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Revista Facultad Nacional de Agronomía

# Evaluation of two milk replacers in the artificial rearing of Anglo-Nubian female goat kids

UNIVERSIDAD NACIONAL DE COLOMBIA

## Evaluación de dos lacto-reemplazantes en la crianza artificial de cabritas Anglo-Nubian

https://doi.org/10.15446/rfnam.v78n1.111475

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## ABSTRACT

Dairy goat production is an alternative for rural development in Buenos Aires province, Argentina. Artificial rearing with milk replacers allows all goat milk to be intended for milking. Although this technology is widespread in cattle, more studies are needed in goats. The aim was to evaluate the artificial rearing of Anglo-Nubian female kids, according to two milk replacers: commercial small ruminant milk replacer (MR) vs. whole cow milk powder (MP). Milk replacers were offered until week 10 of life according to a protocol, complimenting it with solid food after week three. The following were evaluated: survival (SUR), live weight (LW), daily live weight gain (DLWG), age (week) in which the kids reached 10 kg (LW10) and multiplied by 2.5 their birth weight (BWx2.5), glycemia (GLY), diarrhea incidence (DI), and cost of milk replacer per kid (COST). SUR was 100% in both treatments. Despite detecting differences in LW in week six in favor of MP, both groups reached similar LW at the end of the rearing period. Results for DLWG, LW10, BWx2.5, and DI did not differ between treatments. There was no effect of treatment on GLY; however, age affected it. COST was lower for MR. It is concluded that, although both milk replacers allow similar and adequate growth of kids, the use of a milk replacer formulated for small ruminants significantly reduces the cost of artificial rearing.

**Keywords:**
Artificial feeding
Dairy goats
Growth
Preweaning period
Production costs

## RESUMEN

El tambo caprino es una alternativa productiva para el desarrollo rural en la provincia de Buenos Aires, Argentina. La crianza artificial con lacto-reemplazantes permite destinar toda la leche al ordeñe. Si bien esta tecnología está ampliamente difundida en vacunos, son necesarios más estudios en caprinos. El objetivo fue evaluar la crianza artificial de cabritas Anglo-Nubian según dos lacto-reemplazantes: sustituto lácteo formulado para rumiantes menores (MR) vs. leche en polvo entera vacuna (MP). Los lacto-reemplazantes fueron ofrecidos hasta la semana 10 de vida según protocolo, complementándose a partir de la semana 3 con alimento sólido. Se evaluó: supervivencia (SUR), peso vivo (LW), ganancia diaria de peso vivo (DLWG), semana en que las cabritas alcanzaron 10 kg (LW10) y multiplicaron por 2,5 su peso al nacimiento (BWx2,5), glucemia (GLY), cuadros diarreicos (DI) y costo del lacto-reemplazante por cabrita (COST). SUR fue del 100% en ambos tratamientos. Pese a detectarse diferencias en el LW en la semana seis a favor de MP, al final del período de crianza, ambos grupos alcanzaron similar LW. Tampoco se encontraron diferencias entre los tratamientos para DLWG, LW10, BWx2,5 y DI. No hubo efecto del tratamiento sobre GLY, aunque hubo efecto de la edad. COST fue menor para MR. Se concluye que ambos lacto-reemplazantes permiten un crecimiento similar y adecuado de las cabritas. Sin embargo, la utilización del sustituto lácteo formulado para rumiantes menores disminuye significativamente los costos de la crianza artificial.

**Palabras clave:**
Alimentación artificial
Cabras lecheras
Crecimiento
Período predestete
Costos de producción

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Received: July 25, 2024; Accepted: September 24, 2024
Rev. Fac. Nac. Agron. Medellín 78(1): 11025-11035. 2025
ISSN 0304-2847 / e-ISSN 2248-7026

In Argentina, goat production is mainly developed in arid areas, under extensive conditions, for meat and milk in the north and fiber in the south (Martínez and Suárez 2018). In recent years, goat production began to develop out of its traditional areas in more intensive systems. In Buenos Aires province, goat stock has been increasing, reaching 273% in 2008-2017 (Ghibaudi et al. 2018) and mainly intended to dairy. Such production is facilitated by the agroecological characteristics of this province (humid temperate climate, with mean temperatures from 7-11 °C to 20-25 °C, and average annual rainfall of 800 mm) (DPE 2020) and its proximity to major consumer centers. This activity has several advantages that could contribute to rural development: a) it can be performed in small areas (small farmers); b) it is usually carried out with family labor, which would promote rural settlement; c) it can be related to rural tourism ; d) it allows smallholders to generate value-added products, for example, goat milk can be processed in the farm; e) both goat meat and milk and their derivatives have benefits for healthily human nutrition.

In goat dairy farms, rearing kids naturally with their dams or artificially with goat milk represents a high opportunity cost due to the decrease in milk production in the industry. Therefore, artificial rearing based on milk replacers has been proposed. In addition, to allowing all the milk to be intended for milking, artificial rearing offers other advantages: improved growth of triplets and quadruplets, uniformed weaning groups, accelerated ruminant transition, better health control of kids, etc. (Castroalonso et al. 2003; Quintana Quiñonez 2018). However, its results depend on several factors (environment, nutrition, genetics, health, management, etc.) (Balasopoulou et al. 2022; Vickery et al. 2022), so it is necessary to develop accurate protocols.

The duration of artificial rearing depends on the production objective. When comes to obtain replacement females, it is usually extended up to three months (Chacón-Hernández and Boschini-Figueroa 2015). However, it can be as short as 45 days if animals are intended for slaughter (Tacchini et al. 2006). Another important factor is cost, so other criteria, such as target live weight or a proportional increment of birth live weight, rather than age, have been proposed for weaning (Datt et al. 2023).

The concentration and composition of milk replacers are crucial for artificial rearing success. In Buenos Aires province, goat dairy farms have been effectively using cow milk powder due to its advantages, e.g., its high-quality, easily digestible nutrients, and physical form, which simplifies storage (Simonetti et al. 2019). However, it has a high-cost input as competes with its use for human consumption; furthermore, its price is affected by the export market. The presence of a milk replacer formulated for small ruminants in the local market is recent and there's a lack of studies that demonstrate its benefits.

This study aimed to compare the performance of a milk replacer formulated for small ruminants with whole cow milk powder in the artificial rearing of Anglo-Nubian female goat kids.

## MATERIALS AND METHODS

The study was performed following the etic requirements of the Institutional Committee for Care and Use of Experimental Animals (CICUAE) of the Facultad de Ciencias Agrarias (FCA), Universidad Nacional de Lomas de Zamora (UNLZ).

### Location

The assay was developed in the "Small Ruminants Teaching, Training and Research Module" (FCA, UNLZ), municipality of Lomas de Zamora, located in the metropolitan area of Buenos Aires province, Argentina (34°47'18"S and 58°26'56"W).

### Experimental animals

Twenty Anglo-Nubian female goat kids were used. At birth, they were separated from their dams, identified with ear tags and weighted. During their first 48 hours, they were fed colostrum obtained by hand milking and administered through nursing bottles.

### Housing

During the day, the animals were housed in a 35 $m^2$ outdoor pen surrounded by woven wire and provided with a covered area, water troughs and feeders (Figure 1A).

At night, confinement was done in a room equipped with boxes measuring 1.4 $m^2$ each, where animals were grouped in four (Figure 1B). The boxes had slatted floors with a separation of 1 cm between wood strips, to prevent contact with urine and feces. During the first week, the slated floor was covered with wood shaving to help keeping body temperature.


**Figure 1.** Daytime outdoor pen (A) and night indoor boxes (B).

Daily, the boxes were cleaned and disinfected with quaternary ammonium, and the wood shaving was changed. The outdoor pens were regularly sprinkled with lime to prevent diseases.

### Treatments

Female goat kids were assigned to one of two treatments based on their birth weight:

Small Ruminant Milk Replacer (MR; n=10): Fed with Ternelac Plus milk replacer formulated for small ruminants (Ducrem S.A., Argentina), at the recommended concentration for goat kids of 150 g $L^{-1}$. This product has 88.0% dairy components, including skim milk, whey protein and lactose; its non-dairy components are mainly deactivated whole soybean flour.

Whole Cow Milk Powder (MP; n=10): Fed with La Sorianita whole cow milk powder (San Satur S.A., Argentina) at a concentration of 150 g $L^{-1}$.

The chemical composition of both milk replacers is provided in Table 1.

**Table 1**. Chemical composition of milk replacers used for artificial rearing of Anglo-Nubian female goat kids.

| Parameter | MR*(2) | MP** |
|---|---|---|
| Crude protein (min)% | 25.0 | 26.1 |
| Total fat (min)% | 25.0 | 26.4 |
| Crude fiber (max)% | 0.50 | 0.00 |
| Lactose (max)% | 36.0 | 38.5 |
| Metabolizable energy (Mcal $kg^{-1}$)(1) | 4.65 | 5.03 |
| Ash (max)% | 9.00 | 4.00 |
| Calcium (max)% | 1.20 | 1.10 |
| Phosphorus (min)% | 0.65 | 0.77 |
| Moisture (max)% | 4.65 | 4.86 |

*Small ruminant milk replacer.
**Whole cow milk powder.
(1)Metabolizable energy was calculated from information provided by the manufacturers, based on Yeom et al (2002)
(2)Additives: minerals (copper, zinc, iron, magnesium, manganese, iodine, selenium and cobalt), vitamins ($B_1$, $B_2$, $B_3$, $B_5$, $B_6$, $B_7$, $B_9$, $B_{12}$ and $D_3$) colorants and flavorings.

### Feeding and management

Feeding was carried out following a gradual transition from colostrum to milk replacer during the first three days. Thereafter, feeding followed the scheme of Table 2.

**Table 2.** Feeding scheme used for artificial rearing of Anglo-Nubian female goat kids.

| Week | Liquid diet scheme | | Solid feed scheme | | |
|---|---|---|---|---|---|
| | * L $d^{-1}$ | Daily feeding shifts | Alfalfa hay | Starter feed(1) | Alfalfa pellets |
| 1** | 0.5 to 0.75 L $d^{-1}$ | 2 | - | - | - |
| 2 | 1 L $d^{-1}$ | 2 | - | - | - |
| 3(2) | 1 L $d^{-1}$ | 2 | Ad libitum | Ad libitum | - |
| 4 | 1.2 L $d^{-1}$ | 2 | Ad libitum | Ad libitum | - |
| 5 | 1.5 L $d^{-1}$ | 2 | Ad libitum | Ad libitum | - |
| 6 | 1.5 L $d^{-1}$ | 2 | Ad libitum | Ad libitum | - |
| 7 | 1.5 L $d^{-1}$ | 2 | Ad libitum | Ad libitum | - |
| 8 | 1 L $d^{-1}$ | 2 | Ad libitum | Limited to 300 g | Ad libitum |
| 9 | 0.75 L $d^{-1}$ | 1 | Ad libitum | Limited to 300 g | Ad libitum |
| 10 | 0.5 L $d^{-1}$ | 1 | Ad libitum | Limited to 300 g | Ad libitum |

*Liquid diet (small ruminant milk replacer or whole cow milk powder) 150 g $L^{-1}$.
**A gradual adaptation of goat kids to the consumption of their respective milk replacers was carried out, starting from goat's milk. During the first six feeding shifts in the following proportions of goat's milk/milk replacer were used: 75-25%; 50-50%; 25-75%.
(1)Composed by 18.0% minimum crude protein, 3.0% minimun total fat, 7.5% minimun crude fiber, 8.8% maximun ash, 0.8% minimun calcium, 0.6% minimun phosphorus and 2,700 kcal $kg^{-1}$ metabolizable energy.
(2) Goat kids began to be offered drinking water.

As shown, feeding was done twice a day (800 and 1,700 h) until the end of week eight and thereafter, once a day during the afternoon feeding shift. Both milk replacers were prepared with potable water at 50 °C for better dissolution and supplied at 37 to 42 °C. Initially, they were administered with nursing bottles and later on, with individual buckets equipped with a plastic probe connected to a nipple for goat kids (Figure 2). Nipples were placed in an upper position to allow the passage of the milk replacer by suction and not by gravity, to reduce losses due to dripping.

**Figure 2.** Milk replacer supply system (bucket with teat).

From the third week, the diet was completed with starter feed for early weaned calves (Marcelo E. Hoffmann e Hijos S.A.) and alfalfa hay. The starter feed was offered ad libitum until an average daily consumption of 300 g per animal, when it was restricted, and alfalfa pellets were incorporated ad libitum. Alfalfa hay was always available. They had also access to drinking water ad libitum.

**Sampling and records**

Survival rate (SUR; %): Rate of live kids at the end of the tenth week of artificial rearing.

Live weight (LW; kg): Weight at birth and then once a week until the tenth week. Measurements were taken in fasting state (in the morning, before milk intake, and without access to liquids and solids for at least 12 h), using a digital scale with a precision of 10 g.

Daily live weight gain (DLWG; g day$^{-1}$): Daily weight gain during rearing. It was calculated by dividing the difference between the final (10th week) and the initial weight (birth weight) by the elapsed period (70 days).

Reaching 10 kg LW (LW10): Age in weeks when all goat kids in each group reached 10 kg.

Multiplying their birth weight by 2.5 (BWx2.5): Age in weeks when all goat kids in each group reached a weight 2.5 times their birth weight.

Glycemia (GLY; mg dl$^{-1}$): Concentration of glucose in plasma. Samples were taken every two weeks from week four. A disposable syringe and a 21 G (25x8) needle were used to extract 2 mL of blood from the jugular vein. The collected volume was placed in an Eppendorf tube containing 20 µL of EDTA solution supplemented with potassium fluoride as an anti-glycolytic agent to preserve samples from glycolysis (anticoagulant G, Wiener Lab). The samples were centrifuged at 3,500 rpm for 15 min. Then, plasma was separated, transferred to 0.5 mL Eppendorf tubes, and stored at -20 °C until analysis. Plasma samples were sent to a private laboratory (Dorronsoro Laboratory, Animal division. Las Flores, Buenos Aires, Argentina) for analysis by spectrophotometry using Mindray BS-200 equipment.

Diarrhea incidence (DI; %): Proportion of goat kids that presented diarrhea disorders and duration of the episodes. Immediately before milk replacer administration, the ano-caudal region of each goat kid was observed to identify signs of diarrhea.

Cost of milk feeding per goat kid (COST; US$ kg$^{-1}$): Cost of both milk replacers relative to the number of weaned goat kids in each treatment at week ten. The prices on July 2023 were 3.39 US$ kg$^{-1}$ and 5.68 US$ kg$^{-1}$ for the milk replacer for small ruminants and whole cow milk powder, respectively, both placed in the processing plant.

**Statistical analysis**

LW was analyzed by PROC MIXED for repeated measurements, according to the treatment (MR vs. MP), the age (weeks 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10), and its interaction. The structure of the variance-covariance matrix, selected following the Akaike criterion, was a heterogeneous autoregressive matrix of order 1. Tukey's test was used for multiple comparisons. Variables related to the target weights (LW10 and BWx2.5) and SUR were evaluated using Fisher's exact test according to the treatment. Effect of treatment on DLWG was evaluated by PROC GLM. GLY was analyzed using PROC MIXED for repeated measurements, including the treatment (MR vs. MP), the age (weeks 4, 6, 8, and 10), and its interaction. The matrix structure selected, following the Akaike criterion, was autoregressive of order 1. Tukey's test was used for post-hoc comparisons. COST was calculated as a partial direct cost of using each milk replacer per weaned goat kid. All analyses were performed using SAS statistical software (2023).

## RESULTS AND DISCUSSION

**Effect on survival rate (SUR)**

The survival rate of kids at weaning was 100% for both treatments. These results are consistent with those previously obtained by Simonetti et al. (2019) and by other authors (Galotta 2018; Arias et al. 2022) with the same breed, under similar conditions. Feeding with a milk replacer for goat kids offered ad libitum (Delgado-Pertíñez et al. 2009a, 2009b) also resulted in 100% survival for Florida and Payoya breeds when rearing was done until four weeks of age.

Among the factors that determine the survival of artificially reared kids are the number of animals as well as the uniformity of the group at the start of rearing. Castroalonso et al. (2003), in a trial conducted with a high number (n=354) of replacement kids selected from the Canary Islands Group, obtained a high mortality rate (25.0%) using a specific milk replacer for goat kids and feeding through nursing bottles twice a day. According to these authors, the determining factors were the age differences and the low weight at the start of artificial rearing for half of the animals. In their work, the main causes of detected mortality were: malnutrition, due to inability to adapt to the feeding system; colibacillary diarrhea, due to deficient colostrum intake; pneumonia, due to environmental factors; and enterotoxemia, resulting from overconsumption of feed. Regarding commercial dairy goat farms, a survey conducted by Correa (2006) in Buenos Aires (Argentina) stated that mortality during artificial lactation was 27.2%. According to the results found by Balasopoulou et al. (2022) in Germany, the lack of individual control of colostrum intake, the inability to identify health problems and early weaning with inappropriate weights, are the main factors that decrease survival.

In this trial, the use of bedding made of wood shaving, together with collective housing in pens, could have contributed to prevent deaths due to hypothermia. Another important requirement for the correct management of artificial rearing is the intensive dedication of operators.

### Effect on live weight (LW) and daily live weight gain (DLWG)

When analyzing weight evolution (Table 3), an interaction between age (week) and treatment (MR and MP) was detected (*P*<0.01). LW in MP was higher only in week six (*P*<0.05). At the end of artificial rearing, both treatments showed a similar LW (*P*>0.10), with a difference of only 180 g, representing less than 1.30% of the average live weight.

DLWG throughout artificial rearing was 153 and 157 g for MR and MP, respectively, not resulting in significant differences (*P*>0.10).

**Table 3.** Live weight evolution (LW; kg) in Anglo-Nubian female goat kids fed with small ruminant milk replacer (MR) or whole cow milk powder (MP) (lsmeans (min.-max.); SEM: standard error of the mean).

| Age (weeks) | Treatment | | SEM | *P*-value |
|---|---|---|---|---|
| | MR | MP | | |
| 0 | 3.20 (2.72-3.87) | 3.17 (2.68-3.71) | 0.148 | 0.800 |
| 1 | 3.78 (3.30-4.36) | 3.83 (3.48-4.25) | 0.146 | 0.798 |
| 2 | 4.53 (4.15-5.19) | 4.82 (4.20-5.25) | 0.182 | 0.267 |
| 3 | 5.41 (4.81-5.99) | 5.69 (5.09-6.27) | 0.146 | 0.174 |
| 4 | 6.45 (5.86-7.49) | 6.79 (6.26-7.08) | 0.165 | 0.151 |
| 5 | 7.91 (7.20-9.32) | 8.24 (7.76-8.57) | 0.199 | 0.253 |
| 6 | 9.03 (8.27-10.48) | 9.60 (8.91-10.2) | 0.193 | 0.037* |
| 7 | 10.4 (9.17-12.1) | 10.9 (9.69-12.0) | 0.268 | 0.239 |
| 8 | 11.6 (10.5-13.6) | 11.7 (10.1-12.9) | 0.294 | 0.821 |
| 9 | 12.9 (11.6-15.9) | 13.0 (10.6-14.2) | 0.381 | 0.960 |
| 10 | 13.9 (12.3-17.5) | 14.1 (10.7-15.4) | 0.470 | 0.739 |

*Indicates statistical differences between treatments (*P*<0.05).

The results regarding weight-related variables are affected by aspects such as sex, breed, milk replacer composition and duration of rearing period. DLWG obtained in this study are comparable to those indicated as acceptable for replacement kids by Bach et al. (2010). Galotta (2018), working with Anglo-Nubian kids fed with powdered milk up to eight weeks of age, obtained 143±8.4 g day$^{-1}$, thus reaching a weaning weight of 10.4 kg. In the present study, LW at week eight was 11.6 kg for MR and 11.7 kg for MP, and DLWG was 150 g day$^{-1}$ in MR and 153 g day$^{-1}$ in MP.

In a previous study by Simonetti et al. (2019), feeding goat kids of this breed with calf milk replacer or whole cow milk powder, both at 13.8% dry matter, registered weights of 12.5 and 13.7 kg, respectively, at week 10, resulting significantly different; this could be due to the low-fat content of the calf milk replacer. However, when rearing was extended until week 12, similar weights were achieved (14.4 and 14.8 kg), probably due to compensation through solid feed consumption. In their recent study, Arias et al. (2022) compared the growth of kids of the same breed fed with calf milk replacer and milk replacer for small ruminants, used at 18.0% up to week six; they found a non-significant difference in DLWG (129 vs. 137 g day$^{-1}$, respectively), but a tendency in favor to the specific milk replacer. Their results are similar to that found in this work, where DLWG at week six for MR was 138 g day$^{-1}$. It is interesting to note that in the mentioned study the milk replacer was offered in a higher concentration, but this did not lead to better DLWG.

Delgado-Pertíñez et al. (2009a, b) evaluated the live weight of Florida and Payoya kids raised with their mothers versus ad libitum supply of a milk replacer formulated for small ruminants (23.7% crude protein and 25% total fat) at 17% w/w, obtaining 7.41 and 6.99 kg for the mentioned breeds, respectively, at four weeks of age. These results are higher than those obtained in the present study for MR at week four (6.45 kg). Delgado-Pertíñez et al. (2009a, b) pointed out that live weights were higher in artificial rearing for the Florida breed and in natural rearing for Payoya. These results indicate that, in artificial rearing, it may be useful to adjust the amount of dry matter of the replacer to that of the dam's milk, at least when working with dual-purpose breeds, such as Anglo-Nubian. Differences between Delgado-Pertíñez et al. (2009a, b) and the present study may be due, among other factors, to the breed and the way of supply (ad libitum or not).

Regarding general recommendations, the dry matter content of milk replacer will influence the volume consumed. Liquid consumption during artificial rearing is approximately 25% of live weight up to four weeks of age and 15.0% of live weight thereafter (Quintana Quiñonez 2018). A suitable milk replacer for kids should contain a high proportion of dairy protein (close to 90%) instead of vegetable sources, 20.0 to 28.0% protein and 16.0 to 24.0% fat (Martínez and Suárez 2018).

The partial substitution of dairy by vegetable protein in milk replacers is commonly made to reduce costs; however, this can affect the growth rate. In this study, although the presence of soybean meal in the specific small ruminant milk replacer, no effect on live weight was found. Additionally, according to Yeom et al. (2002), the protein-to-fat ratio in the milk replacer should be taken into account, because it may affect protein retention in the animal's body, which in turn affects weight gain. When the energy supply is limited, part of the protein provided by the milk replacer is used as an energy source, decreasing the efficiency of protein utilization for growth. These authors found a significant effect on average daily live weight gain, when the crude protein to metabolizable energy ratio was high (equivalent to 46.7 g kcal$^{-1}$), partially attributable to the increased consumption of milk replacer offered ad libitum. This ratio was even higher in the present trial, corresponding to 53.76 and 53.70 g kcal$^{-1}$ for MR and MP, respectively.

**Effect on reaching 10 kg LW (LW10) and multiplying their birth weight by 2.5 (BWx2.5)**

All goat kids in both treatments reached 10 kg at week eight. The average age when the kids achieved this weight was 47.5 days for MR and 45.7 days for MP. Atasoglu et al. (2008), working in a partial natural lactation system, lasted 55 days to reach 10 kg.

All goat kids in MR and MP reached the objective of multiplying by 2.5 their birth weight (BWx2.5) at week six. This coincides with Ugur et al. (2004) who, working with Saanen kids, did not find significant differences in body measurements between groups weaned at 45 or 60 days, indicating that weaning could take place at six weeks as long as growth objectives are reached. It is important to note that in this trial, only 20.0% of the goat kids in MR registered this value at week five of age, vs. 70.0% in MP, which allows to consider earlier weaning when using powdered milk, as long as other conditions, e.g. adequate solid food intake, are met. The average age when kids reached BWx2.5 was 36.4 days for MR and 33.6 days for MP, making this criterion earlier than LW10.

Gökdal et al. (2017), evaluating Saanen and Alpine kids in partial suckling systems and supplementing with milk replacer, managed to triple the birth weight at 42 days, without differences between breeds. Galotta (2018), using Anglo-Nubian kids, obtained the same percentage of live weight gain compared to birth weight (55.0%)

when using whole cow milk powder (150 g $L^{-1}$) and goat milk in artificial rearing until 24 days of age. In the present trial, the weight gain proportions at that moment (estimated on the weights of weeks three and four) were 81.1% for MR and 94.0% for MP.

Among the criteria to determine the weaning time are age, weight, and average daily intake of solid food. Weaning criteria used in commercial goat farms are varied. A survey conducted by Vickery et al. (2022) worldwide agrees that the main weaning criterion used is age (72.9%), followed by the target weight. In this survey, 22% of farmers used both criteria. According to Gökdal et al. (2017), live weight is a more accurate criterion than age to wean.

Datt et al. (2023) indicate that weaning at 10 rather than 7 kg would lead to better growth later on. So, the proportion of kids reaching 10 kg at the end of rearing was one of two target weights evaluated in the present study. However, the above-mentioned authors, stated that, due to the great number of factors that may affect growth (genetic, maternal nutrition, sex, litter size, feeding, etc.), it might not be suitable to use a fixed weight or age to define weaning time; instead, other parameters like body condition score or growth based on birth weight could be more appropriate. For this reason, the multiplication of birth weight by 2.5 proposed by Datt et al. (2023) was used in this study.

### Effect on glycemia (GLY)

Regarding GLY, no interaction between treatment and week was detected (Table 4). There were also no significant differences between treatments (90.7 vs. 94.2 mg $dl^{-1}$ for MP and MR, respectively) ($P$>0.10). However, it was affected by age, with a decrease observed through the weeks.

**Table 4.** Glycemia evolution (mg $dl^{-1}$) in Anglo-Nubian female goat kids fed with small ruminant milk replacer (MR) or whole cow milk powder (MP) (lsmeans (min.-max.); SEM: standard error of the mean).

| Age (Weeks) | Lsmeans (min.–max.) | SEM | *P-value* |
|---|---|---|---|
| 4 | 98.3 (84.0-131)$^{a}$ | 1.85 | 0.0009 |
| 6 | 93.2 (81.0-106)$^{b}$ | 1.83 | |
| 8 | 90.6 (80.0-110)$^{bc}$ | 1.88 | |
| 10 | 87.6 (74.0-99.0)$^{c}$ | 1.85 | |
| **Treatment** | | | |
| MR | 94.2 (78.0-106) | 1.82 | 0.190 |
| MP | 90.7 (74.0-131) | 1.82 | |
| **Treatment x Age** | | | 0.266 |

Different letters indicate statistical differences between weeks, given the media of treatments ($P$<0.05).

The results obtained in this study differ from those of Simonetti et al. (2019), who found lower glycemia from week six onwards for Anglo-Nubian kids fed with either powdered milk or calf milk replacer. Galotta (2018), working with Anglo-Nubian kids raised with cow milk powder, found 110 and 89.3 mg $dl^{-1}$ in weeks 6 and 9, respectively. Tacchini et al. (2006) evaluated the response of Saanen x Criollo kids to a commercial milk replacer, finding blood glucose values (close to 98.0 mg $dl^{-1}$) on day 25 comparable to those of the present study at 28 days. Similarly, Aufy et al. (2009), reported 97.0 mg $dl^{-1}$ of glycemia at this age. Paez Lama et al. (2014) did not detect a difference in glycemia between criollo kids raised by their dams vs. artificially reared, but they did detect an age effect, similar to which was found in this study.

At birth, the function of the ruminant digestive system resembles that of non-ruminants. The transition to a functional rumen is accompanied by anatomical and physiological changes, including colonization of the rumen by fermentative bacteria, anatomical development of rumen papillae and modification of endogenous metabolism from glycolytic to glycogenic (Baldwin et al.

2004). The absence of differences in glycemia obtained herein between treatments suggests that the changes in the metabolic pathways regarding to the energy source had similar development in both of them.

Smith and Sherman (2009) indicate that the normal range of blood glucose in adult goats is between 50.0 and 75.0 mg $dl^{-1}$, with an average of 62.8 mg $dl^{-1}$. According to these authors, values outside this range can indicate gastrointestinal problems. In the present study, the kids did not reach normal values in either of the two treatments at the end of the trial. This contrasts with the results previously obtained (Simonetti et al. 2019), where normal range values were already found at week six and the kids had blood glucose levels close to the mean (67.7 mg $dl^{-1}$) at week eight. According to Abbasi et al. (2012), kids from four months of age have blood glucose values corresponding to those of adults and do not show variations related to the energy level of the diet. Aufy et al. (2009) working with Saanen kids found that the evolution of glycemia tends to depend more on the weaning management, such as the reduction of milk replacer volume offered or the introduction of weaning solid mixtures, than on the milk replacer itself.

**Effect on diarrhea incidence (DI)**

The incidence of diarrhea was not significant in any treatment. For MR, diarrheal cases were detected in weeks two (two kids, 20.0%) and four (one kid, 10.0%). In MP, the presentation was similar, with diarrhea detected in weeks two (one kid, 10.0%) and four (two kids, 20.0%). Their durations were very brief, as symptom remission was observed by the next feeding shift or the next day. These results are better than those of a previous study (Simonetti et al. 2019), with DI in more animals when a milk replacer formulated for calves was used. Such difference could be attributed, at least partially, to the fact that the non-specific milk replacer, generally formulated with a considerable amount of whey, contains a high proportion of lactose, that can cause intolerance in goat kids. Furthermore, unlike such previous trials (Simonetti et al. 2019), DI was not related to the transition from colostrum to milk replacer or to an increase in volume intake.

Murray et al. (2008) detected severe cases of diarrhea until four weeks of age and lasting up to 15 days in Boer and Boer crossbred kids fed milk replacer (for both, calves and small ruminants); these diarrheas affected daily gain, not reaching the target weight of 15 kg for weaning at 84 days. However, kids fed either by their dams or artificially with goat or cow milk presented mild diarrhea, lasting one to three days, which did not affect weight gain.

The “Neonatal Diarrhea Complex” appears from the interaction among etiological agents, animal’s immune status, and rearing management factors (hygiene, housing density) (Smith and Sherman 2009). It is relevant to note that, typical of an intensive system with susceptible categories, the hygiene of facilities and implements is crucial for reducing diarrheas caused by pathogens. As previously detailed in methodology, the hygiene guidelines adopted in the present assay (box cleaning, wood shaving change and lime sprinkled) in addition to the facility’s design to keep kids away from other categories, seem to have been efficient. However, diarrheas can occur in the absence of enteric pathogens. They can be caused by physicochemical factors that alter the osmotic balance during intestinal absorption; among them, excessive intake or incorrect reconstitution of milk replacer can affect abomasal renine activity so that the components of the replacer would not reach the intestine under optimal conditions for degradation and subsequent absorption (Martínez and Suárez 2018). Moreover, simple indigestion, acute carbohydrate consumption, copper deficiency and intoxications might generate diarrheas (Smith and Sherman 2009).

**Effect on the cost of milk feeding per goat kid (COST)**

The consumption of milk replacer per weaned kid was 10.7 kg in each treatment. Thus, the cost of the milk replacer per weaned kid (COST) was US$ 36.29 for MR and US$ 60.79 for MP. These values imply a cost difference of 67.5% in favor of MR.

If the results obtained regarding the target weights are considered, weaning could be anticipated by 2 weeks in the case of LW10 and by 4 weeks in the case of BWx2.5, without impacting the subsequent development of the goats (Datt et al. 2023). This would reduce milk replacer costs by 12.3% for both treatments in the case of LW10 and by 33.9% in the case of BWx2.5. Additionally, the possibility of weaning at 5 weeks could be taken into account in the case of MP, due to the high proportion of goats that reached BWx2.5 at this point, which would reduce costs by 48.7%. In such a case, it would be advisable to combine this weaning criterion with, for example, the level of solid food consumption, to reduce the probability of post-weaning weight loss.

Paez Lama et al. (2013) reported that artificial rearing of criollo kids up to 45 days old was not economically viable, being 80.4% higher than natural lactation. The authors found that these results were due to two factors: the increase in labor costs and the lower price per liter of marketable goat milk compared to milk replacer. Tacchini et al. (2006) indicated that a commercial milk replacer for small ruminants was 154% more expensive per weaned Saanen x Criollo crossbred kid than a self-formulated replacer based on goat whey, cow milk powder, brewer's yeast and fish meal. In contrast, Delgado-Pertíñez et al. (2009a, b) found that the economic outcome of using a replacer for small ruminants improved the margins of dairy systems in Payoya and Florida breeds.

Taking into account that dairy goat farms in Argentina are commonly of small scale, so depending on family labor, it is important to highlight that feeding represents the most important cost in artificial rearing systems. Cow milk powder is a high-cost input since it competes with its use for human consumption; Furthermore, it is an important exportable product and its price and availability are affected by the international market.

## CONCLUSION

In dairy goat farms, artificial rearing with milk replacers allows all goat milk to be intended for the market. In Argentina, although this technology is widespread in cattle, more studies are needed in goats. In alignment with such directive, the aim was to evaluate two milk replacers, a commercial small ruminant milk replacer and whole cow milk powder, for artificial rearing of Anglo-Nubian female kids. Taking into account the lack of differences in all evaluated variables (survival, growth related measures, glycemia, and diarrheas), the small ruminant milk replacer should be recommended, with the advantage of reducing the cost associated with liquid feeding. This study intends to help with the development of more accurate and economically viable feeding protocols, which could be further adopted by small ruminant farmers.

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