Artigo Original

v. 7 n. 2 (2026)
ISSN: 2675-8008
Revista Multidisciplinar em Saúde

ACESSO ABERTO

Data de Recebimento:
01/03/2026

Data de Aceite:
02/04/2026

Data de Publicação:
23/04/2026

Autor correspondente:
Mateus de Andrade da Silva, Doutorando, Faculty of Agrarian Science, Federal University of Grande Dourados – UFGD, Rod. Dourados-Itahum, km 12, 79804-970, Dourados, MS, Brazil. Contact phone number (preferably WhatsApp): (92)99341-5774
E-mail de contato: mateus.andrade.medvet@gmail.com

Citação:
SILVA, M.A, et al; Milk Urea Nitrogen (MUN) as an Indicator of Environmental Sustainability and Public Health in Dairy Production: A One Health Perspective

Revista Multidisciplinar em Saúde, v. 7, n. 2, 2026. https://doi org/10.51161/integrar/rems/4781

DOI: 10.51161/integrar/rems/4781
Editora Integrar© 2026.

MILK UREA NITROGEN (MUN) AS AN INDICATOR OF ENVIRONMENTAL SUSTAINABILITY AND PUBLIC HEALTH IN DAIRY PRODUCTION: A ONE HEALTH PERSPECTIVE

Mateus de Andrade da Silva[a*], Cristiny Santos Braga[a], Antonio Bruno Magalhães Lima[a], Laryssa dos Santos Rudek[a], Gisele Santos da Silva[b], Lívia Batista Campos[c], Fabiana Ribeiro Caldara[a], Laura Priscila Araújo Amaro Maciel[d], Michel do Vale Maciel[d]

[a] Federal University of Grade Dourados, Mato grosso do Sul (MS), Brasil.
[b] Centro Universitário Fametro – CEUNI-FAMETRO, Amazonas (AM), Brasil.
[c] Federal Institute of Paraíba – IFPB, Paraíba (PB), Brasil.
[d] Federal University of Amazonas - UFAM, Amazonas (AM), Brasil.

ABSTRACT

The intensification of dairy production has increased environmental and sanitary concerns related to low nitrogen utilization efficiency and nitrate water contamination. In this context, Milk Urea Nitrogen (MUN) emerges as a metabolic biomarker capable of integrating productive efficiency, environmental sustainability, and public health. Under the One Health perspective, MUN monitoring allows for understanding the interface between animal physiology, milk quality, and water resource security. This study aims to analyze the role of MUN as a bio-strategic indicator at the One Health interface, investigating its relationship with animal metabolic efficiency, milk stability, and environmental impact through nitrate leaching. An integrative literature review was conducted using the Scopus database, focusing on studies that link nitrogen management in dairy farming to environmental sustainability, milk quality, and public health. Evidence demonstrates that MUN is a diagnostic tool with moderate heritability, enabling the selection of "environmentally friendly" animals that exhibit higher nitrogen utilization efficiency (NUE) and lower urinary residue loads. Dietary interventions with bioactive compounds and alternative forages proved effective in reducing MUN and, consequently, the gray water footprint, which can reach up to 11,110 liters of water per liter of milk in high-intensification scenarios. MUN monitoring transcends nutritional adjustment, acting as a sentinel indicator for aquifer preservation and drinking water safety. The integration of genetics and precision nutrition based on MUN is indispensable to decouple dairy production from ecosystem degradation, promoting animal, environmental, and public

health in an integrated manner.

Keywords: Leaching; Milk stability; Nitrogen; Nitrate; One Health; Gray water footprint

INTRODUÇÃO

The intensification of dairy production systems in recent decades has fostered significant advances in productive efficiency; however, it has also increased concerns regarding its environmental and sanitary impacts. In systems based on high-yielding pastures and protein supplementation, dairy farming exhibits relatively low nitrogen utilization efficiency (NUE), as only about 25 to 35% of the ingested nitrogen (N) is effectively converted into milk protein. The surplus is mostly excreted, primarily via urine, making it the main vector of nitrogen losses to the environment (Pereira et al., 2025; Marshall et al., 2021).

Once excreted, urinary nitrogen, predominantly in the form of urea, is rapidly hydrolyzed in the soil, being converted into ammonia (NH_3), nitrogen oxides (N_2O), and nitrate (NO_3^-). Part of this nitrogen contributes to atmospheric greenhouse gas emissions, while another significant fraction is leached into deep soil layers, reaching aquifers and surface water bodies. Water contamination by nitrate is directly linked to the eutrophication of aquatic ecosystems and relevant risks to human health, including infant methemoglobinemia and potential associations with endocrine disorders and gastrointestinal tract neoplasms (Joy et al., 2022).

In this context, dairy production is understood not merely as an agricultural activity, but as a component of an interdependent system connecting animal health, environmental integrity, and public health a structural principle of the One Health approach (Wielinga; Schlundt, 2015). Animal metabolic efficiency, therefore, plays a central role in mitigating environmental impacts and preventing indirect sanitary risks.

Traditionally, Milk Urea Nitrogen (MUN) has been employed as a nutritional adjustment tool, allowing for the assessment of the balance between rumen-degradable protein and dietary energy availability. High MUN values indicate protein excess or nutritional imbalance, reflecting lower efficiency in nitrogen incorporation into microbial crude protein and subsequent higher urinary excretion (Martins et al., 2024; Marchand et al., 2024).

However, recent evidence expands the interpretation of this indicator. MUN should not be understood solely as a reflection of dietary management, but as a metabolic biomarker of individual nitrogen utilization efficiency, showing moderate heritability and potential for genetic selection (MUN Breeding Values - MUNBV) (Marshall; Gregorini, 2021). Animals with lower MUN values demonstrate lower nitrogen concentration per urination event, reducing the nitrogen load deposited on the soil and, consequently, the leaching potential (Marshall et al., 2022). Thus, MUN establishes a measurable link between animal physiology and environmental sustainability.

In addition to the genetic dimension, strategic nutritional interventions have shown the capacity to modulate nitrogen partitioning. The use of functional forages and plant-derived bioactive compounds can increase NUE and reduce urinary excretion, reinforcing the possibility of integrating genetics, precision nutrition, and environmental management into a less polluting production model (Marshall et al., 2021; Xiong et al., 2025).

Although urea present in milk does not pose a direct toxicological risk to consumers at typical levels, MUN reflects the metabolic balance of the herd and can impact milk composition and its physicochemical stability (such as ethanol stability), with implications for industrial processing and the quality of food offered to the population (Schmitz et al., 2024; Martins et al., 2024). Thus, proper MUN management addresses not only environmental sustainability but also food safety.

Despite the observed scientific progress, gaps remain in the integration of the metabolic, environmental, and sanitary dimensions of MUN. The fragmentation between zootechnical, environmental, and epidemiological studies limits a systemic understanding of this biomarker's role in the dairy chain under the One Health perspective.

Given this, the objective of this study is to analyze Milk Urea Nitrogen (MUN) as a strategic indicator at the interface of metabolic efficiency, environmental sustainability, and public health. By consolidating recent evidence, we aim to demonstrate that the monitoring and strategic management of MUN can constitute a pragmatic tool to decouple productive intensification from ecosystem degradation, promoting an environmentally responsible and sanitarily secure dairy industry.

METHODOLOGY

Study design and theoretical approach

This study was developed as an integrative literature review with a qualitative and exploratory approach. The method was chosen because it allows the synthesis and critical interpretation of studies addressing Milk Urea Nitrogen (MUN) from different but complementary perspectives, including animal metabolism, nitrogen use efficiency, milk quality, environmental sustainability, and public health. The review was guided by the One Health perspective, considering the interdependence between animal health, environmental integrity, and human well-being. Rather than proposing a systematic review or meta-analysis, the study aimed to organize and critically discuss recent scientific evidence on the role of MUN as an indicator at the interface between dairy production, environmental sustainability, and public health.

Search strategy and databases

Data collection was conducted in the Scopus (Elsevier) database, selected for its multidisciplinary coverage and strong indexing in Agricultural Sciences, Veterinary Medicine, Environmental Sciences, and Public Health. The literature search was carried out in January 2026.

To maximize retrieval sensitivity and avoid premature exclusion of potentially relevant studies, no restrictive filters were applied regarding chronological period, language, or document type during the initial search stage. In addition, a complementary manual search was conducted to support the theoretical background of the manuscript, especially regarding the One Health framework and broader conceptual discussions related to environmental sustainability, food safety, and nitrogen metabolism. These complementary references were used exclusively for contextual and theoretical support and were not considered part of the final analytical sample of the review.

Search operationalization

The bibliographic search was structured into four thematic axes (Table 1), applied to the title, abstract, and keywords fields (TITLE-ABS-KEY) in Scopus. Boolean operators were used to combine descriptors related to the central dimensions of the review: (i) the One Health perspective; (ii) nitrogen use efficiency and environmental sustainability; (iii) milk quality and technological stability; and (iv) public health implications associated with nitrate contamination.

Table 1. Thematic axes, search keywords, records retrieved, and studies included in the final analytical sample from the Scopus database

Strategic Axis	Investigation Scope	Search Keywords	Records retrieved	Studies included in the final analytical sample
I. One Health Perspective	Animal-Environment-Human Health Interface	("Milk Urea Nitrogen" OR "MUN") AND "dairy cows" AND ("nitrogen excretion" OR "ammonia emission") AND ("public health" OR "One Health")	7	4
II. Sustainability	Nitrogen Efficiency and Environmental Impact	("Milk Urea Nitrogen" OR "MUN") AND "nitrogen utilization efficiency" AND ("environmental impact" OR "nitrate leaching")	1	1
III. Milk Quality	Physicochemical Properties and Processing	("Milk Urea Nitrogen" OR "MUN") AND ("milk composition" OR "milk quality") AND ("dairy processing" OR "milk stability")	2	2
IV. Public Health	Water Resource Contamination	("Nitrogen excretion" OR "nitrate leaching") AND "dairy production" AND ("drinking water contamination" OR "methemoglobinemia")	3*	2
Total			13	9

*One duplicate record was identified and removed in Axis IV prior to final inclusion. Source: Prepared by the author (2026).

The descriptors were defined according to the objective of the review, seeking to identify studies that examined MUN as a central or closely associated indicator in dairy cattle systems. As shown in Table 1, the four search strategies retrieved 13 records in total. After title, abstract, and full-text assessment, and after the removal of one duplicate record identified in Axis IV, nine studies composed the final analytical sample of the review.

Selection, eligibility, and sample composition

The selection process involved successive stages of title reading, abstract screening, and full-text assessment. Eligible studies were those addressing Milk Urea Nitrogen (MUN), nitrogen excretion, nitrogen use efficiency, milk quality, nitrate leaching, or public health implications related to dairy production systems.

Studies that were not directly related to dairy cattle, did not address the thematic scope of the review, or lacked relevance to the proposed analytical dimensions were excluded after title, abstract, and full-text assessment. After this refinement process, nine studies composed the final analytical sample of the review, as presented in Table 2. Complementary references obtained through manual search were used only to support the theoretical and conceptual discussion of the manuscript and were not included in the final analytical sample.

Because this was an integrative literature review with a qualitative and interpretative scope, the selection process was described narratively rather than through a formal flowchart. The emphasis of the method was placed on thematic relevance, analytical coherence, and conceptual contribution of the studies included in the final sample.

RESULTS AND DISCUSSION

The analysis of the included studies suggests that Milk Urea Nitrogen (MUN) may extend beyond its traditional use as a nutritional adjustment parameter and may also contribute to the evaluation of metabolic efficiency, milk quality, and environmental implications in dairy production systems. Across the selected studies, lower MUN values were generally associated with improved nitrogen utilization and, in some contexts, with reduced urinary nitrogen losses, although the magnitude and interpretation of these relationships varied according to study design, production conditions, and analytical focus.

The reviewed evidence encompasses different approaches, including genetic selection for low Milk Urea Nitrogen Breeding Values (MUNBV), phenotyping for nitrogen use efficiency, dietary interventions with functional forages, and supplementation with bioactive compounds. Taken together, these studies indicate that MUN can be interpreted as a relevant monitoring parameter in discussions on nitrogen partitioning and sustainability, but its use should be understood within the limits of the available evidence and the heterogeneity of the studies included.

In addition, studies addressing milk physicochemical stability and variation in MUN according to breed and lactational stage broaden the discussion by showing that this biomarker may also have practical relevance for herd monitoring and milk quality management. In this sense, MUN may be discussed as a connecting variable between productive efficiency, food quality, and environmental concerns under the One Health perspective.

The systematization of the evidence obtained, considering the location of the study, the primary focus, and the interface with the One Health pillars (animal, environmental, and public), is presented in Table 2.

Table 2. Characterization of the included studies and main findings related to MUN from a One Health perspective

Author (Year)	Location	Primary Focus	Main Findings (MUN/N)	One Health Interface
Joy et al. (2022)	NZL	Public Health	Gray water footprint: 433 to 11,110 L of water per L of milk produced.	Public: Risk of methemoglobinemia due to nitrate contamination of drinking water.
Marchand et al. (2024)	CAN	Mineral Nutrition	Excessive mineral supplementation increased MUN (11.7 vs. 9.7 mg/dL).	Animal/Environmental: Excess minerals and N increase the risk of soil contamination.

Marshall et al. (2021)	NZL	Genetics and Diet	Low MUNBV cows (10.6 mg/dL) + Plantain reduced urinary N excretion.	Animal/Environmental: Genetic selection reduces the N load per urine patch.
Marshall et al. (2022)	NZL	Excretion Behavior	Low MUNBV and Plantain reduced urinary N concentration by 28%.	Environmental/Public: Mitigation of nitrate leaching in grazing systems.
Marshall; Gregorini (2021)	NZL	Conceptual Review	MUN as a biomarker with moderate heritability (0.15–0.44).	Perspective: The animal as an active solution for ecosystem regeneration.
Martins et al. (2024)	BRA	Milk Quality	Average MUN of 14.58 mg/dL; used as a dietary monitoring indicator.	Public/Quality: Ensuring the physicochemical stability of food products.
Pereira et al. (2025)	NZL	Phenotyping	Low MUN increased Nitrogen Utilization Efficiency (NUE) by 14.5%.	Animal/Environmental: Efficient animals alter the soil microbiome and reduce N2O.
Schmitz et al. (2024)	BRA	Physiology and Breed	MUN variation between Holstein and Jersey according to lactational stage.	Animal/Public: Precision nutrition to avoid technological losses (LINA/UNAM).
Xiong et al. (2025)	CHN	Bioactive Compounds	Isoflavones reduced MUN (14.56 to 12.85 mg/dL) and urinary N.	Animal/Environmental: Metabolic modulation via natural extracts for sustainability.

Prepared by the author (2026).

MUN as an indicator of metabolic efficiency and nitrogen partitioning

Historically, the monitoring of Milk Urea Nitrogen (MUN) was used as a dietary management tool to balance rumen-degradable protein and energy. However, the evidence compiled in this review indicates that MUN transcends nutritional response, establishing itself as a biomarker of individual metabolic efficiency and nitrogen (N) partitioning. In dairy production, nitrogen utilization efficiency (NUE) is inherently low, with only approximately 30% of ingested N being converted into animal products (milk and body protein), while about 60% of the surplus is excreted via urine, representing a critical bottleneck for the sector's sustainability.

In this context, the studies by Marshall et al. (2021) and Marshall et al. (2022) contribute to a broader interpretation by demonstrating that cows with low Milk Urea Nitrogen Breeding Values (low MUNBV) exhibit a distinct physiology regarding waste excretion. It was consistently observed that these animals present a lower urinary N concentration per urination event and, consequently, a lower Urinary Urea Nitrogen (UUN) load per hectare. A critical point revealed by this research is that genetic selection for low MUN can reduce urinary N concentration even in scenarios where the total volume of excreted N does not undergo drastic changes, suggesting a modulation in the animal's renal and metabolic dynamics.

Complementing this view, Pereira et al. (2025) reinforce that phenotyping for low MUN identifies individuals with significantly higher NUE. From a One Health perspective, this individual metabolic profile may be relevant: MUN is no longer seen merely as a reflection of what the cow consumes but is interpreted as an indicator of how the animal processes this nutrient.

A cautious interpretation of these findings suggests that animals with lower MUN may present more favorable nitrogen partitioning patterns under certain production conditions, potentially reducing environmental pressure without necessarily impairing productive performance. In this context, MUN monitoring may be viewed as a complementary management tool for discussing metabolic efficiency and nitrogen losses within the One Health framework.

MUN and environmental impact: from urine to the gray water footprint

Urinary nitrogen excretion is recognized as the primary vector of environmental degradation in dairy production systems. It is estimated that approximately 20% to 30% of the nitrogen present in urine is leached into groundwater as nitrate (NO3), a process that occurs when the N load deposited exceeds the plants' absorption capacity and the soil's retention capacity (Marshall et al., 2021).

In this sense, MUN assumes the role of a predictive indicator of environmental risk. As demonstrated by Marshall et al. (2022), the use of strategies that reduce MUN, such as pasture diversification with plantain (Plantago lanceolata), decreases the N concentration in the urine patch, mitigating the leaching potential. However, when nitrogen utilization efficiency is neglected, the environmental cost is alarming.

The study conducted in Canterbury, New Zealand, by Joy et al. (2022), provides a critical dimension of this impact by introducing the concept of Gray Water Footprint (GWF). The authors revealed that between 433 and 11,110 liters of water are required to dilute the leached nitrate for every liter of milk produced, in order to maintain water potability standards. This drastic variation depends on the rigor of the applied environmental regulations, but even the minimum value significantly exceeds global water footprint estimates, highlighting that dairy intensification without metabolic control is unsustainable.

A cautious interpretation of these data suggests that elevated MUN may be associated with dietary or metabolic conditions linked to greater urinary nitrogen losses, which, under certain environmental circumstances, may contribute to nitrate leaching and increased pressure on water resources. However, this relationship should not be interpreted as uniformly direct or isolated, since the environmental fate of excreted nitrogen also depends on soil characteristics, pasture management, climatic conditions, and regulatory thresholds. From a One Health perspective, reducing MUN may therefore represent a relevant complementary strategy for mitigating environmental risk and supporting water security in dairy production areas.

Mitigation Strategies: Precision Nutrition and Bioactive Compounds

The modulation of MUN through dietary interventions represents one of the most agile strategies to align dairy production with One Health principles. As observed by Marchand et al. (2024), inadequate mineral management, specifically providing trace minerals above recommendations, can increase MUN (11.7 vs. 9.7 mg/dL), signaling metabolic inefficiency that results in higher fecal and urinary excretion. This finding reinforces that precision nutrition should focus not only on macronutrients but also on a rigorous mineral balance to prevent the animal from becoming a disperser of metallic and nitrogenous residues into the soil.

In line with this approach, the search for biologically safe alternatives to synthetic additives has revealed the potential of plant secondary compounds. Xiong et al. (2025) demonstrated that supplementation with red clover isoflavones promotes a linear and quadratic reduction in MUN, optimizing plasma amino acid metabolism. From a One Health perspective, the use of these natural extracts is doubly advantageous: it improves nitrogen utilization efficiency by the animal (Animal Health) and reduces ammonia volatilization and nitrate leaching (Environmental Health), without compromising the biological safety of the food produced.

A critical reading of this evidence suggests that MUN may function as a useful marker of dietary nitrogen balance in dairy systems. While mineral excess appears to be associated with higher MUN values, dietary strategies involving bioactive compounds or specific forages may contribute to more favorable nitrogen partitioning patterns. Thus, strategic dietary manipulation can be discussed as a potentially useful approach for reducing the environmental burden of dairy production, although its effectiveness may vary according to feeding system, herd profile, and production context.

Implications for milk quality and public health

Finally, the stability of the final product is the link that connects animal metabolism to the consumer's table. Brazilian studies by Martins et al. (2024) and Schmitz et al. (2024) highlight that, although MUN varies according to breed and lactational stage, its monitoring is essential to ensure the technological quality of milk. Imbalanced MUN levels can coexist with protein stability issues, such as Unstable Non-Acid Milk (UNAM/LINA), affecting industrial processing and the supply of safe food.

In broader terms, the literature reviewed suggests that inadequate nitrogen management in dairy systems may have implications that extend beyond herd metabolism, including possible effects on water quality and, indirectly, on public health. In this discussion, MUN should be interpreted not as an isolated determinant, but as a potentially informative marker within a wider set of nutritional, environmental, and sanitary variables. Under the One Health perspective, its relevance lies in helping connect animal efficiency, milk quality, and environmental stewardship, rather than in serving as a standalone predictor of public health outcomes.

Scientific gaps and future perspectives

Despite significant advances in understanding MUN as a multifaceted indicator, this integrative review has identified critical gaps that limit the fully integrated implementation of One Health in the dairy chain. The primary weakness lies in data fragmentation: although there is robust evidence correlating MUN to metabolic efficiency (Marshall et al., 2021) and the physicochemical quality of milk (Martins et al., 2024), studies that integrate MUN levels, the Gray Water Footprint (GWF), and actual public health epidemiological indicators into a single analytical matrix remain scarce.

There is a pressing need for longitudinal studies that track the nitrogen cycle from the mammary gland to the aquifer over several seasons. Most current research offers temporal "snapshots" (cross-sectional studies), which may mask the cumulative dynamics of nitrate in soil and water, as highlighted by the impact study in Canterbury (Joy et al., 2022). Furthermore, the integration between animal genetics and quantitative environmental assessment is still incipient. Although the heritability of MUN is known, there is a lack of models quantifying, at a watershed scale, how much genomic selection for low MUN could reduce, in real numbers, the dilution requirement for drinking water (GWF).

Consequently, the transition from theory to practice requires that MUN shifts from a retrospective monitoring metric to a tool for predictive sanitary and environmental surveillance. The development of decision support systems that connect bulk tank MUN history with local water contamination risk models would represent the pinnacle of One Health application. Overcoming these gaps will allow dairy production to not only reduce its impact but to act as a regenerative system, ensuring food security without compromising the water security of future generations.

CONCLUSION

This integrative review consolidates Milk Urea Nitrogen (MUN) as a fundamental sentinel indicator for the viability of modern livestock farming under the aegis of One Health. The evidence demonstrates that MUN transcends nutritional adjustment, acting as a biomarker of heritable metabolic efficiency that allows for the identification of inherently less-polluting animals. By integrating genetics, precision nutrition with bioactive compounds, and environmental monitoring, it is possible to drastically mitigate urinary nitrogen excretion, directly protecting soil integrity and groundwater potability a critical factor for human health in the face of the increasing gray water footprint of dairy production.

It is concluded, therefore, that the strategic management of MUN is a pragmatic and indispensable solution to decouple dairy intensification from ecosystem degradation, ensuring that animal efficiency is, ultimately, the safeguard of planetary health.

CONFLICT OF INTEREST

The authors declare that there are no financial, personal, or professional conflicts of interest that could have influenced the integrity of this integrative review. The study was developed for strictly scientific purposes, aiming to analyze Milk Urea Nitrogen (MUN) as a strategic indicator at the interface of metabolic efficiency, environmental sustainability, and public health under the One Health perspective.

REFERENCES

JOY, M.K., RANKIN, K., LUTTERMAN, A. The grey water footprint of milk due to nitrate leaching from dairy farms in Canterbury, New Zealand. **Australasian Journal of Environmental Management,** v. 29, n. 2, p. 177–199, 2022. Disponível em: https://doi.org/10.1080/14486563.2022.2068685. Acesso em: 10 jan. 2026.

MARCHAND, C. et al. Effects of feeding sulfate trace minerals above recommendations on nutrient digestibility, rumen fermentation, lactational performance, and trace mineral excretion in dairy cows. **Journal of Dairy Science,** v. 107, n. 10, p. 7983–7995, 2024. Disponível em: https://doi.org/10.3168/jds.2024-24761. Acesso em: 21 jan. 2026.

MARSHALL, C. J. et al. Nitrogen balance of dairy cows divergent for milk urea nitrogen consuming either plantain or perennial ryegrass. **Animals,** v. 11, n. 8, p. 2464, 2021. Disponível em: https://doi.org/10.3390/ani11082464. Acesso em: 05 fev. 2026.

MARSHALL, C. J. et al. Urine and fecal excretion patterns of dairy cows divergent for milk urea nitrogen breeding values consuming either a plantain or ryegrass diet. **Journal of Dairy Science,** v. 105, n. 5, p. 4218–4236, 2022. Disponível em: https://doi.org/10.3168/jds.2021-21490. Acesso em: 07 jan. 2026.

MARSHALL, C. J.; GREGORINI, P. Animal as the solution: Searching for environmentally friendly dairy cows. **Sustainability** v. 13, n. 18, p. 10451, 2021. Disponível em: https://doi.org/10.3390/su131810451. Acesso em: 12 jan. 2026.

MARTINS, F. A. et al. Characterization of variables related to high stability of raw cow milk. **Journal of Dairy Research,** v. 91, n. 1, p. 89–95, 2024. Disponível em: https://doi.org/10.1017/S0022029924000049. Acesso em: 20 jan. 2026.

PEREIRA, A. B. D. et al. Animal as the Solution II: Phenotyping for Low Milk Urea Nitrogen A1PF Dairy Cows. **Animals,** v. 15, n. 1, p. 32, 2025. Disponível em: https://doi.org/10.3390/ani15010032. Acesso em: 20 fev. 2026.

SCHMITZ, A. P. et al. Variation in bovine milk stability according to lactational stage and genetic group. **Journal of Dairy Research,** v. 91, n. 2, p. 233–238, 2024. Disponível em: https://doi.org/10.1017/S0022029924000372. Acesso em: 13 jan. 2026.

SILVA, M. de A. da et al. Composição do leite como indicador metabólico-nutricional em vacas leiteiras à pasto. **Observatório de la Economía Latinoamericana**, v. 23, n. 9, p. e11313, 2025. Disponível em: https://doi.org/10.55905/oelv23n9-013. Acesso em: 23 jan. 2026.

WIELINGA, P. R.; SCHLUNDT, J. (2014). One health and food safety. In Confronting Emerging Zoonoses: **The One Health Paradigm.** Tokyo: Springer, 2014. p. 213–232. Disponível em: https://doi.org/10.1007/978-4-431-55120-1_10. Acesso em: 23 jan. 2026.

XIONG, Z. et al. Effects of red clover isoflavone on lactation performance, milk quality and nitrogen metabolism in dairy cows. **Animal Nutrition,** v. 22, p. 191–200, 2025. Disponível em: https://doi.org/10.1016/j.aninu.2025.03.010. Acesso em: 23 jan. 2026.