agriculture

MDPI

Article

Interactions between Social Hierarchy and Some Udder Morphometric Traits upon Colostrum and Milk Physicochemical Characteristics in Crossbred Dairy Goats

Ma. Silvia Castillo-Zuñiga [1,2], César A. Meza-Herrera [3,*], Guadalupe Calderón-Leyva [1], Nicolas López-Villalobos [4], Cayetano Navarrete-Molina [5], Jorge A. Bustamante-Andrade [6], Pablo I. Sifuentes-Lamónt [1], Jessica M. Flores-Salas [1] and Francisco G. Véliz-Deras [1]

[1] Universidad Autónoma Agraria Antonio Narro, Unidad Laguna, Periférico Raúl López Sánchez y Carretera a Santa Fe, Torreón 27054, Coahuila, Mexico; mscz1970@hotmail.com (M.S.C.-Z.); gcalderon06@hotmail.com (G.C.-L.); pablo_lamont@outlook.com (P.I.S.-L.); jesflor13@hotmail.com (J.M.F.-S.); velizderas@gmail.com (F.G.V.-D.)
[2] Centro de Bachillerato Tecnológico Agropecuario No. 1, Torreón 27410, Coahuila, Mexico
[3] Universidad Autónoma Chapingo, Unidad Regional Universitaria de Zonas Áridas, Bermejillo 35230, Durango, Mexico
[4] Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Palmerston North 442, New Zealand; n.lopez-villalobos@massey.ac.nz
[5] Universidad Tecnológica de Rodeo, Departamento de Química, Área Tecnología Ambiental, Rodeo 35760, Durango, Mexico; navarretemolina1977@gmail.com
[6] Universidad Juárez del Estado de Durango, Facultad de Agricultura y Zootecnia, Venecia 35111, Durango, Mexico; abaj_86@hotmail.com
* Correspondence: cmeza2020@hotmail.com or cmezah@chapingo.mx

Citation: Castillo-Zuñiga, M.S.; Meza-Herrera, C.A.; Calderón-Leyva, G.; López-Villalobos, N.; Navarrete-Molina, C.; Bustamante-Andrade, J.A.; Sifuentes-Lamónt, P.I.; Flores-Salas, J.M.; Véliz-Deras, F.G. Interactions between Social Hierarchy and Some Udder Morphometric Traits upon Colostrum and Milk Physicochemical Characteristics in Crossbred Dairy Goats. *Agriculture* **2022**, *12*, 734. https://doi.org/10.3390/agriculture12050734

Received: 13 April 2022
Accepted: 16 May 2022
Published: 23 May 2022

Abstract: The possible relationship between udder morphometric variables (UMVs), chemical quality (CHQ) of both colostrum (CA), and milk (MK), as affected by goat's social rank (SR) (i.e., low-LSR, or high-HSR), was assessed. In late June, goats (Alpine–Saanen–Nubian x Criollo; n = 38; 25° N) were estrus-synchronized and subjected to a fixed-time artificial insemination protocol. Thereafter, in October, while a behavioral study was performed in confirmed-pregnant goats to define the SR classes (n = 15), live weight (LW), body condition (BCS), and serum glucose (GLUC) were registered on the last day of the behavioral study. The expected kidding date was 25 November. Both the UMVs (i.e., seven dates) and the CHQ (i.e., either one for CA and three times for MK) were collected across time (T). The UMVs involved udder perimeter (UDPER, cm), udder diameter (UDDIA, cm), left-teat (LTPER, cm) and right-teat perimeter (RTPER, cm), left-teat (LTLT, cm) and right-teat length (RTLT, cm), left-teat diameter (LTDIA, cm) and right-teat diameter (RTDIA, cm), and medium suspensory ligament (MSL, cm). The registered CHQ variables for both CA and MK were fat (FAT), protein (PRO), lactose (LAC), nonfat solids (NFS), freezing point (FP), and total solids (TS). The possible effect of SR, T, and the SR × T interaction upon the described response variables was tested. While LW favored the HSR goats (54.6 vs. 48.2 ± 1.7 kg; $p < 0.05$), neither BCS nor GLUC differed ($p > 0.05$) between SR. An SR × T interaction affected ($p < 0.05$) most UMVs (i.e., UDPER, MSL, LTLT, RTLT, LTDIA, and RTDI). UMV differences were associated with both changes across time and between SR. Whereas RTLT, LTDIA, RTDIA, and MSL showed their highest values one week prior to kidding, the largest UDPER values ($p < 0.05$) occurred within the week of kidding. Additionally, HSR goats showed increased values regarding UDPER, MSL, and LTLT. No differences ($p < 0.05$) between SR occurred regarding the CA-CHQ (i.e., FAT, PRO, LAC, NFS, FP, and TS). Still, an SR x T interaction affected ($p < 0.05$) the MK content of FAT, PRO, and NFS; while the largest values ($p < 0.05$) occurred on Day 7 postpartum, the other MK constituents decreased as the lactation advanced. Further, the HSR goats showed an enlarged MK-CHQ (i.e., FAT, PRO, and NFS). HSR goats merged some central behaviors such as aggressiveness, assertiveness, and supremacy to have primacy to feed access, augmenting their LW. Whereas said bodyweight advantage was not reflected upon in CA-CHQ, HSR goats augmented some morphological udder values (i.e., UDPER, MSL, and LTLT) and produced the best MK-CHQ (i.e., > FAT, > PRO, and > NFS) during early lactation. Therefore, both social rank (i.e., HSR goats), as well as the temporal transition stage from the last third of pregnancy to the first phase of lactation (i.e., time), operated as important modulators upon both udder architecture and milk quality in crossbred dairy goats under a dry-semiarid production system.

Keywords: goats; udder development; colostrum and milk quality; social dominance; live weight

1. Introduction

Goats have a multifaceted social arrangement, with a social hierarchy preserved by agonistic and affiliative behaviors; they are social and gregarious animals. A steady social milieu provides them with conditions to adapt to the environment by means of social learning and well-being, as suggested by the low threshold to respond to stressful events [1–3]. Although there is some information regarding the effect of social behavior with respect to productive efficiency, the significance of this relationship has not been appropriately explained, especially in goats [4]. Indeed, studies addressing the importance of social hierarchy in goat production and reproduction are neither recent nor abundant, highlighting what was formerly reported [5–7]. Domestic herbivores under grazing schemes exert social dominance, especially when grass is available ad libitum [8,9]. If there is greater feed availability and diversity, the dominant animal will have priority access to the best quality resources with respect to subordinate animals [10–12]. Said dominance in the herd's social hierarchy ensures access to the best available feed, either in grasslands or pastures, which in turn has a positive and significant effect on the live weight of the dominant animal. Moreover, a higher live weight is positively aligned with better metabolic status and greater productive and reproductive capacity [13].

In confined animals living in restrained environments, large animal densities can generate an even higher level of hostility and greater disturbance, promoting aggressive behavior and injuries, parallel to a reduction in the live weight, especially in animals of low hierarchical rank [14,15]. Even in group feeding under intensive and semi-intensive production schemes, it is considered that continuous competition among the members of the herd causes adverse results, not only regarding the provision of adequate space for feeders, but also regarding access to the ration feeding, because the ingestion behavior of the subordinates is habitually disturbed by the dominants; on top of that, goats exert a highly selective diet intake [16,17]. In addition, feed consumption is affected by other factors such as time of day, environmental temperature, season of the year, and other issues involved in the social hierarchy, affecting access to feed while generating animal rivalry and social disturbance [3,18].

Goat milk has been rooted in various civilizations and cultures worldwide [19]. During the last decade, world production of goat milk (*Capra hircus*) has increased by 12%, from 17.6 Mt in 2010 to almost 20.0 Mt in 2019, and the manufacture of goat cheese has increased by 18%, from 460.5 Kt in 2010 to 567.1 Kt in 2019 [20]. Mexico has close to 9 million goats, mainly crossbred animals and primarily under arid and semiarid ecotypes; in 2020, goat production generated almost 40,000 tons of meat and 167,000 tons of milk [21,22]. The Comarca Lagunera, an agroecological area situated in the arid lands of northern Mexico, has one of the main goat concentrations in the Americas, reaching first place in the production of goat milk at the national level, generating significant economic income mainly based on organic milk and meat production, the latter backing the social, economic, and biotic sustainability of producers [21–23]. Goat milk production involves different variables, not only physiological, but also ethological, and even morphological, with respect to the goat udder, which impact the quantity and quality of colostrum and milk [24]. In this regard, the most influential period in the development of the mammary gland, which determines not only the milk yield but the quality of the colostrum milk, is aligned to the live weight, body condition, and metabolic status of the goat in the last third of gestation and first stage of lactation [25,26]. Additionally, the feed consumption of subordinate animals is generally disturbed by dominant animals, which can affect the main physicochemical characteristics not only in the production and richness of colostrum, but also of milk [27]. Building on said findings, we hypothesized that in goats, a high social rank status leads to priority feed access, increasing both live weight and, in turn, udder morphometric values, affecting the quality of both colostrum and milk. Hence, this study aims to test such a hypothesis in crossbred dairy goats under a subtropical dry-hot environment.

2. Material and Methods

2.1. General

All the exerted experimental procedures, methods, and handling of the animals used in this study fulfilled the guidelines for ethical use, care, and animal welfare in research at both international [28] and national [29] levels, with reference Institutional Approval Number UAAAN-UL-20-3059.

2.2. Location, Environment, and General Management during the Reproductive Transition Pretrial Period

The study was performed in northern Mexico (Durango; 25°46′ N and 103°21′ W), under dry-hot semiarid subtropical conditions, at 1100 m above sea level, with a mean annual rainfall of 266 mm (range: 163 to 504 mm; June–September). The variations of the photoperiod in the region are 13:41 h during the summer solstice and 10:19 h during the winter solstice [30]. Adult goats of the crossbred dairy type (Alpine–Saanen–Nubian × Criollo, n = 38; 2–3 lactations) were considered during the pretrial phase (i.e., transition from anestrous to reproductive season; June–July). Both environmental conditions and general female management prior to the experimental period were homogeneous with those previously described, although our study was performed during the transition from anestrous to reproductive season (i.e., mid-June) [12,31].

Briefly, once the goats' anestrus status was confirmed in mid-June by means of two transrectal ultrasound scans, using a 7.5 MHz human prostate transducer (Aloka 500, MHz linear array; Corometrics Medical Systems, Inc., Wallingford, CT, USA), goats were subjected to an estrus induction protocol; upon estrus confirmation, all goats (n = 38) were subjected to a fixed-time artificial insemination (FTAI) procedure by the end of June, as previously outlined [31]. Thereafter, all the FTAI goats, and goats up to the first 4 months of pregnancy, were managed under the rangeland-based grazing system, predominant in the Comarca Lagunera [31]. Concisely, the rangeland has native vegetation typical of aridland ecotypes such as *Cenchrus ciliare*, *Cynodon dactylon*, *Bouteloua* spp., *Sorghum halepense*, *Atriplex canescens*, sprouts and fruits from *Prosopis glandulosa*, and *Acacia farnesiana*; grazing was exerted from 10:00 to 18:00 h.

In general, the amount of range vegetation available is around 2000 kg dry matter ha^{-1}, with browse (60%) and forage herbs (40%) providing the main rangeland available feed biomass. Goats were daily directed to different grazing–browsing sites through feeding paths of approximately 6 to 8 km; thus, location-linked grazing restrictions can be considered minor. Additionally, goats were subcutaneously dewormed (Ivermectin 1%, Baymec, Bayer, Mexico City, Mexico) and also received doses of vitamin A (500,000 IU), D3 (75,000 IU), and E (50 mg) (Vigantol: ADE + Selenium, 250 mL, Zapopan, Jalisco, Mexico) one month prior to the FTAI protocol. Additionally, water, shades, and mineral salts (17% P, 3% Mg, 5% Ca, and 75% NaCl) were freely accessible during the experimental period [32].

2.3. Experimental Period: Defining the Social Rank among Female Goats

From the original 38 pregnant FATI goats, a total of 15 goats (51.4 ± 1.7 kg, body weight and 2.27 ± 0.13 units, body condition score) were considered to perform a 7-day behavioral study to define the social rank, either low (LSR) or high (HSR). This study was conducted during late October (i.e., 20–26 October), around 30 d prior to the expected average kidding date (i.e., 25 November). The behavioral test (n = 15) was carried out at feeding time (08:00, 13:00, and 17:00 h; 60 min each; 180 min day^{-1}, during 7 days) for a total of 1260 min (i.e., 21 h), as previously described [12]. The main behavioral goat-to-goat exerted interactions were recorded: hitting, threats, pushing, chasing, escaping, and evasion. Of note, the outlined agonistic contacts between two goats, either an instigator or a victim, exerting either physical contact or not, which eventually resulted in the physical displacement of an animal by the other, were considered ad hoc signs of the aggressive nature and social status of the assessed goats. Subsequently, with the information obtained from such behavioral interactions, that is, the result of winning or losing, a success index (SI) was individually obtained by using the formula:

$$\text{SI} = \text{number of won events}/(\text{number of won events} + \text{number of lost events}) \quad (1)$$

Based on the attained SI, the tested goats (n = 15) were classified into two social ranks: low-ranking goats (LSR; SI from 0 to 0.49; n = 7) and high-ranking goats (HSR; SI from 0.5 to 1; n = 8). Once the social rank based on the success index was defined, the variables live weight (LW, kg), body condition (BCS, units), and serum glucose (mg mL^{-1}) of the social-ranked goats were quantified on the last day of the behavioral test (i.e., 26 October). A blood sample was collected by jugular venipuncture to quantify serum glucose concentrations (AccuCheck Sensor Comfort, Roche, Mexico) with a reliability of 95%. A timeline of actions of the main activities carried out during the experimental period is shown in Figure 1.

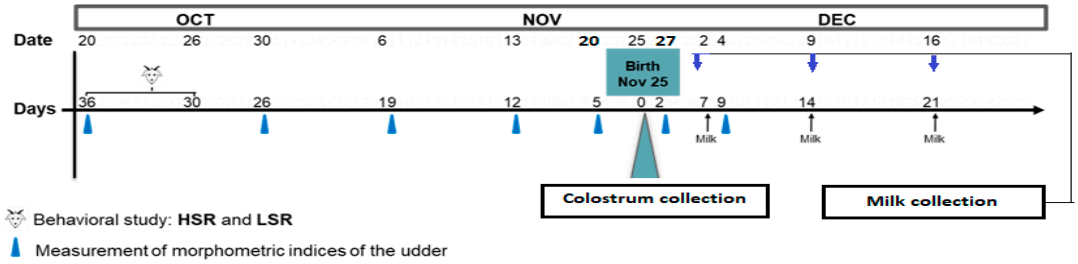

Figure 1. Timeline of actions along with the experimental period. A behavioral study was conducted in all the experimental units (n = 15) to determine the goat social rank, either high (HSR) or low (LSR). The behavior test was carried out at feeding time (08:00, 13:00, and 17:00) for a period of 60 min (i.e., 180 min total d^{-1} during 7 days). At the time of parturition and before kid suckling, a sample of 20 mL of colostrum was individually collected per goat from both udders; samples were pooled to generate a homogeneous mixture; the same process was performed during the milk postpartum sampling.

2.4. Measurement of Udder Morphometric Variables According to the Social Rank Status

2.4.1. Udder Morphometric Quantification

The morphological measurements of the udder were also quantified by a single trained technician using a Vernier (i.e., 30 cm) and tape measure (i.e., 100 cm). The udder of the experimental pregnant goats (n = 15), derived from the FTAI procedure, was measured weekly from Day 36 prepartum to Day 7 postpartum: 20 and 23 October; 6, 13, 20, and 27 November; and 4 December. The morphometric variables of the udder considered were: udder perimeter (UDPER, cm), udder diameter (UDDIA, cm), left-teat perimeter (LTPER, cm), right-teat perimeter (RTPER, cm), left-teat length (LTLT, cm), right-teat length (RTLT, cm), left-teat length diameter (LTDIA, cm), right-teat diameter (RTDIA, cm), and medium suspensory ligament (MSL, cm) according to the social rank (i.e., LSR and HSR) and time (i.e., 7 times); (Figure 2).

2.4.2. Colostrum and Milk Physicochemical Quantifications

At the time of parturition and before kid suckling, each goat was hand-milked, and a sample of 20 mL of colostrum was individually collected from both udders; samples from each goat were pooled to form a homogeneous mixture. Subsequently, colostrum samples were kept at 4 °C to later perform the chemical composition analyses. The response variables of the goat colostrum constituents were: fat (FATCA, %), protein (PROCA, %), lactose (LACCA), %), nonfat solids (NFSCA, %), freezing point (FPCA, units), and total solids (TSCA, %). Subsequently, the same procedure was carried out to evaluate the milk by chemical quality; the response variables registered to evaluate the goat milk constituents were: fat (FATMK, %), protein (PROMK, %), lactose (LACMK), %), nonfat solids (NFSMK, %), freezing point (FPMK, units), and total solids (TSMK, %) according to the social rank (i.e., LSR and HSR) and time (i.e., 3 times). Colostrum and milk component content was determined using a LactiCheck (LC-01 RR, Page and Pedersen International, Ltd., Hopkinton, MA, USA), after calibration for goat milk, as outlined by the manufacturer.

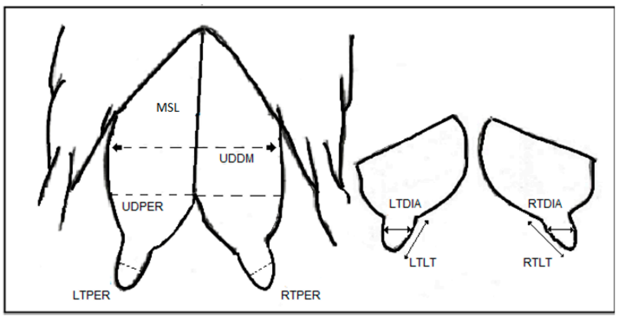

Figure 2. Morphological udder response variables considered: udder perimeter (UDPER, cm), udder diameter (UDDIA, cm), left-teat perimeter (LTPER, cm), right-teat perimeter (RTPER, cm), left-teat length (LTLT, cm), right-teat length (RTLT, cm), left-teat length diameter (LTDIA, cm), right-teat diameter (RTDIA, cm), and medium suspensory ligament (MSL, cm) registered from crossbred dairy goats (Alpine–Saanen–Nubian x Criollo; n = 15) in Northern Mexico (25° N).

2.5. Statistical Analyses

A split-plot ANOVA for repeated measures across time was used to evaluate the udder morphological variables: udder perimeter (UDPER, cm), udder diameter (UDDIA, cm), left-teat perimeter (LTPER, cm), right-teat perimeter (RTPER, cm), left-teat length (LTLT, cm), right-teat length (RTLT, cm), left-teat length diameter (LTDIA, cm), right-teat diameter (RTDIA, cm), and medium suspensory ligament (MSL, cm). Likewise, a split-plot ANOVA was also developed to evaluate the milk components, fat (FAT,%), protein (PROT,%), lactose (LAC,%), nonfat solids (NFS,%), freezing point (FP, °C), and total solids (TS,%), as affected by social rank (i.e., LSR and HSR). In both split-plot analyses, the goat was the experimental unit; the fixed effects of social rank (i.e., LSR, HSR) and sampling day (Time) were assessed using a MIXED model for repeated measures across time, with time as the repeated measure and the social-ranked goat as the repeated subject, regarded as a random error term. Additionally, a simple one-way ANOVA was developed in order to evaluate the components of colostrum, fat (FAT, %), protein (PRO, %), lactose (LAC, %), nonfat solids (NFS%), freezing point (FP, °C), and total solids (TS,%), according to social rank (i.e., LSR or HSR) in crossbred dairy goats (Alpine–Saanen–Nubian x Criollo; n = 15). Since no differences occurred between social rank regarding litter size (i.e., prolificacy), this variable was not considered in the final statistical models. Least-square means and standard errors for each class of social rank status, sampling time, and their interaction were computed; multiple mean comparisons were solved by means of Fisher's least significant differences. All statistical analyses were done using the procedures of SAS statistical package version 9.2; a significant difference between means was set at $p < 0.05$.

3. Results

The relationships between live weight (LW), body condition (BCS), and serum glucose (GLUC) according to social rank in crossbred dairy goats are shown in Table 1. The response variable LW was the only one that differed ($p < 0.05$) between social ranks, with an absolute difference of 6.4 kg favoring the HSR group. This difference between groups with respect to the LW was not reflected ($p > 0.05$) with respect to the variables BCS (2.27 $\pm$ 0.13 units) and GLUC (40.03 $\pm$ 2.26 mg mL^{-1}).

Table 1. Least-square means ± standard error for live weight (LW, kg), body condition score (BCS, units), and serum glucose concentration (GLUC, mg mL^{-1}) according to either low or high social rank (i.e., LSR and HSR) in crossbred (Alpine–Saanen–Nubian × Criollo; n = 15) dairy goats in northern Mexico (25° N) [1,2].

	Social Rank		
	LSR [1]	HSR [1]	*p*-Value
LW (kg)	48.20 ± 1.80 [b]	54.60 ± 1.63 [a]	0.017
BCS (units)	2.27 ± 0.14 [a]	2.27 ± 0.12 [a]	0.979
GLUC (mg mL^{-1})	40.88 ± 2.37 [a]	39.18 ± 2.15 [a]	0.601

[a,b] Least-square means without a common superscript within response variable (i.e., lines), differ ($p < 0.05$). [1] In October, a behavioral study was carried out to define the social ranks, either low (LSR), or high (HSR) social rank. [2] Most conservative standard error is presented.

3.1. Effect of Social Rank and Time upon Udder Morphometric Components in Crossbred Dairy Goats

The dependent variables of the goat udder morphometric, components considering udder perimeter (UDPER, cm), udder diameter (UDDIA, cm), left-teat perimeter (LTPER, cm), right-teat perimeter (RTPER, cm), left-teat length (LTLT, cm), right-teat length (RTLT, cm), left-teat length diameter (LTDIA, cm), right-teat diameter (RTDIA, cm), medium suspensory ligament (MSL, cm) according to the social rank (i.e., LSR and HSR), and time (i.e., seven times), are shown in Table 2. No differences ($p > 0.05$) between social ranks occurred for any of the udder morphometric components response variables. However, the response variables UDPER, LTLT, RTLT, LTDIA, RTDIA, and MSL differed ($p < 0.05$) across time. Interestingly, when comparing the initial (October 20) and the final (December 04) values for UDDIA and MSL, an increased value ($p < 0.05$) for both variables occurred on the last date of the experimental period. The opposite scenario occurred with respect to the response variables LTLT, RTLT, LTDIA, and RTDIA, whose values decreased ($p < 0.05$) by the end of the measurement period.

Table 2. Least-square means ± s.e. for goat udder morphometric components considering udder perimeter (UDPER, cm), udder diameter (UDDIA, cm), left-teat perimeter (LTPER, cm), right-teat perimeter (RTPER, cm), left-teat length (LTLT, cm), right-teat length (RTLT, cm), left-teat length diameter (LTDIA, cm), right-teat diameter (RTDIA, cm), and medium suspensory ligament (MSL, cm) as affected by either social rank (i.e., LSR and HSR) and time (i.e., 7 times) in crossbred (Alpine–Saanen–Nubian × Criollo; n = 15) dairy goats in northern Mexico (25° N) [1,2].

Variables (cm)	Social Rank (SR)		Time (T)								*p*-Value	
	LSR	HSR	20 Oct	30 Oct	6 Nov	13 Nov	20 Nov	27 Nov	4 Dec	s.e. [2]	SR	T
UDPER	37.7 [ab]	38.5 [ab]	27.9 [c]	35.3 [b]	39.5 [ab]	41.8 [ab]	39.9 [ab]	43.6 [a]	38.8 [ab]	**2.4**	**0.68**	**0.04**
UDDIA	9.5 [a]	10.8 [a]	9.7 [a]	14.1 [a]	9.8 [a]	9.6 [a]	9.2 [a]	10.0 [a]	8.6 [a]	**1.8**	**0.34**	**0.42**
LTPER	7.5 [a]	7.6 [a]	8.0 [a]	7.5 [a]	7.8 [a]	7.3 [a]	8.7 [a]	6.8 [a]	6.7 [a]	**1.2**	**0.89**	**0.86**
RTPER	7.6 [a]	7.6 [a]	8.2 [a]	7.2 [a]	8.3 [a]	7.4 [a]	8.7 [a]	6.9 [a]	6.3 [a]	**1.2**	**0.97**	**0.89**
LTLT	5.6 [ab]	5.7 [ab]	5.7 [ab]	7.4 [a]	5.8 [ab]	5.9 [ab]	6.3 [ab]	4.4 [b]	4.1 [b]	**0.8**	**0.83**	**0.04**
RTLT	5.8 [abc]	5.7 [abc]	5.7 [ab]	6.9 [a]	6.5 [ab]	6.6 [ab]	6.4 [abc]	4.3 [bc]	3.9 [c]	**0.8**	**0.98**	**0.04**
LTDIA	2.0 [ab]	2.0 [ab]	2.2 [ab]	3.0 [a]	1.9 [bc]	1.8 [bc]	2.5 [ab]	1.6 [bc]	1.1 [c]	**0.3**	**0.85**	**0.04**
RTDIA	2.0 [ab]	2.0 [ab]	2.4 [ab]	2.9 [a]	2.1 [ab]	1.8 [bc]	2.5 [ab]	1.6 [bc]	1.1 [c]	**0.3**	**0.99**	**0.04**
MSL	19.5 [abc]	20.1 [abc]	17.2 [bc]	16.6 [c]	21.8 [ab]	23.0 [a]	20.8 [abc]	20.1 [abc]	19.3 [abc]	**1.7**	**0.64**	**0.03**

[a,b,c] Least-square means without a common superscript within response variable differ ($p < 0.05$). [1] In October, a behavioral study was carried out to define the social ranks, either low (LSR) or high (HSR) social rank. [2] Most conservative standard error is presented.

3.2. Effect of the Interaction Social Rank × Time upon Udder Morphometric Components in Crossbred Dairy Goats

A social rank × time interaction affected ($p < 0.05$) the morphometric variables UDPER, LTLT, RTLT, LTDIA, RTDIA, and MSL; yet, the other udder values were not affected (i.e., UDDIA, LTPER, and RTPER). Most of the observed social rank × time were interaction effects were related to the large response variable differences were observed across time ($p < 0.05$). Indeed, while the variables RTLT, LTDIA, RTDIA, and MSL showed their highest values the week before kidding, the variables UDPER and MSL showed a continuous and ascending increase from the first measurement (i.e., 20 October), achieving the highest values one week prior to kidding (i.e., MSL), as well as within the week of kidding (i.e., UDPER). However, for the variables UDPER (T6), MSL (T6 and T7), and LTLT (T2 and T5), increased values occurred in the HSR group (Table 3).

Table 3. Least-square means ± s.e. for the interaction social rank (i.e., LSR and HSR) and time (i.e., 7 times) for goat udder morphometric components considering udder perimeter (UDPER, cm), udder diameter (UDDIA, cm), left-teat perimeter (LTPER, cm), right-teat perimeter (RTPER, cm), left-teat length (LTLT, cm), right-teat length (RTLT, cm), left-teat length diameter (LTDIA, cm), right-teat diameter (RTDIA, cm), and medium suspensory ligament (MSL, cm) in crossbred (Alpine–Saanen–Nubian × Criollo; $n = 15$) dairy goats in northern Mexico (25° N) [1,2].

Variables (cm)	20 Oct		30 Oct		6 Nov		13 Nov		20 Nov		27 Nov		4 Dec			*p*-Value
	LSR	HSR	LSR	HSR	LSR	HSR	LSR	HSR	LSR	HSR	LSR	HSR	LRS	HSR	s.e. [2]	SR × T
UDPER	27.7^{d}	28.1^{d}	34.3^{c}	36.1^{bc}	$39.2^{a–c}$	$39.8^{a–c}$	41.7^{ab}	41.9^{ab}	$39.7^{a–c}$	$41.5^{a–c}$	41.3^{b}	45.5^{a}	$39.5^{a–c}$	$43.2^{a–c}$	**2.2**	**0.001**
UDDIA	9.4^{a}	10.2^{a}	9.4^{a}	9.4^{a}	9.8^{a}	9.8^{a}	10.0^{a}	9.5^{a}	9.3^{a}	9.1^{a}	9.7^{a}	10.4^{a}	8.6^{a}	8.8^{a}	**0.6**	**0.614**
LTPER	8.1^{ab}	8.0^{ab}	7.0^{b}	7.9^{ab}	7.9^{ab}	7.8^{ab}	7.0^{b}	7.6^{ab}	7.9^{ab}	9.4^{a}	7.2^{ab}	6.4^{b}	7.3^{ab}	6.2^{b}	**0.8**	**0.411**
RTPER	8.4^{ab}	8.1^{ab}	$6.9^{a–c}$	$7.4^{a–c}$	$8.0^{a–c}$	8.6^{ab}	$6.8^{a–c}$	$7.9^{a–c}$	8.3^{ab}	9.1^{a}	$7.5^{a–c}$	6.5^{bc}	$7.2^{a–c}$	5.6^{c}	**0.9**	**0.248**
LTLT	$5.7^{b–e}$	$5.8^{b–d}$	6.8^{b}	8.0^{a}	$5.8^{b–d}$	$5.7^{b–d}$	5.9^{bc}	5.9^{bc}	$5.7^{b–e}$	6.9^{a}	$5.1^{b–e}$	3.9^{e}	$4.2^{c–e}$	4.0^{de}	**0.6**	**0.001**
RTLT	$5.8^{a–c}$	$5.6^{a–d}$	6.7^{a}	7.0^{a}	6.5^{ab}	6.4^{ab}	6.8^{a}	6.5^{ab}	$5.6^{b–d}$	7.0^{a}	$4.7^{a–d}$	3.9^{d}	4.1^{cd}	3.8^{d}	**0.7**	**0.001**
LTDIA	2.2^{bc}	2.2^{bc}	3.1^{a}	2.9^{a}	$1.8^{b–d}$	1.9^{bcd}	$1.5^{c–e}$	$1.9^{b–d}$	2.5^{ab}	2.5^{ab}	1.7^{cd}	$1.6^{c–e}$	1.0^{e}	1.2^{de}	**0.2**	**0.001**
RTDIA	$2.4^{b–d}$	$2.4^{b–d}$	3.1^{a}	2.8^{ab}	$1.9^{c–f}$	$2.2^{b–e}$	$1.6^{e–g}$	$2.0^{c–f}$	2.5^{abc}	$2.4^{a–c}$	$1.7^{d–g}$	1.5^{fg}	1.1^{g}	1.1^{g}	**0.2**	**0.001**
MSL	$17.1^{e–g}$	$17.3^{d–g}$	16.7^{fg}	16.5^{g}	$21.0^{a–d}$	22.5^{ab}	23.5^{a}	22.7^{ab}	$20.3^{a–f}$	$21.2^{a–c}$	$18.4^{c–e}$	20.8^{ab}	$18.3^{c–g}$	20.7^{ab}	**1.3**	**0.005**

[a,b,c,d,e,f,g] Least-square means without a common superscript within response variable differ ($p < 0.05$). [1] In October, a behavioral study was carried out to define the social ranks, either low (LSR) or high (HSR) social rank. [2] Most conservative standard error is presented.

3.3. Effect of Social Rank upon Colostrum Quality Composition in Crossbred Dairy Goats

The dependent variables of the goat colostrum constituents, fat, protein, lactose, nonfat solids, freezing point, and total solids, as affected by the social rank (i.e., LSR and HSR), are shown in Table 4. No differences ($p > 0.05$) between social ranks (i.e., LSR and HSR) were observed with respect to the quality of the colostrum. Therefore, these results suggest that variables LW, BCS, or even GLUC are not directly related to the components that define the quality of colostrum (Table 4).

Table 4. Least-square means ± standard error for goat colostrum constituents, fat (FATCA, %), protein (PROCA, %), lactose (LATCA), %), nonfat solids (NFSCA, %), freezing point (FPCA, units), and total solids (TSCA, %) according to the social rank (i.e., LSR and HSR) in crossbred (Alpine–Saanen–Nubian × Criollo; $n = 15$) dairy goats managed under semi-intensive conditions in northern Mexico (25° N) [1,2,3].

Variables, (%)	Social Rank		
	LSR	HSR	*p*-Value
FATCA	7.2 ± 2.2	7.6 ± 2.0	0.892
PROCA	10.6 ± 1.7	10.0 ± 1.6	0.804
LACCA	3.3 ± 0.3	2.6 ± 0.3	0.184
NFSCA	12.0 ± 2.4	15.6 ± 2.2	0.300
FPCA	0.3 ± 0.0	0.3 ± 0.0	0.284
TSCA	23.1 ± 3.0	22.3 ± 2.7	0.838

[1] No differences for any of the response variables occurred between LSR and HSR; most conservative standard error is presented. [2] In October, a behavioral study was carried out to define the social ranks, either low (LSR) or high (HSR) social rank. [3] Most conservative standard error is presented.

3.4. Effect of Social Rank and Time upon Milk Quality Composition in Crossbred Dairy Goats

The milk constituents quantified in this study, that is fat, protein, lactose, nonfat solids, freezing point, and total solids according to the social rank (i.e., LSR and HSR) and time (i.e., three times), in crossbred dairy goats are shown in Table 5. No effect of the social rank ($p > 0.05$) was observed with respect to MK-CHQ shown in all the analyzed components. Regarding the time factor, however, only the PROMK and NFSMK variables showed the highest values ($p < 0.05$) at Time 1 and later showed a reduction as the lactation stage advanced.

Table 5. Least-square means ± standard error for goat milk constituents, fat (FATMK, %), protein (PROMK, %), lactose (LACMK), %), nonfat solids (NFSMK, %), freezing point (FPMK, units), and total solids (TSMK, %) according to the social rank (i.e., LSR and HSR) and time (i.e., 3 times) in crossbred (Alpine–Saanen–Nubian × Criollo; $n = 15$) dairy goats in northern Mexico (25° N) [1,2].

Variables	Social Rank		Time			*p*-Value
	LSR	HSR	1	2	3	
FATMK, %	3.5 ± 0.5 ^{a}	4.2 ± 0.5 ^{a}	4.6 ± 0.6 ^{a}	3.2 ± 0.6 ^{a}	3.8 ± 0.7 ^{a}	0.380
PROMK, %	3.2 ± 0.1 ^{ab}	3.4 ± 0.1 ^{a}	3.8 ± 0.2 ^{a}	3.3 ± 0.2 ^{ab}	2.7 ± 0.2 ^{b}	0.470
LACMK, %	4.1 ± 0.1 ^{a}	4.2 ± 0.1 ^{a}	4.3 ± 0.1 ^{a}	4.0 ± 0.1 ^{a}	4.2 ± 0.1 ^{a}	0.491
NFSMK, %	7.8 ± 0.3 ^{ab}	8.3 ± 0.3 ^{a}	8.8 ± 0.3 ^{a}	8.1 ± 0.3 ^{ab}	7.3 ± 0.4 ^{b}	0.324
FPMK, °C	0.4 ± 0.0 ^{a}	0.4 ± 0.0 ^{a}	0.4 ± 0.01 ^{a}	0.4 ± 0.01 ^{a}	0.4 ± 0.02 ^{a}	0.742
TSMK, %	11.9 ± 0.7 ^{a}	12.8 ± 0.8 ^{a}	13.6 ± 0.9 ^{a}	11.7 ± 0.9 ^{a}	11.7 ± 1.0 ^{a}	0.461

[a,b] Least-square means without a common superscript within response variable differ ($p < 0.05$). [1] In October, a behavioral study was carried out to define the social ranks, either low (LSR) or high (HSR) social rank. [2] Most conservative standard error is presented.

3.5. Effect of the Interaction Social Rank × Time upon Udder the Milk Components in Crossbred Dairy Goats

An SR × T occurred regarding FATMK, PROMK, and NFSMK (Table 6). Although LACMK, FPMK, and TSMK were not influenced ($p > 0.05$) by the SR × T interaction, larger FATMK, PROMK, and NFSMK values occurred at T2 in the HSR group. Regarding the variables LACMK, NFSMK, and TSMK, the highest values also occurred in T1. The FPMK variable was affected ($p > 0.05$) neither by social rank, nor by sampling time (Table 6).

Table 6. Least-square means ± standard error for the interaction social rank (i.e., LSR and HSR) and time (i.e., 3 times) regarding the goat milk constituents for fat (FATMK, %), protein (PROMK, %), lactose (LACMK), %), nonfat solids (NFSMK, %), freezing point (FPMK, units), and total solids (TSMK, %) according to the social rank (i.e., LSR and HSR) and time (i.e., 3 times) in crossbred (Alpine–Saanen–Nubian × Criollo; $n = 15$) dairy goats in northern Mexico (25° N) [1,2].

Variables	Time 1		Time 2		Time 3		*p*-Value
	LSR	HSR	LSR	HSR	LSR	HSR	
FATMK (%)	4.6 ± 0.6 ^{ab}	4.7 ± 0.6 ^{a}	2.7 ± 0.4 ^{b}	3.7 ± 0.4 ^{a}	3.3 ± 0.6 ^{ab}	4.4 ± 0.7 ^{ab}	0.049
PROMK (%)	3.8 ± 0.2 ^{a}	3.8 ± 0.2 ^{a}	3.1 ± 0.2 ^{bc}	3.5 ± 0.1 ^{a}	2.6 ± 0.1 ^{c}	2.9 ± 0.1 ^{b}	0.002
LACMK (%)	4.5 ± 0.2 ^{a}	4.2 ± 0.2 ^{ab}	3.7 ± 0.2 ^{b}	4.3 ± 0.2 ^{a}	4.2 ± 0.2 ^{ab}	4.2 ± 0.2 ^{ab}	0.165
NFSMK (%)	9.0 ± 0.4 ^{a}	8.7 ± 0.4 ^{ab}	7.5 ± 0.4 ^{cd}	8.6 ± 0.4 ^{ab}	7.1 ± 0.3 ^{d}	7.7 ± 03 ^{bc}	0.013
FPMK (°C)	0.4 ± 0.0 ^{a}	0.4 ± 0.0 ^{a}	0.4 ± 0.0 ^{a}	0.4 ± 0.01 ^{a}	0.4 ± 0.0 ^{a}	0.4 ± 0.0 ^{a}	0.941
TSMK (%)	13.7 ± 0.9 ^{a}	13.6 ± 0.8 ^{ab}	11.0 ± 0.9 ^{b}	12.4 ± 0.8 ^{ab}	11.0 ± 0.9 ^{b}	12.3 ± 1.0 ^{ab}	0.106

[a,b,c] Least-square means without a common superscript within response variable differ ($p < 0.05$). [1] In October, a behavioral study was carried out to define the social ranks, either low (LSR) or high (HSR) social rank. [2] Most conservative standard error is presented.

4. Discussion

Our working hypothesis stated that a high social rank status leads to priority feed access, increasing live weight aligned with augmented udder morphometric values; thereafter, increased quality of both colostrum and milk would be expected in high-social-ranked crossbred dairy goats. According to our general results, such a working hypothesis cannot be rejected. In fact, both the social rank, mainly the high-social-ranked goats, as well as time of sampling, considered the temporal stage of the last third of pregnancy and its transition to the first phase of lactation, operated as key modulators upon both udder architecture, as well as milk quality, with no effect of social rank upon colostrum quality in crossbred dairy goats managed under semi-extensive, dry-semiarid conditions (≈260 mm rainfall yearly). Our research outcomes endorse that high-social-ranked goats merged some essential behaviors such as aggressiveness, assertiveness, and supremacy to have primacy to feed access, augmenting live weight. Even though such an increased body weight advantage was not reflected upon in an enlarged colostrum quality, there were witnessed increases in both udder morphometric size (i.e., UDPER, MSL, and LTLT) and milk quality (i.e., fat, protein, and nonfat solids) in the HSR goats.

Goats are a gregarious species with complex social interactions between dominant and subordinate animals. High-ranking animals generally exert priority access to more and better available resources, which favor productive performance [8,12,33–37]. This high hierarchy is positively correlated to privileged access to food, which generally translates into greater increases in live weight in the dominant groups (i.e., HSR) [12]. In addition to a higher LW and BCS and even metabolic state, a high social rank generates greater reproductive and productive success [12,13,37–41]. Our main research outcomes are aligned with such aforementioned findings.

In goats, a positive relationship has been described between udder morphological measurements and milk production [42]. When evaluating the relationship between udder characteristics and milk production in goats, a positive association was observed; then, such findings were also positively aligned with increases in LW and BCS across time [43,44]. These results are consistent with our study since the udder variables UDPER, MSL, LTLT, RTLT, LTDIA, and RTDIA showed increased values when comparing the initial values with respect to those obtained at the end of the experimental period. Therefore, the transition from the third trimester of gestation to the early stage of lactation positively affected some of the main components of the architecture of both the udder and the nipple. Other studies have reported positive associations between udder morphometry with respect to milk quality and yield, not only in goats, but also in cattle and sheep [45–49]. Although increases in udder morphometry components (i.e., UDPER, MSL, and LTLT) and some quality milk constituents (i.e., FAT, PRO, and NFS) occurred in the HSR in our study, such a scenario was not observed when the colostrum quality was evaluated; in fact, no differences occurred between social ranks.

Studies aimed at understanding the modulation of the colostrum quality components are of fundamental relevance due to the central role that colostrum exerts upon both peri- and postnatal kid survival and also upon the sustainability of the production system itself [50]. As in other mammals, kids are born with low levels of immunoglobulins [51,52] and, therefore, depend on an adequate intake of colostrum to obtain passive immunity that guarantees a competent future health status [53,54]. Additionally, a higher protein concentration of colostrum, mainly immunoglobulins, promotes faster colonization of the intestine by anaerobic bacteria. Moreover, a density >1.070 g/cm^3 enhanced the growth of *Lactobacilli* and *Bifidobacterium* spp., which reduced hostile microflora, such as *Coliforms* or *Enterococci*, improving in parallel the daily weight gains of the newborn [55]. In this context, although a higher social rank generates a greater live weight in goats, which should be positively aligned with the viability of the kids as they have better access to better-quality colostrum [56–59], such a physiologic scenario was not observed in our study.

For millennia, goat milk has been a central issue of human nutrition in different cultures and civilizations, due to its great similarity to human milk [24]. Goat milk is composed of 85.5% water and 14.5% of total solids, which are made up of fat, protein, carbohydrates, and minerals; said composition largely evidences the high quality of goat milk [27,60]. The production and quality of milk are influenced not only by intrinsic factors (i.e., genetic background, production level, lactation stage, physiological state), but also by extrinsic factors as well (i.e., year, season of the year, feed quality). Certainly, both in extensive and semi-extensive systems, the season of the year defines the availability of pasture and directly affects milk composition [61].

Other extrinsic factors include temperature, herd management, milking system, feeding, health status, and duration of the dry period, among others [62,63]. However, limited information has been generated regarding the interplay between social behavior and milk production; most studies have been focused on disentangling the social interaction with respect to animal growth and reproductive performance [8,12,33–35,37,40]. Nonetheless, milk quality can also be modulated by the social array or production system; when compared to housed cows, grazing cows interacted more socially, increased affiliative interactions, and produced higher-quality milk (i.e., > fat%, > urea, mg mL^{-1}, and < somatic cells and bacterial count, log10 mL^{-1}) [64]. In line with such findings, in our study, the HSR goats demonstrated increased milk quality, with augmented fat, protein, and nonfat solids percentages during early lactation regarding the LSR goats ($p < 0.05$). A possible physiometabolic scenario explaining such outcomes is that the higher LW observed in the HSR goats could have granted better performance when competing against the LSR goats regarding the feed intake while partitioning nutrients are partitioned, privileging milk quality, especially its fat, protein, and nonfat solids content. According to our literature search, this study seems to be the first report assessing the main interactions between social hierarchy, live weight, metabolic status, udder architecture, and milk quality in goats.

5. Conclusions

Although we still have a disconnected understanding about the interplay that goat social rank, live weight, and some udder morphometric traits exert upon colostrum and milk quality, our results endorse that high-social-ranked goats merged some central behaviors such as aggressiveness, assertiveness, and supremacy to have primacy to feed access, augmenting their live weight. Whereas said body weight advantage was not reflected upon in colostrum quality, the high-social-ranked goats improved some morphological udder values (i.e., UDPER, MSL, and LTLT), and produced milk with increased quality, specifically with augmented fat, protein, and nonfat solids content at specific points during the early stages of lactation. Therefore, our results confirmed our working hypothesis in that both the social rank, mainly the high-social-ranked goats, as well as the temporal stage of the last third of pregnancy and the first phase of lactation (i.e., time), operated as important modulators upon both udder architecture, as well as milk quality, in crossbred dairy goats managed under a semi-extensive, dry-semiarid production system, the latter scenario being fundamental for the sustainability of marginal goat production systems, the producer and his family.

Author Contributions: Conceptualization, M.S.C.-Z., C.A.M.-H. and F.G.V.-D.; Data curation, M.S.C.-Z., C.A.M.-H., G.C.-L. and N.L.-V.; Formal analyses, M.S.C.-Z., C.A.M.-H. and N.L.-V.; Funding acquisition, G.C.-L., J.A.B.-A. and F.G.V.-D.; Investigation, M.S.C.-Z., C.N.-M., N.L.-V., J.M.F.-S. and P.I.S.-L.; Methodology, M.S.C.-Z., C.A.M.-H., G.C.-L., N.L.-V., C.N.-M. and F.G.V.-D.; Project administration, G.C.-L., J.M.F.-S. and P.I.S.-L.; Resources, G.C.-L., N.L.-V., J.M.F.-S. and F.G.V.-D.; Supervision, C.A.M.-H.; Writing—original draft, C.A.M.-H. All authors have read and agreed to the published version of the manuscript.

Funding: Our study was supported by the National Council of Science and Technology (CONACYT, Mexico) through the Research Sectorial Fund SAGARPA-CONACYT: 2017-4-291691. The authors also acknowledge partial financial support from the International Collaborative Projects CONACYT-FOMIX-DURANGO, DGO-2008-C01-87559, and DGO-2009-C02-116746, funded by the CONACYT-COCYTED, the General Direction for Research and Graduate Studies, Chapingo Autonomous University, the Conventional Projects Initiative (UACH-DGIP-REBIZA-IBIODEZA/15-510-400-2) Mexico, and the ALFA-III-ALAS Project, DCI-ALAS/A9.09.01/08/19189/161-358/ALFA-III-82, financed by the European Union.

Institutional Review Board Statement: The animal study protocol was approved by the UAAN-UL, with reference number UAAAN-UL-20-3059.

Informed Consent Statement: Not applicable.

Data Availability Statement: The datasets used along with this research are available from the corresponding author on reasonable request.

Acknowledgments: The authors acknowledge the Research Sectorial Fund SAGARPA-CONACYT and the Graduate Students from the "Agro livestock Production Graduate Program, UAAAN-UL, Mexico. (*In Loving Memory, Dr. Santiago Zuñiga-García, 1985–2020; M.Sc. Sergio Yong-Wong, 1964–2020*).

Conflicts of Interest: The authors declare that they have no known competing financial interest or personal relationship that would have appeared to influence the work reported in this paper.

References

1. Pitcher, B.J.; Briefer, E.F.; Baciadonna, L.; McElligott, A.G. Cross-modal recognition of familiar conspecifics in goats. *R. Soc. Open Sci.* **2017**, *4*, 160346. [CrossRef] [PubMed]
2. Napolitano, F.; Serrapica, M.; Braghieri, A.; Claps, S.; Serrapica, F.; De Rosa, G. Can we monitor adaptation of juvenile goats to a new social environment through continuous qualitative behaviour assessment? *PLoS ONE* **2018**, *13*, e0200165. [CrossRef] [PubMed]
3. Zobel, G.; Neave, H.W.; Webster, J. Understanding natural behavior to improve dairy goat (*Capra hircus*) management systems. *Transl. Anim. Sci.* **2018**, *3*, 212–224. [CrossRef] [PubMed]
4. Miranda-de La Lama, G.C.; Mattiello, S. The importance of social behaviour for goat welfare in livestock farming. *Small Rumin. Res.* **2010**, *90*, 1–10. [CrossRef]
5. Alvarez, L.; Arvizu, R.R.; Luna, J.A.; Zarco, L.A. Social ranking and plasma progesterone levels in goats. *Small Rumin. Res.* **2010**, *90*, 161–164. [CrossRef]
6. Ungerfeld, R. Sexual behavior of medium-ranked rams toward non-estrual ewes is stimulated by the presence of low-ranked rams. *J. Vet. Behav.* **2012**, *7*, 84–87. [CrossRef]
7. Ungerfeld, R.; Lacuesta, L. Social rank during pre-pubertal development and reproductive performance of adult rams. *Anim. Reprod. Sci.* **2010**, *121*, 101–105. [CrossRef]
8. Barroso, F.G.; Alados, C.L.; Boza, J. Social hierarchy in the domestic goat: Effect on food habits and production. *Appl. Anim. Behav. Sci.* **2000**, *69*, 35–53. [CrossRef]
9. Bica, G.S.; Machado Filho, P.; Carlos, L.; Teixeira, D.L.; de Sousa, K.T.; Hötzel, M.J. Time of grain supplementation and social dominance modify feeding behavior of heifers in rotational grazing systems. *Front. Vet. Sci.* **2020**, *7*, 61. [CrossRef]
10. Di Virgilio, A.; Morales, J.M. Towards evenly distributed grazing patterns: Including social context in sheep management strategies. *PeerJ* **2016**, *4*, e2152. [CrossRef]
11. Hussein, A.N.; Al-Marashdeh, O.; Bryant, R.H.; Edwards, G.R. Relationship between social dominance and milk production of dairy cows grazing pasture. *Proc. N. Z. Soc. Anim. Prod.* **2016**, *76*, 69–72.
12. Zuñiga-Garcia, S.; Meza-Herrera, C.A.; Mendoza-Cortina, A.; Otal, J.; Perez-Marín, C.; Lopez-Flores, N.M.; Carrillo, E.; Calderon-Leyva, G.; Gutierrez-Guzman, U.N.; Véliz-Deras, F.G. Effect of social rank upon estrus induction and some reproductive outcomes in anestrus goats treated with progesterone + eCG. *Animals* **2020**, *10*, 1125. [CrossRef] [PubMed]
13. Zuñiga-Garcia, S.; Meza-Herrera, C.A.; Mendoza-Cortina, A.; Perez-Marin, C.; Lopez-Flores, N.M.; Guillén-Muñoz, J.M.; Arellano-Rodriguez, G.; Gutierrez-Guzman, U.N.; Bustamante-Andrade, J.A.; Luna-Orozco, J.R.; et al. Does Size Matters? Relationships among Social Dominance and Some Morphometric Traits upon Out-of-Season Reproductive Outcomes in Anestrus Dairy Goats Treated with P4+ eCG. *Biology* **2020**, *9*, 354. [CrossRef] [PubMed]
14. Estevez, I.; Andersen, I.L.; Nævdal, E. Group size, density and social dynamics in farm animals. *Appl. Anim. Behav. Sci.* **2007**, *103*, 185–204. [CrossRef]
15. Vas, J.; Andersen, I.L. Density-Dependent Spacing Behaviour and Activity Budget in Pregnant, Domestic Goats (*Capra hircus*). *PLoS ONE* **2015**, *10*, e0144583. [CrossRef]
16. Manousidis, T.; Kyriazopoulos, A.P.; Parissi, Z.M.; Abraham, E.M.; Korakis, G.; Abas, Z. Grazing behavior, forage selection and diet composition of goats in a Mediterranean woody rangeland. *Small Rumin. Res.* **2016**, *145*, 142–153. [CrossRef]
17. Neave, H.W.; von Keyserlingk, M.A.; Weary, D.M.; Zobel, G. Feed intake and behavior of dairy goats when offered an elevated feed bunk. *J. Dairy Sci.* **2018**, *101*, 3303–3310. [CrossRef]
18. Hartley, A.; Shrader, A.M.; Chamaillé-Jammes, S. Can intrinsic foraging efficiency explain dominance status? A test with functional response experiments. *Oecologia* **2019**, *189*, 105–110. [CrossRef]
19. Escareño, L.; Wurzinger, M.; Iñiguez, L.; Soelkner, J.; Salinas, H.; Meza-Herrera, C.A. Dairy goat production systems in dry areas: Status-quo, perspectives and challenges. *Trop. Anim. Health Prod.* **2013**, *45*, 17–34. [CrossRef]
20. Food and Agriculture Organization of the United Nations (FAO). FAOSTAT Statistics Database. Available online: http://www.fao.org/faostat/en/#data (accessed on 27 August 2021).

21. Navarrete-Molina, C.; Meza-Herrera, C.A.; Ramirez-Flores, J.J.; Herrera-Machuca, M.A.; Lopez-Villalobos, N.; Lopez-Santiago, M.A.; Veliz-Deras, F.G. Economic evaluation of the environmental impact of a dairy cattle intensive production cluster under arid lands conditions. *Animal* **2019**, *13*, 2379–2387. [CrossRef]
22. Navarrete-Molina, C.; Meza-Herrera, C.A.; Herrera-Machuca, M.A.; Lopez-Villalobos, N.; Lopez-Santos, A.; Veliz-Deras, F.G. To beef or not to beef: Unveiling the economic environmental impact generated by the intensive beef cattle industry in an arid region. *J. Clean. Prod.* **2019**, *231*, 1027–1035. [CrossRef]
23. Navarrete-Molina, C.; Meza-Herrera, C.A.; Herrera-Machuca, M.A.; Macias-Cruz, U.; Veliz-Deras, F.G. Not all ruminants were created equal: Environmental and socio-economic sustainability of goats under a marginal-extensive production system. *J. Clean. Prod.* **2020**, *255*, 120237. [CrossRef]
24. Clark, S.; García, M.B.M. A 100-year review: Advances in goat milk research. *J. Dairy Sci.* **2017**, *100*, 10026–10044. [CrossRef] [PubMed]
25. Davis, S.R. Triennial lactation symposium/BOLFA: Mammary growth during pregnancy and lactation and its relationship with milk yield. *J. Anim. Sci.* **2017**, *95*, 5675–5688. [CrossRef] [PubMed]
26. Flores-Najera, M.J.; Cuevas-Reyes, V.; Vazquez-García, J.M.; Beltran-Lopez, S.; Meza-Herrera, C.A.; Mellado, M.; Negrete-Sanchez, L.O.; Rivas-Jacobo, M.A.; Rosales-Nieto, C.A. Milk yield and composition of mixed-breed goats on rangeland during the dry season and the effect on the growth of their progeny. *Biology* **2021**, *10*, 220. [CrossRef] [PubMed]
27. Isidro-Requejo, L.M.; Meza-Herrera, C.A.; Pastor-López, F.J.; Maldonado, J.A.; Salinas-González, H. Physicochemical characterization of goat milk produced in the Comarca Lagunera, Mexico. *Anim. Sci. J.* **2019**, *90*, 563–573. [CrossRef] [PubMed]
28. American Dairy Science Association (ADSA). *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching. American Society of Animal Science, and the Poultry Science Association*, 4th ed.; ADSA: Champaign, IL, USA, 2020; 227p, ISBN 978-1-7362930-0-3. Available online: https://www.asas.org/docs/default-source/default-document-library/agguide_4th.pdf?sfvrsn=56b44ed1_2 (accessed on 2 September 2021).
29. National Academy of Medicine (NAM). *Guide for the Care and Use of Laboratory Animals*, 1st ed.; National Academy of Medicine-Mexico and the Association for Assessment and Accreditation of Laboratory Animal Care International: Mexico City, Mexico, 2010.
30. Instituto Nacional de Estadística y Geografía—National Institute of Statistic and Geography (INEGI). México En Cifras. 2021. Available online: https://www.inegi.org.mx/app/areasgeograficas/ (accessed on 2 September 2021).
31. Bustamante-Andrade, J.A.; Meza-Herrera, C.A.; Rodríguez-Martínez, R.; Santos-Jimenez, Z.; Ángel-García, O.; Gaytán-Aleman, L.R.; Gutierrez-Guzman, U.N.; Esquivel-Romo, A.; Véliz-Deras, F.G. Luteogenesis and embryo implantation are enhanced by exogenous Hcg in goats subjected to an out-of-season fixed-time artificial insemination protocol. *Biology* **2021**, *10*, 429. [CrossRef]
32. National Research Council (NRC). *Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids*; The National Academies Press: Washington, DC, USA, 2007. [CrossRef]
33. Alvarez, L.; Martin, G.B.; Galindo, F.; Zarco, L.A. Social dominance of female goats affects their response to the male effect. *Appl. Anim. Behav. Sci.* **2003**, *84*, 119–126. [CrossRef]
34. Andersen, I.L.; Bøe, K.E. Resting pattern and social interactions in goats—The impact of size and organisation of lying space. *Appl. Anim. Behav. Sci.* **2007**, *108*, 89–103. [CrossRef]
35. Fournier, F.; Festa-Bianchet, M. Social dominance in adult female mountain goats. *Anim. Behav.* **1995**, *49*, 1449–1459. [CrossRef]
36. Côté, S. Dominance hierarchies in female mountain goats: Stability, aggressiveness and determinants of rank. *Behaviour* **2000**, *137*, 1541–1566. [CrossRef]
37. Ungerfeld, R.; Correa, O. Social dominance of female dairy goats influences the dynamics of gastrointestinal parasite eggs. *Appl. Anim. Behav. Sci.* **2007**, *105*, 249–253. [CrossRef]
38. Alvarez, L.; Zarco, L.; Galindo, F.; Blache, D.; Martin, G.B. Social rank and response to the "male effect" in the Australian Cashmere goat. *Anim. Reprod. Sci.* **2007**, *102*, 258–266. [CrossRef] [PubMed]
39. Alvarez, L.; Ramos, A.L.; Zarco, L. The ovulatory and LH responses to the male effect in dominant and subordinate goats. *Small Rumin. Res.* **2009**, *83*, 29–33. [CrossRef]
40. Côté, S.D.; Festa-Bianchet, M. Reproductive success in female mountain goats: The influence of age and social rank. *Anim. Behav.* **2001**, *62*, 173–181. [CrossRef]
41. Santiago-Moreno, J.; Gómez-Brunet, A.; Toledano-Díaz, A.; Pulido-Pastor, A.; López-Sebastián, A. Social dominance and breeding activity in Spanish ibex (*Capra pyrenaica*) maintained in captivity. *Reprod. Fertil. Dev.* **2007**, *19*, 436–442. [CrossRef]
42. Jena, S.; Malik, D.S.; Kaswan, S.; Sharma, A.; Kashyap, N.; Singh, U. Relationship of udder morphometry with milk yield and body condition traits in Beetal goats. *Indian J. Anim. Sci.* **2019**, *89*, 204–208.
43. Keskin, S.; Kor, A.; Karaca, S. Use of factor analysis scores in multiple linear regression model for determining relationships between milk yield and some udder traits in Goats. *J. Appl. Anim. Res.* **2007**, *31*, 185–188. [CrossRef]
44. Susilorini, T.E.; Maylinda, S.; Surjowardojo, P. Importance of body condition score for milk production traits in Peranakan Etawah goats. *J. Biol. Agric. Health* **2014**, *4*, 151–157.
45. Abisoye, F.O.; Adedibu, I.I.; Kabir, M.; Barje, P.P.; Ugbojah, O.G. Evaluation of Udder and Teat Traits in Relation to Somatic cell Count in Sokoto Gudali and White Fulani cows in Nigeria. *Niger. J. Anim. Sci. Technol.* **2021**, *4*, 102–110.
46. Assan, N. Morphology and its relationship with reproduction and milk production in goat and sheep. *Sci. J. Zool.* **2020**, *9*, 123–137. [CrossRef]

47. Erduran, H.; Dag, B. Determination of factors affecting milk yield, composition and udder morphometry of Hair and cross-bred dairy goats in a semi-intensive system. *J. Dairy Res.* **2021**, *88*, 265–269. [CrossRef] [PubMed]
48. Margatho, G.; Quintas, H.; Rodríguez-Estévez, V.; Simões, J. Udder morphometry and its relationship with intramammary infections and somatic cell count in serrana goats. *Animals* **2020**, *10*, 1534. [CrossRef] [PubMed]
49. Sharma, A.; Sharma, S.; Singh, N.; Sharma, V.; Pal, R.S. Impact of udder and teat morphometry on udder health in Tharparkar cows under climatic condition of hot arid region of Thar Desert. *Trop. Anim. Health Prod.* **2016**, *48*, 1647–1652. [CrossRef] [PubMed]
50. Oudshoorn, H.M.; Paibomesai, M.A.; Cant, J.P.; Osborne, V.R. Nutritional strategies used on dairy goat farms in Ontario. *Prof. Anim. Sci.* **2016**, *32*, 484–494. [CrossRef]
51. Argüello, A.; Castro, N.; Zamorano, M.J.; Castroalonso, A.; Capote, J. Passive transfer of immunity in kid goats fed refrigerated and frozen goat colostrum and commercial sheep colostrum. *Small Rumin. Res.* **2004**, *54*, 237–241. [CrossRef]
52. Castro, N.; Capote, J.; Alvarez, S.; Argüello, A. Effects of lyophilized colostrum and different colostrum feeding regimens on passive transfer of immunoglobulin G in Majorera goat kids. *J. Dairy Sci.* **2005**, *88*, 3650–3654. [CrossRef]
53. Stonos, N.; Wootton, S.K.; Quinton, M.; Karrow, N. Seroprevalence of small ruminant lentivirus infection in Ontario goat herds. *Small Rumin. Res.* **2013**, *114*, 284–288. [CrossRef]
54. Weaver, D.M.; Tyler, J.W.; Van Metre, D.C.; Hostetler, D.E.; Barrington, G.M. Passive transfer of colostral immunoglobulins in calves. *J. Vet. Intern. Med.* **2000**, *14*, 569–577. [CrossRef]
55. Puppel, K.; Gołębiewski, M.; Konopka, K.; Kunowska-Slósarz, M.; Slósarz, J.; Grodkowski, G.; Przysucha, T.; Balcerak, M.; Madras-Majewska, B.; Sakowski, T. Relationship between the quality of colostrum and the formation of microflora in the digestive tract of calves. *Animals* **2020**, *10*, 1293. [CrossRef]
56. Castro, N.; Gómez-González, L.A.; Earley, B.; Argüello, A. Use of clinic refractometer at farm as a tool to estimate the IgG content in goat colostrum. *J. Appl. Anim. Res.* **2018**, *46*, 1505–1508. [CrossRef]
57. Kessler, E.C.; Bruckmaier, R.M.; Gross, J.J. Immunoglobulin G content and colostrum composition of different goat and sheep breeds in Switzerland and Germany. *J. Dairy Sci.* **2019**, *102*, 5542–5549. [CrossRef] [PubMed]
58. Kessler, E.C.; Bruckmaier, R.M.; Gross, J.J. Comparative estimation of colostrum quality by Brix refractometry in bovine, caprine, and ovine colostrum. *J. Dairy Sci.* **2021**, *104*, 2438–2444. [CrossRef] [PubMed]
59. Santiago, M.R.; Fagundes, G.B.; do Nascimento, D.M.; Faustino, L.R.; da Silva, C.M.G.; Dias, F.E.F.; Pereira, S.A.; Arrivabene, M.; Cavalcante, T.V. Use of digital Brix refractometer to estimate total protein levels in Santa Inês ewes' colostrum and lambs' blood serum. *Small Rumin. Res.* **2020**, *182*, 78–80. [CrossRef]
60. Schettino-Bermúdez, B.S.; Gutiérrez-Tolentino, R.; Vega y León, S.; Escobar-Medina, A.; Pérez-González, J.J.; González-Ronquillo, M. Composición láctea y perfil de ácidos grasos en leche de cabra de Guanajuato, México. *Rev. Salud Anim.* **2018**, *40*, e01.
61. Vieitez, I.; Irigaray, B.; Callejas, N.; González, V.; Gimenez, S.; Arechavaleta, A.; Grompone, M.; Gámbaro, A. Composition of fatty acids and triglycerides in goat cheeses and study of the triglyceride composition of goat milk and cow milk blends. *J. Food Compos. Anal.* **2016**, *48*, 95–101. [CrossRef]
62. Lôbo, A.M.B.O.; Lôbo, R.N.B.; Facó, O.; Souza, V.; Alves, A.A.C.; Costa, A.C.; Albuquerque, M.A.M. Characterization of milk production and composition of four exotic goat breeds in Brazil. *Small Rumin. Res.* **2017**, *153*, 9–16. [CrossRef]
63. Salvador, A.; Martínez, G.; Alvarado, C.; Hahn, M.; Pariacote, F.; Vazquez-Armijo, J.F. Características físico químicas y composición de la leche de cabras mestizas canarias en condiciones tropicales. *Rev. Fac. Cienc. Vet.* **2016**, *57*, 53–60.
64. Di Grigoli, A.; Di Trana, A.; Alabiso, A.; Maniaci, G.; Giorgio, D.; Bonanno, A. Effects of grazing on the behaviour, oxidative and immune status, and production of organic dairy cows. *Animals* **2019**, *9*, 371. [CrossRef]