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RURAL EXTENSION AND SUSTAINABILITY IN DAIRY FARMING: MILK UREA NITROGEN AS A TOOL FOR TECHNICAL, REPRODUCTIVE, AND ENVIRONMENTAL GUIDANCE

EXTENSÃO RURAL E SUSTENTABILIDADE NA PECUÁRIA LEITEIRA: O NITROGÊNIO UREICO NO LEITE COMO FERRAMENTA DE ORIENTAÇÃO TÉCNICA, REPRODUTIVA E AMBIENTAL

EXTENSIÓN RURAL Y SOSTENIBILIDAD EN LA GANADERÍA LECHERA: EL NITRÓGENO UREICO EN LECHE COMO HERRAMIENTA DE ORIENTACIÓN TÉCNICA, REPRODUCTIVA Y AMBIENTAL

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Abstract: Dairy farming requires technical tools that assist in decision-making regarding nutritional management, milk quality, and environmental sustainability. This study aimed to evaluate metabolic-nutritional milk indicators as support instruments for Technical Assistance and Rural Extension (TARE) carried out through university extension programs on farms located in the São Francisco do Caramuri community, in the transition zone between the municipalities of Manaus, Rio Preto da Eva, and Itacoatiara, Amazonas. Individual milk samples from 67 dairy cows (Girolando and crossbred) kept in extensive grazing systems were analyzed, as well as buffalo herds assisted by the extension action. Milk urea nitrogen (MUN), protein, fat, and somatic cell count (SCC) levels were determined. Cattle showed an average MUN of 18.54 mg/dL, situated at the upper limit of the reference range (10–18 mg/dL), while buffaloes showed an average of 31.03 mg/dL, indicating a possible imbalance in the dietary protein:energy ratio. Milk protein remained at 3.04% in cattle and 3.09% in buffaloes. Fat averaged 2.03% in cattle and 5.00% in buffaloes. SCC remained below the legal limit in both species. The results allowed for guiding producers on adjusting protein supplementation and continuous monitoring of quality indicators, strengthening evidence-based technical decision-making. It is concluded that the use of laboratory indicators in the context of rural extension contributes to greater nutritional efficiency, environmental sustainability, and qualification of production management in dairy systems.
Keywords: Nitrogen use efficiency, Metabolic monitoring, Grazing systems, Reproductive performance, Technology transfer.

Resumo: A pecuária leiteira demanda ferramentas técnicas que auxiliem a tomada de decisão quanto ao manejo nutricional, à qualidade do leite e à sustentabilidade ambiental. O presente trabalho teve como objetivo avaliar indicadores metabólico-nutricionais do leite como instrumentos de apoio à Assistência Técnica e Extensão Rural (ATER) realizada por meio da extensão universitária em cinco propriedades rurais pertencentes a produtores de bovinos leiteiros, representando 100% dos produtores da comunidade Comunidade São Francisco do Caramuri, na zona de transição entre os municípios de Manaus, Rio Preto da Eva e Itacoatiara, Amazonas. Foram analisadas amostras individuais de leite de 67 vacas leiteiras (Girolando e mestiças) mantidas sob método extensivo de manejo do pastejo, bem como rebanhos bubalinos assistidos pela ação extensionista. Determinaram-se os níveis de nitrogênio ureico no leite (NUL), proteína, gordura e contagem de células somáticas (CCS). Os bovinos apresentaram média de NUL de 18,54 mg/dL, situando-se no limite superior da faixa de referência (10–18 mg/dL), enquanto os bubalinos apresentaram média de 31,03 mg/dL, indicando possível desequilíbrio na relação proteína:energia da dieta. A proteína do leite manteve-se em 3,04% nos bovinos e 3,09% nos bubalinos. A gordura apresentou média de 2,03% nos bovinos e 5,00% nos bubalinos. A CCS permaneceu abaixo do limite legal em ambas as espécies. Os resultados permitiram orientar os produtores quanto ao ajuste da suplementação proteica e ao monitoramento contínuo dos indicadores de qualidade, fortalecendo a tomada de decisão técnica baseada em evidências. Conclui-se que a utilização de indicadores laboratoriais no contexto da extensão rural contribui para maior eficiência nutricional, sustentabilidade ambiental e qualificação da gestão produtiva em sistemas leiteiros.
Palavras-chave: Eficiência de utilização do nitrogênio, Monitoramento metabólico, Sistemas de pastejo, Desempenho reprodutivo, Transferência de tecnologia.

Resumen: La ganadería lechera demanda herramientas técnicas que ayuden en la toma de decisiones respecto al manejo nutricional, la calidad de la leche y la sostenibilidad ambiental. El presente trabajo tuvo como objetivo evaluar indicadores metabólico-nutricionales de la leche como instrumentos de apoyo a la Asistencia Técnica y Extensión Rural (ATER) realizada a través de la extensión universitaria en fincas ubicadas en la Comunidad São Francisco do Caramuri, en la zona de transición entre los municipios de Manaus, Rio Preto da Eva e Itacoatiara, Amazonas. Se analizaron muestras individuales de leche de 67 vacas lecheras (Girolando y mestizas) mantenidas en sistema de pastoreo extensivo, así como rebaños de búfalos asistidos por la acción extensionista. Se determinaron los niveles de nitrógeno ureico en leche (NUL), proteína, grasa y recuento de células somáticas (RCS). Los bovinos presentaron una media de NUL de 18,54 mg/dL, situándose en el límite superior del rango de referencia (10–18 mg/dL), mientras que los búfalos presentaron una media de 31,03 mg/dL, lo que indica un posible desequilibrio en la relación proteína:energía de la dieta. La proteína de la

leche se mantuvo en 3,04% en los bovinos y 3,09% en los búfalos. La grasa presentó una media de 2,03% en los bovinos y 5,00% en los búfalos. El RCS permaneció por debajo del límite legal en ambas especies. Los resultados permitieron orientar a los productores sobre el ajuste de la suplementación proteica y el monitoreo continuo de los indicadores de calidad, fortaleciendo la toma de decisiones técnicas basada en evidencias. Se concluye que la utilización de indicadores de laboratorio en el contexto de la extensión rural contribuye a una mayor eficiencia nutricional, sostenibilidad ambiental y cualificación de la gestión productiva en sistemas lecheros.
Palabras clave: Eficiencia en el uso del nitrógeno, Monitoreo metabólico, Sistemas de pastoreo, Desempeño reproductivo, Transferencia tecnológica.

INTRODUCTION

Contemporary dairy farming faces the challenge of balancing productive efficiency, environmental sustainability, and economic viability in increasingly intensive production systems. The growing pressure to reduce nitrogen emissions and achieve greater nutrient use efficiency imposes the need for technical tools that assist in field decision-making. In this context, milk urea nitrogen (MUN) has been widely recognized as a metabolic-nutritional indicator capable of reflecting the balance between ruminally degradable protein (RDP) and dietary energy availability, allowing for inferences regarding nitrogen utilization efficiency by the animals (WEBB et al., 2021).

MUN represents an indirect measure of blood urea concentration and is directly related to the excess of ruminal ammonia not incorporated into microbial protein. High values indicate nutritional imbalance and greater urinary nitrogen excretion, which implies economic losses and an increase in the polluting potential of dairy activities. Studies demonstrate that diets with higher crude protein (CP) content significantly elevate nitrogen excretion without proportional gains in production, thereby reducing nitrogen use efficiency (RAUCH et al., 2021; HALLAJIAN et al., 2021). Conversely, very low MUN concentrations may signal protein deficiency or limitations in ruminal fermentation, compromising productive performance.

Beyond environmental and economic implications, recent evidence points to an association between high MUN concentrations and reduced reproductive performance, including increased days open and lower conception rates, reinforcing its role as an integrated indicator of system efficiency (ALMEIDA et al., 2021; LAROCHE et al., 2021). Thus, MUN transcends purely nutritional interpretation, serving as a strategic tool for metabolic monitoring and fine-tuning of diets in dairy systems.

In the field of rural extension, incorporating MUN as a technical guidance instrument allows for the translation of scientific evidence into practical recommendations accessible to producers. The experience gained in rural communities in the interior of Amazonas state, in the municipalities of Manaus, Rio Preto da Eva, and Itacoatiara, has shown that the systematic use of MUN as a metabolic marker facilitates nutritional decision-making in grazing systems, contributing to the reduction of protein waste and the improvement of productive efficiency. Therefore, this study proposes to discuss MUN not only as a biochemical indicator but as an extension tool focused on the environmental, reproductive, and economic sustainability of dairy farming.

MATERIALS AND METHODS

This university extension action was developed by students from the Postgraduate Programs in Animal Science at the Federal University of Amazonas (UFAM), adopting a methodological approach based on action research and technology transfer, with a focus on integrating scientific knowledge and local production practices. The activity was conducted in five production units situated in the São Francisco do Caramuri community (Geographic

coordinates: -3.0701004; -59.3874805), located in the territorial transition zone between the municipalities of Manaus, Rio Preto da Eva, and Itacoatiara, in the state of Amazonas.

A total of 67 dairy cows were evaluated, predominantly Girolando-type animals and crossbred dairy cattle with no formally recorded genetic composition, a condition commonly observed in smallholder dairy systems in the Amazon region. The animals were maintained under an extensive pasture management system consisting of *Urochloa brizantha* cv. Marandu, *Megathyrsus maximus* cv. BRS Quênia, and MG12 Paredão. Dietary management was similar during the dry and rainy seasons, consisting of strategic supplementation associated with local forage availability. The central focus of the extension action was the discussion of nitrogen utilization efficiency in the diet and its relationship with environmental sustainability and productive performance.

For the technical evaluation of protein efficiency, individual milk samples were collected from each animal following a standardized milking hygiene protocol. Teats were first inspected and, when necessary, cleaned to remove visible dirt. The strip cup test (black-bottom cup) was performed to detect clinical mastitis. Subsequently, pre-dipping was carried out using a disinfectant solution specific for dairy cow teats, ensuring complete immersion of the teat or application via spray. The disinfectant was allowed to act for 30 seconds, followed by thorough drying with disposable paper towels to prevent contamination of the milk sample. Additionally, the California Mastitis Test (CMT) was performed as a rapid screening method for the detection of subclinical mastitis. After these procedures, approximately 50 mL of milk were collected individually from each animal into sterile universal collection containers. The samples were properly sealed and stored in insulated polystyrene boxes containing reusable gel ice packs to maintain refrigeration until laboratory analysis.

Milk composition analyses were carried out at the Dairy Laboratory (LABLAC) of the Federal University of Amazonas (UFAM), located at the Institute of Social Sciences, Education and Animal Science (ICSEZ), Campus Centro, Rua Alberto Mendes – Palmares, Parintins, Amazonas, Brazil. The analyses were performed using a FoodLab Jr. portable multiparameter milk analyzer, which allowed the determination of milk urea nitrogen (MUN), protein, fat and other compositional parameters. The laboratory contact email is lablac@ufam.edu.com.br.

After collection, the milk samples were stored in insulated polystyrene boxes containing reusable gel ice packs and maintained under refrigeration between 2 and 7 °C. The samples were transported on the same day to the city of Manaus while maintaining the cold chain conditions. From Manaus, the samples were shipped via regional river transport (express boats departing from the Porto do Produtor Rural terminal) to the municipality of Parintins, Amazonas. Upon arrival, the samples were immediately received by the technical staff of the Dairy Laboratory (LABLAC) at the Federal University of Amazonas (UFAM), where the laboratory analyses were conducted.

RESULTS

Individual milk samples from farms assisted under the extension action were analyzed, including both cattle and buffalo herds. The consolidation of laboratory data allowed for the characterization of the metabolic-nutritional profile of the monitored animals, with emphasis on nitrogen utilization efficiency indicators and milk compositional quality.

Milk Urea Nitrogen (MUN) and Milk Protein

The average milk urea nitrogen values are presented in Figure 1. The observed average MUN in cattle was 18.54 mg/dL, while in buffaloes it was 31.03 mg/dL. In cattle, the values were situated at the upper limit of the range physiologically considered adequate in the

literature (10–18 mg/dL), indicating a borderline condition regarding dietary nitrogen utilization. On the other hand, buffaloes showed values significantly above the reference range, evidencing a possible imbalance in the dietary protein–energy ratio, with indications of an excess of ruminally degradable protein (RDP) or energy limitation for the proper incorporation of nitrogen into microbial synthesis.

The difference observed between species demonstrates a higher risk of inefficiency in dietary nitrogen utilization in buffaloes, with potential economic and environmental repercussions, considering the higher nitrogen excretion associated with elevated MUN levels.

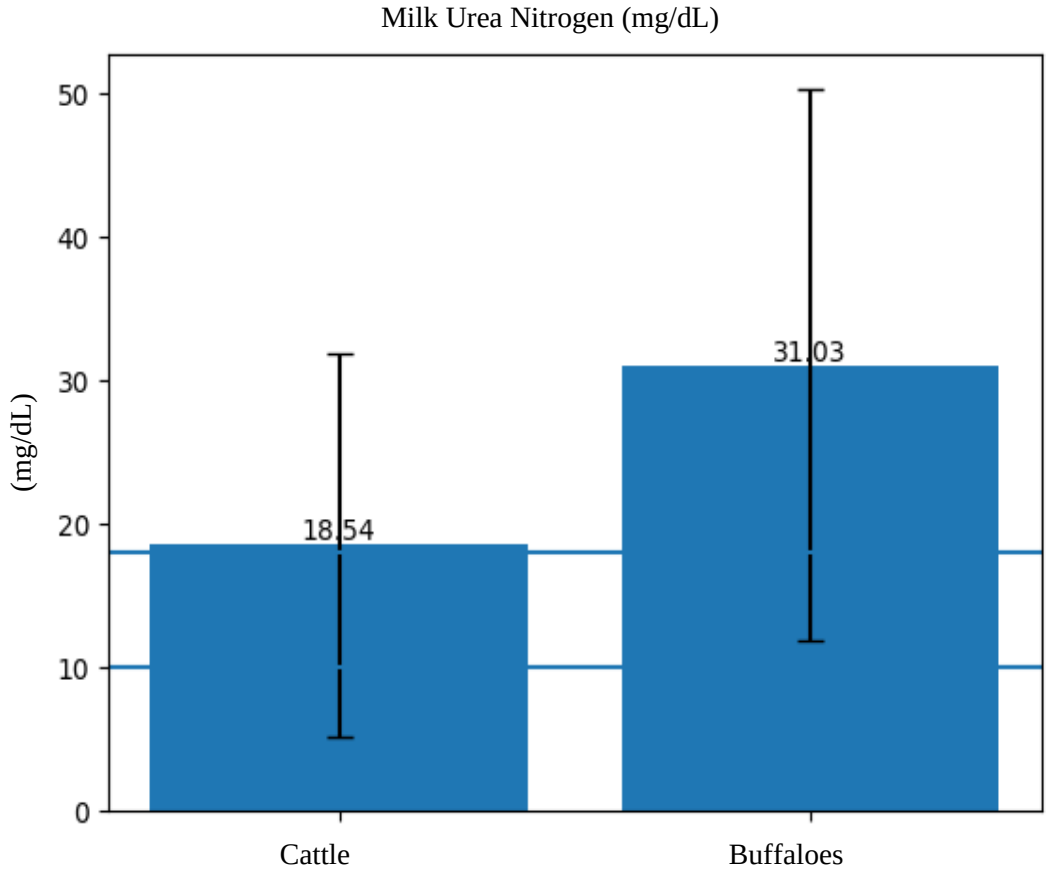


Figure 1. Average milk urea nitrogen (MUN) values in cattle and buffaloes assisted by the extension action. Horizontal lines indicate the reference range considered adequate (10–18 mg/dL).

Average milk protein values are presented in Figure 2. The average concentration was 3.04% in cattle and 3.09% in buffaloes, showing similar behavior between the evaluated species.

Both results remained within the minimum standards established by current legislation for refrigerated raw milk, indicating adequate metabolic functionality and integrity of mammary protein synthesis in the monitored herds. The observed stability suggests that, in general, there was no severe dietary protein deficiency that compromised the production of caseins and other milk protein fractions.

Comparatively, the difference between cattle and buffaloes was discrete, reinforcing that, under the observed management conditions, the milk protein fraction showed relative stability even in the face of variations detected in MUN levels. This behavior indicates that

milk protein concentration did not directly reflect the excess circulating nitrogen observed especially in buffaloes, suggesting that part of the additional dietary nitrogen was not directed to milk protein synthesis, but possibly eliminated via urinary excretion.

From a productive standpoint, maintaining adequate protein levels is relevant both for the technological quality of the milk and for the commercial value of the product, considering that the protein fraction constitutes one of the main parameters used in quality-based payment systems.

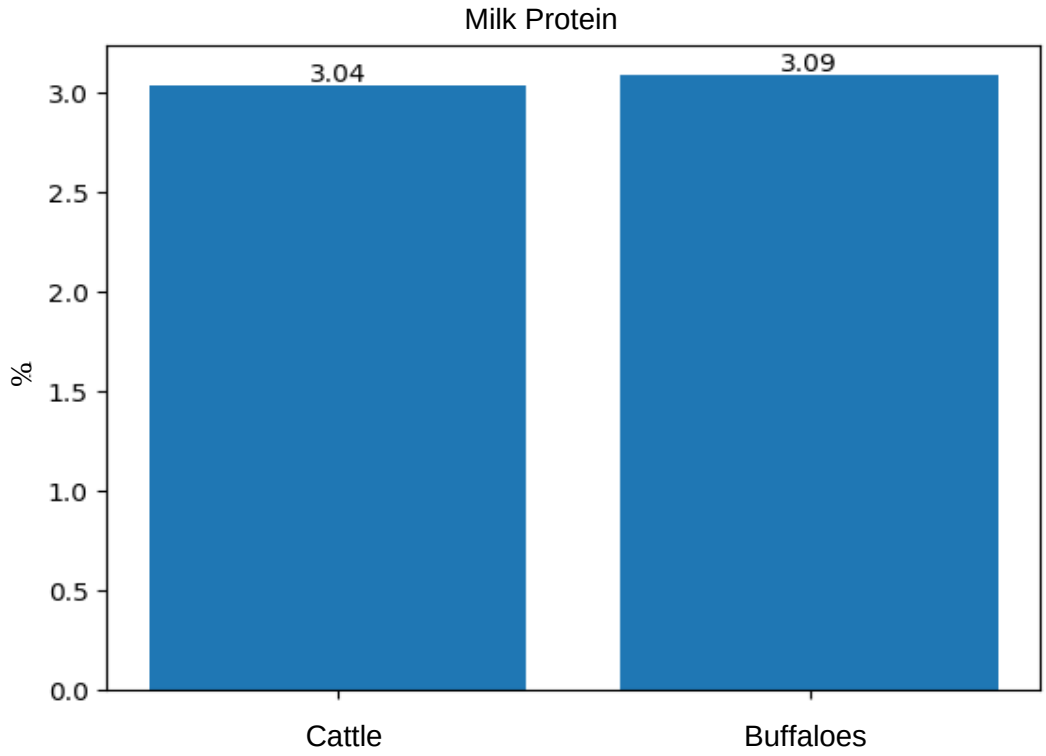


Figure 2. Average milk protein values (%) in cattle and buffaloes assisted by the extension action.

The average milk fat values are presented in Figure 3. An average of 2.03% was observed in cattle and 5.00% in buffaloes, showing a significant difference between the evaluated species.

The higher lipid content observed in buffalo milk is in line with the physiological profile of the species, characterized by a higher concentration of total solids and a greater proportion of fat compared to bovine milk. This characteristic grants buffalo milk higher industrial yield, especially in the production of derivatives such as cheese and butter.

In cattle, although the average fat values are within acceptable ranges, a level below the minimum recommended by legislation for refrigerated raw milk (3.0%) was observed, which may be associated with nutritional factors, especially the balancing of physically effective fiber (peNDF) and dietary carbohydrates. Milk fat is particularly sensitive to changes in the ruminal environment, being influenced by the roughage:concentrate ratio and the ruminal fermentation profile.

From a productive standpoint, the difference observed between the species reinforces the need for specific nutritional strategies for each system, considering the metabolic requirements and the potential for commercial milk valuation.

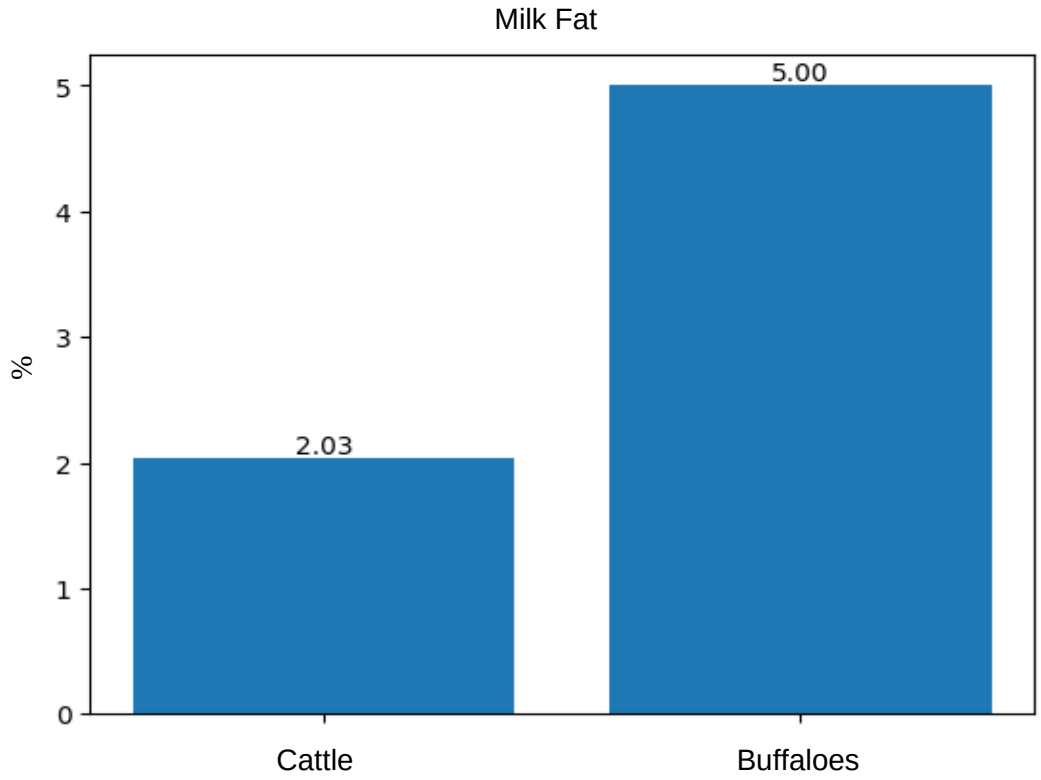


Figure 3. Average milk fat values (%) in cattle and buffaloes assisted by the extension action.

Both values are below the maximum limit of 500,000 SC/mL, as established by Normative Instruction No. 76/2018, indicating an adequate sanitary condition of the mammary gland in the assisted herds. Maintaining SCC levels within legal standards demonstrates that, under the evaluated conditions, the management systems adopted were sufficient to preserve the hygienic-sanitary quality of the milk.

Although buffaloes presented higher average values than cattle, this difference does not characterize sanitary impairment, remaining within the range considered satisfactory. SCC is widely recognized as an indirect indicator of mammary health and the occurrence of subclinical mastitis, serving as an essential parameter in the assessment of milk quality.

From an extension perspective, the results indicate that the guidance regarding milking practices and sanitary management has been effective, contributing to the maintenance of the quality of the milk produced in the monitored farms.

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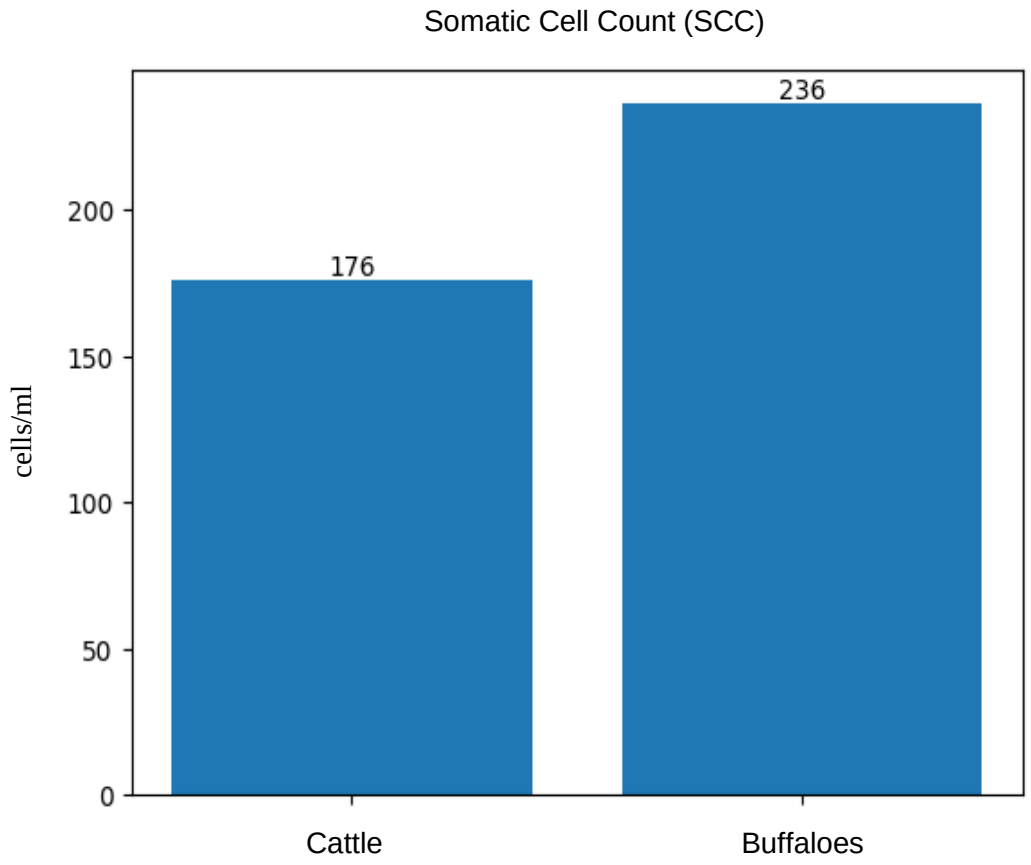


Figure 4. Average somatic cell count (SCC/mL) values in cattle and buffaloes assisted by the extension action.

DISCUSSION

The extension action in the community was carried out through periodic technical visits to the assisted farms over a period of six months. During this period, producers received technical assistance twice a month, allowing continuous monitoring of milk production indicators and the discussion of management strategies related to herd nutrition and milk quality. These visits promoted direct interaction between researchers, students, and producers, enabling the interpretation of laboratory results and the application of technical recommendations in a participatory manner. Within this context, milk urea nitrogen (MUN) was introduced as a practical metabolic indicator to support decision-making regarding the balance between dietary protein and energy in dairy herds.

The adoption of MUN as a monitoring tool was well accepted by the producers, who demonstrated increasing interest in understanding the relationship between nutrition and milk quality. The technical guidance provided during the extension action contributed to improvements in milking practices and nutritional management, particularly in the formulation of diets adjusted to the physiological categories of the animals and seasonal variations in forage availability, especially during the dry period. As a result, producers reported improvements in milk production and greater awareness regarding nitrogen utilization efficiency, reducing the risk of excessive nitrogen excretion into the environment. Additionally, the strengthening of community organization led producers to participate more actively in the local association, facilitating continued technical assistance through partnerships with institutions such as SENAR and veterinary professionals from the community. These outcomes reinforce the role of extension actions as instruments capable of

promoting sustainable management practices and improving productive efficiency in smallholder dairy systems.

The results obtained in this study demonstrate that the laboratory evaluation of milk composition, especially milk urea nitrogen (MUN), constitutes a strategic tool to support decision-making in grazing production systems. Within the context of the extension action developed, the generated data were used not only as a one-time diagnosis but also as a technical instrument to guide individualized nutritional interventions in the assisted farms.

The high MUN levels observed, particularly in buffaloes, indicated a possible imbalance in the dietary protein–energy ratio, suggesting an excess of degradable protein or a relative energy deficiency. Based on this finding, producers were guided to revise supplement formulation, with emphasis on the adequacy of energy concentrate supply and the adjustment of crude protein (CP) levels to improve dietary nitrogen utilization efficiency. This guidance aimed to reduce economic losses associated with protein waste while also minimizing nitrogen excretion into the environment.

Regarding milk fat, the results reinforce the importance of proper balancing of physically effective fiber (peNDF) and the roughage–concentrate ratio, especially in cattle herds where average values were below the recommended level. In this sense, producers were advised to monitor the quality of the offered forage and avoid excessive concentrate that could compromise the ruminal environment and consequently affect milk fat synthesis.

Regarding somatic cell count (SCC), the values remained within the limits established by current legislation, indicating an adequate sanitary condition of the mammary gland. Nevertheless, the importance of maintaining good milking and hygiene practices was reinforced with producers as a preventive strategy to avoid future increases in these indices.

Overall, the extension activity allowed the transformation of laboratory data into practical recommendations, strengthening the producers' capacity to interpret metabolic-nutritional indicators and use them as a basis for evidence-based technical decisions. Thus, the action contributed to the promotion of greater productive efficiency, environmental sustainability, and the improvement of milk quality in the assisted farms.

CONCLUSION

This university extension action demonstrated that the use of laboratory indicators, particularly milk urea nitrogen (MUN), can transform technical data into practical tools to support decision-making in dairy production systems. The interpretation of the results allowed the identification of nutritional management weaknesses, especially in buffalo herds, supporting targeted recommendations to improve dietary nitrogen utilization efficiency and reduce potential environmental impacts.

In addition to the technical outcomes, the extension activity strengthened the interaction between the university and local producers, promoting greater understanding of metabolic-nutritional indicators and increasing autonomy in herd management decisions. These results reinforce that rural extension actions based on scientific evidence and participatory approaches represent an important strategy to promote productive efficiency, environmental sustainability, and improvements in milk quality in smallholder dairy systems.

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