2024 SCIENCELINE

Online Journal of Animal and Feed Research

Volume 14, Issue 2: 116-123; March 25, 2024

ISSN 2228-7701

DOI: https://dx.doi.org/10.51227/ojafr.2024.14

PHYSICOCHEMICAL COMPOSITION OF CRIOLLO AND CRIOLLO X SAANEN GOAT MILK ACCORDING TO AGE AND PARITY IN THE CENTRAL HIGHLANDS OF PERU

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Supporting Information

RESEARCH ARTICLE
PII: S222877012400014-14
Received: January 23, 2024
Revised: March 22, 2024
Accepted: March 23, 2024

ABSTRACT: Present study aimed to analyze the physicochemical composition of goat milk based on the type of animal, age, and parity in Chupuro, Junin region in the country of Peru. A total of 24 goats were randomly selected, and divided into two groups: 12 native goats and 12 native goats crossed with Saanen. These groups (G1, G2, and G3) included three age categories (1.8, 2.5, and 3.2 years) and three parity levels (first, second, and third parity). The animals were monitored and fed considering their conversion and nutritional requirements. Before the morning milking, 100 ml of milk was extracted in sterile bottles, followed by agitation for 3 to 5 minutes, and the samples were transported using conservation and cooling techniques in a thermal box with ice cubes. These samples were analyzed in the special laboratory. Measurements of pH, acidity, density, lactose, total solids, fat, and protein were conducted using milk analyzer. The findings for the Criollo breed revealed a pH of 6.35 ± 0.31, a lactose concentration of 4.35%, total solids of 11.62 ± 1.31%, protein content of 4.12 ± 0.35%, and fat content of 3.40 ± 0.91%. In comparison, the Criollo x Saanen crossbreed exhibited a pH of 6.43 ± 0.13%, a lactose concentration of 4.45%, total solids of 12.63 ± 0.92%, protein content of 4.26 ± 0.28%, and fat content of 3.95 ± 0.69%. The results indicated that there were no significant differences in the types of milk from native goats and native goats crossed with Saanen. However, significant differences ($P<0.05$) were observed in density, lactose, total solids, fat, and protein between groups of different ages and parity levels. Crossbreeding with the Saanen breed is well received in the region, as it serves to improve milk production, with favorable percentages of fat, protein, lactose, and total solids.

Keywords: Milk quality, Native goats, Parity, Physicochemical composition, Saanen breed.

INTRODUCTION

The caprine species has gained prominence in global markets (Villalobos, 2005; Bidot, 2017). Goat milk constitutes approximately 3% protein, representing a significant protein contribution to the diet, particularly for pregnant or lactating mothers. Additionally, goat's milk serves as a highly digestible food source (Haenlein, 2004; Ocampo et al., 2016). Moreover, goat farming in rural areas of developing countries contributes to the production of meat, milk, skin, fur, and manure (Resendiz et al., 2021).

Ninety-seven percent of the caprine population is concentrated in Asia, Africa, and Latin America, with Asia holding the majority at approximately 51% of the total population (FAOFAST, 2023). The Mediterranean region stands out as the primary hub for dairy goats, with India, Bangladesh, and Sudan emerging as the key producers of goat milk (Rai et al., 2001; FAOFAST, 2023). In Latin America, the largest caprine populations are observed in Brazil, Mexico, Argentina, Peru, and Bolivia, engaging in activities that serve as both economic drivers and essential food sources for human consumption (Miranda, 2021). In contrast to the advanced production technologies employed in Asian countries (Shinde et al., 2016), Latin American caprine production predominantly relies on traditional systems, utilizing native breeds by being a predominant breed and often operating with limited or no technological interventions (Montesinos et al., 2018; Rodríguez and Ortiz, 2020).

In Peru, the estimated caprine population is 1,771,630 heads, with the highest percentage located in the Piura region (19.5%), followed by Ayacucho (11.7%), Huancavelica (9.7%), Ancash (9.6%), and Lima (9.3%) (Management, 2019). The composition of goat milk is influenced by factors such as breed, environment, number of births, and age of the goat, among others (Guo et al., 2001; Dewettinck et al., 2008; Chilliard et al., 2014). The pH of milk is slightly acidic, due to the presence of citric acid, carbonic anhydride, casein, lactalbumin, phosphates, and chlorides (Cabrera-Beltran et al., 2022), contains 13% more calcium (Ocampo et al., 2016), and enhances the absorption of copper and iron (Da Silva et al., 2015).

Citation: Garcia-Olarte E, Carhuas JN, Guillen MAF, Tacza AA, and Ramos EER (2024). Physicochemical composition of Criollo and Criollo x Saanen goat milk according to age and parity in the central highlands of Peru. *Online J. Anim. Feed Res.*, 14(2): 116-123. DOI: https://dx.doi.org/10.51227/ojafr.2024.14

It is known that the milk from Creole and Saanen goats is a whitish, thick liquid, whose characteristics vary significantly based on the breed, diet, lactation period, and health status of the mammary gland of the animal (Chilliard et al., 2014) Furthermore, goat milk possesses superior organoleptic characteristics and a notable advantage in absorbing odors, in compared to other species such as cattle (Dewettinck et al., 2008).

The pH of cow's milk is acidic, whereas goat milk is alkaline (Cabrera-Beltran et al., 2022). The protein content is associated with phosphates, serving as a buffer in individuals with gastric ulcers and causing fewer allergic reactions, such as intolerance (Collard and McCormick, 2021). Additionally, goat milk contains 13% more calcium than cow's milk (Ocampo et al., 2016) and enhances the absorption of copper and iron (Da Silva et al., 2015). Conjugated linoleic acid and coenzyme Q are also present in goat milk, conferring anticancer properties. Conjugated linoleic acid has been the subject of studies suggesting that it may have inhibitory effects on the growth of certain types of cancer cells and tumor formation (Bidot, 2017).

Limited research exists on the physicochemical composition of goat milk in the regions of Peru, particularly in Junin, which is crucial information for enhancing the productive capabilities of this species to benefit producers. Consequently, the objective of this study was to analyze the physicochemical composition of Criollo and Criollo x Saanen goat milk according to age and parity in the central highlands of Peru.

MATERIALS AND METHODS

Ethical regulations

The procedures and ethics of this research work were based on the "Code of Ethics for Scientific Research". They were authorized by letter N° 005-GRJ-DRA-AAC-PERÚ-2022. Likewise, was conducted by international and national guidelines for the care and use of research animals.

Area study

The study was conducted in the corral located in the Chupuro district (Figure 1), situated 15 kilometers from the city of Huancayo in the Junin region, Peru. The area is positioned on the left bank of the Mantaro River at an altitude of 3175 meters above sea level, with an average annual rainfall of 650 mm (Senamhi, 2023). Prior to commencing the research, visits to the corral were undertaken to identify goats and characterize them based on age and animal type (Criollo and Criollo x Saanen).

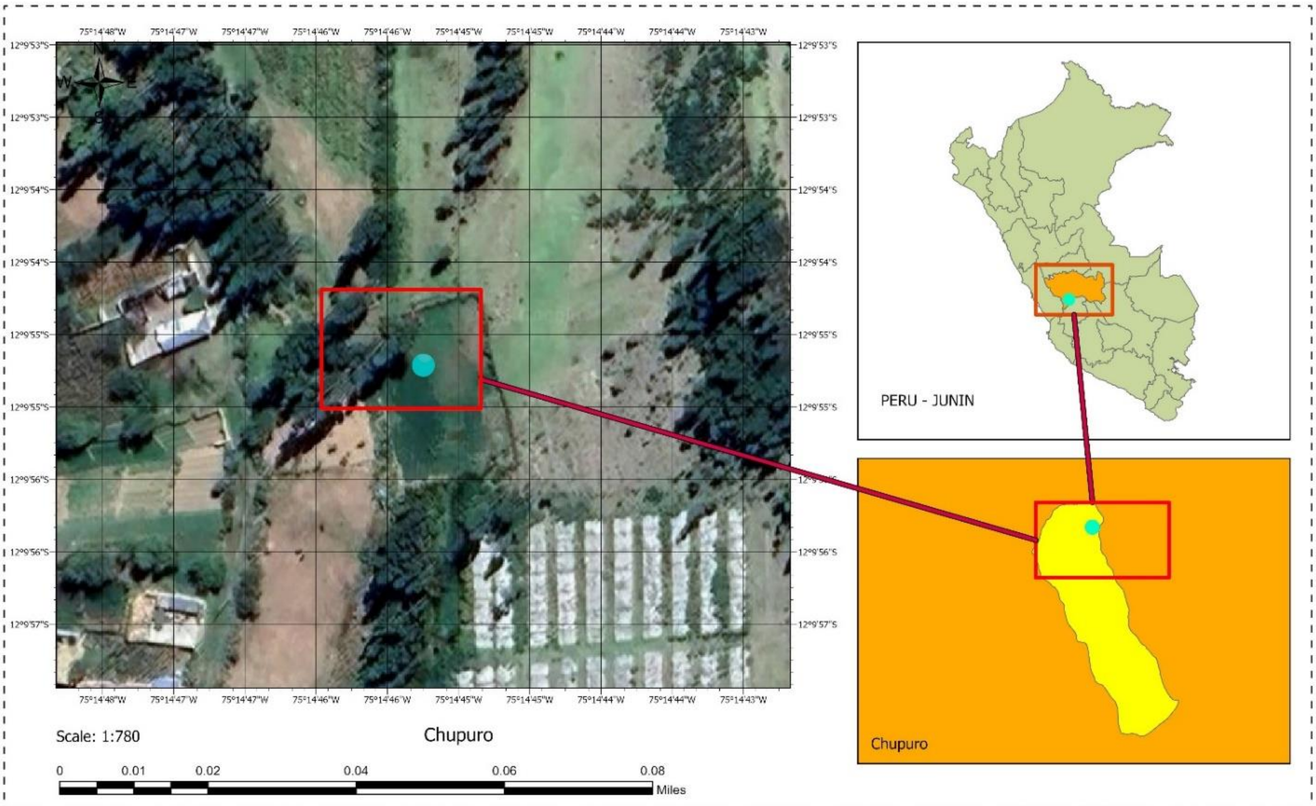

Figure 1 - Location of the study

Animals and distribution

Twenty-four lactating goats were selected, were randomly selected, comprising 12 Criollo and 12 Criollo x Saanen (Figure 2a), categorized into three age groups: G1 (1.8 years and first kidding), G2 (2.5 years and second kidding), and G3 (3.2 years and third kidding); each group consisting of n=8. The animals were individually identified with ear tags for monitoring, and these tags were chosen based on the owner's records to specifically select goats of the specified ages. All animals originated from the same farm and received consistent management practices. They were exclusively pasture-fed with alfalfa (*Medicago sativa*) (Figure 2b). Milking was carried out using a mechanical method, with only one milking per day. The Criollo x Saanen animals belong to the F1 generation resulting from this crossbreeding.

Milk sampling and data collection

A subclinical mastitis test was conducted to eliminate potential confounding factors that could impact the samples. Milk samples were aseptically extracted from each goat before the commencement of milking and post-teat disinfection, utilizing sterile containers. The minimum sample was the total number of animals under investigation with a convenience sample (24 samples). A four-minute agitation of the milk preceded the collection process, adhering to the methodology outlined by Salvador et al. (2016). Subsequently, samples were promptly transferred in a thermal-insulated container with ice packs to ensure proper refrigeration during transit to the Animal Nutrition Laboratory at the Faculty of Zootechnics, National University of the Center of Peru, for subsequent analysis (Guo et al., 2001).

The physicochemical composition of the milk was determined by analyzing fresh milk samples using an automated milk analyzer (Lactoscan S, Milkotronic) (Figure 2d). This apparatus assessed key variables, including pH, density, lactose content, total solids, fat, and protein.

Figure 2 - Procedure: (a) Criollo and Criollo x Saanen goats; (b) Pasture feeding with alfalfa; (c) Samples for analysis; (d) Lactoscan.

Statistical Analysis

The data recorded by the equipment were entered and organized in Microsoft Excel. Differences in ages (1.8, 2.5, and 3.2 years) and parity (first, second, and third) were assessed using analysis of variance (ANOVA), followed by a Tukey post-hoc test. The model used was: $Yij=\mu+\tau i+\beta j+eij$, where Yij is the response variable (physicochemical composition), μ is the overall mean, τi is the effect of ages, βj is the effect of parity, and eij is the experimental error. A significance level of ($p < 0.05$) was considered indicative of a significant difference. Statistical analyses were conducted using the open-source software SPSS 23 (Maswar, 2017).

RESULTS AND DISCUSSION

Physicochemical composition by parturition and age

Table 1 illustrates the physicochemical composition of goat milk, revealing significant differences ($p < 0.05$)

attributed to age and parity. A higher protein percentage is observed in goats aged 3.2 years (third parity), followed by those at 2.5 years (second parity) and 1.8 years (first parity), with values of 4.37%, 4.30%, and 4.25%, respectively. These findings surpass those reported by Alpízar-Solís and Elizondo-Salazar (2019), who documented a protein percentage of 3.27%, likely due to their use of mixed Saanen x Nubian x LaMancha breed goats. Collard and McCormick (2021) also recorded a protein percentage of 3.5%. Similarly, Maldonado-Jaquez et al. (2017) reported 3.37% protein in stall-fed goats, highlighting a decrease in protein concentration in confined goats (Salinas-González et al., 2015). In contrast, these results fall below those reported by Tarazona et al. (2020), who noted a protein content of 5.45%, attributable to the use of Dorper breed sheep. The observed variations in protein content can be attributed to breed and parity differences. It is well-documented that protein percentages increase during the peak of production (3 years and 3 parities) due to udder development (Lozano et al., 2021).

Table 1 - Physicochemical composition of goat's milk in relation to its age ± standard errors ($\bar{X} \pm S\bar{x}$).

Parameters	1.8 years (First birth)	2.5 years (Second delivery)	3.2 years (Third delivery)	P-value
pH	$6.69^{a} \pm 0.45$	$6.73^{b} \pm 0.35$	$6.67^{a} \pm 0.10$	0.006
Acidity (°D)	16.0 ± 0.2	16.0 ± 0.3	16.3 ± 0.2	0.123
Density g/ml	$1.031^{a} \pm 0.0123$	$1.035^{b} \pm 0.005$	$1.037^{b} \pm 0.031$	0.021
Lactose (%)	$4.39^{a} \pm 0.21$	$4.56^{b} \pm 0.15$	$4.68^{c} \pm 0.22$	0.002
Total solids (%)	$11.97^{a} \pm 1.01$	$12.39^{b} \pm 1.41$	$13.2^{c} \pm 0.9$	0.001
Grease (%)	$3.07^{a} \pm 0.14$	$3.39^{b} \pm 0.11$	$3.99^{c} \pm 0.11$	0.001
Protein (%)	$4.25^{a} \pm 0.43$	$4.30^{b} \pm 0.45$	$4.37^{c} \pm 0.45$	0.004

a,b,c Means within a column with different superscripts differ significantly (P<0.05).

Table 2 - Milk production by age and number of births (Criolla and Saanen x Criolla) ± standard errors ($\bar{X} \pm S\bar{x}$).

Age	Production (kg/day)	Lactation duration (days)	Milk production kg/lactation
1.8 (first delivery)	$1.6^{a} \pm 0.1$	$180^{a} \pm 0.1$	$288^{a} \pm 1.2$
2.5 (second calving)	$2.4^{b} \pm 0.2$	$180^{a} \pm 0.1$	$432^{b} \pm 0.1$
3.2 (third parturition)	$3.0^{c} \pm 0.2$	$180^{a} \pm 0.1$	$540^{c} \pm 0.1$
P-value	0.0005	0.125	0.321

a,b,c Means within a column with different superscripts differ significantly (P<0.05).

Table 3 - Physicochemical characteristics and milk composition between breeds (Criollo and Criollo x Saanen) ± standard errors ($\bar{X} \pm S\bar{x}$).

Parameters	Criollo	Criollo x Saanen	P-value
pH	$6.35^{a} \pm 0.31$	$6.43^{a} \pm 0.13$	0.123
Acidity (°D)	15 ± 0.05	15 ± 0.03	0.521
Density g/ml	$1.02^{a} \pm 0.006$	$1.035^{b} \pm 0.0008$	0.010
Lactose (%)	$4.35^{a} \pm 0.08$	$4.45^{b} \pm 0.09$	0.001
Total solids (%)	$11.62^{a} \pm 1.31$	$12.63^{b} \pm 0.92$	0.003
Grease (%)	$3.40^{a} \pm 0.91$	$3.95^{b} \pm 0.69$	0.001
Protein (%)	$4.12^{a} \pm 0.35$	$4.26^{b} \pm 0.28$	0.002

a,b,c Means within a column with different superscripts differ significantly (P<0.05).

Table 4 - Milk production by breed (Criollo and Criollo x Saanen)

Parameters	Milk production kg/day	Lactation duration (days)	Milk production kg/lactation
pH	$1.8^{a} \pm 0.2$	$180^{a} \pm 0.01$	$324^{a} \pm 1.23$
Acidity (°D)	$2.5^{b} \pm 0.4$	$180^{a} \pm 0.01$	$450^{b} \pm 2.23$
P-value	0.0012	0.421	0.003

a,b Means within a column with different superscripts differ significantly (P<0.05).

Table 1 highlights that the optimal outcomes were observed in goats aged 3.2 years (third parity) for fat, lactose, and total solids at 3.99%, 4.56%, and 13.2%, respectively. These findings closely align with the results reported by Salinas-González et al. (2015), who documented 4.1%, 4.95%, and 13.14% for fat, lactose, and total solids, respectively, in stall-fed goats. Similar results are also noted by Ocampo et al. (2016), reporting percentages of 4.44%, 4.20%, and 12.59% for fat, lactose, and total solids. The numerical variations in results can be attributed to the study's focus on Criollo goats, which exhibit a lower lactose percentage, advantageous for tolerance in humans (Villalobos, 2005). Additionally, goat milk is known to be more digestible due to differences in the size of fat globules (Calvache García and Navas Panadero, 2012; Nayik et al., 2022). The dispersed nature of these globules facilitates easy metabolism by digestive enzymes, enhancing overall digestion (Kondyli et al., 2012; Eseceli et al., 2021). It is noteworthy that the obtained results fall within the stipulated standards for milk derivatives according to CODEX STAN 243.2003 (FAOFAST, 2023).

Regarding fat content (Table 1), the observed percentage (3.99%) underscores the balance between the detrimental effects of cholesterol and the positive contribution of polyunsaturated omega-3 fatty acids, known for their role in preventing cardiovascular diseases (García et al., 2014). Additionally, the presence of linoleic acid, which possesses anticancer properties, contributes to the health benefits associated with this fat composition (García et al., 2014). Maldonado-Jaquez et al. (2017) demonstrated a fat content of 4.3%, working with grazing goats. Generally, grazing leads to higher fat concentrations compared to goats kept in confinement (Mancilla-Leytón et al., 2013). However, fat content is not solely influenced by grazing; it is also dependent on factors such as age, lactation period, and parity (Vargas, 2019; Caroprese et al., 2016). Fat is a principal component of total solids, and both exhibit similar patterns. The Reyes García et al. (2017) reports a fat content of 3.8% for goats, a result consistent with the findings of this investigation.

Regarding density (Table 1), values of 1.037 g/ml, 1.035 g/ml, and 1.031 g/ml were observed for 3.2 (third parity), 2.5 (second parity), and 1.8 (first parity), respectively. These results align with findings reported by (de Oliveira et al., 2021), who documented a density of 1.00 g/mL. This decrease in density is attributed to the creaming process, as fat is a component of total solids. Similarly, it corresponds with the outcomes reported by Gabas et al. (2012), who identified density values around 1.03 g/mL in goats based on total solids and temperature. The density values exhibit a strong dependence on the total solids content, decreasing as the solvent fraction increases (Gabas et al., 2012). According to N.T.P 202.001-2003 (INDECOPI, 2003), the research results fall within the acceptable range defined by Peruvian standards.

Regarding pH (Table 1), similar values of 6.69, 6.73, and 6.67 were reported for 1.8 years (first parity), 2.5 years (second parity), and 3.2 years (third parity), respectively. These results closely align with those reported by Zain (2013), who indicated a pH of 6.67. The slight variation can be attributed to the presence of CO_2, citrate, proteins (including casein and whey proteins), collectively known as non-lactic acidity, in freshly milked milk (Zain, 2013). Acidification due to bacterial activity can lead to a decrease in pH below the normal range of 6.5 – 6.7 (Swadayana et al., 2012). Conversely, higher pH values could be indicative of potential mastitis (Kandeel et al., 2019). The identified pH values fall within the normal range for fresh goat milk (6.5 – 6.8) (Miller and Lu, 2019).

In terms of milk production (Table 2), it is evident that goats aged 3.2 years (third parity) achieved superior results, producing 3.0 liters/day over a lactation duration of 180 days, resulting in a total production of 540 kg/lactation. Arnal et al. (2018) emphasized the close correlation between milk production and lactation duration. The age of the goats and the number of parities per lactation significantly influence production levels (Gráff et al., 2018; Zamuner et al., 2020). Furthermore, as shown in Table 3 Criollo x Saanen crossbred goats (2.5 kg/day) outperformed Criollo goats (1.8 kg/day). Multiple studies have consistently demonstrated that dairy goats (breed-specific) exhibit higher production levels compared to Criollo goats (León et al., 2012).

CONCLUSION

The physicochemical composition of goat milk improves as the goat matures, and by the third parity, it exhibits higher milk quality. The production and physicochemical properties of milk are influenced by various factors, among which age, parity (number of births), and the breed of the animal stand out. Crossbreeding with the Saanen breed has demonstrated a positive impact compared to the Criollo breed, gaining widespread acceptance in the region. These crosses significantly contribute to enhancing milk production, displaying favorable percentages of fat, proteins, lactose, and total solids. These outcomes are comparable to those of specialized goat breeds such as the French Alpine, Anglo, and Blonde.

DECLARATIONS

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Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Authors' contribution

Edgar Garcia-Olarte: Execution of the research; Jordan Ninahuanca Carhuas: Statistical analysis and editing; Maria Antonieta Flores Guillen: laboratory analysis; Armando Aquino Tacza: animal non-monitoring; Erick Esteban Rojas Ramos: data collection.

Acknowledgments

The authors would like to thank the personnel involved, the laboratory workers, and the faculty of zootechnics, as well as Mr. Luis Perez, for the availability of his animals.

Consent to publish

All authors agree to the publication of this manuscript.

Competing interests

The authors have not declared any competing interest.

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