

## Effect of fortified milk on body weight and immunological status in goat kids

## Efecto de la leche fortificada sobre el peso vivo y estado inmunológico en cabritos

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**ABSTRACT.** The objective of this study was to evaluate the effect of treatment with the commercial product Super Cria Goats Milk 65, from birth to weaning, on weight gain and hematological parameters in goat kids. Two groups were compared: Control Group (CG; 16 kids: 10 males, 6 females) and Artificial Lactation Group (ALG; 22 kids: 14 males, 8 females). During the experimental period, 4 kids from the ALG showed mechanical diarrhea. From day 20, CG kids ( $9.9 \pm 0.19$  kg;  $184 \pm 0.45$  g d<sup>-1</sup>) showed significantly higher body weights and daily gain than ALG ( $7.65 \pm 0.20$  kg;  $111 \pm 0.24$  g d<sup>-1</sup>) ( $p < 0.05$ ). Likewise, CG kids had higher serum immunoglobulin concentrations, which is consistent with hematological results that showed elevated leukocyte and erythrocyte counts ( $p < 0.05$ ). In contrast, platelets were higher in ALG kids ( $p < 0.05$ ). Despite these differences, no mortality was observed in either group. These findings suggest that fortified milk may be a suitable alternative for use in different goat production systems under specific conditions and for: commercial milk, triplet births, mastitis, calf rejection, orphaned offspring, or disease prevention. Although naturally raised kids showed better growth and immune profile, ALG kids reached an acceptable weight ( $8.37 \pm 0.12$  kg) by market standards, compared to CG kids ( $11.5 \pm 0.24$  kg) at weaning. These results contribute to a paradigm shift for producers in the region regarding the use of artificial lactation.

**Keywords:** Lactation, goat (*Capra hircus*), immunoglobulins, goat kids.

**RESUMEN.** El objetivo de este estudio fue evaluar el efecto del tratamiento con el producto comercial Super Cria Goats Milk 65, a partir del nacimiento de los cabritos hasta el destete, sobre la ganancia de peso y parámetros hematológicos en cabritos. Dos grupos fueron comparados: Grupo Control (CG; 16 cabritos: 10 machos, 6 hembras) y Grupo Lactancia Artificial (ALG; 22 cabritos; 14 machos, 8 hembras). Durante el periodo experimental, 4 cabritos del ALG presentaron diarrea mecánica. A partir del día 20, los cabritos CG ( $9.9 \pm 0.19$  kg;  $184 \pm 0.45$ g/d) mostraron pesos corporales y ganancia diaria significativamente mayores a ALG ( $7.65 \pm 0.20$  kg;  $111 \pm 0.24$ g/d) ( $p < 0.05$ ). Asimismo, los cabritos CG tuvieron mayores concentraciones de inmunoglobulina sérica, lo cual coincide con resultados hematológicos que mostraron conteos elevados de leucocitos y eritrocitos ( $p < 0.05$ ). Por el contrario, las plaquetas fueron mayores en los cabritos ALG ( $p < 0.05$ ). A pesar de estas diferencias, no se observó mortalidad en ninguno de los grupos. Estos hallazgos sugieren que la leche fortificada puede ser una alternativa adecuada cuando: la leche se destina a la venta comercial, nacimientos de trillizos, mastitis, rechazo de crías, crías huérfanas o prevención de enfermedades. Si bien los cabritos criados de forma natural presentaron un mejor crecimiento y perfil inmunitario, los cabritos ALG alcanzaron un peso aceptable ( $8,37 \pm 0,12$  kg) para los estándares de mercado, en comparación con los CG ( $11,5 \pm 0,24$  kg) al destete. Estos resultados contribuyen a un cambio de paradigma para los productores de la región respecto al uso de la lactancia artificial.

**Palabras clave:** Lactancia, cabra (*Capra hircus*), inmunoglobulinas, cabritos.

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## INTRODUCTION

Goat farming is a livestock activity that has supported the livelihoods of rural populations, particularly in arid and semi-arid regions, by providing a vital source of income for meeting basic needs (Navarrete-Molina *et al.* 2020). In Mexico, the national goat inventory is estimated at approximately 9 million animals (SIAP 2024), with more than 400 000 located in the Comarca Lagunera region (SIAP 2024). This region is a key agricultural zone and ranks first in goat milk production nationwide. The lactation process for goat kids in the Comarca Lagunera is natural, with restricted access. This is due to the region's predominant sedentary extensive production system. The goats are allowed to graze, and the goat kids remain in the management pen. Upon the goats' arrival, nursing continues (Navarrete-Molina *et al.* 2020). As in other latitudes, reproductive seasonality in goats is regulated by photoperiod, resulting in a natural period of seasonal anestrus from March to May (Alvarado-Espino *et al.* 2019). This leads to seasonal fluctuations in the production of milk, kids, and goat-derived products (Meza-Herrera *et al.* 2019). Milk is the main commercial product for goat producers; however, its availability varies throughout the year. Moreover, a single kid consumes approximately 60 liters of milk during its first two months of life (Niemann-Boehle 2017), highlighting the need for alternative feeding strategies such as fortified milk or milk replacers (De Palo *et al.* 2015). These alternatives are especially relevant in cases of multiple births, maternal death, udder defects that prevent nursing, mastitis, offspring rejection, or to reduce the risk of disease transmission through milk. Under such conditions, artificial rearing becomes a practical alternative. Artificial lactation is defined as the practice of feeding neonates with reconstituted milk, typically via bottle feeding, with the aim of optimizing milk production for commercial purposes (Chaguendo *et al.* 2023). In recent decades, this technique has expanded due to increasing demand for goat milk for human consumption (Ghibaudo and Simonetti, 2025). Milk replacers are formulated to meet the nutritional requirements of kids in early life and ensure adequate growth and development when maternal milk is unavailable or insufficient, or when commercial milk sale is prioritized. The quality of milk replacers significantly influences weight gain and digestive health, especially in intensive production systems (McCoard *et al.* 2021). For example, Bugti *et al.* 2016 reported that the average body weight of kids managed on whole milk was higher (6.5 kg per kid) compared to the kids managed on milk replacer with 5.77 kg average body weight after 4 weeks. However, the use of milk replacers or fortified milk limits the passive transfer of immunity provided by colostrum, which is critical to developing the immune system via immunoglobulin intake (Zhou *et al.* 2023). This can only occur when the milk replacer is administered from the first day of birth, where the transmission of passive immunity may be affected, after 24 hours there is no such effect anymore. The immunological status is acquired through colostrum, which is defined as the first milk secretion after birth through the mammary glands. It contains a large amount of nutrients, including immunoglobulins (Ig), hormones, enzymes and growth factors (Övet, 2023). Passive immunity is acquired by kids through the consumption of colostrum in the first hours of life, which is why natural nursing is essential in any production system (Zhou *et al.* 2023). However, when there are triple births, orphaned babies, mastitis, or maternal rejection, the use of artificial nursing using fortified milk can be justified. This will never be better than natural milk. Nevertheless, it has been used as an alternative solution for goat producers in the situations mentioned above. Fortified

milk or milk substitute used in artificial lactation of mammals must have physical, chemical, and nutritional characteristics similar to milk and be water-soluble (Abdelsattar *et al.* 2025). Additionally, probiotics are added, which are live microorganisms that, when used as dietary supplements, provide a health benefit to the consumer (Zamuner *et al.* 2023). Based on this context, the present study aimed to evaluate the effect of a liquid diet based on fortified milk on weight change, average daily gain, fortified milk intake, immunoglobulin concentration, and hematological parameters in goat kids reared under artificial lactation, born to multiparous, crossbred does adapt to the environmental conditions of the Comarca Lagunera, as a goat area with high productive potential at the national level, where milk production is a priority, which is why artificial lactation using milk fortified with probiotics benefits the development and survival of the offspring (McCoard *et al.* 2021 during the lactation period until weaning.

## MATERIALS AND METHODS

### Ethics and Animal Welfare

All experimental procedures, methods, test management and experimental units used in this study complied with the guidelines for the ethical use, care and welfare of research animals at international (FASS 2010) and national levels (NAM 2010).

### Location of the experimental site

The study was conducted at the goat farm of the Faculty of Agriculture and Zootechnics (FAZ) of the University Juárez of the State of Durango (UJED), located in the Ejido Venecia, Gómez Palacio Durango, part of the Comarca Lagunera, an agroecological zone in the arid north of Mexico. This region has a dry climate with an average annual temperature of 21°C, ranging from 37°C (May-August) in summer to 0°C (November-February) in winter (INEGI 2024).

### Management of pregnant females

Twenty pregnant goats were selected from a herd of 135 multi-breed crossbred (Alpine, Saanen, Nubian x Criollo) multi-parous goats adapted to the Comarca Lagunera region. All the goats in this study underwent a transabdominal ultrasound (Chison ECO-5, with a 12-inch probe) to determine pregnancy. Once pregnancy was confirmed, the goats were transferred to the FAZ UJED goat post for weight and body condition measurements, parameters used to form both groups homogeneously.

### Treatments

The 20 pregnant goats were randomly assigned to two treatments. The first group was called the Control Group, and it was based on natural nursing with restricted access as the producers of the Comarca Lagunera. (CG, n = 10) and the Artificial Lactation Group (ALG, n = 10). Both groups were homogeneous in body weight ( $54.6 \pm 2.5$  kg) and body condition ( $2.6 \pm 0.1$  units). Weight was determined using a scale (Truper Electronic Hanging Scale, 300 kg capacity) with a precision of 5 g. Body condition was determined using the method previously described for this species by Walkden-Brown *et al.* (1997), which uses a scale point of 1 (very thin) to 4 (very fat). Goats from CG

and ALG were fed for 45 days in the handling pens with a balanced ration based on their physiological status, which was balanced and contained 1.2 kg alfalfa hay (18% CP), 400 g of rolled corn (3.2 Mcal kg<sup>-1</sup> DM ME, 8.6% CP) and 100 g of soybean meal (49% CP) per animal twice a day in the morning and afternoon as suggested by the National Research Council (NRC), 2007. The goats were hand-milked once daily at 08:00 h. All were subcutaneously dewormed (1% Ivermectin, Baymec, Bayer, Mexico City, Mexico) one month before the start of the study; they were freely provided with water and mineral salts. Births began on December 7, 2024, in the CG, with the first birth in the ALG group on December 8. The last birth in the artificially fed group was on December 19, and in the control group on December 20, 2024. Goat kids in CG (16 goat kids: 10 males, 6 females) remained with their mother and were nursed to acquire passive immunity through colostrum. The goat kids in this group were verified to ingest colostrum to ensure the transmission of immunity and remained with their mother from birth until weaning. Goat kids in the ALG (22 goat kids; 14 males, 8 females) received commercial product Super Cria Goats Milk 65 fortified milk, made with goat's milk (Table 1), this group was artificially fed twice a day, in the morning and in the afternoon, as indicated in the product recommendation, at a rate of 120 g 900 mL<sup>-1</sup> at a temperature of 37 °C. This treatment began at birth; the goat kids had no contact with their mothers and did not consume colostrum. The same method was used for the consumption of fortified milk, with an average daily consumption of 250 mL. The product was offered until the goat kids felt satisfied. Consumption of natural and artificial milk was similar in both groups, since goat kids in the CG group were weighed before and after nursing to determine consumption and, therefore, average the consumption of goat kids in the ALG. The weight of the goat kids at birth was recorded immediately after the mother finished cleaning them, so as not to disrupt the establishment of the mother-kid bond in the CG, while in the ALG, physical contact between mother and kid was not allowed. The goat kids in the control group were separated from their mothers and nursed twice a day until they were satisfied. The CG kids were weaned on day 45 in the same way as the ALG kids. They were housed in an adjoining pen within the main pen, where they slept, as goat farmers in the region do, so that maternal milk production could be measured by the difference in weight between the goat kids. The sex of the all-goat kids was recorded, and each kid was identified with an ear tag. The goat kids received milk and milk substitute respectively, in addition to consuming water, and at the end of the experimental period, rolled corn and hayed alfalfa leaves.

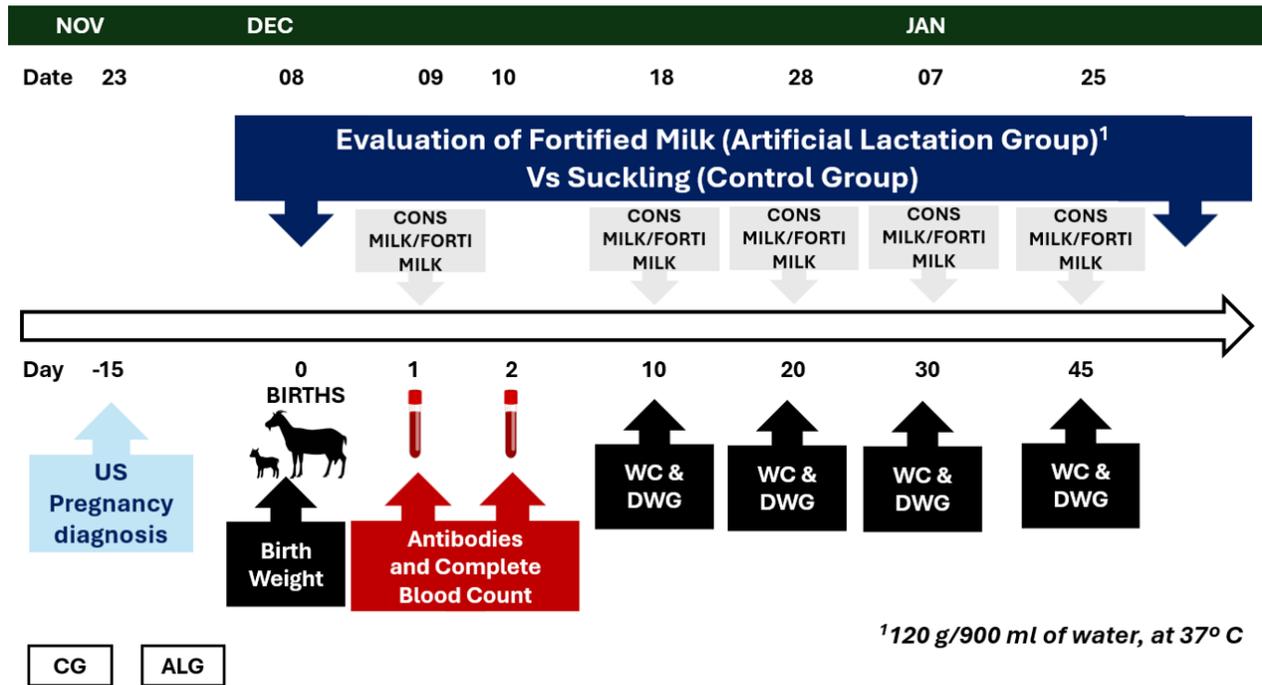
**Table 1.** Chemical composition of Super Cria Goats Milk 65, made from goat's milk, fortified milk added with probiotics (*Bacillus licheniformis* and *Bacillus subtilis*) Not less than 2.2 X 10<sup>9</sup> CFU g<sup>-1</sup>, 450 g ton<sup>-1</sup>.

Component	%
Crude Protein	30
Crude Fat	36
Crude Fiber	0.15
Calcium	300 mg 100 g <sup>-1</sup>
Phosphorus	500 mg 100 g <sup>-1</sup>
Vitamin A	40 000 IU kg <sup>-1</sup>
Vitamin D	16 000 IU kg <sup>-1</sup>
Vitamin E	45 IU kg <sup>-1</sup>

**Variables evaluated**

**Weight change of goat kids and daily weight gain**

This variable was also determined at birth (Figure 1) and at 10, 20, 30, and 45 days postpartum (weaning weight). Daily weight gain was determined by dividing the weight change by the days between each weighing (10 days). A scale (Truper Electronic Hanging Scale, 300 kg capacity) with a precision of 5 g was used to measure the weight of the goat kids.



**Figure 1.** Schematic representation of the experimental protocol, using fortified milk in goats and its effect on Weight Change (WC) and Daily Weight Gain (DWG), as well as their blood antibody blood count values, and the times when milk and fortified milk consumption were measured in goat kids of multiracial multiparous goat offspring adapted to the Comarca Lagunera.

**Colostrum, Milk and Fortified Milk Consumption**

Colostrum consumption was determined in the first day of life of the CG kids, weighing the kids before and after colostrum consumption, as well as the consumption of fortified milk in the ALG kids, using graduated bottles that showed the amount of milk ingested. The average milk consumption of CG goat kids was determined by weighing them before nursing from their mothers and weighing them after nursing. This was determined from birth to weaning. For ALG goat kids, it was determined by readings from bottles and containers used for artificially suckling goat kids from birth to weaning. In the morning and in the afternoon, as indicated in the product recommendation, at a rate of 120 g 900 mL<sup>-1</sup> at a temperature of 37 °C. This treatment began at birth; the goat kids had no contact with their mothers and did not consume colostrum. The same method was used for the consumption of fortified milk, with an average daily consumption of 250 mL. The product was offered until the goat kids felt satisfied. This response variable was measured on days 1, 10, 20 and 30 postpartum.

## Immunoglobulin Concentrations in Blood Plasma and Complete Blood Count

Immunoglobulin concentrations in the blood plasma of goat kids (CG,  $n = 5$ ; ALG,  $n = 5$ ) were measured using a 7 mL vacuum tube and jugular vein puncture. Blood samples were centrifuged at 3 000 rpm for 15 minutes at 15°C. Blood serum was immediately taken to a laboratory, where antibody concentrations in  $\text{mg dL}^{-1}$  were determined by refractometry (Misco PA202X-003-105 Digital Refractometer Brand: Selectum, Ohio USA.) to determine immunoglobulin levels (1.2-6.5  $\text{g dL}^{-1}$ ). To corroborate the refractometric information of the goat kids, a complete blood count was performed on 10 goat kids from both groups (CG,  $n = 5$ ; ALG,  $n = 5$ ). The age of goat kids at the time of blood analysis was 1 and 2 days postpartum. This study was performed by the Clinical Analysis and Veterinary Pathology Laboratory of La Laguna S.C. in Gómez Palacio, Durango. This variable was determined using a 7 ml vacuum tube and jugular vein puncture. The samples were refrigerated until they arrived at the laboratory for the corresponding determination (VETSCAN HM5, Comprehensive Hematologic Analysis with 5-Part Differential, Zoetis, Madrid Spain, using the technique, also known as electrical impedance spectroscopy). The same goat kids were used for immunoglobulin analysis and for the complete blood count. Blood samples for this analysis were immediately sent to the laboratory.

## Statistical Analysis

This study used a completely randomized design, repeated measures analysis of variance (ANOVA) for goat kids' weight and daily weight gain variables, and a Student's *t* test for independent groups for antibody concentration and blood count variables. Differences between treatments were accepted if  $p < 0.05$ . Tukey's post hoc test was used when necessary. The SAS statistical package was used to analyze the response variables (SAS version 9.4).

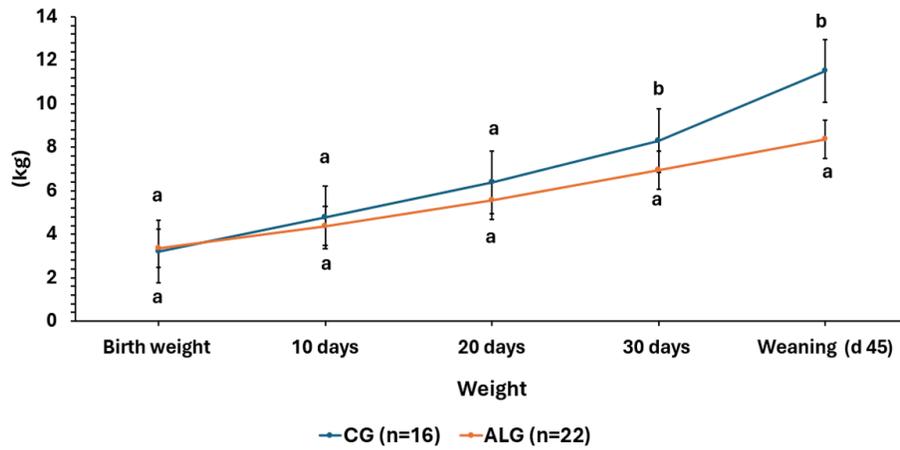
## RESULTS

### Weight change of goat kids and daily weight gain

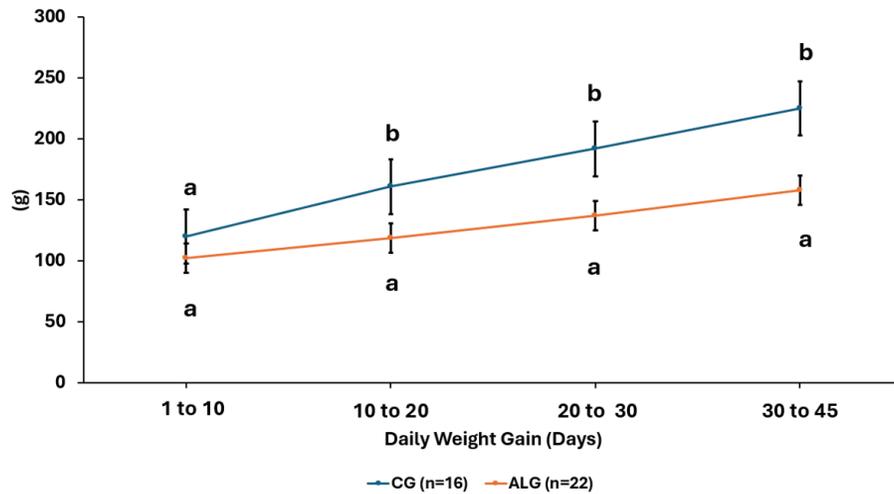
As shown in Figure 2, no significant differences were observed between the CG and ALG during the first 20 days postpartum ( $p > 0.05$ ). However, from day 30 onward, CG goat kids consistently exhibited higher body weights compared to ALG goat kids ( $p < 0.05$ ), with a final weight difference of 3.13 kg on day 45 in favor of the CG group. Similarly, average daily weight gain (DWG) was greater in the CG group between days 20 and 45 postpartum ( $p < 0.05$ ) (Figure 3). Interestingly, no significant differences were observed in DWG between groups during the first 20 days postpartum ( $p \geq 0.05$ ), with an average DWG of  $100.33 \pm 0.26$  g.

### Colostrum, milk and fortified milk intake

Daily intake of colostrum, milk, (CG) and fortified milk (ALG) did not differ significantly between groups across all evaluated time points ( $p > 0.05$ ), as shown in Table 2. On average, CG goat kids consumed 856  $\text{mL day}^{-1}$ , while ALG goat kids consumed 782  $\text{mL day}^{-1}$  of fortified milk, suggesting that intake volume was not a limiting factor for growth performance.



**Figure 2.** Average weight of goat kids at birth, 10, 20, 30 and 45 days postpartum ( $\pm$  SEM) fed with colostrum and natural milk (CG) and fortified milk (ALG) Super Cria Goats Milk 65, offspring of multi-breed goats adapted to the Comarca Lagunera (25° LN). <sup>a,b</sup> Response variables with different superscripts are different ( $p < 0.05$ ).



**Figure 3.** Average daily weight gain (DWG) of goat kids on days 1 to 10, 10 to 20, 20 to 30 and 30 to 45 postpartum ( $\pm$  EEM) fed with colostrum and natural milk (CG) and with fortified milk (ALG) Super Cria Goats Milk 65, through artificial lactation of goat kids of multi-breed goats adapted to the Comarca Lagunera (25° LN). <sup>a,b</sup> Response variables with different superscripts are different ( $p < 0.05$ ).

**Table 2.** Average consumption ( $\pm$  SEM) of colostrum and milk (CG, Control Group) and fortified milk (ALG, Artificial Lactation) the first day of lactation, 10, 20, 30 and 45 days postpartum in goat kids of multi-breed goats adapted to the Comarca Lagunera (25° LN).

Variable (Intake, ml)	CG (n = 16)	ALG (n = 22)
Colostrum/Fortified Milk (d 0-1)	380 $\pm$ 15 <sup>a</sup>	290 $\pm$ 17 <sup>a</sup>
Milk/Fortified Milk (d 4-10)	550 $\pm$ 26 <sup>a</sup>	520 $\pm$ 23 <sup>a</sup>
Milk/Fortified Milk (d 11-20)	780 $\pm$ 05 <sup>a</sup>	720 $\pm$ 14 <sup>a</sup>
Milk/Fortified Milk (d 21-30)	945 $\pm$ 18 <sup>a</sup>	904 $\pm$ 09 <sup>a</sup>
Milk/Fortified Milk (d 31-45)	1 200 $\pm$ 12 <sup>a</sup>	1 087 $\pm$ 26 <sup>a</sup>

<sup>a,b</sup> Response variables with different superscripts within the lines are different ( $p < 0.05$ ).

## Hematological Parameters and immunoglobulin concentration in blood plasma

Hematological evaluation (Table 3) revealed that CG goat kids had significantly higher leukocyte and erythrocyte counts ( $p < 0.05$ ), indicating enhanced immune and oxygen-carrying capacity likely resulting from colostrum intake. In contrast, ALG goat kids exhibited significantly higher platelet counts ( $p < 0.05$ ), although all values remained within physiological ranges. No differences were observed in other parameters such as hemoglobin, hematocrit, or mean corpuscular indices ( $p > 0.05$ ). As shown in Table 3, serum immunoglobulin concentration at two days postpartum was significantly higher in CG goat kids compared to ALG goat kids ( $p = 0.01$ ). The immunological status values of ALG goat kids are below the minimum permissible levels, compared to those of CG.

**Table 3.** Blood serum hemogram and concentration of immunoglobulins in blood serum of goat kids at 2 days postpartum ( $\pm$  SEM) of goat kids that were fed with fortified milk through Artificial Lactation Group (ALG,  $n = 5$ ) with Super Cria Goats Milk and natural lactation, Control Group (CG,  $n = 5$ ) offspring of multi-breed goats adapted to the Comarca Lagunera (25° LN).

Blood Serum Hemogram	CG (n = 5)	ALG (n = 5)
Leukocytes (4-13 m)	10 459 $\pm$ 1 000.33 <sup>a</sup>	6 340 $\pm$ 1 965.61 <sup>b</sup>
Granulocytes		
Segmented N (20-50%)	37 $\pm$ 1.03 <sup>a</sup>	46 $\pm$ 5.84 <sup>a</sup>
Band N (0-2%)	0.25 $\pm$ 0.22 <sup>a</sup>	0.20 $\pm$ 0.20 <sup>a</sup>
Eosinophils (0-10%)	3 $\pm$ 1.07 <sup>a</sup>	0.20 $\pm$ 0.20 <sup>a</sup>
Basophils (%)	0	0
Agranulocytes		
Lymphocytes (40-70%)	57 $\pm$ 2.15 <sup>a</sup>	52 $\pm$ 5.50 <sup>a</sup>
Monocytes (0-4%)	2 $\pm$ 0.66 <sup>a</sup>	1 $\pm$ 0.40 <sup>a</sup>
Erythrocytes (8-18 million)	16 106 000 $\pm$ 603,171.62 <sup>a</sup>	8 992 000 $\pm$ 392,726.37 <sup>b</sup>
Hemoglobin (8-12 g 100 mL <sup>-1</sup> )	11 $\pm$ 0.55 <sup>a</sup>	9 $\pm$ 0.37 <sup>a</sup>
Hematocrit (25-38%)	34 $\pm$ 1.39 <sup>a</sup>	27 $\pm$ 0.81 <sup>a</sup>
Mean Corpuscular Volume (MCV) (16-30 fl)	21 $\pm$ 0.68 <sup>a</sup>	23 $\pm$ 1.72 <sup>a</sup>
Mean Corpuscular Hemoglobin (MCH) (5.2-8 pg)	7 $\pm$ 0.24 <sup>a</sup>	7 $\pm$ 0.37 <sup>a</sup>
Mean Corpuscular Hemoglobin Concentration (MCHC) (30-36 g dL <sup>-1</sup> )	32 $\pm$ 0.37 <sup>a</sup>	33 $\pm$ 0.49 <sup>a</sup>
Platelets (300-600 10 <sup>9</sup> /l)	507 $\pm$ 52.61 <sup>b</sup>	949 $\pm$ 109.73 <sup>a</sup>
Fibrinogen (100-500 mg dL <sup>-1</sup> )	540 $\pm$ 32.56 <sup>a</sup>	548 $\pm$ 50.93 <sup>a</sup>
Immunoglobulins (mg dL <sup>-1</sup> )	6 800 $\pm$ 312 <sup>a</sup>	3 200 $\pm$ 654 <sup>b</sup>

<sup>a,b</sup> Response variables with different superscripts within the lines are different ( $p < 0.05$ ).

## DISCUSSION

The results of this study support our working hypothesis that fortified milk used in artificial lactation is a viable strategy for feeding goat kids from birth to weaning, especially when milk production is prioritized for sale. This is evidenced by the observed weight change (WC), daily weight gain (DWG), and antibody concentrations in blood, where ALG goat kids (fed fortified milk) achieved competitive weights compared to CG goat kids (naturally suckled with restricted access). However, it is important to emphasize that colostrum, as the initial secretion after birth, remains essential for offspring survival, a benefit observed in CG goat kids but limited in ALG goat

kids, which showed lower weight gains yet maintained market competitiveness. The ALG kids showed mechanical diarrhea due to the change in the dose of fortified milk. This only occurred in 4 offspring in this group; diarrhea did not occur in the CG. In another species, a study conducted on lambs showed that the young are prone to weaning stress and being separated from their mothers at an early age, so they are frequently artificially reared on milk replacer, which leads to stress caused by early weaning (Freitas-de-Melo *et al.* 2022 ) and difficulties in adapting to milk replacer due to excessive dosage or inadequate temperature levels increases the number of offspring with diarrhea (Wang *et al.* 2019 ). However, it is important to mention that the use of milk fortified with probiotics brings important benefits to goat kids, by creating a favorable intestinal environment for microbial populations, in addition to in stressful environments, microbes and ingredients in directly administered feed can play a key role in limiting the severity of dysbiosis caused by disruption of normal intestinal homeostasis (Zommiti and Ferchichi 2021).

Considering that milk is the primary product sold by goat producers in the extensive sedentary production system prevalent in the Comarca Lagunera, fortified milk represents an excellent nutritional alternative. Given that this fortified milk is derived from goat milk, it offers greater digestibility compared to cow milk-based substitutes commonly available (Siddiqui *et al.* 2024). Consequently, goat kids fed fortified milk can reach market weights that provide good economic returns for producers. In our study, weight change was similar between CG and ALG goat kids during the first 20 days, but from day 30 onward, CG goat kids exhibited significantly higher weight and DWG despite similar milk consumption between groups ( $p > 0.05$ ). Similar trends were reported by Delgado-Pertiñez *et al.* (2009), who observed higher total milk production and growth in naturally reared Payoya goats compared to artificially reared ones.

Additional studies by Argüello *et al.* (2007) and López *et al.* (2001) corroborate these findings, showing that natural lactation promotes faster growth rates (up to 32% faster) and greater daily weight gains than artificial systems. For example, López *et al.* 2001 reported that naturally reared male goat kids reached 10 kg by 35 days, whereas artificially reared goat kids did not reach 9 kg until day 41. Our observed higher DWG in naturally suckled goat kids from day 30 to 45 ( $p < 0.05$ ) is consistent with Argüello *et al.* (1999), who documented higher daily gains (212 g vs. 150 g) in naturally reared Canary goat kids.

This disparity is likely attributable to the superior quality of colostrum and natural milk compared to fortified milk, including the critical intake of colostrum in the first postpartum days. Colostrum is rich in nutrients and bioactive compounds that promote growth and support the differentiation and function of early somatic cells, essential for the nutritional, immunological, and developmental needs of neonatal goat kids (Zhou *et al.* 2023, Farooq *et al.* 2024). Colostrum contains both nutritive and non-nutritive bioactive components (Övet 2023), which likely contributed to the observed differences in weight gain compared to the probiotics present in fortified milk.

Regarding immunoglobulin concentrations, significantly higher levels were detected in CG goat kids (6 800 mg dL<sup>-1</sup>) compared to ALG goat kids (3 200 mg dL<sup>-1</sup>;  $p < 0.05$ ), reflecting the superior passive immune transfer afforded by colostrum during natural lactation. These results highlight the superior passive immune transfer through colostrum in naturally reared goat kids, as no immunoglobulin enhancement was observed in the fortified milk group. Passive immunity in

neonatal goats primarily depends on colostral immunoglobulin G (IgG), which comprises approximately 85% of total immunoglobulins in goat colostrum (Roth, 2004; González-Cabrera *et al.* 2025). Intestinal absorption of IgG is most efficient immediately after birth and declines rapidly within the first 24 hours (Villarreal *et al.* 2005; Perez-Marín *et al.* 2023). The high maternal ability of goats and the vigorous suckling behavior of goat kids facilitate this critical immunological transfer (Villarreal *et al.* 2005).

In reference to the blood count, the values of the leukocyte and erythrocyte variables were higher for the CG goat kids ( $p = 0.03$  and  $p = 0.02$  respectively), with respect to the ALG goat kids which showed values at the lower permissible limits for both variables, low levels of leukocytes in the blood, this was most likely because the fortified milk does not provide the same amount of antibodies as the colostrum and milk consumed by the CG goat kids, indicating enhanced immune and oxygen-carrying capacity likely resulting from colostrum intake, while in reference to platelets, the ALG goat kids showed values above the upper permissible limit ( $p < 0.05$ ) which is a consequence of various factors such as infections (Martínez-Grimaldo *et al.* 2018), that correlate with a low level of immunoglobulins, however, it is important to mention that there were no deaths in the ALG goat kids which shows that the fortified milk showed a positive effect on the goat kids.

Furthermore, colostrum contains immunomodulatory cytokines that regulate pro- and anti-inflammatory responses and provide protection against pathogens (Takeuchi and Akira 2010, El-Loly 2022, Geginat *et al.* 2016, Sienkiewicz *et al.* 2021). Hence, colostrum can be considered a superfood for goat kids, providing vital nutrients and immune protection crucial for survival. Nonetheless, fortified milk produced from goat milk emerges as a practical alternative for rearing goat kids when natural nursing is not possible or when milk sales take priority. Importantly, all ALG goat kids survived, indicating that fortified milk can sustain kid viability under such conditions.

The limitations of this study are that although the use of milk replacers or fortified milk in goats in the region has increased, not all producers accept the change, being traditionalists, however, with conclusive results as is the case, the paradigm shift is achieved, in addition to the fact that not all producers have the means to acquire a commercial fortified dairy product like the one we used in this study, the perspectives of this study are broad, due to the genetic and productive potential of the Comarca Lagunera in the breeding of multibreed goats and ensuring the survival of goats until weaning, through alternative sources for lactation such as artificial lactation with fortified milk. Although it was only a commercial product tested, new scientific questions arise to test in other production systems and with different specialized genotypes.

## CONCLUSIONS

Fortified milk is a valuable alternative when farmers prioritize milk sales, as is the case in the Comarca Lagunera, where they also face insufficient milk for lactation, manage multiple births, deal with mastitis, face contagious milk-borne diseases, or experience orphaned or rejected kids. Fortified milk also helps increase income for producers and decrease the prevalence of diseases transmitted from goats to offspring, maintaining an adequate weight of the kids. Antibody

concentration did not significantly affect the survival of kids in any of the groups, probably due to the beneficial effects of probiotic-fortified milk on ALG kids. Therefore, feeding both formula and fortified milk helps extend the productive life of goats and improves income in extensive production systems. With the completion of this study, new opportunities are opening up to ensure competitive weaning weights for kids with adequate immune status to ensure their survival.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest in this article.

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