Journal of Research and Development 11[26]1-6: e51126106
Article

Physicochemical characterization of goat whey from different cheese processes

Caracterización Fisicoquímica del lactosuero caprino de diferentes procesos de elaboración de queso

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SECIHTI classification:

Area: Biology, Chemistry and Life Science
Field: Life Sciences
Discipline: Biochemistry
Subdiscipline: Food biochemistry

https://doi.org/10.35429/JRD.2025.11.26.5.1.6
Article History:
Received: January 30, 2025
Accepted: December 10, 2025

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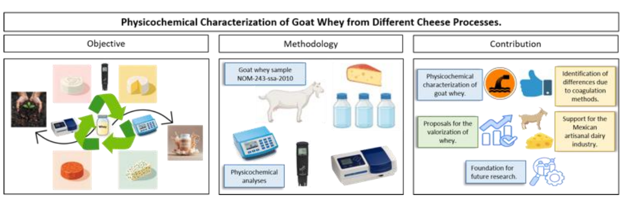
Abstract

This study characterizes the physicochemical properties of goat whey from four cheese processes (spreadable cream, Camembert, lactic-set, and feta) at an artisanal dairy in Queretaro, Mexico. Parameters including pH, electrical conductivity, total dissolved solids, soluble proteins, nitrates, phosphates, and potassium were analyzed using standardized methods (NOM-243-SSA1-2010). Results show variations: pH (3.20–4.20), electrical conductivity (7.30–9.43 mS/cm), total dissolved solids (3.50–4.70 ppt), and soluble proteins (1.50–2.07 mg/mL), influenced by coagulation methods (acidic, mixed, or enzymatic) and brine addition in feta. These differences highlight whey's potential for applications such as functional foods, animal feed, or fertilizers, promoting its valorization. This work supports sustainable practices in the mexican dairy industry, fostering a circular economy through byproduct reuse and waste reduction.



Goat whey, Cheese-making, Physicochemical properties

Resumen

Este estudio caracteriza propiedades fisicoquímicas del lactosuero caprino derivado de cuatro procesos de elaboración de queso (crema untable, camembert, coagulación láctica y feta) de una lechería artesanal en Querétaro, México. Se analizaron parámetros como pH, conductividad eléctrica, sólidos disueltos totales, proteínas solubles, nitratos, fosfatos y potasio, siguiendo métodos estandarizados (NOM-243-SSA1-2010). Los resultados revelaron variaciones: pH (3.20-4.20), conductividad eléctrica (7.30-9.43 mS/cm), sólidos disueltos (3.50-4.70 ppt) y proteínas solubles (1.50-2.07 mg/mL), influenciadas por los métodos de coagulación (ácida, mixta o enzimática) y la adición de salmuera en feta. Estas diferencias destacan el potencial del lactosuero para aplicaciones como alimentos funcionales, alimentación animal o fertilizantes, promoviendo su valorización. Este trabajo fomenta prácticas sostenibles en la industria láctea mexicana, apoyando la economía circular mediante la reutilización de subproductos y la reducción de residuos.

Lactosuero caprino, Elaboración de queso, Propiedades Fisicoquímicas

Area: Physicochemical characterization of goat whey

Citation: Mandujano-González, Virginia, Álvarez-Cervante, Jorge, Morales-Aguilar, Santiago and Alonso-Segura, Diana. [2025]. Physicochemical characterization of goat whey from different cheese processes. 11[26] 1-6: e51126106.

Introduction

Whey, the liquid by-product of cheese production, represents both an environmental challenge and an untapped economic opportunity due to its high organic load, with a biochemical oxygen demand (BOD) often exceeding 40,000 mg/L, rendering it a significant pollutant if improperly managed [1]. In Mexico, goat cheese production has gained prominence, particularly within small- and medium- scale agro-industries, contributing to local economies and cultural heritage [2].

However, the whey generated during these processes is frequently discarded without further use, wasting valuable components such as lactose, soluble proteins (e.g., β-lactoglobulin, α-lactalbumin), and minerals like calcium, potassium, and phosphorus [3, 4]. This practice not only exacerbates environmental issues but also overlooks the potential for whey valorization in applications such as functional foods, animal feed, or biogas production [5, 6].

The physicochemical properties of whey vary significantly depending on the cheese-making process, which can involve enzymatic, acidic, or mixed coagulation methods. These variations influence the composition of whey, including pH, conductivity, protein content, and mineral profiles, which in turn affect its potential for reuse or treatment [7, 8].

While previous studies have characterized whey from cow's milk or single types of goat cheese, there is a lack of comparative data on whey derived from diverse goat cheese production processes, particularly in the Mexican context [3].

This study addresses this gap by conducting a comprehensive physicochemical characterization of goat whey obtained from four distinct cheese-making processes -spreadable cream cheese, Camembert, lactic-set cheese, and feta- produced at a small-scale dairy in Queretaro, Mexico. By analyzing parameters such as pH, electrical conductivity, total dissolved solids, soluble proteins, and key minerals (nitrates, phosphates, and potassium), this work provides novel insights into the compositional differences driven by coagulation and processing methods.

In the Mexican context, goat milk production has shown sustained growth, with Querétaro emerging as a key region due to its artisanal cheese-making tradition and proximity to urban markets [2]. However, the management of whey remains a critical challenge for small-scale producers, who often lack infrastructure for its treatment or valorization. According to Rodríguez-Afonso, A. [6], the implementation of good manufacturing practices (GMP) in dairy processing units is essential to ensure whey quality from the moment of separation, minimizing microbial contamination and preserving functional components such as proteinas and minerals. This is particularly relevant in artisanal settings like Granja La Serpentina, where manual processes dominate and hygienic control directly influences whey composition.

Furthermore, recent studies have demonstrated the technical and economic feasibility of transforming whey into value-added products. For instance, León-López et al. [9] developed fermented whey-based beverages supplemented with hydrolyzed collagen, achieving high protein content (up to 9.75 g/L), enhanced antioxidant activity (up to 48% ABTS radical inhibition), and in vitro bioavailability exceeding 70%, making them suitable for functional food applications. Similarly, Rodríguez-Afonso [6] designed a biogas plant for treating organic by-products, including whey, at the Benijos cheese factory (La Orotava), achieving CO_2 emission reductions and generating digestate as organic fertilizer, with a projected investment and energy return based on renewable biogas. These initiatives align with the principles of circular economy and sustainable development promoted by SECIHTI, emphasizing the reuse of agro-industrial by products to generate renewable energy and reduce environmental impact.

This study contributes to this framework by providing comparative data on whey from four cheese-making processes, enabling the identification of optimal valorization routes based on physicochemical profiles. The central hypothesis of this study is that differences in cheese-making techniques significantly alter the physicochemical properties of goat whey, enabling the identification of tailored strategies for its treatment or valorization.

ISSN: 2444-4987
RENIECYT-SECIHTI: 1702902

Mandujano-González, Virginia, Álvarez-Cervante, Jorge, Morales-Aguilar, Santiago and Alonso-Segura, Diana. [2025]. Physicochemical characterization of goat whey from different cheese processes. 11[26] 1-6: e51126106.
https://doi.org/10.35429/JRD.2025.11.26.1.1.6

This research not only contributes to the scientific understanding of goat whey but also supports sustainable practices in the mexican dairy industry by proposing alternatives for whey management. By comparing whey from multiple cheese types, this study offers a unique perspective on its potential applications, aligning with global efforts to reduce food industry waste and promote circular economy principles [1, 5, 6].

Methodology

Samples collection. Whey samples were collected from the production of spreadable cream cheese, camembert, lactic-set cheese, and feta, crafted at Granja la Serpentina, located in El Marques, Queretaro, Mexico. The samples were obtained directly during the whey separation in the artisanal cheese-making process using goat´s milk, following the guidelines of NOM-243-SSA1-2010 [8], a Mexican standard for daily products safety and quality, to ensure representativeness and hygiene during collection. Each sample (n=3 per cheese type) had a volume of 500 mL and was collected in autoclaved glass jars. The samples were kept at 4 ºC during transport to the laboratory and analysed within 24 hours of collection to minimize microbial growth or chemical degradation.

Physicochemical Analyses

The following parameters were evaluated:

– **pH, Electrical conductivity and Total dissolved solids:** Calibrated with buffer solutions of pH 4.0 and 7.0 at 20 °C (Hanna Instruments, model HI-98129).

– **Soluble proteins:** Quantified by the Bradford method [10], using standard solutions of bovine serum albumin (BSA) prepared from a 2 mg/mL stock solution. A calibration curve was constructed with known BSA concentrations. Absorbance was measured at 595 nm using a UV-Vis spectrophotometer, and results were expressed in mg/mL.

– **Nitrate, phosphate, and potassium:** Quantified using a Multiparameter Photometer for Nutrient Analysis (Hanna Instruments, model HI-83200) with specific reagent kits for each analyte provided by the manufacturer. Results were expressed in mg/L [11].

– **Statistical Analysis.** To evaluate the differences in the physicochemical parameters of goat whey according to cheese type, a one-way analysis of variance (ANOVA) was performed at a 95% significance level ($p < 0.05$). When significant differences were identified, a post-hoc Tukey's mean comparison test was conducted to determine specific differences between cheese types. All statistical analyses were performed using Minitab Statistical Software (version 22). Results are presented as mean values ± standard deviation (n = 3 per cheese type) in the results section.

Results

The physicochemical composition of goat whey from four cheese-making processes (spreadable, camembert, lactic, and feta) was analyzed, revealing significant variations attributable to differences in coagulation and processing methods (Table 1, mean values ± standard deviation, n=3 per cheese type). The results for pH, electrical conductivity, total dissolved solids (TDS), soluble proteins, nitrates, phosphates, and potassium are presented below, with comparisons to literature values for sweet whey.

Box 1

Table 1

Results of the physicochemical analyses

Physicochemical Analyses	Spreadable cream	Camembert	Lactic-set	Feta
pH	4.20 ± 0.10^{a}	3.57 ± 0.11^{b}	3.20 ± 0.02^{c}	3.20 ± 0.02^{c}
Electrical conductivity (mS/cm)	7.3 ± 0.6^{b}	7.66 ± 0.10^{b}	7.37 ± 0.04^{b}	9.43 ± 0.09^{a}
Total dissolved solids (ppt)	3.50 ± 0.16^{c}	3.8 ± 0.04^{b}	3.76 ± 0.05^{bc}	4.70 ± 0.11^{a}
Soluble proteins (mg/mL)	2.07 ± 0.15^{a}	1.95 ± 0.02^{a}	1.50 ± 0.05^{b}	1.82 ± 0.09^{a}
Nitrate (mg/mL)	0.34 ± 0.11^{c}	3.20 ± 0.10^{b}	4.60 ± 0.01^{a}	1.40 ± 0.05^{c}
Phosphate (mg/mL)	$0.48\pm.00^{b}$	0.56 ± 0.03^{a}	0.15 ± 0.01^{d}	0.24 ± 0.01^{c}
Potassium (mg/mL)	1 ± 0^{c}	2.02 ± 0.50^{a}	1.81 ± 0.11^{b}	2.03 ± 0.50^{a}

a, b, c, d Means within a row not sharing a superscript letter differ significantly (p<0.05) according to Tukey´s HSD test.

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The pH ranged from 3.20 to 4.20, with spreadable cheese whey being the least acidic (4.20 ± 0.10), followed by camembert (3.57 ± 0.11), and lactic and feta wheys the most acidic (3.20 ± 0.02). These low pH values confirm the whey as acid whey, resulting from acidic (lactic, feta) or mixed (spreadable, camembert) coagulation processes, which enhance lactic acid production during fermentation or ripening. In contrast, sweet whey typically exhibits higher pH values (5.6–5.9) due to enzymatic coagulation with minimal acidification [5, 8].

Electrical conductivity varied from 7.30 to 9.43 mS/cm, with feta whey showing the highest value (9.43 ± 0.09 mS/cm), which differed significantly from the other types, while the remaining whyes showed similar values (7.3 – 7-66 mS/cm). The elevated conductivity in feta is attributed to brine addition, increasing sodium and chloride ions, while acidic or mixed coagulation in other processes reduces mineral solubility, particularly calcium and magnesium [9]. Sweet whey typically shows higher conductivity (8.0–11.0 mS/cm) due to greater mineral retention [5].

TDS ranged from 3.50 to 4.70 ppt, with feta whey having the highest (4.70 ± 0.11 ppt), differing significantly from the others, followed by camembert (3.80 ± 0.04 ppt), lactic (3.76 ± 0.05 ppt), and spreadable (3.50 ± 0.16 ppt). The high TDS in feta reflects increased mineral content from brine, while acidic coagulation reduces TDS in other wheys due to mineral precipitation. Sweet whey typically has higher TDS (60–92 ppt) [7].

Soluble proteins ranged from 1.50 to 2.07 mg/mL, with spreadable whey showing the highest content (2.07 ± 0.15 mg/mL), followed by camembert (1.95 ± 0.02 mg/mL), which did not differ significantly from feta (1.82 ± 0.09 mg/mL), but were higher than lactic (1.50 ± 0.05 mg/mL). Mixed coagulation in spreadable cheese retains more proteins (e.g., β-lactoglobulin, α-lactalbumin), while prolonged acidification in lactic whey increases protein precipitation into the curd. Sweet whey typically contains higher soluble proteins (6–10 mg/mL) due to minimal precipitation [9].

Mineral contents showed marked differences. Nitrates were highest in lactic whey (4.60 ± 0.01 mg/mL), differing significantly from the others, with the lowest in spreadable (0.34 ± 0.11 mg/mL). Phosphates were highest in camembert (0.56 ± 0.03 mg/mL) and lowest in lactic (0.15 ± 0.01 mg/mL), reflecting precipitation of calcium phosphates under acidic conditions. Potassium levels were similar in camembert (2.02 ± 0.50 mg/mL), lactic (1.81 ± 0.11 mg/mL), and feta (2.03 ± 0.50 mg/mL), but lower in spreadable (1.00 ± 0.01 mg/mL). Brine in feta enhances potassium retention, while acidic coagulation reduces mineral solubility [3].

These results highlight that acidic or mixed coagulation, along with brine addition in feta, significantly influences the physicochemical properties of goat whey, distinguishing it from sweet whey reported in the literature.

Conclusions

This study confirms that cheese-making techniques (acid, enzymatic, or mixed coagulation) significantly alter the physicochemical properties of goat whey, with variations in pH (3.20–4.20), electrical conductivity (7.30–9.43 mS/cm), dissolved solids (3.50–4.70 ppt), soluble proteins (1.50–2.07 mg/mL), and minerals such as nitrates, phosphates, and potassium.

These differences, influenced by acidification and brining (in feta), distinguish acidic whey from the sweet whey reported in literature, highlighting its lower protein and mineral content.

The results suggest valorisation opportunities: whey from spreadable cheese, rich in proteins, is ideal for functional foods, while feta whey, high in solids, could be used in animal feed or fertilizers.

For sustainable management, biological treatments are recommended. Future research on lactose profiles and the economic viability of these applications is suggested.

This work promotes sustainable practices in the mexican dairy industry, encouraging by product reuse and a circular economy.

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Declarations

Funding

The authors declare that this research did not receive any external funding.

Conflict of interest

The authors declare no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Mandujano-González, Virginia: Contributed to the idea of the project, manuscript elaboration, methodology, analysis of the results and conclusions.

Alvárez-Cervantes, Jorge and Alonso-Segura, Diana: Provided technical support.

Morales-Aguilar, Santiago: Contributed to the development and application of analytical methods.

Availability of data and materials

The data supporting the findings of this study, including raw measurements of physicochemical parameters (pH, electrical conductivity, total dissolved solids, soluble proteins, nitrates, phosphates, and potassium) are available from the corresponding author, Virginia Mandujano-González, upon reasonable request.

Acknowledgements

The authors express their gratitude to the Universidad Tecnológica de Corregidora and the Universidad Politécnica de Pachuca for providing laboratory facilities and institutional support. We also thank Granja la Serpentina, El Marqués, Querétaro, for supplying the goat whey samples used in this study.

Abbreviations

ANOVA: Analysis of Variance
BSA: Bovine Serum Albumin
HSD: Honestly Significant Difference
GMP: Good Manufacturing Practices

References

Antecedents

[1] Solís-Oba, A., Solís-Oba, M.M., Teniza-García, O., & Martínez-Casares, R.M. (2023). Proposal for taking advantage of whey. Revista Bio Ciencias, 10, e1392.

[2] Tajonar, K., López-Díaz, C. A., Sánchez-Ibarra, L. E., Chay-Canul, A. J., González-Ronquillo, M., & Vargas-Bello-Pérez, E. (2022). A Brief Update on the Challenges and Prospects for Goat Production in Mexico. Animals, 12(7), 837.

[6] Rodríguez-Afonso, A. (2025). Proyecto de planta de biogás para el tratamiento de subproductos orgánicos de la quesería de Benijos en el tm de la Orotava. [Tesis de grado]. Universidad de La Laguna.

Basics

[8] Secretaría de salud. (2010). NOM-243-SSA1-2010. Productos y servicios. leche, fórmula láctea, producto lácteo combinado y derivados lácteos. Disposiciones y especificaciones sanitarias. Métodos de prueba. Diario oficial de la federación.

[9] León-López, A., Pérez-Marroquín, X. A., Campos-Lozada, G., Campos-Montiel, R. G., & Aguirre-Álvarez, G. (2020). Characterization of Whey-Based Fermented Beverages Supplemented with Hydrolyzed Collagen: Antioxidant Activity and Bioavailability. Foods, 9(8), 1106.

[9] Sanmartín, B., Díaz, O., Rodríguez-Turienzo, L., Cobos, A. (2012). Composition of caprine whey protein concentrates produced by membrane technology after clarification of cheese whey. Small Ruminant Research, 105 (1–3, 186-192. ISSN 0921-4488.

[10] Bio-Rad Laboratories. (2007). Quick Start™ Bradford Protein Assay Instruction Manual. Bio-Rad Laboratories.

[11] Bartošová, A., Michalíková, A., Sirotiak, M. & Soldán, M. (2013). Comparison of Two Spectrophotometric Techniques for Nutrients Analyses in Water Samples. Research Papers Faculty of Materials Science and Technology Slovak University of Technology 20(32), 8-19.

Supports

[5] Macedo, A., Azedo, D., Duarte, E., & Pereira, C. (2021). Valorization of Goat Cheese Whey through an Integrated Process of Ultrafiltration and Nanofiltration. Membranes, 11(7), 477.

[7] Park, Y.W., Juárez, M., Ramos, M., & Haenlein, G.F.W. (2007). Physico-chemical characteristics of goat and sheep milk. Small Ruminant Research. 68(1-2), 88–113. ISSN 0921-4488

Differences

[3] Rangel-Ortega, S. d. C., Campos-Múzquiz, L. G., Charles-Rodríguez, A. V., Palomo-Ligas, L., Solanilla-Duque, J. F., Flores-Gallegos, A. C., & Rodríguez-Herrera, R. (2024). Dietary Factors and Production Season Effect on the Properties of Goat Cheese. Dairy, 5(3), 346-359.

[4] Ramírez-Rivera, E. J, Juárez-Barrientos, J. M, Rodríguez-Miranda, J, Díaz-Rivera, P, Ramón-Canul, L. G, Herrera-Corredor, J. A, Hernández-Serrano, M. I, & Lara, E. H (2017). Typification of a fresh goat cheese of Mexico by path models. Turkish Journal of Veterinary & Animal Sciences 41(2), 213-220.

Discussions

[1] Solís-Oba, A., Solís-Oba, M.M., Teniza-García, O., & Martínez-Casares, R.M. (2023). Proposal for taking advantage of whey. Revista Bio Ciencias, 10, e1392.

[5] Macedo, A., Azedo, D., Duarte, E., & Pereira, C. (2021). Valorization of Goat Cheese Whey through an Integrated Process of Ultrafiltration and Nanofiltration. Membranes, 11(7), 477.

[7] Park, Y.W., Juárez, M., Ramos, M., & Haenlein, G.F.W. (2007). Physico-chemical characteristics of goat and sheep milk. Small Ruminant Research. 68(1-2), 88–113. ISSN 0921-4488

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