# Long-term Supplementation Affects the Production, Composition and Lactation Curve of Local Grazing Goats

## La suplementación a largo plazo afecta a la producción, la composición y la curva de lactación de cabras de pastoreo locales

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### Abstract

Twenty-four local goats were divided into two treatments: 1) control group fed only on grazing, and 2) supplemented group, which received supplemental feeding before parturition and during lactation. The highest values of milk production per goat, total milk production, days in milk production fat, protein and lactose yield per day were observed in goats of the supplemented treatment. No treatment effect was found for peak lactation production, persistence of peak production, duration of peak lactation production phase, total yield and fat, protein and lactose concentration, nor for milk production per goat, total milk production and days in milk production by type of calving (single or double). Wood's curve parameters had the lowest standard error of the estimator in control group, but the highest values of the estimator in supplemented group. We concluded that long-term dietary supplementation of local goats in northern Mexico increases milk production and milk protein, fat and lactose. In addition, it positively influences the estimation of lactation curve parameters.

**Keywords**
nutrition • small farmers • goats • milk quality

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## Resumen

Veinticuatro cabras locales se dividieron en dos tratamientos: 1) grupo control alimentadas solo a través del pastoreo, y 2) grupo suplementado que recibió alimentación suplementaria antes del parto y durante la lactación. Los valores más altos de producción de leche por cabra, producción total de leche, días en producción de leche, rendimiento de grasa, proteína y lactosa por día se observaron en las cabras del tratamiento control. No se observó ningún efecto del tratamiento sobre el pico de producción en lactación, la persistencia del pico de producción, la duración de la fase de pico de producción en lactación, el rendimiento total y la concentración de grasa, proteína y lactosa, ni sobre la producción de leche por cabra, producción total de leche y días en producción de leche según el tipo de parto (simple o doble). Los parámetros de la curva de Wood presentaron el error estándar más bajo del estimador en grupo control, pero los valores más altos del estimador en el grupo suplementado. Concluimos que la suplementación dietética a largo plazo de cabras locales en el norte de México incrementa la producción de leche, la proteína, grasa y lactosa en leche. Además, la suplementación influye positivamente en la estimación de los parámetros de la curva de lactación.



**Palabras clave**

nutrición • pequeños productores • cabras • calidad de la leche


## Introduction

Breeding of local, native or indigenous goats offers nutritional and economic benefits, constituting a constant source of raw milk and dairy products, particularly for rural families (2, 17). Nevertheless, the scarce knowledge on production potential and milk composition of indigenous breeds has contributed to their replacement by specialized breeds.

In the arid and semi-arid marginalised regions of Mexico, to engage in goat production is common practice for smallholders (24). In these regions, goat herds are predominantly composed of animals referred to as criollos (15). This term is now widely accepted as a designation for 'locals', a category of goats that lack a clearly defined phenotype due to the introduction of diverse breeds, including Alpina, Saanen, Nubia and Toggenburg, through crossbreeding. This production system generates supplementary income in marginal regions in the north of the country, enhancing quality of life of families in these populations (25).

In this regard, several public genetic improvement programs have tried to introduce purebred (exotic) animals into local populations. However, most producers, particularly in northern Mexico, use animals *phenotypically* like purebreds, without genetic records or certainty regarding the expected improvement in production, leading to an erosion process in these populations, already well adapted to particular management conditions (24). This turns critical since genetic variability ensures animals cope with adverse environmental conditions (16).

Moreover, given overgrazed lands, poor soils, and periods of low rainfall, local breeds in extensive grazing systems show productive rates below the global average. Despite this, goats respond positively to supplementary feeding, and where strategies including both grazing and supplementation are incorporated, they improve profitability, milk production and its components than with solely grazing (3). However, supplementary feeding schemes for livestock are only offered during critical seasons, helping animals through drought events (10). Thus, establishing these feeding programs to exploit the production potential of local breeds constitutes an important issue (4), especially in northern Mexico. Although no studies in this region approach long-term supplementation of local goats, other studies have compared productivity under stabled conditions compared to grazing goats. These studies indicate that stabled goats produce 78% (14) and 71% (9) more milk than grazing goats, allowing us to infer that a long-term supplementation program can significantly increase milk production.

Our hypothesis stated that a long-term feed supplementation program increases overall productivity of goats. The objective was to evaluate goat response to a long-term feed supplementation program considering milk production, protein, lactose and milk fat composition and yield, and obtain a lactation curve.

## Material and methods

This study strictly follows animal welfare and ethical guidelines according to the American Dairy Science Association, National Academy of Medicine (1, 6) and Mexican Institutionally with the approval of the project "Technological options to improve the productivity of extensive goat system in northern Mexico".

Twenty-four local goats with similar live weight (LW), body condition score (BCS; on a scale of 1 to 4), kidding number, and gestational age were taken from a commercial herd (n=125) located in Viesca, Coahuila, México, situated among 24° N and 102° W, at 1100 m a. s. l. Goats were assigned into two homogeneous groups under a repeated measures design. Treatments were randomly assigned to experimental units. Treatments were: 1) Control group (CG; n=12), LW of 38.5±4.8 kg, 1.9±0.2 BCS, 2.1±0.9 kidding's per goat, and 104±6 gestation days, fed with plant species normally obtained during grazing; 2) Supplemented group (SG; n=12), LW of 38.3±6.6 kg, 1.8±0.3 BCS, 2.2±1.2 kidding's per goat, and 104± 5 gestation days, received supplementary feeding (table 1) at a rate of 1.5% of animal LW, 45 days before kidding and throughout lactation (210 days in production).

Regular animal management is characterized by a prophylactic health management calendar, where the herd is vaccinated and dewormed twice a year. Animals grazed for approximately 9 h $d^{-1}$ and returned to resting pens at 18:00 h, with access to fresh water.

The supplemented group was sheltered in individual pens of 2 x 3 m each. After grazing, animals were fed for approximately 10 minutes per goat, till full consumption.

**Table 1.** Ingredients and chemical composition of the total mixed diet as a supplement for local lactating goats under the extensive grazing system in northern Mexico.

**Tabla 1.** Ingredientes y composición química del suplemento para cabras lactantes locales bajo el sistema de pastoreo extensivo en el norte de México.

| Ingredient | Quantity (g kg DM) | Nutritional content | |
|---|---|---|---|
| Rolled corn | 18.0 | CP | 18.7 |
| Rolled sorghum | 18.0 | ADF | 21.6 |
| Wheat bran | 9.0 | NDF | 32.7 |
| Soybean paste | 9.0 | NEm | 1.8 |
| Alfalfa hay | 35.0 | NEl | 1.5 |
| Molasses | 8.0 | | |
| Urea | 1.0 | | |
| Vitamin and Mineral premix* | 2.0 | | |

DM= dry matter; CP= crude protein; ADF= acid detergent fiber; NDF= neutral detergent fiber; NEm= net energy for maintenance (MCal/g kg EM); NEl= net energy for lactation (Mcal/g kg EM); *=mineral premix Ovi3ways® BIOTECAP Group.

MS= materia seca; PC= proteína bruta; FAD= fibra detergente ácido; FDN= fibra detergente neutro; NEm= energía neta de mantenimiento (MCal/g kg EM); NEl= energía neta de lactación (Mcal/g kg EM); *=premezcla mineral Grupo BIOTECAP Ovi3ways®.

Forage samples were collected during grazing (26), by observing chosen species. Forage samples were oven-dried at 65°C until constant weight, crushed in a hammer mill and sent to AGROLAB laboratory (Gómez Palacio, Durango, México) where a basic analysis was carried out with NIR (Foss NIRSystems 5000 M-Analyzer, Denmark). At the beginning of the study, (end of rainfall season) 14 plant species consumed were identified. Later, at the start of the dry season (middle of the experimental period) only 7 plant species and some crop-residues were identified.

The supplemented group was fed after grazing, individually, at 20:00 h, minimizing substitution effect on forage consumption while grazing (15), and until full consumption.

At parturition, kidding type, *i.e.* single or twins, and milk production were weekly assessed by the weighing-suckling-weighing technique (7), between 6:00 and 8:00h and until weaning (30 days of age), starting the 5th day after kidding to ensure adequate colostrum consumption. The technique consisted of offspring weighing before and after suckling, after which MP was measured by weight difference. Once kids were weaned, MP was daily measured through individual production obtained from hand-milking until ceased milk production. Milk production expressed in grams (g) was measured using a standard electronic hook-type scale with a capacity of 45 kg±5 g (Metrology, Nuevo León, México). Milk quality (fat, protein, and lactose contents) was evaluated every 15 days with a 50ml sample, using the Milkoscope Expert Automatic® equipment (Razgrad, Bulgaria). Milk production per goat (MPG) and fat, protein, and lactose yields per day were measured according to the equation:

$$y= [(Pn+P(n-1)/2]* d$$

where
y = MPG and fat, protein, and lactose yields
Pn = Milk production on control day n
P(n-1) = milk production on previous control day
d = days between two controls

For lactation curve analysis, 1334 productive records of milk production (MP; n=574), and milk quality (MQ; n=760) were analysed. Total milk production per lactation (TMPL) and total fat, protein, and lactose yields per lactation (kg) were calculated using the Fleischamn method (2009), based on the following equation:

$$yi = (P1*D1+ \sum Pi+Pj+1/2* Di+Pk+1*DBR)$$

where
yi = trait
P1 = Milk production on the first record
D1 = interval between kidding and the first record
Pi, j, k = Milk production on the i,j,k-th record
Di = interval between the i-th record and the i+1(i=1,…,k) record
DBR = assumed as the number of days between recordings (7 in MP and 15 in MQ)

Variables determining the lactation curve were days in milk production (DMP; time between kidding and drying), production at lactation peak (PLP, kg; highest production), peak time production (PTP, d; time in which the doe reaches the highest yield); and duration of the lactation peak production phase (DLPPP, d; period of greatest production maintenance) (14).

Wood's incomplete gamma function, in its non-linear form (26), determined the parameters characterizing the lactation curve under the model:

$$yn=an^{b}e^{-cn}$$

where
yn = milk and/or fat, protein, and lactose production on the n-th day of lactation
e = base of the natural logarithm "a", "b" and "c" : constants
"a" = a scale factor, milk production or milk component at the beginning of lactation
"b" = rate of rise in milk production to peak
"c" = rate of decline in milk production to drying up

Statistical analysis was performed with SAS v9.4 statistical package. MPG, TMPL, PLP, PTP, DMP, DLPPP, content, and total fat, protein, and lactose yields were analyzed under a repeated measure mixed-effects model in a complete randomized design using the MIXED procedure. The model included the main effects of treatments, periods, and the interaction of treatment by period. The appropriate covariance structure for the analysis was determined by testing different structures, and the covariance structure with negative or near-zero values was chosen according to the Akaike and Schwartz criteria. MPG, TMP, and DMP were analysed by type of birth.

## Results

Table 2 shows lactation results. The SG presented the higher values ($p<0.05$) for MPG, TMPL, and DMP variables. No effect was found for type of birth between treatments ($p>0.05$) for fat, protein, and lactose contents, nor for MPG, TMPL and DMP. The MPG increased 31% (0.140 kg) in SG goats with respect to CG. No differences were found for PLP, PTP, and DLPPP between treatments ($p>0.05$). Production peaks occurred on the third week at day 19 of lactation in both groups, with an average of 1.141 kg for SG and 0.820 kg for CG.

**Table 2.** Production performance by treatment and type of birth in local goats from northern Mexico.

**Tabla 2.** Desempeño productivo por tratamiento y tipo de parto en cabras locales del norte de México.

| By Treatment | | | |
|---|---|---|---|
| | **SG** | **CG** | **P-Value** |
| **Milk production per goat (kg d$^{-1}$)** | 0.580±0.02 | 0.440±0.02 | <0.0001 |
| **Total milk production per lactation (kg)** | 107.48±6.92 | 67.20±7.21 | 0.0008 |
| **Days in milk production (d)** | 184.49±9.62 | 151.98±10.02 | 0.0344 |
| **Peak lactation production (kg)** | 1.140±0.03 | 0.820±0.03 | 0.0756 |
| **Persistence of peak production (d)** | 19.0±2.00 | 19.0±2.00 | 0.9873 |
| **Duration of peak lactation production phase (d)** | 21.0±3.98 | 21.0±2.10 | 0.9602 |
| **Fat (%)** | 6.17±0.53 | 5.35±0.53 | 0.3093 |
| **Protein (%)** | 3.90±0.31 | 3.35±0.31 | 0.2490 |
| **Lactose (%)** | 5.83±0.47 | 5.01±0.47 | 0.2504 |
| **By kidding type** | | | |
| | **Single** | **Double** | **P-Value** |
| **Milk production per goat (kg d$^{-1}$)** | 0.500±0.002 | 0.540±0.02 | 0.0584 |
| **Total milk production per lactation (kg)** | 89.50±8.70 | 94.12±5.88 | 0.5067 |
| **Days in milk production (d)** | 175.49±12.09 | 168.98±8.18 | 0.6480 |

SG= Supplemented group; CG= Control group; C.V. = Coefficient of variation.

SG= Grupo suplementado; CG= Grupo de testigo; C.V.= Coeficiente de variación.

No differences were found in milk fat, protein, and lactose percentages among treatments ($p>0.05$; table 3, page 160). Yet, differences were found between groups ($p<0.05$) in fat, protein, and lactose yields measured as kg d$^{-1}$. Furthermore, patterns of these components through lactation (figure 1, page 160) were similar, with different magnitude trends between treatments. In both groups, fat peaked at 47 days, and then decreased steadily until day 120. After day 120, fat content increased again and remained constant until the end of lactation. Meanwhile, protein and lactose showed average ranges throughout lactation between 2.9 and 3.1% and 4.2 and 4.6%, respectively. Also, a slight decrease was noted between 75 and 90 days for fat, protein and lactose contents (figure 1, page 160).

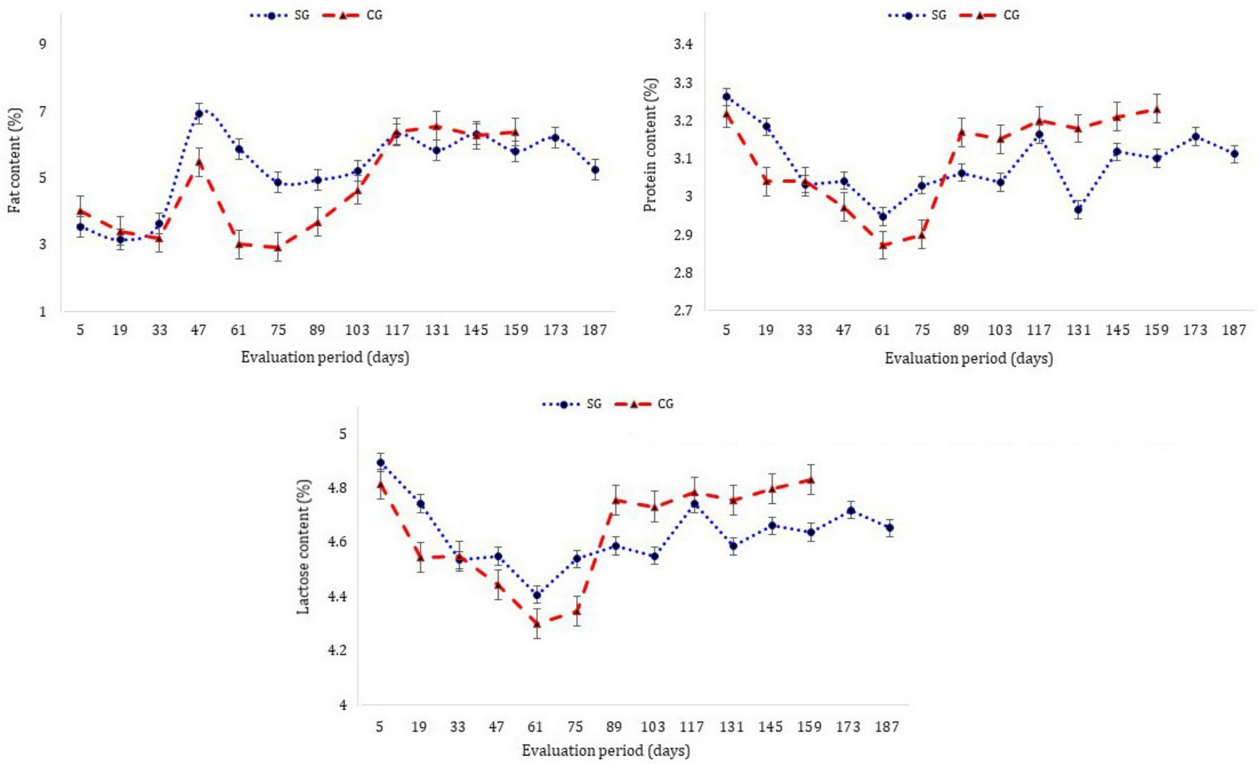
**Table 3.** Content (%) and yield (kg$^{-1}$) per day of fat, protein, and lactose between treatments in local goats from northern Mexico.

**Table 3.** Contenido (%) y rendimiento (kg$^{-1}$/día) de grasa, proteína y lactosa entre tratamientos en cabras locales del norte de México.

| | SG | CG | P-Value | |
|---|---|---|---|---|
| | | | Treatment | Treat*Time |
| **Fat (%)** | 5.26±0.19 | 5.30±0.20 | 0.6654 | 0.5417 |
| **Protein (%)** | 3.09±0.02 | 3.10±0.03 | 0.5651 | 0.5049 |
| **Lactose (%)** | 4.63±0.03 | 4.64±0.04 | 0.7162 | 0.6961 |
| **Fat (kg d$^{-1}$)** | 0.032±0.0021 | 0.027±0.0023 | 0.0121 | 0.5192 |
| **Protein (kg d$^{-1}$)** | 0.021±0.0013 | 0.017±0.0015 | 0.0026 | 0.4578 |
| **Lactose (kg d$^{-1}$)** | 0.030±0.0022 | 0.025±0.0020 | 0.0024 | 0.4591 |

SG= Supplemented group; CG= Control group; Treat*Time= Interaction treatment* time effect. C.V= Coefficient of variation.

SG= Grupo suplementado; CG= Grupo testigo; Treat*Time= Efecto de interacción tratamiento*tiempo. C.V= Coeficiente de variación.




SG= Supplemented group; CG= Control group. / SG= Grupo suplementado; CG= Grupo de testigo.

**Figure 1.** Content (%) of fat, protein, and lactose in milk through lactation in local goats of northern Mexico.

**Figura 1.** Contenido (%) de grasa, proteína y lactosa en leche a lo largo de la lactancia en cabras locales del norte de México.

Table 4 (page 161), shows parameters a, b, and c characterizing milk production curve and fat, protein, and lactose yields. Likewise, figure 2 (page 161), shows milk production and milk components (fat, protein and lactose). Model best fit resulted for CG data in all variables, given a lower standard error. However, the higher estimator values ($p<0.05$) for parameter "a" and lower values for parameters "b" and "c" ($p>0.05$) were found in all variables for SG, indicating better productive performance throughout lactation for SG goats.

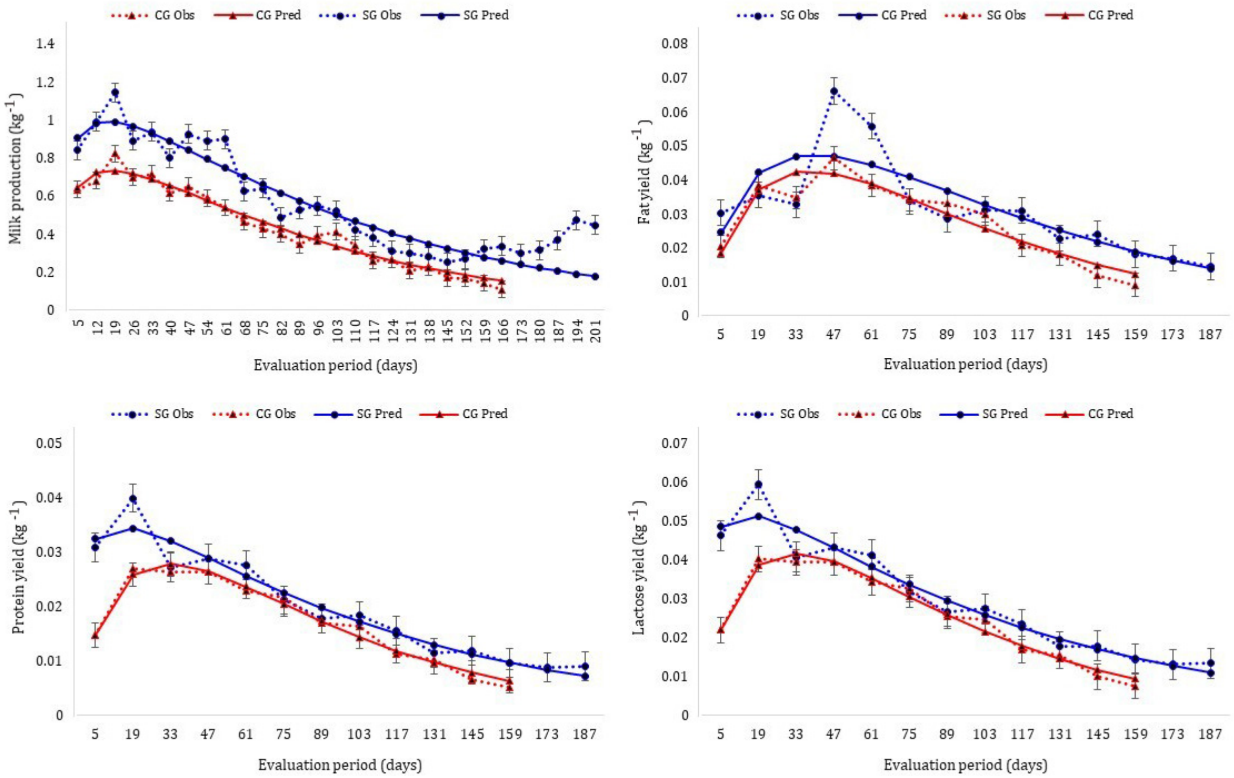
**Table 4.** Estimation of lactation curve parameters obtained through Wood's incomplete gamma function ([a, b, c]) according to treatments for local goats in northern Mexico.

**Tabla 4.** Estimación de los parámetros de la curva de lactancia obtenidos mediante la función gamma incompleta de Wood ([a, b, c]) según tratamientos para cabras locales del norte de México.

| Trait | Parameter | SG ± S.E. | CG ± S.E. | P-Value |
|---|---|---|---|---|
| Milk yield | a | 0.7848±0.1648 | 0.4303±0.0485 | 0.0256 |
| | b | 0.1390±0.0780 | 0.2841±0.0437 | 0.0482 |
| | c | 0.0103±0.0016 | 0.0155±0.0010 | 0.4821 |
| Fat | a | 0.0107±0.0068 | 0.0064±0.0022 | 0.0396 |
| | b | 0.5558±0.2157 | 0.7143±0.1235 | 0.0252 |
| | c | 0.0142±0.0039 | 0.0187±0.0024 | 0.1325 |
| Protein | a | 0.0264±0.0043 | 0.0059±0.0009 | 0.0534 |
| | b | 0.1628±0.1598 | 0.6258±0.0554 | 0.0039 |
| | c | 0.0115±0.0114 | 0.0196±0.0012 | 0.0638 |
| Lactose | a | 0.0397±0.0063 | 0.0088±0.0013 | 0.0335 |
| | b | 0.1598±0.0629 | 0.6260±0.0562 | 0.0069 |
| | c | 0.0114±0.0015 | 0.0195±0.0012 | 0.3211 |

SG= Supplemented group; CG= Control group; S.E.= Standard error; "a"= milk production or milk component at the beginning of lactation; "b"= rate of rise in milk production to peak; "c"= rate of decline in milk production to drying up.

SG= Grupo suplementado; GC= Grupo testigo; E.S.= Error estándar; "a"= producción de leche o componente lácteo al inicio de la lactación; "b"= tasa de aumento de la producción de leche hasta el pico de producción; "c" = tasa de disminución de la producción de leche hasta el secado.




SG= Supplemented group; CG= Control group; Obs= Observed; Pred= Predicted; Prod= Production.

SG= Grupo suplementado; CG= Grupo testigo; Obs= Observado; Pred= Predicho; Prod= Producción.

**Figure 2.** Milk production and yield curves of fat, protein, and lactose in milk in local goats of northern Mexico.

**Figura 2.** Curvas de producción de leche y rendimiento de grasa, proteína y lactosa en leche en cabras locales del norte de México.

## Discussion

After supplementation, positive effects were observed in milk production per goat, total production per lactation, days in milk production, and yield components, as noted by Bushara and Godah (2018) for desert goats in Sudan and by Otaru *et al.* (2020) in Red Sokoto goats in Nigeria.

Production levels of goats in SG were superior to other local genotypes (West African dwarf goats and Red Sokoto) receiving supplementary feeding (19), with lower values for CG, demonstrating the productive potential of this Mexican genotype. These animals significantly enriched production under improved environmental conditions like nutrient supply (20). Similarly, production levels differed from the reported by Oliveira *et al.* (2012) for Nubian goats (1.08 kg) whith a supplementation of 1.5% of the LW. Nevertheless, considering this particular case, exotic dairy breeds show a higher, though lower quality, milk production level than local goats (4). In our study, goats increased milk production, without affecting milk quality.

Results regarding PLP, PTP, and DLPPP were consistent with Salinas-González *et al.* (2015) and creole goats in Coahuila, México, where maximum milk production (0.848 kg) was found on day 16 of lactation. DLPPP was recorded on early lactation from days 12 to 33 in both groups, differing from Waheed and Khan (2013) for Beetal goats. These authors found a production peak of 1.340 kg, higher than in our study, with a maximum production phase in mid lactation (weeks 7-9) and a shorter duration. In addition, Henao *et al.* (2017) mentioned a lower PTP (10.02 d) for mestizo goats of Colombia and a higher PLP (1.710 kg $d^{-1}$) than the stated for our local goats. Local goats in northern Mexico are used for milk production, but the duration of lactation is mostly unknown (25).

Regarding TMPL, Arabia goats in Algeria and Carpathian goats in Rumania produce 168 kg and 160 kg, respectively (13) higher than our local goats. On the other hand, the control group had TMPL values above the reported for indigenous and mestizo goats from southern and northern Mexico (24, 25) with an average lactation length of 105 days. However, this control TMPL was lower than the 82.9 kg of indigenous goats in Morocco with lactations of 117 days (12). This valuable information prevents underutilization, erosion or elimination of superior productive animals (25).

On the other hand, SG showed a DMP of 32.5 days higher than CG, coinciding with the range reported for Bornova and Saanen goats in Turkey (180-200 d) (23), but under the 210 days reported for Alpine goats in Colombia (11). Likewise, CG coincided with lactation ranges (141-160 d) found in Sirohi goats in India under feeding supplementation (3). This information reveals that local goats in northern Mexico considerably improve DMP and TMPL when supplemented, evidencing feasibility of establishing genetic improvement schemes to increase milk production (8).

Regarding milk composition, the lowest values considering all components were found between the 5$^{th}$ and 7$^{th}$ week of lactation, just after production peaks, in accordance with Currò *et al.* (2019) for Italian indigenous goats. Component behaviour along lactation in local goats of northern Mexico has a constant trend. Fat varies less than 2%, while protein and lactose vary less than 0.3%, agreeing with Salinas-González *et al.* (2015) for local goats of northern Mexico, although total values were slightly lower for fat and superior in protein and lactose contents. Additionally, in Nguni, Boer, and Indigenous genotypes from South Africa, milk fat varies 3.5% throughout lactation while protein and lactose vary 0.5 and 0.7% respectively (13) coinciding with our patterns and maximum initial, lower middle and medium late values in lactation.

When supplementary feeding was offered, our contents of fat, protein, and lactose were superior to those reported by de Oliveira *et al.* (2020) for Nubian goats, even considering those goats produced more milk of poorer quality with more fat and lactose than other genotypes (3). Local or indigenous goats show better quality than specialized breed goats for milk production (5).

Regarding curve parameters, Takma *et al.* (2009) found superior “a” and “c” values for Bornova goats. Rojo-Rubio *et al.* (2015) found superior “a” and “b” parameters, but lower “c” values in Alpine, Saanen, and Anglo-Nubian goats. Torres-Hernández *et al.* (2022b), reported superior values in “a”, and lower “b” and “c” in local goats from northern Mexico without supplementation, while Zambom *et al.* (2017) showed superior results in "a", but lower in "b" and "c" in supplemented Saanen goats from Brasil.

Our results highlight the productive potential of local goats from northern Mexico, since despite lactation curve parameters are lower than others, long-term feed supplementation promotes an increase in parameter "a" and lower declination values before and after production peaks (parameters "b" and "c") for MP and milk fat, protein, and lactose.

## Conclusions

We conclude that under our experimental conditions, continuous supplementation from 1.5% of live weight in local goats of northern Mexico increases milk production and quality. Supplementation helps this local genotype express whole genetic potential.

In addition, continuous supplementary feeding from the last third of gestation increases milk production throughout lactation. Yet, this increase in production influences the standard error for the curve parameters, under or overestimating the predicted values.

It is essential to validate the findings of this study with the supplement used and with other supplements available in arid and semi-arid regions with goat attitude. This will facilitate the generation of additional feed options for use by small goat producers.

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