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Performance and chemical composition of milk in Criolla Formoseña and Anglo Nubian goats from Formosa, Argentina

Desempeño y composición química de la leche en cabras Criolla Formoseña y Anglo Nubian de Formosa, Argentina

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The average body weight, average daily and cumulative production, lactation peak, and chemical composition of milk were compared in Criollas Formoseñas and Anglo Nubian goats in Formosa (Argentina). A total of 18 third-kidding goats were evaluated, grouped by breed and under the same feeding and management system, for 13 weeks after weaning. Body weight and daily milk production were recorded, and two weekly samples were taken to determine the percentages of fat, protein, and lactose. The data were analyzed using descriptive statistics, Kruskal-Wallis test, and Spearman correlations. The average body weight was higher for Anglo Nubian than for Criollas Formoseñas (50.81±4.01 vs. 43.56±4.03 kg, p=0.01), as well as the average daily production (1.15±0.17 vs. 0.77±0.14 kg/d, p<0.01) and the accumulated production (103.86±15.65 vs. 69.35±12.54 kg, p<0.01). The lactation peak (p<0.01) was higher in Anglo Nubian (1.80±0.38 kg/d, week 5) compared to Criollas Formoseñas (1.32±0.30 kg/d, week 6). In the dairy composition, Criollas Formoseñas showed higher fat contents (5.70±0.11 vs. 5.12±0.18 %) and lactose (5.11±0.16 vs. 4.63±0.14 %) than Anglo Nubian (p<0.01), without differences in proteins (4.18±0.13 vs. 4.22±0.09 %, p>0.05). The significant correlations were average body weight-average daily production (0.59), average body weight-fat (−0.66), average body weight-lactose (−0.48), average daily production-fat (−0.73), average daily production-lactose (−0.70), fat-lactose (0.69). It is concluded that the Anglo Nubian goats had higher milk production, while the Criollas Formoseñas showed a chemical composition with a higher fat and lactose content.

Key words: *dairy, goats, lactation curve, local breeds, small farms*

Se comparó en cabras Criollas Formoseñas y Anglo Nubian el peso corporal medio, la producción media diaria y acumulada, el pico de lactancia y la composición química de la leche en Formosa (Argentina). Se evaluaron 18 cabras de tercera parición, agrupadas según raza y bajo un mismo sistema de alimentación y manejo, durante 13 semanas posteriores al destete. Se registraron el peso corporal y la producción diaria de leche, y se realizaron dos muestreos semanales para determinar los porcentajes de grasa, proteína y lactosa. Los datos se analizaron mediante estadística descriptiva, prueba de Kruskal-Wallis y correlaciones de Spearman. El peso corporal medio fue mayor para en Anglo Nubian que en Criollas Formoseñas (50.81±4.01 vs. 43.56±4.03 kg, p=0.01), al igual que la producción media diaria (1.15±0.17 vs. 0.77±0.14 kg/d, p<0.01) y la producción acumulada (103.86±15.65 vs. 69.35±12.54 kg, p<0.01). El pico de lactancia (p<0.01) fue superior en Anglo Nubian (1.80±0.38 kg/d, semana 5) respecto a Criollas Formoseñas (1.32±0.30 kg/d, semana 6). En la composición láctea, Criollas Formoseñas presentó mayores contenidos de grasa (5.70±0.11 vs. 5.12±0.18 %) y lactosa (5.11±0.16 vs. 4.63±0.14 %) que Anglo Nubian (p<0.01), sin diferencias en proteínas (4.18±0.13 vs. 4.22±0.09 %, p>0.05). Las correlaciones significativas fueron peso corporal medio-producción media diaria (0.59), peso corporal medio-grasa (−0.66) peso corporal medio-lactosa (−0.48), producción media diaria-grasa (−0.73), producción media diaria-lactosa (−0.70), grasa-lactosa (0.69). Se concluye que las Anglo Nubian presentaron mayor producción de leche, mientras que las Criollas Formoseñas mostraron una composición química con mayor contenido de grasa y lactosa.

Palabras clave: *caprinos, curva de lactancia, fincas pequeñas, lechería, razas locales*

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Introduction

Goats are notable for their remarkable adaptability. They can intake everything from highly nutritious grasses in temperate climates to poorly digestible vegetation in arid steppes. Throughout history they have played a fundamental role in human subsistence, providing milk, meat, fiber, leather, manure and labor, which demonstrate their versatility in different climates and production systems (González *et al.* 2021).

In Argentina, goat raising has traditionally focused on the production of kids aged 45 to 60 days for sale, as well as on family consumption of capons and adult goats. Only between 5 % and 20 % of establishments are dedicated to milk production, which is mainly used for the production of fresh cheeses for self-consumption and the surplus products are sold (De La Rosa Carbajal 2011). In addition, in some cases, milk is used in the piglets or calves feeding (Martínez and Suárez 2018).

In Laguna Yema town, in Formosa province (Argentina) there is a population of Creole goats that, it is estimated, descend from the specimens introduced by the first colonizers. These animals represent a fundamental resource for rural development, providing sustenance to a large number of small farmers. However, despite their rusticity and adaptability, goats have historically been underestimated, being blamed for aridity, overgrazing and soil erosion, without considering the wide benefits they provide (Lanari *et al*. 2019).

Although the genetic characterization, reproductive parameters of females and males, as well as the productive characteristics (weight evolution from birth to 18 months) of the Criollos Formoseños goats have been studied, to date, the dairy characterization and the differences in the chemical composition of the milk between this local breed and the Anglo Nubian, widely distributed in the Formosa region, have not been precisely determined (Revidatti *et al.* 2013 and Lanari *et al*. 2019).

This study aimed to compare in Criolla Formoseñas and Anglo Nubian goats, under the same management and feeding system in the central-western region of Formosa (Argentina), the average body weight, daily and accumulated milk production, the week of highest yield (lactation peak) and the chemical composition of milk.

Materials and Methods

Study location: The study was carried out at the Provincial Goat Farm of the Center for Validation of Agricultural Technologies (CEDEVA) of Laguna Yema (figure 1; -24.267092442674365, -61.25092103420744), dependent on the Government of Formosa province. The cabin is located on Provincial Route N°. 37, which crosses National Route N°. 81.

Figure 1. Georeference of CEDEVA, Laguna Yema, Formosa Province, Argentina

The region has a warm subtropical climate with a continental dry season, with annual rainfalls ranging between 700 and 800 mm, concentrated mainly between November and April. The frost-free period lasts for 310 days, being the most common frosts between May and August. The prevailing winds come from the north and south (Government of Formosa Province 2025).

Animals and management: The study included 18 adult female goats, belonging to the Anglo Nubian (n=9) and Criollo Formoseño (n=9) genotypes. In each genotype, five animals were five years old and four animals were six years old. All goats were in their third lactation, having been bred during the second half of February, with winter kidding and variability between kids less than 15 days. The body condition of the animals ranged from 3 to 3.5 points on the scale of 1 to 5 (Ghosh *et al.* 2019).

Health and nutritional management was carried out in accordance with the recommendations of De La Rosa Carbajal (2011) for the region. During the first 120 days of gestation, feeding consisted of restricted rotational grazing of 6 to 7 h daily in paddocks planted with Gatton panic (*Megathyrsus maximus*), with a total stocking rate of 0.9 EV ha^{-1} (Ledesma *et al.* 2017). Additionally, during the confinement (remaining hours) in the pens, the goats were offered Gatton panic hay (as a source of fiber), water and mineral salts *ad libitum.*

The goats belly was confined from 30 days before the expected kidding date until the end of the trial. Both genotypes received the same diet, with 15 % TP (true protein) and an energy concentration of 8.42 MJ (2.04 Mcal) of metabolizable energy (ME) per kg of dry matter (DM), according to the recommendations of the National Research Council (2007).

The diet was formulated with cracked corn (80 %), alfalfa hay (19 %) and urea (1 %) and was offered based on 4 % of the average body weight of each lot (breed). An equivalent supply of food and nutrients was ensured in terms relative to the live weight of the animals. Additionally, Gatton panic hay was provided *ad libitum* as a source of fiber. This nutritional strategy was before and during lactation to standardize diet quality and minimize the influence of extrinsic factors on productive performance and milk composition.

In addition, the kids stayed with their mothers for two weeks, then weaning and transfer to the kid barn took place, a facility specifically designed to house and handle unweaned kids, allowing their artificial feeding.

Milking and evaluation of milk production: Milking was manually carried out, replicating the traditional system used in the region for the Creole genotype, in order to maintain representative management conditions. Two daily milking were performed (8:30 a.m. and 16:30; Argentine Standard Time, ART, UTC −3). After weaning, milk production sampling was extended for the following 13 weeks.

Daily milk production (kg/d) was monitored from Monday to Friday. A WeiHeng® brand digital hanging scale (maximum capacity of 40 kg, precision of 10 g) was used for the measurement. Likewise, body weight was recorded every 15 days using a Crane Scale® brand digital hanging scale (model OSC-L, maximum capacity of 300 kg, accuracy of 100 g).

To evaluate the chemical composition of milk (fat, total proteins and lactose), two weekly samplings were carried out, corresponding to the first milking performed on Tuesdays and Fridays of each week. The samples were refrigerated (between 1 and 4 °C), sent and analyzed following the protocols established by the ALECoL laboratory (Asociación del Litoral de Entidades de Control Lecher) located in Esperanza, Santa Fe, Argentina. The determination of the components was carried out using a Master ECO ultrasonic milk analyzer (Milkotester Ltd.), quickly, without the use of chemical reagents.

Study variables and statistical analysis: The variables considered were average body weight (kg), average daily milk production (kg/d), total accumulated production (sum of daily production, in kg), peak of the lactation curve (maximum weekly production), expressed in kg/d, milk composition (percentage values of fat, total proteins and lactose, expressed per 100 mL of milk).

First, descriptive statistics were performed for each variable, including the mean, standard deviation, standard error, minimum and maximum values, and the percentage coefficient of variation, considered as a proportional measure of data variability. Normality was assessed using the modified Shapiro-Wilk test ($p>0.10$). Since the variables did not fulfill the assumption of normality, non-parametric analyses were applied for the comparison between genotypes.

In addition, lactation curves were developed for both genotypes using Microsoft Excel from the average weekly production values, identifying the productive peak. For descriptive purposes, a polynomial regression fit was applied to represent the production trend during lactation in each genotype. For the analysis of lactation peak, the maximum individual value of daily production recorded during the evaluated period was considered for each goat. These values were compared between genotypes using the Kruskal-Wallis test ($p<0.05$), considering the genotype as an effect.

Finally, Spearman's correlation ($p<0.05$) was used to analyze the association between average body weight, average daily milk production and the chemical composition of milk (fat, protein and lactose). The analysis was performed on the entire group of animals, considering that both breeds shared management and feeding conditions.

Data analysis was performed using the InfoStat-Statistical program (Di Rienzo *et al*. 2020).

Results and Discussion

Table 1 presents the descriptive statistics values of the productive variables and chemical composition, broken down by genotype, as well as the results of the non-parametric variance test.

The analysis revealed statistically significant differences between both genotypes in terms of body weight, with higher values in the Anglo Nubian goats. Spearman's correlation matrix (table 2) showed a moderate positive association between body weight and daily milk production, according to Mukaka (2012) criteria.

A higher body weight can have relevant productive implications, since greater mass is usually associated with higher milk production (Silva *et al*. 2021). However, this also implies an increase in resource intake, which could represent a limitation in traditional production systems (Maldonado-Jáquez *et al.* 2017, 2025).

The body weights recorded in this study were higher than those reported for local goats in Mexico, such as ~35 kg in La Comarca and ~38 kg in Coahuila (Maldonado-Jáquez *et al.* 2017, 2025). In turn, they were lower than the 60 kg reported for Anglo Nubian goats of French and North American origin (Maşner 2020). In this context, the observed values place both populations of Formosa within the characteristic range of eumetric breeds.

The average daily production values and the total accumulated production values significantly favored the Anglo Nubian breed. Likewise, the percentage coefficient of variation was higher in the Criolla Formoseña, which agrees with what Gama (2024) pointed out, who shows that in local genotypes a higher genetic diversity is usually expressed in a higher productive variability.

Table 1. Descriptive and comparative statistics of productive variables and milk chemical composition in Anglo Nubian (AN) and Criolla Formoseña (CF) goats (Formosa, Argentina)

Variable	Breed	Mean	S.D.	S.E.	CV	Min	Max	p*value
Average body weight, kg	AN	50.81	4.01	1.42	7.90	43.66	56.24	0.0104
	CF	43.56	4.03	1.42	9.25	37.79	50.95	
Average daily production, kg/d	AN	1.15	0.17	0.06	15.07	0.84	1.44	0.0006
	CF	0.77	0.14	0.05	18.09	0.65	1.09	
Total cumulative production, kg	AN	103.86	15.65	5.53	15.07	75.98	129.6	0.0006
	CF	69.35	12.54	4.43	18.09	58.68	97.94	
Total fats in milk, %	AN	5.12	0.18	0.06	3.52	4.90	5.40	0.0002
	CF	5.70	0.11	0.04	1.96	5.55	5.84	
Total proteins in milk, %	AN	4.22	0.09	0.03	2.14	4.04	4.30	0.6690
	CF	4.18	0.13	0.05	3.11	4.00	4.36	
Lactose, %	AN	4.63	0.14	0.05	2.99	4.45	4.81	0.0002
	CF	5.11	0.16	0.06	3.1	4.88	5.32	

S.D.: standard deviation, S.E.: standard error, CV: coefficient of variation (%), Min: minimum, Max: maximum. *Kruskal-Wallis test according to breed ($p<0.05$)

Table 2. Spearman correlation coefficients between productive variables and chemical composition parameters of milk in Anglo Nubian and Criolla Formoseña goats

Variable	ABW	ADP	Fat	Prot.	Lact.
ABW	-	0.59*	−0.66**	NS	−0.48*
ADP		-	−0.73*	NS	−0.70*
Fat			-	NS	0.69*
Prot.				-	NS
Lact.					-

ABW: average body weight, ADP: average daily production, Fat: total fats in milk, Prot.: total proteins in milk, Lact.: lactose (%), NS: not significant, *$p<0.05$, **$p<0.01$

The daily production values recorded in Criolla Formoseña population from Formosa were higher than those reported for Creole genotypes from Bolivia (0.44 kg/d, Stemmer and Zárate 2016), developed in traditional extensive systems. Likewise, both evaluated populations showed lower production levels than those reported for Anglo Nubian goats in Brazil (1.47 kg/d, Silva *et al.* 2021), managed in grazing systems (Buffel grass - *Cenchrus ciliaris*) and supplementation. In contrast, the values were markedly lower than those reported for Anglo Nubian goats in their third lactation in Moldova (3.12 kg/d), in semi-intensive systems with predominant grazing of *Medicago* spp. (Maşner 2020). These differences reflect the interaction between genotype, management system and environmental conditions, factors that jointly condition the expression of productive potential.

Figure 2 shows the lactation curves of both genotypes in the same management and feeding system, previously described, with a descriptive polynomial fit to represent the general shape of each one, which allows the observed differences to be interpreted as a differential response to the same productive environment.

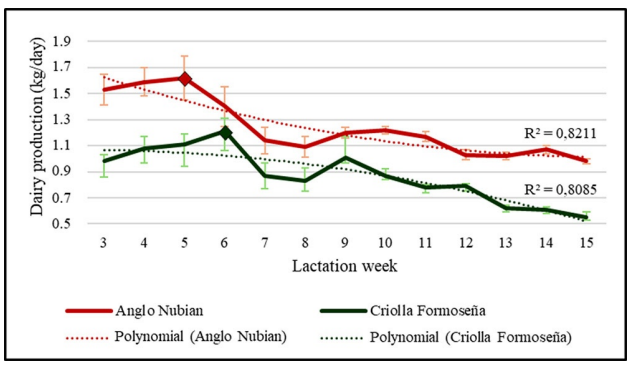

Figure 2. Lactation curves with their standard errors (SE) and polynomial regression fit for descriptive purposes. The maximum point for each genotype is showed with a rhombus

In this context, the higher production and persistence of the Anglo Nubian reflect a higher relative dairy potential compared to the Criolla Formoseña, which is favorable for systems oriented towards milk production. In contrast, Criolla Formoseña shows a more pronounced decrease after the peak,

which configures a productive pattern that could be adapted to traditional extensive systems, in which adaptation to the environment and rusticity are priority attributes.

Regarding lactation peak, when considering the maximum individual value of daily production recorded for each goat, there were significant differences between genotypes (p=0.008). Anglo Nubian goats (1.80±0.38 kg/d) showed a higher maximum production than the Criollas Formoseñas (1.32±0.30 kg/d).

The week in which the maximum production was recorded did not statistically differ between both genotypes (p=0.8437). In descriptive terms, the lactation was concentrated between weeks 5-6, although the Anglo Nubian showed higher variability in the week of occurrence of the maximum. Although the peak time was comparable between genotypes, the magnitude of the maximum productive was higher in the Anglo Nubian.

In herds of Saanen goats, Catota-Gómez *et al.* (2016) reported that the production peak in third-kidding goats occurs at 53 days postkidding, that is, approximately two weeks later than observed in Anglo Nubian goats evaluated in Formosa. However, in both cases the peak is recorded before the expected range for dairy biotypes, which is usually located around the eighth week of lactation (Martínez and Suárez 2018).

This advance of the productive peak is part of a general pattern, characterized by an increase in production during the first or second month of lactation, followed by a progressive decline, a pattern described by Ortega Chávez (2016) in both goats in the United States and also recorded in this study.

Isidro-Requejo *et al.* (2017) reported that, in local goats in northern Mexico, the production peak occurred between the fifth and sixth week of lactation, depending on the applied treatment, which agrees with the obtained results in Formosa.

The results show that breed had a marked influence on milk composition, with significant differences in fat (p=0.0002) and lactose (p=0.0002) levels. The Criollas Formoseñas showed higher contents of both components compared to the Anglo Nubian. However, the protein content between genotypes did not significantly differ (p=0.6690), indicating a similar response of this component under the evaluated conditions.

Additionally, Spearman's correlation matrix between milk production and milk quality parameters (table 2) allowed for a deeper analysis of the relation between the production level and the chemical composition of the milk. The average daily production was negatively and significantly associated with fat content and lactose content, with moderate to high magnitudes according to the correlation strength interpretation criteria proposed by Mukaka (2012). Likewise, the fat content showed a positive and moderate to high correlation with the lactose content.

The differences in milk composition between genotypes, as well as the inverse relation between production level and concentration of some components, have been described by Praharani *et al*. (2015), who pointed out that genotypes with lower milk production tend to have higher concentrations of solids, which is attributed to less dilution of the components in lower production volumes. Similarly, Isidro-Requejo *et al.* (2017) observed that, in goats under extensive management, the fat content remained relatively stable during lactation, suggesting that the homogeneity of this component could be associated with the adaptation of the Creole genotype to its environment (Gama 2024).

The low variability in dairy components, particularly in the fat content of the Criollas Formoseñas, shows a homogeneous compositional profile under the evaluated production conditions. This performance is consistent with what was showed by Salvador and Martínez (2007), who describe that some genotypes have higher compositional stability during lactation. It is also relevant when considering that genetics can influence on the levels of milk components as well as on the stability of their expression (Boshoff *et al.* 2024).

It is highlight that, unlike what was recorded in previous meta-analyses, where milk production is negatively associated with the fat and protein content of milk (Salvador and Martínez 2007 and Akshit *et al.* 2024), in this study the protein component remained independent of the production level. This result suggests higher stability of the protein fraction in the face of variations in daily production.

Regarding lactose, Meng *et al.* (2025) reported concordant results in Guanzhong goats. The highest-performing animals showed lower concentrations of this component, in line with the negative association observed in this study between daily production and percentage of lactose.

Under the conditions of this research, the results show that the increase in the production level is associated with changes in the concentration of fat and lactose, while the protein content remains independent of daily production.

Conclusions

Productive and compositional differences were identified among the evaluated goat genotypes. Anglo Nubian goats showed higher values for average body weight, average daily and total accumulated milk production, higher magnitude of lactation peak, and higher productive persistence. In contrast, the Criollas Formoseñas showed a higher concentration of fat and lactose in the milk and lower variability in these components. At the population level, body weight was positively associated with daily production, while the productive level showed negative relations with fat and lactose concentration, without showing associations with protein content.

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