2025 vs 2023 (6,788 kg from 6,723 kg, with Romanian Spotted Cattle as majority breed - 80% share in the Group total) - even if the share of cows in lactation and cows in lactation plus heifers decreased for each category with ~ 1 pp for the same period. These yearly production levels were above the level of 5,907-5,868 kg per lactation every year, as registered for Romanian Spotted Cattle included in Official Production Control between 2013-2021 (Romanian Breeding Society ACVBR-SIM, Romanian Spotted Cattle Breed Breeding Program, 2025). We may underline the high focus of all evaluated Groups for a stable category share of cows in lactation and also combined with specific effective management practices for a stable or positive development of category share of cows in lactation and heifers– as an anchor to secure the stability of quantitative milk production per farm and the level of revenues, even if the value performance/cow is highly dependent by the received price per kilogram of milk sold for processing. The development of 2023-2025 yearly milk production/cow as a comparison among the groups is presented in the Figure 1.

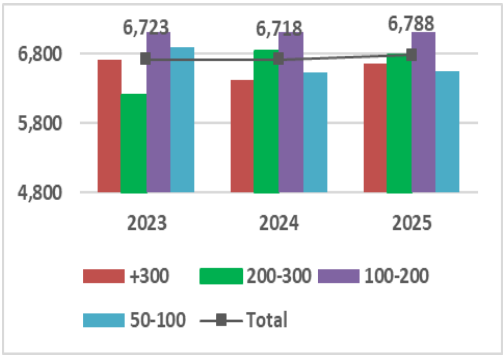

Figure 1. 2023-2025 yearly milk production/cow (kg)

For a much higher representativity, the above data were compared with the yearly average performance in RO and EU and compared to average national performance of DE, FR and PL. The performance of all groups is much higher than RO national average, in 2025 for Group Total with +79.58%, and with a

maximum of +91.74% for Group 100 - 200 and with a minimum of +73.21% for the Group 50 - 100 cattle.

At the same time, it's known that Romania owns the highest share in EU of agricultural exploitations below 2 cattle (~67%) and between 2 and 9 heads (~30%) (Maxim et al., 2025) - which means that more than 95% of RO agricultural exploitations number are just for subsistence and practically without chance to be economically feasible. Implicitly, all these very small exploitations are decreasing significantly RO average of yearly milk production per cow, national average being a very low one in the EU (National Institute of Statistics - Romania, 2025, Animal production. Eurostat, 2025, Milk and milk products, retrieved from https://ec.europa.eu/eurostat/ databrowser/ explore/all/alltheme; SectionAgriculture/ Agriculturalproduction; Dracea, 2020).

As effect, it is more relevant to compare the performance of all the groups with EU average and the countries mentioned above considering that in EU, in average, ~94% of total milk production is sold for processing - compared to RO where the share is below 35% (The National Institute of Statistics of Romania, 2025, Animal production. Eurostat, 2025, Milk and milk products, retrieved from https:/ec.europa.eu/ /eurostat/databrowser/explore/all/alltheme; SectionAgriculture/Agriculturalproduction).

For 2025, the yearly milk production of Group Total represented 82.36% (6,788 kg milk) from EU average (8,242 kg), in a decreasing trend, from 86.18% in 2023; the reason is the higher pace of yearly milk production/ cow increase in EU of 5.6 pp in 2025 vs 2023 (8,242 kg vs 7,800 kg) comparing just +0.97% in 2025 vs 2023 for the Group Total. Analysing per each group, the highest 2025 performance had the Group 100 - 200 cattle where the share of yearly milk production/cow from EU average was 87.93% and the lowest was at Group 50 - 100 cattle with a share of 79.44% from EU average (Eurostat, 2026, Milk and milk products statistics, retrieved from https:// ec.europa .eu/ euro stat/statistics-explained/index.php?title=Milk _and_milk_product_statistics#Data_sources).

Considering that from the analysed countries, only Poland has a performance below EU average - but showing significant efforts to increase the yearly rhythm to reduce the gap - it is obvious that the negative difference in performance vs all these countries is even higher. This evaluation was especially relevant in the context Romania is EU member and implicitly the Romanian farmers are part of the same EU milk market, implying raw material, fat and protein milk constituents, dairy products – therefore milk could travel without trade barriers within EU and the transport cost per unit of fat or per unit of protein is less and less a barrier if we discuss about transportation of concentrated milk or dairy products with a high content of dry matter, such as cheese, milk powder, butter or even cream. Additionally, these aspects underline not only the high importance of milk quantity performance/ cow but also the high contribution in revenues performance of a stronger fat and protein milk raw material content – issues that will be addressed further. Based on the GLM test, average milk production/cow was highly significantly influenced by farm size category (p<0.001). Although the peak of production was observed in 2024 within the 100-200 group, the temporal factor did not exert a statistically significant effect on overall yields. Specifically, LSD post-hoc analysis revealed significant differences between the 50-100 group and all other categories: 100-200 (p=0.012), 200-300 (p=0.001), and >300 (p<0.001). Furthermore, highly significant differences were identified between the 100-200 and >300 groups (p<0.0001), as well as between the 200-300 and >300 group (p<0.001). The 2023-2025 group performance comparison vs RO, EU and vs DE, FR and PL averages it's presented in Figure 2.



Figure 2. 2023-2025 yearly milk production/cow and group compared with RO, EU, DE, FR and PL (kg)

2023-2025 dynamics of physics - chemical milk quality parameters

The **fat and protein milk content** are considered essential milk parameters with a direct impact in the processing yields into dairy products; both milk farmers and processors, have a high focus to continuously improve the milk content in fat and protein; at EU level different standards exist concerning the minimal fat and protein milk content versus the basic milk price paid by the processors to the farms and also bonification and malus systems for these two parameters could be agreed between the two parts as part of their direct milk selling/purchasing contract. During 2023-2025, the **milk fat content** registered a continuous yearly increase for all 4 groups. Implicitly for the Group Total the fat content raised from a level of 3.84% in 2023 to 3.96% in 2025, with an intermediary increase to 3.88% in 2024; the weighted average fat content for the entire period is 3.89% and with a standard deviation of 0.043. The highest fat content of 3.94% (standard deviation of 0.077) had the Group 50 - 100 cattle, followed by Group +300 with 3.91% (standard deviation of 0.068) and Group 100 - 200 with 3.88% fat (standard deviation of 0.034); the lowest fat of 3.84% (standard deviation of 0.044) was registered at Group 200 - 300 - but which also had the highest yearly milk production/cow increase of 9.83% for the same period 2023- 2025. The highest rhythm of 0.19 pp to increase the fat percentage was revealed at Group 50 -100, from 3.85% in 2023 to 4.04% in 2025, while the lowest increasing rhythm of fat content of 0.02 pp had the Group 50 - 100, from 3.86% in 2023 to 3.88% in 2025. A Multivariate General Linear Model (GLM) revealed that size group exerted a significant influence on fat composition (p=0.045). Specifically, Fisher's Least Significant Difference (LSD) post-hoc analysis indicated significant variances between the 50-100 and 100-200 groups (p=0.022), as well as between the 50-100 and 200-300 groups (p=0.014). Conversely, the year of sampling did not yield a statistically significant effect on milk fat levels. The evolution of fat content/group/year and compared to performance of Group Total is described in Figure 3.

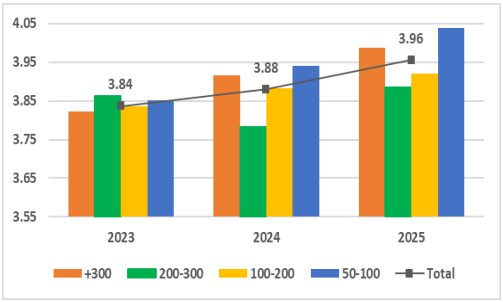

Figure 3. 2023-2025 yearly milk fat content dynamic compared among the four groups and Group Total (%)

Similarly to the criteria of yearly milk production/cow, for having a more relevant conclusion, the results concerning milk fat content dynamic were compared with the yearly average performance in Romania (RO) and European Union (EU) and with average national performance of DE, FR and PL. The performance of all groups is higher than RO national average during the period 2023-2025, except 2024 when the Group Total performance was below - at 3.88% vs 3.90% fat; implicitly, there were two groups with the fat content lower than RO average (Group 200 - 300 at 3.77% fat and Group 100 - 200 at 3.88% fat). Overall, all the groups had a fat content below EU average, even lower than Poland (which is still under EU average) and consistently below Germany and France which both performed still below EU average (CLAL, 2026, EU milk fat supply 2023-2025, retrieved from https://www.clal.it/en/?section=milkfat_supply_eu).

It is relevant that the pace of fat content rhythm of increase is higher between 2023 and 2025 for the analysed groups (e.g. 014 pp for the Group Total and the highest rhythm of 0.19 pp Group 50 - 100) vs EU total rhythm of 0.04 pp.

In absolute values, in 2025 The Group Total fat content was 3.96% with the highest fat content of 4.04 % for the Group 50-100 vs RO average of 3.8%, Poland 4.07%, France and Germany at 4.10% and EU average of 4.16%. Overall, these are encouraging results which underline the high investments the milk farms analyzed did during last years to enhance their milk quality performance to be more competitive vs the EU high milk quality performance already in place. The yearly evolution of fat content/ group and compared to yearly average performance of RO, EU, PL, DE and FR is presented in Figure 4.



Figure 4. 2023-2025 yearly milk fat content /group compared with RO, EU, DE, FR and PL (%)

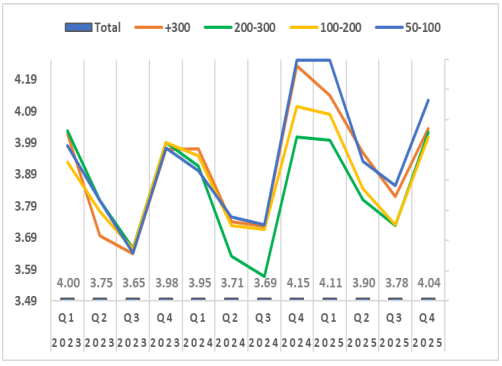

Figure 5. 2023-2025 quarterly milk fat content /group compared with RO, EU, DE, FR and PL (%)

Considering that the demand for fat is not constant during the year, traditionally a higher demand during winter and lower during summer, but still with a high unpredictability during last years at international and EU level due to changes in consumers behaviors trend and due to international political and trade regulation changes, the curve of fat content seasonality during the year was also studied for all 32 farms grouped in the mentioned 4 groups and Group Total. The trend of seasonality is the same for all the groups with higher fat content in winter and lower in summer and with a highest fat content of 4.25% and an amplitude of seasonality of 0.21 pp at the Group 50 - 100 cattle and lower seasonality for the rest of the groups - the lowest fat content and lowest deviations between seasons at Group 200 - 300 cattle. As Group Total, the amplitude of deviations vs the yearly average was for summer [(quarter) Q2 & Q3] between 0.17…0.19 pp and between 0.15…0.27 pp for winter (Q4 & Q1). This evolution could have a positive effect for both farmers and processors as the demand for fat, to be processed in dairy products such as cream, butter, other categories, is structurally higher for winter when also the peak of fat content was met to all four groups studied. The 2023-2025 evolution of fat content per quarter and group compared to quarterly average fat content of Group Total is presented in Figure 5.

During 2023-2025 the **milk protein content** registered a continuous yearly increase for all 4 groups. Implicitly for the Group Total the protein content raised from a level of 3.44% in 2023 to 3.51% in 2025, with an intermediary increase to 3.47% in 2024; the weighted average protein content for the entire period is 3.48% and with a standard deviation of 0.073.

The highest protein content of 3.53% (standard deviation of 0.034) had the Group +300 cattle, followed by Group 50 - 100 with 3.51% (standard deviation of 0.074) and the Group 200 - 300 with 3.45% protein (standard deviation of 0.040); the lowest protein of 3.37% (standard deviation of 0.026) was registered at Group 100 - 200 – but, as mentioned above, which also had the highest yearly milk production/cow increase of 9.83% for the same period 2023-2025. The highest rhythm of 0.14 pp to increase the protein percentage was revealed at Group 50-100, from 3.42% in 2023 to 3.56% in 2025, while the lowest increasing rhythm of protein content of 0.06 pp had the Group 100 - 200, from 3.34% in 2023 to 3.40% in 2025.

Although the highest protein values were recorded in 2025, the year of sampling did not exert a statistically significant influence on protein composition. In contrast, farm size was found to have a highly significant effect (p=0.001). Except for the comparison between the 50 - 100 and 200 - 300 groups, Fisher's Least Significant Difference (LSD) post-hoc tests revealed significant variances between the 100 - 200 and 200 - 300 groups (p=0.05). Furthermore, high levels of significance were observed between the 50 - 100 and 100 - 200 groups (p=0.001) and between the 100 - 200 and +300 groups (p<0.0001). The yearly evolution of protein content split per group and compared to the yearly average performance of Group Total is described below in Figure 6.

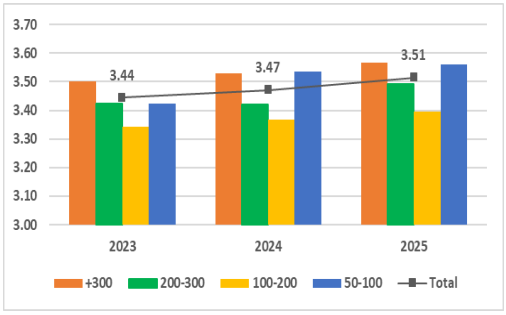

Figure 6. 2023-2025 yearly milk protein content dynamic among the four groups and Group Total (%)

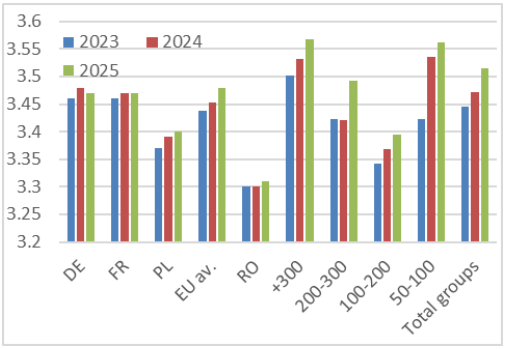

Figure 7. 2023-2025 yearly milk protein content /group compared with RO, EU, DE, FR and PL (%)

Similarly to the criteria of yearly milk production/cow, for more relevant conclusions, the milk protein dynamic was compared with the yearly average performance in Romania and European Union and vs the average national performance of DE, FR and PL.

The performance of all groups is significantly Above RO national average for the period 2023-2025. Overall, all groups had a yearly protein content above EU average, and even higher than Polish national average performance, which is still under EU average, and Germany and France national averages (which performed close to EU average) (CLAL, 2026, EU milk protein supply 2023-2025, retrieved from http://www.clal.it/en/?section=milkprotein_supply.eu).

The pace of protein content increasing rhythm is higher between 2023 and 2025 for the analysed groups, e.g. 0.07 pp for Group Total and the highest rhythm of 0.14 pp for Group 50 - 100), vs EU rhythm of 0.04 pp. In absolute values, in 2025 The Group Total protein content was 3.51% with the highest fat content of 3.56 % for the Group +300 vs RO average of 3.31%, Poland 3.40%, France and Germany at 3.47 and EU average of 3.48%.

Even if the comparison of group results was made vs national or EU averages, the groups protein content results, together with the fat milk content development, underline the high focus of all evaluated milk farms from all four groups to continuously increase their milk quality performance – as a strong need for to be able to compete with the milk quality available on the EU milk market.

The yearly evolution of protein content split per group and compared to the yearly average performance of RO, EU, PL, DE and FR is presented in Figure 7.

Similarly to fat, the curve of protein content seasonality was also studied for 2023 - 2025 for all 32 farms per the 4 groups and as Group Total. The trend of seasonality is the same for all the groups with higher protein content in winter and lower in summer. The highest protein content/ quarter of 3.72% and an amplitude of seasonality of 0.18 pp had the Group +300 cattle and with a lower seasonality and amplitude of quarterly protein content for the rest of the groups - the lowest fat content and lowest deviations between seasons at Group 100 - 200 cattle. As Group Total, the amplitude of deviations vs the yearly average was for summer season (Q2 & Q3) between 0.07…0.10 pp and between 0.10…0.18 pp for winter (Q4 & Q1). Similarly to fat, this development has a synergic effect for farmers (in terms of revenues per kg of milk) and for processors (concerning the production yields) as the demand for protein (to be transformed in dairy products – e.g. cottage, natural cheese) is structurally higher for winter when also the peak of protein content was registered to all four groups of farms analyzed. The variables of year, group size, and quarter exerted a highly significant influence on the observed outcomes, respective milk quantity, fat and protein level ($P<0.0001$). Regarding temporal variations, while milk yield and protein content exhibited highly significant fluctuations across years, fat percentage remained stable between 2023 and 2024. However, fat content differed highly significantly when comparing 2023-2025 and 2024-2025 ($P<0.0001$). Group size also significantly impacted yield, fat, and protein levels ($P<0.0001$). Specifically, LSD post-hoc analysis revealed highly significant differences

(P<0.01) between the following group size: 50 - 100 vs. 100 - 200, 50 - 100 vs. 200 - 300, and 200 - 300 vs. +300. Seasonality, analyzed by quarter (Q), showed that milk quantity in Q2 was significantly different from Q1, Q3, and Q4 (P<0.0001). Furthermore, the LSD test indicated highly significant variances in fat levels across all quarters, except for the Q1 vs. Q4 comparison. Similarly, protein levels differed significantly between all quarters, except for the comparison between Q2 and Q3.

The average fat content and protein content for Group Total (for fat from 3.84% in 2023 to 3.96% in 2025 and for protein from 3.44% in 2023 to 3.51% in 2025) are below the maximal level of 4.02% fat registered in 2013 and respectively significantly higher than the maximal milk protein content of 3.29% registered in 2020 by the Romanian Spotted Cattle included in the Official Production Control (OPC) between 2013 and 2021, (Romanian Breeding Society ACVBR- SIM, Romanian Spotted Cattle Breed Breeding Program, 2025). The data mentioned above (referring to the Official Production Control 2013-2021, Romanian Spotted Cattle) are superior vs the result of OPC from 1994 when the fat content was 3.85…3.95% and the average milk production per cow was between 4,345…5,388 kg (Dinescu & Tontsch, 2005). This development expressed the farmers' focus to increase the milk production per animal, even in the detriment of fat content, in order to increase the revenues per cow (based on an increased milk quantity per animal); this trend has the disadvantage of lower fat supply and availability in the context of an international higher demand for milk fat.

The evolution of protein content per quarter during 2023 and 2025 and split per group and compared to the quarterly average of Group Total is presented in Figure 8.

During 2023-2025 the **milk lactose content** evaluated to all 4 groups registered value in the normal range of cow milk content of 3.6%...5.5% and closer every year to the mean of ~5% (FAO, Gateway to dairy production and products, 2026, retrieved from https://www.fao.org/dairy-production-products/products/milk-composition/en). Except 2024, when lactose content had 0.1 pp decrease vs 2023 (from 4.65% to 4.64% at Group Total - a decrease which come from Group +300 (0.1 pp from 4.65 to 4.64%) and Group 200 - 300 (0.2 pp from 4.66 to 4.64%), the lactose content yearly raised for all the groups. Implicitly for the Group Total the lactose content grew overall (2025 vs 2023) from a level of 4.65% in 2023 to 4.69% in 2025; the weighted average lactose content for the entire period is 4.66% and with a standard deviation of 0.022.

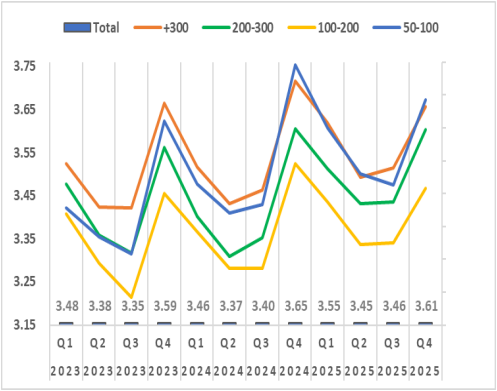

Figure 8. 2023-2025 quarterly milk protein content/ group compared with RO, EU, DE, FR and PL (%)

The peak of lactose content was reached in 2025 for all the groups, while the Group 50 - 100 cattle had the highest value of 4.74% (standard deviation of 0.044), followed by Group 200 -300 with 4.72% (standard deviation of 0.041) and the Group +300 with 4.68% lactose (standard deviation of 0.020); the lowest lactose level of 4.65% (standard deviation of 0.009) was registered at Group 100 - 200, which performed the best concerning yearly milk production/cow (an increase of 9.83% for the same period 2023-2025). The highest rhythm of 0.08 pp of increase of the lactose percentage was revealed at Group 50 - 100, from 4.66% in 2023 to 4.74% in 2025, while the lowest increasing rhythm of protein content of 0.02 pp had the Group 100 - 200, from 4.63% in 2023 to 4.65% in 2025. Relating the results of statistical tests, neither the sampling year nor the farm size category exerted a statistically significant influence on lactose concentration (p>0.05). As an overview, we may consider that all the groups secured positive trends for the dynamic of this indicator, as a positive effect of effective management practices of feed ratio (energy deficit avoided) and of the lactation curve end for their cows in

lactation. The yearly evolution of lactose content/group compared to average performance of Group Total is described in Figure 9.

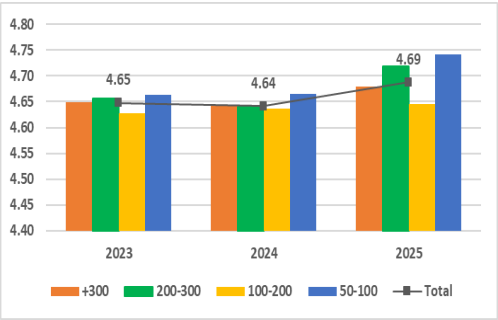

Figure 9. 2023-2025 yearly milk lactose content dynamic among the four groups and Group Total (%)

Between 2023-2025 the studied **milk total dry matter (TDM)** at Group Total and the 4 groups (except Group 200 - 300 in 2024 with a decrease of 0.07 pp from 12.54 to 12.47%) registered a consistent increasing trend. For Group Total the total dry matter content increased from 12.54% in 2023 to 12.75% in 2025 with a pace of 0.07 pp in 2024 and a double pace of 0.14 pp in 2025 (vs previous year); the weighted average TDM content for the entire period is 12.63% and with a standard deviation of 0.111. Considering the increasing trend for all the major milk components (with highest values in 2025) also the highest content of TDM was reached in 2025 to all four groups; highest value of 12.73% (standard deviation of 0.201) at Group 50 - 100 cattle, followed by Group +300 with 12.70% (standard deviation of 0.123) and the Group 200 - 300 with 12.57% TDM (standard deviation of 0.116); the lowest rate of 12.50% (standard deviation of 0.007) was registered at Group 100 - 200. As expected, the highest rhythm of 0.40 pp to increase TDM percentage was registered at Group 50 -100, from 12.53% in 2023 to 12.93% in 2025 - as they also registered the highest yearly increasing rhythm for fat and the second highest for protein. The lowest increasing rhythm of TDM of 0.14 pp had the Group 100 - 200, from 12.43% in 2023 to 12.57% in 2025 - figures which have to be analyzed in the relation to the fact that this group had the highest milk production per cow performance, at the average level 2023-2025 of 7,357 kg, +9.1% vs Group Total average of 6,743 kg/cow.

Relating the results of statistical tests, Total Dry Matter (TDM) was significantly influenced by both the sampling year (p=0.037) and farm size category (p=0.05). According to the LSD post-hoc test, significant differences regarding farm size were observed between the 50-100 and 100-200 groups (p=0.002), the 50-100 and 200-300 groups (P=0.02), and the 100-200 and +300 groups (p=0.008). Furthermore, regarding the year factor, a significant influence was identified between 2023-2025 (p=0.011).

We can pre-conclude that all the groups also expressed a consistent positive development for this indicator, as a positive consequence of the important growth for all main components part of TDM, focus on fat, protein also lactose. The yearly evolution of TDM per group and compared to the yearly average performance of Group Total is described below in Figure 10.

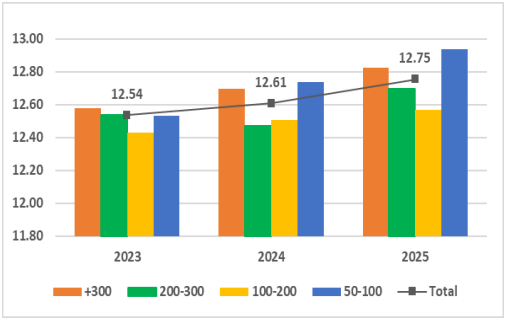

Figure 10. 2023-2025 yearly milk Total Dry Matter dynamic among the four groups and Group Total (%)

For the period of 2023-2025 the milk density showed values in the proximity of average mean for cow milk density of 1.030 g/ml (measured at 20 Celsius degrees) (Agriculture-Institute, 2023, Milk production and milk quality, retrieved from https://agriculture.institute/milk-production-and-quality/density-specific-gravity-of-milk). The Group Total and all 4 groups (except Group 200 - 300 in 2024 with a decrease from 1.0298 in 2023 to 1.0297 of 0.07) registered a stationary or increasing yearly results For Group Total the density from 1.0298 in 2023 to 1.0302 in 2025 with an unchanged 2024 performance vs 2023; the weighted average density for the entire period is 1.0299 and with a standard deviation of 0.0003.

Considering the important increasing fat content for the entire 2023-2025 maintaining and slowly increasing of the milk density it is an appreciated

result which emphasizes the stability and very well managed milk production process in the farms. The highest density (all in 2025) of 1.0304 g/ml (standard deviation of 0.0003) was recorded at Group 50 - 100 and Group 200 - 300 cattle, followed by Group +300 with 1.0303 g/ml (standard deviation of 0.0002); the lowest density of 1.0297 g/ml (standard deviation of 0.0002) was registered at Group 100 - 200.

The highest rhythm of ~0.0007 g/ml (for the entire period 2023-2025) to increase density was registered at Group 200 - 300, from 1.0298 g/ml in 2023 to 1.0304 g/ml in 2025 - as they also registered (together with Group 50 - 100 cattle) the highest density.

The lowest increasing rhythm of TDM of 0.0003 g/ml had the Group +300 and the Group 100 - 200 up to the 2025 level of 1.03033 and 1.0297 g/ml. Regarding the statistical test results, neither the sampling year nor the farm size category exerted a statistically significant influence on milk density (p>0.05).

The yearly evolution of density per group and compared to the yearly average performance of Group Total is described below in Figure 11.

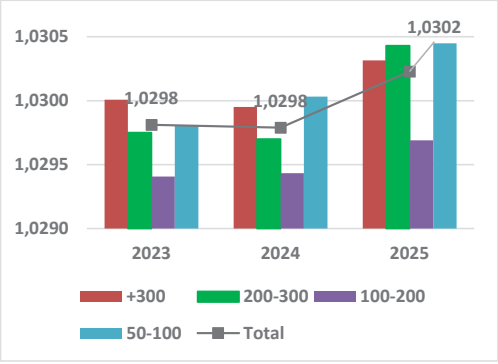

Figure 11. 2023 - 2025 yearly milk density dynamic among the four groups and Group Total (%)

The maximal limits concerning **total bacteria count (TBC) and somatic cells count (SCC)** in the cow milk are transparently expressed in the EU regulation – specifically in the Regulation (EC) No. 853/2004 of the European Parliament and of the European Council of 29 April 2004.

For TBC the limit is maximum 100,000 cfu/ml of milk and calculated as geometrical average of last two months with minimum 2 samples per month. For SCC the maximum limit is 400,000 cells/ml of milk and calculated as geometrical average of last three months with minimum 1sample per month. As the TBC parameter is an indicator of hygiene level of milking process and raw milk storage equipment and the SCC, it reflects the level of mammary gland health, both with direct effects on milk production quantity and quality. On top of being a legal duty according to Regulation (EC) No. 853/2004, all farmers already have in place established measures throughout the entire milk farm processes to reduce as much as possible these values, significantly lower than legal maximal limits.

For all evaluated four groups, both indicators (TBC and SCC) are at a very good level and consistently below the maximal limits, underlining the farmers strong efforts for a high efficiency also for these two parameters. The SCC started in 2023 from 196,032 cells/ml (standard deviation of 7,407) at Group Total and registered an increase of 16.97% until 2025, up to the level of 229,292 cells/ml (standard deviation of 4,160); at groups level the lowest increase (2025 vs 2023) of 10.36% (up to 214,477 cells/ml) was mentioned a Group 50 - 100 and the highest at Group 100 – 200 cattle, + 23.28% up to 212,151 cells/ml).

TBC stayed in a plateau during 2023 – 2025, at the level of ~42,000 ufc/ml as yearly average; as Group Total, 0.33% less TBC in 2025 vs 2023 (at 42,233 ufc/ml and a standard deviation of 205,76) with a maximal deviation of -5.06% TBC ufc/ml for Group 200 - 300 and +6.01% for Group 100 - 200 cattle.

The yearly evolution of TBC and SCC per group and compared to the yearly average performance of Group Total is described below in Figure 12 and Figure 13.

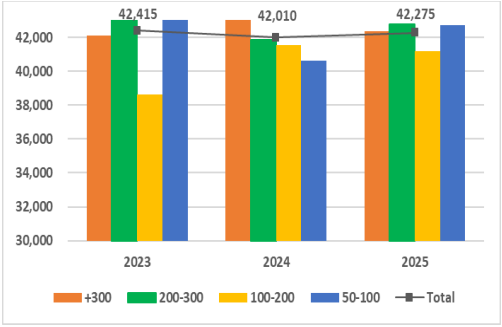

Figure 12. 2023-2025 milk TBC (total number of germs) dynamic among the groups and Group Total (%)

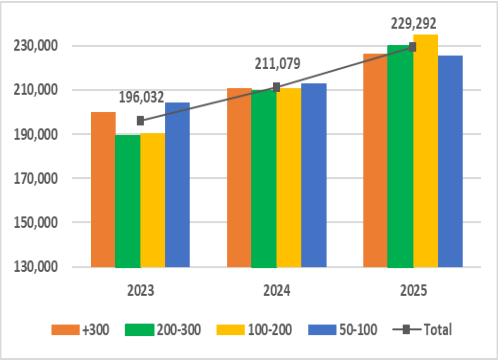

Figure 13. 2023-2025 milk SCC (somatic cells number) dynamic among the groups and Group Total (%)

Concerning the evolution of milk production per cow, the increase rate of EU rhythm of milk production per cow is stronger than the pace that the entire group achieved, leading to an increase in the gap vs. EU average, at ~82% from 86% in 2023 and is even higher compared to performers as France, Germany. Simultaneously, the fat content had a very encouraging dynamic, showing increasing pace of yearly fat content for all groups higher than EU average, with the effect of reducing yearly gap vs. EU average fat percent; for protein content, the performance of all groups is an excellent one, already above EU as well as FR, DE and PL averages. The performance for the rest of the parameters, both physicochemical and microbiological for all the groups, is in line with the EU performance averages.

CONCLUSIONS

Based on the main results and the discussions presented for each criterion during the article, the main conclusion is that for the period 2023-2025, all 32 analyzed cow milk farms from Transylvania – Romania, with Romanian Spotted Cattle as majority breed (~80% share from total herd and at group level from ~75% to ~99% share) performed significantly above Romanian average performance for all evaluated criteria – milk production/cow, fat, protein, density, lactose, total dry matter, density, somatic cells number and total number of germs. The level of influence of different factors such as farm size and yearly evolution for certain parameters such as fat and protein, for all the evaluated criteria and for every group was already presented in detailed *supra* in the article. A detailed analysis of the differences recorded for different parameters between the analyzed groups is already planned within the doctoral thesis in preparation; the focus will be to identify the causes (e.g. breed, growth technology, feeding) and implicitly the categories of improvements recommended especially for those parameters with higher practical and financial impact during the milk processing in dairy products.

Overall business conclusions about the relation between farm size and the milk production quantity and quality dynamics can be expressed only after the technical performance of milk production per group will be evaluated vs. milk production cost and profitability development per group. Such is necessary in order to assess to what extent the management of large vs. small/medium farms manages to reach a stable technical and economic performance, feasible on a long term; this integrated analysis will be a further step of the doctoral thesis in preparation.

Finally, the outlined development is an expression of the significant improvements, of the consistent and long-term investments, as well as of the effective management practices of all the evaluated farms in order to become more competitive on RO and EU milk markets.

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