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Characterization of dairy farms based on the urea nitrogen content of bulk tank milk in Paraná State, Brazil

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ABSTRACT - The objective of this study was to analyze dairy farm characteristics as a function of milk urea nitrogen (MUN) content in the north and west of the state Paraná, Brazil. Milk urea nitrogen serves as an indicator of protein utilization by cows. In view of the high costs of protein in animal diets, this study evaluated farm characteristics that could influence MUN content. For this, 32 dairy farms were randomly selected for application of a questionnaire assessing qualitative and quantitative variables. Interviews and samplings of bulk tank milk were carried out from October 2018 to October 2019. Three clusters of farms were identified: cluster 1, low MUN content (8.07 mg/dL); cluster 2, high MUN content (21.60 mg/dL); and cluster 3, intermediate MUN content (11.90 mg/dL). Clusters 1, 2, and 3 comprised 19, 4, and 9 farms, respectively. No association was found between MUN content and production system (conventional or agroecological). However, clusters differed significantly ($P<0.05$) in total number of cows and number of lactating cows. Differences ($P<0.05$) were also found for milk fat and total solids contents. As MUN is highly influenced by diet protein levels and the analyzed farms used feed based on the same ingredients (corn and soybean), it was not possible to identify which factors influenced MUN content for the studied farm groups.

Keywords: Cluster analysis, milk production, milk production systems

1. Introduction

Milk production holds great importance in the Brazilian economy (Winck and Thaler Neto, 2012) and is considered a traditional and fundamental activity (Gurgel and Nunes, 2019) from economic and social viewpoints. In the state of Paraná, dairy production is mostly carried out on family farms (Casali et al., 2020), that is, agricultural enterprises that rely on family labor (Vedana and Moraes, 2018).

Dietary protein intake is the most critical factor determining milk production in dairy cows (Sinclair et al., 2014; Guliński et al., 2016), explained by the high demand for nitrogen compounds during lactation (Doska et al., 2012; Sinclair et al., 2014). In view of this, farmers use milk urea nitrogen (MUN) to assess whether cattle diets contain an adequate protein level (Guliński et al., 2016; Almeida et al., 2021).

About 25% of dietary N is partitioned to milk (Arriola-Apelo et al., 2014). Nevertheless, MUN levels may vary considerably according to several factors (Guliński et al., 2016), such as excess dietary protein, dietary energy content, protein/energy imbalance (Bostanova et al., 2022), daily amount of concentrate offered to dairy cows, and time of milk sampling (Almeida et al., 2021). Stage of lactation also exerts an important influence on MUN content: the ruminal flora of cows in early lactation is not well adapted to the protein-rich diet offered to cows after calving, potentially leading to an increase in MUN content in the first months of lactation (Menci et al., 2021). It is also important to keep in mind that MUN levels may vary between herds, between groups of cows, and between individual cows within a herd (Doska et al., 2012). The MUN values described in the literature typically range from 10.1 to 14.45 mg/dL (Grande et al., 2009; Doska et al., 2012). Values above this range indicate an excess of N compounds or a lack of carbohydrates in cow diets (Grande et al., 2009).

The excess excretion also causes unfavorable environmental impacts, while the animal's body expends energy to eliminate the excess nitrogen. This wasted energy could otherwise be used in milk production. According to Jonker and Kohn (2001), it is estimated that each unit of urea nitrogen present in milk demands the excretion of nearly 90 g of protein, equivalent to 180 g of soybean meal. Assessing MUN levels can effectively lower production costs, boost milk production, and enhance the efficiency and sustainability of the entire milk production chain.

It is important to highlight that, in most of the dairy farms in Brazil, dairy producers operate within family-oriented structures characterized by limited technological investments (Tramontini et al., 2021; Lima et al., 2023). In this context, it is common to observe the use of nutritionally unbalanced diets, particularly concerning the starch to protein ratio in these diets. This results in an increase in MUN levels (Hristrov et al., 2018). Therefore, there appears to be a correlation between the level of technology adopted in Brazilian dairy farms and MUN levels in the produced milk (Gurgel et al., 2023). Based on this, our hypothesis is that the urea nitrogen content could characterize the structure of the dairy farm production system in Paraná, Brazil. Thus, this study aimed to analyze dairy farm characteristics as a function of MUN levels in northern and western Paraná, Brazil.

2. Material and methods

2.1. Ethical considerations

Research on animals was conducted according to the institutional committee on animal use (protocol no. 3103111018).

2.2. Data collection

For characterization of the study region, we performed a random selection of dairy farms managed under agroecological and conventional systems. The study was limited to the state of Paraná because it holds great importance in milk production in the country. Farms were located in northern and western Paraná, in the following municipalities: Palotina, Marechal Cândido Rondon, Nova Santa Rosa, Maripá, Jandaia do Sul, Paranacity, Santa Fé, Maringá, Iguaraçu, Floresta, Mandaguaçu, and Sarandi.

The interviews and milk sampling from bulk tanks were conducted between October 2018 and October 2019. Data collection involved in-person visits to farms, where a semi-structured questionnaire was administered by an interviewer to 32 dairy farm operators responsible for their respective activities.

2.3. Characterization of dairy production systems

A questionnaire was developed to characterize dairy farms in terms of nutritional information, pasture management, and quantitative variables (milk production and pasture areas, total number of cows, number and percentage of lactating cows, daily milk production, and average milk production per cow), among others. Contacts were obtained from lists provided by EMATER and the Centro de Apoio e Promoção da Agroecologia (CAPA). Participating farmers were also asked to indicate other milk producers.

2.4. Production structure of dairy farms

Production structure was determined from the following six structural and productive variables: milk production area, pasture area, number of lactating cows, percentage of lactating cows, daily milk production, and daily milk production per cow.

The diet provided in this study was carefully monitored to ensure that aflatoxin levels were well below the established safety limits for animal feed. This precautionary measure was taken to safeguard the animals' health and welfare. Aflatoxin contamination in animal feed can pose serious health risks, including impaired growth and liver damage (Girolami et al., 2022). By maintaining feed quality within safe limits, we aimed to minimize any potential influence of aflatoxins on the study results.

2.5. Collection of milk samples

A total of 32 raw milk samples (in duplicate) were collected from bulk tanks on the analyzed farms. Milk was collected into an individual bottle containing preservative (bronopol) and sent for analysis of somatic cell count (SCC), MUN, and chemical composition (protein, fat, lactose, and total solids) at the Programa de Análise de Rebanhos Leiteiros do Paraná (PARLPR) of the Associação Paranaense de Criadores de Bovinos da Raça Holandesa (APCBRH).

2.6. Chemical composition and SCC determination

Chemical composition (fat, lactose, protein, and total solids) and MUN were determined by the infrared method on a Bentley Instruments® FTS analyzer (Minnesota, USA), according to ISO 9622/IDF 141 (IDF, 2012). The SCC determination was performed by flow cytometry using a Bentley Instruments® Somacount FCM equipment (Minnesota, USA), following ISO 13366-2/IDF 148-2 (IDF, 2006).

2.7. Statistical analysis

Farms were subjected to cluster analysis based on MUN content, resulting in the formation of three clusters: cluster 1, low MUN (8.07 mg/dL); cluster 2, high MUN (21.60 mg/dL); and cluster 3, intermediate MUN (11.90 mg/dL). Cluster analysis groups individuals (objects, points, chemical elements, biological species, or units) into classes in such a manner that individuals with similar characteristics are placed in the same class (Valli, 2012). This procedure was performed to investigate nutrition and management factors that may influence MUN content. Thus, after cluster analysis, farm groups were subjected to descriptive analysis for comparison of questionnaire variables.

Data analysis was performed using SPSS Statistics version 20. All behavioral data were checked for normality using the Shapiro-Wilk test and considered to adhere to a normal distribution for $P>0.05$ (Raspa et al., 2022). Those that did not conform to a normal distribution were reported as medians (plus 25-75th percentile). Comparisons were performed using the non-parametric Kruskal–Wallis test at $P<0.05$. The farthest neighbor method was used to define the cluster number, using the quantitative variables. Intercluster variance greater than 75% and intracluster variance below 25% were adopted as clustering criteria (Fávero et al., 2009). Qualitative variables were categorized based on literature data and subsequently compared using Fisher's exact test for proportion difference analysis. Cramér's *V* was also used, which is a correlation coefficient that measures associations between variables on a scale of 0 to 1, in which 0 corresponds to no association and 1 to perfect association (Dancey and Reidy, 2013).

3. Results

Number of cows and number of lactating cows differed significantly between groups (Table 1). These variables are related to milk yield. For instance, cluster 3, which has the largest number of lactating animals, is also the one with the highest daily milk production and milk production per cow. Cluster 3 farms had a daily milk productivity of 97.83 L/ha, well above that of clusters 1 and 2, whose productivities were 72.94 and 62.76 L/ha, respectively. Regarding daily milk production and milk production per animal, cluster 3 had the highest values, followed by clusters 1 and 2.

Milk analysis revealed significant differences in MUN, fat, and total solids between clusters (Table 1). Clusters 1, 2, and 3 had protein contents of 3.24, 3.21, and 3.22 g/100 g, respectively, which did not differ significantly. Farm clusters were also similar in terms of lactose content.

Milk urea nitrogen values differed greatly between clusters. Cluster 1 (low MUN group) comprised 19 farms, cluster 2 (high MUN group) comprised four farms, and cluster 3 (intermediate MUN group) comprised nine farms. The MUN contents of clusters 1, 2, and 3 were 8.07, 21.60, and 11.90 mg/dL.

Cluster 2 included farms with the greatest limitation in terms of milk production and pasture areas. Farms from all three clusters used organic fertilization for pasture and/or did not use pesticides (Table 2), and 46.9% used solely organic fertilization. Cramér's *V* for pasture fertilization was equal to 0.223 (Tables 2 and 3).

The majority of farms had no history of agricultural crop cultivation prior to pasture, indicating that there were no N residues from previous crops or fertilization (Table 4). Cramér's *V* for time since the previous crop was 0.227.

Most farmers (23/32) provided corn silage to cows (Table 5), demonstrating its importance, particularly in times of pasture scarcity. All farms of cluster 3 used corn silage. Cramér's *V* for corn silage use was 0.402.

Table 1 - Analysis of milk production, composition, somatic cell count (SCC), and pasture areas in dairy farms grouped by milk urea nitrogen (MUN) levels

Variable	Cluster 1 (n = 19)	Cluster 2 (n = 4)	Cluster 3 (n = 9)	SEM	P-value
Milk area (ha)	11.59	2.57	8.48	12.059	0.15
Pasture area (ha)	6.26	2.39	5.54	8.763	0.928
Number of cows	32.895a	12.75b	45.444a	28.13	0.049
Number of lactating cows	25.105a	8.0b	29.889a	20.77	0.039
Percentage of lactating cows	77.08	69.18	73.5	22.11	0.838
Daily milk production (L/day)	456.579	150	542	525.03	0.119
Milk production per cow (L/cow)	13.73	11.75	17.33	7.258	0.176
Fat (g/100 g)	3.01a	1.77b	2.87a	0.873	0.043
Protein (g/100 g)	3.24	3.21	3.22	0.257	0.737
Lactose (g/100 g)	4.38	4.21	4.38	0.332	0.367
Total solids (g/100 g)	11.59a	10.08b	11.55a	1.603	0.037
MUN (mg/dL)	8.07b	21.60a	11.90b	5.438	0.0001
SCC (1000 cells/mL)	694.58	627.25	1135.98	1226.97	0.64

SEM - standard error of mean.
Cluster 1, low MUN content (8.07 mg/dL); cluster 2, high MUN content (21.60 mg/dL); cluster 3, intermediate MUN content (11.90 mg/dL).

Table 2 - Types of pasture fertilization

Pasture fertilization	Statistics	Cluster 1	Cluster 2	Cluster 3
No fertilization	Observed frequency, n (%)	5 (26.3%)	0 (0.0%)	1 (11.1%)
	Expected frequency (n)	3.6	0.8	1.7
	Adjusted residual	1.3	−1.0	−0.7
Organic fertilization	Observed frequency, n (%)	8 (42.1%)	3 (75%)	4 (44.4%)
	Expected frequency (n)	8.9	1.9	4.2
	Adjusted residual	−0.7	1.2	−0.2
Organic and chemical fertilization	Observed frequency, n (%)	2 (10.5%)	0 (0.0%)	1 (11.1%)
	Expected frequency (n)	1.8	0.4	0.8
	Adjusted residual	0.3	−0.7	0.2
Chemical fertilization	Observed frequency, n (%)	4 (21.1%)	1 (25%)	3 (33.3%)
	Expected frequency (n)	4.8	1.0	2.3
	Adjusted residual	−0.6	0	0.7
Total		19 (100%)	4 (100%)	9 (100%)

Cluster 1, low milk urea nitrogen (MUN) content (8.07 mg/dL); cluster 2, high MUN content (21.60 mg/dL); cluster 3, intermediate MUN content (11.90 mg/dL).

Table 3 - Frequency of pasture fertilization

Pasture fertilization frequency	Statistics	Cluster 1	Cluster 2	Cluster 3
Once per year	Observed frequency, n (%)	3 (21.4%)	2 (50%)	3 (2.5%)
	Expected frequency (n)	4.3	1.2	2.5
	Adjusted residual	−1.1	0.9	0.5
Twice per year	Observed frequency, n (%)	1 (7.1%)	1 (25%)	0 (0%)
	Expected frequency (n)	-	-	-
	Adjusted residual	−0.1	1.4	−1.0
Three times or more per year	Observed frequency, n (%)	10 (71.4%)	1 (25.0%)	0 (0.0%)
	Expected frequency (n)	8.6	2.5	4.9
	Adjusted residual	1.1	−1.6	0.1
Total		14 (100%)	4 (100%)	8 (100%)

Cluster 1, low milk urea nitrogen (MUN) content (8.07 mg/dL); cluster 2, high MUN content (21.60 mg/dL); cluster 3, intermediate MUN content (11.90 mg/dL).

Table 4 - Time since last crop

Time since last crop	Statistics	Cluster 1	Cluster 2	Cluster 3
No prior crop	Observed frequency, n (%)	7 (41.2%)	3 (75%)	5 (55.6%)
	Expected frequency (n)	8.5	2.0	4.5
	Adjusted residual	−1.1	1.1	0.4
7 months to 1 year	Observed frequency, n (%)	2 (11.8%)	0 (0.0%)	2 (22.2%)
	Expected frequency (n)	2.3	0.5	1.2
	Adjusted residual	−0.3	−0.8	0.9
5 years or more	Observed frequency, n (%)	8 (47.1%)	1 (25%)	2 (22%)
	Expected frequency (n)	6.2	1.5	3.3
	Adjusted residual	1.4	−0.5	−1.1
Total		17 (100%)	4 (100%)	9 (100%)

Cluster 1, low milk urea nitrogen (MUN) content (8.07 mg/dL); cluster 2, high MUN content (21.60 mg/dL); cluster 3, intermediate MUN content (11.90 mg/dL).

Protein supplementation was rarely used by the interviewed farmers. Twenty-six out of 32 farmers (81.25%) did not provide any type of protein supplementation for lactating cows. Thus, this factor was not important for MUN. Most farmers (22/32) used pasture-based systems for rearing, given their cost-effectiveness. This type of system is adopted mainly by small- and medium-scale farms, such as those included in this study. The use of transgenic grains (Table 6) was observed in 20 of the 23 farms that produced silage, characterizing farms with a conventional production system. Cramér's *V* for the use of transgenic grains was 0.343.

Soil correction was not an important factor for MUN (Table 7). In cluster 2, the majority (3/4) of farmers did not perform soil correction. Cramér's *V* for soil correction was 0.199.

Table 5 - Use of corn silage

Use of corn silage	Statistics	Cluster 1	Cluster 2	Cluster 3
No	Observed frequency, n (%)	7 (36.8%)	2 (50%)	0 (0%)
	Expected frequency (n)	5.3	1.1	2.5
	Adjusted residual	1.3	1.0	−2.2
Yes	Observed frequency, n (%)	12 (63.2%)	2 (50%)	9 (100%)
	Expected frequency (n)	13.7	2.9	6.5
	Adjusted residual	−1.3	−1.0	2.2
Total		19 (100%)	4 (100%)	9 (100%)

Cluster 1, low milk urea nitrogen (MUN) content (8.07 mg/dL); cluster 2, high MUN content (21.60 mg/dL); cluster 3, intermediate MUN content (11.90 mg/dL).

Table 6 - Use of transgenic grains

Use of transgenic grains	Statistics	Cluster 1	Cluster 2	Cluster 3
Yes	Observed frequency, n (%)	11 (91.7%)	2 (100%)	6 (66.7%)
	Expected frequency (n)	9.9	1.7	7.4
	Adjusted residual	1.2	0.70	−1.6
No	Observed frequency, n (%)	1 (8.3%)	0 (0%)	3 (33.3%)
	Expected frequency (n)	2.1	0.3	1.6
	Adjusted residual	−1.2	−0.7	1.6
Total		12 (100%)	2 (100%)	9 (100%)

Cluster 1, low milk urea nitrogen (MUN) content (8.07 mg/dL); cluster 2, high MUN content (21.60 mg/dL); cluster 3, intermediate MUN content (11.90 mg/dL).

Table 7 - Soil correction

Soil correction	Statistics	Cluster 1	Cluster 2	Cluster 3
Yes	Observed frequency, n (%)	9 (50%)	1 (25%)	3 (33.3%)
	Expected frequency (n)	7.5	1.7	3.8
	Adjusted residual	1.1	−0.7	−0.6
No	Observed frequency, n (%)	9 (50%)	3 (75%)	6 (66.7%)
	Expected frequency (n)	10.5	2.3	5.2
	Adjusted residual	−1.1	−0.7	−0.6
Total		18 (100%)	4 (100%)	9 (100%)

Cluster 1, low milk urea nitrogen (MUN) content (8.07 mg/dL); cluster 2, high MUN content (21.60 mg/dL); cluster 3, intermediate MUN content (11.90 mg/dL).

In all 32 farms, salt (common salt or mineral salt) was supplied to lactating cows, whether in separate troughs (n = 14) or mixed with roughage (n = 17) (Table 8). Cramér's *V* for salt supplementation was 0.037.

The use of byproducts was predominantly observed in the producers of Cluster 1 (Table 9). Overall, 15 out of 28 farmers used corn + soybean + wheat bran as concentrate and 13 farmers used only soybean + corn (Table 10). Other four farmers did not use concentrate feed (data not shown). Cramér's *V* for concentrate ingredients was 0.216.

Table 8 - Salt supplementation

Form of salt supplementation	Statistics	Cluster 1	Cluster 2	Cluster 3
Separate trough	Observed frequency, n (%)	8 (44.4%)	2 (50%)	4 (44.4%)
	Expected frequency (n)	8.1	1.8	4.1
	Adjusted residual	−0.1	0.2	−0.1
Mixed with roughage	Observed frequency, n (%)	10 (55.6%)	2 (50%)	5 (55.6%)
	Expected frequency (n)	18	2.2	4.9
	Adjusted residual	0.1	−1.1	0.1
Total		18 (100%)	4 (100%)	9 (100%)

Cluster 1, low milk urea nitrogen (MUN) content (8.07 mg/dL); cluster 2, high MUN content (21.60 mg/dL); cluster 3, intermediate MUN content (11.90 mg/dL).

Table 9 - Use of byproducts in cow feed

Byproduct	Statistics	Cluster 1	Cluster 2	Cluster 3
None	Observed frequency, n (%)	10 (52.6%)	3 (75%)	9 (100%)
	Expected frequency (n)	13.1	2.8	6.2
	Adjusted residual	−2.4	0.3	2.4
Cassava pulp	Observed frequency, n (%)	2 (10.5%)	0 (0%)	0 (0%)
	Expected frequency (n)	1.2	0.3	0.6
	Adjusted residual	1.2	−0.6	−0.9
Chopped sugarcane	Observed frequency, n (%)	1 (5.3%)	0 (0%)	0 (0%)
	Expected frequency (n)	0.6	0.1	0.3
	Adjusted residual	0.8	−0.4	−0.6
Oat straw	Observed frequency, n (%)	1 (5.3%)	0 (0%)	0 (0%)
	Expected frequency (n)	0.6	0.1	0.3
	Adjusted residual	0.8	−0.4	−0.6
Corn grits	Observed frequency, n (%)	1 (5.3%)	1 (25%)	0 (0%)
	Expected frequency (n)	0.6	0.3	0.3
	Adjusted residual	0.8	1.7	−0.6
Soybean hull	Observed frequency, n (%)	3 (15.8%)	0 (0%)	0 (0%)
	Expected frequency (n)	1.8	0.4	0.8
	Adjusted residual	1.5	−0.7	−1.1
Citrus pulp	Observed frequency, n (%)	1 (5.3%)	0 (0%)	0 (0%)
	Expected frequency (n)	0.6	0.1	0.3
	Adjusted residual	0.8	−0.4	−0.6
Total		19 (100%)	4 (100%)	9 (100%)

Cluster 1, low milk urea nitrogen (MUN) content (8.07 mg/dL); cluster 2, high MUN content (21.60 mg/dL); cluster 3, intermediate MUN content (11.90 mg/dL).

Chemical fertilization is the main type of fertilization of grain crops for silage production, regardless of the cluster (Table 11). On the other hand, most producers do not use irrigation (Table 12). It was possible to observe that 70.96% of the evaluated farms had a conventional production system and only 31.25% of farms had an agroecological production system (Table 13).

Table 10 - Concentrate ingredients

Concentrate ingredient	Statistics	Cluster 1	Cluster 2	Cluster 3
Corn + soybean + wheat bran	Observed frequency, n (%)	10 (62.5%)	1 (33.3%)	4 (44.4%)
	Expected frequency (n)	8.6	1.6	4.8
	Adjusted residual	1.1	−0.7	−0.7
Soybean + corn	Observed frequency, n (%)	6 (37.5%)	2 (66.7%)	5 (55.6%)
	Expected frequency (n)	7.4	1.4	4.2
	Adjusted residual	−1.1	0.7	0.7
Total		16 (100%)	3 (100%)	9 (100%)

Cluster 1, low milk urea nitrogen (MUN) content (8.07 mg/dL); cluster 2, high MUN content (21.60 mg/dL); cluster 3, intermediate MUN content (11.90 mg/dL).

Table 11 - Fertilization of grain crops for silage production

Type of fertilization	Statistics	Cluster 1	Cluster 2	Cluster 3
Does not perform fertilization	Observed frequency, n (%)	1 (8.3%)	0 (0%)	1 (11.1%)
	Expected frequency (n)	1.0	0.2	0.8
	Adjusted residual	−0.1	−0.5	0.3
Organic fertilization	Observed frequency, n (%)	0 (0%)	0 (0%)	1 (11.1%)
	Expected frequency (n)	0.5	0.1	0.4
	Adjusted residual	−1.1	−0.3	1.3
Organic and chemical fertilization	Observed frequency, n (%)	5 (41.7%)	0 (0%)	3 (33.3%)
	Expected frequency (n)	4.2	0,7	3.1
	Adjusted residual	0.7	−1.1	−0.1
Chemical fertilization	Observed frequency, n (%)	6 (50%)	2 (100%)	4 (44.4%)
	Expected frequency (n)	6.3	1.0	4.7
	Adjusted residual	−0.2	1.4	−0.6
Total		12 (100%)	2 (100%)	9 (100%)

Cluster 1, low milk urea nitrogen (MUN) content (8.07 mg/dL); cluster 2, high MUN content (21.60 mg/dL); cluster 3, intermediate MUN content (11.90 mg/dL).

Table 12 - Pasture irrigation

Pasture irrigation	Statistics	Cluster 1	Cluster 2	Cluster 3
No	Observed frequency, n (%)	15 (88.2%)	2 (50%)	7 (87.5%)
	Expected frequency (n)	14.1	3.3	6.6
	Adjusted residual	0.9	−1.9	0.4
Yes	Observed frequency, n (%)	2 (11.8%)	2 (50%)	1 (12.5%)
	Expected frequency (n)	2.9	0.7	1.4
	Adjusted residual	−0.9	1.9	−0.4
Total		17 (100%)	4 (100%)	8 (100%)

Cluster 1, low milk urea nitrogen (MUN) content (8.07 mg/dL); cluster 2, high MUN content (21.60 mg/dL); cluster 3, intermediate MUN content (11.90 mg/dL).

Table 13 - Proportion of farms with agroecological or conventional production systems in each cluster

Variable	Category	Cluster 1	Cluster 2	Cluster 3	Probability
Type of system	Conventional	40.63% (n = 13)	9.38% (n = 3)	18.75% (n = 6)	1000
	Agroecological	18.75% (n = 6)	3.13% (n = 1)	9.38% (n = 3)	

n - number of farms analyzed in each cluster.
Cluster 1, low milk urea nitrogen (MUN) content (8.07 mg/dL); cluster 2, high MUN content (21.60 mg/dL); cluster 3, intermediate MUN content (11.90 mg/dL).

4. Discussion

It should be noted that pasture is the most economical source of nutrients for livestock, particularly in developing countries such as Brazil (Silva et al., 2008). It was observed that the majority of farms in clusters 1 and 2 used organic fertilizers. Adequate fertilization, soil correction, and pasture management are essential, as these practices can intensify forage yield and nutritional quality (Gurgel et al., 2021; Costa et al., 2021).

Herd productivity is considered an important performance parameter in rural production, as well as a competitiveness indicator (Parré et al., 2011; Olimpio et al., 2022). According to Çilek and Tekin (2005), livestock productivity stems from a combination of genotypic and environmental conditions. Environmental conditions can be classified into factors with measurable effects (age, year, season, milking frequency, etc.) and factors with immeasurable effects (infectious diseases, parasitic infestations, etc.).

From the results, it can be seen that only cluster 1 had a fat content above 3%. This finding differs from the results of Noro et al. (2006), who found a mean fat content of 3.54%. Milk fat content can be affected by diet (Noro et al., 2006; Schingoethe et al., 2017; Pitta et al., 2018), lactation phase, presence of mastitis, rumen fermentation (Pereira, 2014), age, breed, and energy balance (Souza et al., 2016). Arora et al. (2013) analyzed raw milk samples and found a protein content of 3.3 g/100 g, similar to those observed in the current study. Milk protein has high biological value, and milk is considered an important source of protein in the human diet, providing approximately 3.2 g/100 g (Pereira, 2014).

The lactose values in milk from clusters 1, 2, and 3 (4.38, 4.2, and 4.38 g/100 g, respectively) were similar to those reported by Arora et al. (2013). Lactose, the main carbohydrate present in milk, is a disaccharide composed of glucose and galactose units (Pereira, 2014). The content is related to several biological and physiological factors, such as udder health, energy balance, and animal metabolism (Costa et al., 2019). The main function of lactose is osmoregulation, being responsible for approximately 50% of the osmotic pressure of milk. During milk production, 9 L of water is secreted for every 5 g of lactose synthesized by the mammary gland (Menéndez González et al., 2010; Lin et al., 2016).

Milk urea nitrogen measurement serves as a tool to estimate N partitioning to milk (Correa-Luna et al., 2019). It is important to meet the protein requirements of cows to avoid N losses (Arriola-Apelo et al., 2014) and excess intake. Urea is a normal constituent of milk, part of the non-protein N fraction (Almeida et al., 2021). It is well known that an increase in MUN may be a reflection of the inefficient use of crude protein from the diet (Henao-Velásquez et al., 2014; Almeida et al., 2021). Samples taken from bulk milk tanks do not allow for individual monitoring of cows, which may be offered different feeds and dietary levels of protein (Bittante, 2022). Milk urea nitrogen can be influenced by herd management, parity, days in lactation, season of the year, breed, genetic selection, pasture N fertilization, pasture irrigation, metabolic factors, and environmental factors (Doska et al., 2012; Almeida et al., 2021; Bittante, 2022).

Somatic cell count was not changed depending on the clusters evaluated, showing that there is no well-defined relationship between the technological level of the farms and the health of the mammary gland. Somatic cell count is a useful predictor of intramammary infection and, therefore, an important parameter for milk quality assessment, hygiene control, and mastitis monitoring (Bradley and Green, 2005; Sharma et al., 2011; Li et al., 2014; Souza et al., 2016). According to Egyedy et al. (2022), SCC values of less than 100,000 cells/mL are considered normal, reflecting a healthy mammary gland, whereas SCC values above 200,000 cells/mL are suggestive of bacterial infection. The SCC values observed here were higher than 200,000 cells/mL, indicating the presence of mammary gland infection. High SCC values negatively influence the quality of raw milk, as subclinical mastitis is associated with low milk production, low protein content, poor hygiene, changes in milk consistency (density), and problems during processing, as well as presence of pathogenic organisms (Sharma et al., 2011; Souza et al., 2016). In addition to intramammary infection, other factors influence SCC, such as lactation stage, milking frequency, age, breed, parity, and season of the year (Malik et al., 2018).

Several techniques can be used to manage SCC, such as pre- and post-dipping, use of gloves by milkers, control of cows with mastitis (cows with mastitis are the last ones to be milked), daily udder inspection of dry cows for mastitis detection, and use of the California mastitis test, among others (Farag et al., 2023). In the current study, on none of the evaluated farms did workers wear gloves during milking.

The farm clusters with the lowest MUN content were those in which the majority of farmers used corn silage in cow diets. Corn is the ideal plant for ensiling due to its high dry matter content, low buffering capacity, and high concentration of soluble carbohydrates. However, it is a crop demanding in soil fertility and water (Pereira et al., 2021). Farms using corn silage as a forage source likely employ more technology and maintain a more balanced diet in terms of carbohydrates and proteins. Furthermore, corn silage provides a more effective contribution to supplying energy to lactating cows compared with other silages (Gurgel et al., 2019). Hence, this forage source may aid in the utilization of N by ruminal microorganisms, owing to the better starch to protein ratio in the diets

The type of grain fertilizer used for silage production did not influence MUN, as most farmers (20/32), independent of the cluster, used chemical fertilizers for corn. In cluster 1, the frequency of pasture fertilization was mainly three times a year or more (Table 5). In cluster 2, most farms (2/4) performed fertilization once a year. It is evident that dietary N does not stem solely from pasture but also from other feed ingredients.

As observed in this study, organic fertilization helps reduce production costs and contributes to the correct disposal of animal waste. Organic material is used as crop fertilizer because of its chemical composition and carbon to nitrogen ratio (Araujo et al., 2011). Solid organic waste such as animal manure is an interesting alternative for increasing forage productivity and quality, given its ability to promote soil fertility, increase yield, improve soil chemical and physical properties, minimize pollution, and increase the use efficiency and nutritional quality of feed at a low cost (Pereira et al., 2020). Most of the global agricultural demand for N is met by N fertilizers; nevertheless, legumes are also used as N sources (Wezel and Peeters, 2014; Adams et al., 2018), particularly in agroecological systems. In these types of systems, mineral deficits are generally supplemented using fertilizers. Another factor that may influence pasture N content is the season of the year. Gerdes et al. (2000) found that pasture (*Brachiaria brizantha* Stapf. 'Marandu', *Setaria sphacelata* [Schum.] Moss var. *sericea* [Stapf.] 'Kazungula', and *Panicum maximum* Jacq. 'Tanzânia') had the highest protein content in autumn.

Meyer et al*.* (2006), analyzing the milk quality of 7,006 Holstein cows, found a mean MUN content of 13.3 mg/dL, similar to the mean of cluster 3 (intermediate MUN content). In cluster 2, the mean MUN content was 21.60 mg/dL, well above the value reported by Meyer et al. (2006) and Doska et al. (2012). That high content might be attributed to nutritional factors, such as high dietary protein levels, low protein use efficiency (Kim and Lee, 2021), and inadequate balance of dietary protein and carbohydrate levels (Erickson and Kalscheur, 2020). However, non-nutritional factors, such as parity and season of the year (Fatehi et al., 2012), might also influence MUN. The lowest mean MUN content was observed in cluster 1 (8.07 mg/dL), attributed to low dietary protein intake and animal genetics (Beatson et al., 2019).

Although we have explored various characteristics of agricultural practices in MUN, we have been unable to identify the specific factors influencing this parameter. There seem to be numerous confounding variables interacting with MUN in milk, categorized into two main groups: those related to the level of technology on farms and those related to dietary aspects. Furthermore, the breed and category of animals seem to interfere with the metabolization and use of nutrients (Vettori et al., 2023).

We emphasize the need to further research in this area to establish effective strategies for reducing N excretion and, consequently, improving the nutritional efficiency of diets. These strategies involve the use of machine learning techniques (Cavallini et al., 2023) and the development of equations to estimate nutritional requirements, taking into account regional specificities (Gurgel et al., 2023). This aims to increase efficiency in carbon and N utilization while reducing costs (Cavallini et al., 2023).

5. Conclusions

According to the characteristics of the production systems of dairy farms in the state of Paraná, Brazil, no positive association was found between MUN and type of production system. Given that cow nutrition greatly influences MUN content and that the evaluated farms used diets based on the same ingredients (corn and soybean), it was not possible to identify which factor influenced MUN content in the studied farm groups.

Data availability

All data generated or analyzed during this study are included in this published article.

Author contributions

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Conflict of interest

The authors declare no conflict of interest.

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