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RELATIONSHIPS AMONG SOCIAL HIERARCHY, BODY WEIGHT, CONFORMATION, AND SEXUAL BEHAVIOR DURING GROWTH PERIOD OF CREOLE GOAT BUCKS

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ABSTRACT

The objective of this study was to investigate possible associations between body weight, conformation, testicular biometry, semen characteristics, and sexual behavior of young Creole bucks with high (HSH), medium (MSH), and low (LSH) social hierarchy (SH). A total of 15 young Creole bucks, aged 2-3-month-old with mean body weight of14.6 ± 3.3 kg were used. Social behavior frequency was analyzed by chi-square test. Body weight, live body measurement, testosterone and semen characteristics were analyzed using a mixed-effects model. Pearson correlation coefficients was obtained for body weight, linear body measures, indexes, testicular and semen characteristics, sexual behavior, and social hierarchy. The HSH bucks presented more aggression events with contact ($P \leq 0.05$). SH had a significant effect on live weight (22.5 kg), anamorphosis index (72.9), compactness index (37.37), and live body measurement, with HSH and MSH bucks being superior to LSH bucks. Scrotal circumference (21.6 cm), testicular biometry, and odor (2.5) were higher in HSH and MSH bucks than in LSH bucks ($P \leq 0.05$). The ejaculate volume (0.52 mL), spermatozoa concentration (1.06 million/ml), and mass motility (2.3) were higher in HSH bucks than in LSH bucks ($P \leq 0.05$). SH influenced libido (34.9%), mount latency (68.7 s), and response times (56.5 s); HSH bucks had more consummatory sexual behavior (36.5 %) than LSH bucks ($P \leq 0.05$). Significant ($P \leq 0.05$) correlations were observed between live body measurement, testicular and sexual characteristics to SH. It was concluded that young Creole bucks with medium and high social hierarchy had better testicular characteristics, semen quality, higher frequency of consummatory sexual behavior, and higher linear body measurement than Creole bucks with low social hierarchy.

Keywords: conformation traits; libido; social dominance, semen characteristics.

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INTRODUCTION

In Mexico the goat species stands out from other productive animals for its characteristics under rustic conditions that allows them to adapt in extreme environments (Barrera-Perales *et al.*, 2018). Goat farming has allowed the livelihood of the most disadvantaged classes of human society, through the marketing and consumption of meat and milk that contribute to family income and food security (Chaudhari *et al.*, 2018). The livestock sector faces the current challenge of generating food that provides animal protein, under constant pressure of the exponential and accelerated growth of human society and the environmental problem considering the greenhouse gases generated by the livestock (Navarrete-Molina *et al.*, 2020). Due to the above, goat farming must increase productive efficiency, adapt to changing scenarios, generate sustainable forms of animal and zoogenetic resources based on the identification and registration of reproductive parameters with high discrimination capacity. The adoption of these strategies on goat production system will allow improvements in social guarantees that will fight hunger, poverty and food access (Navarrete-Molina *et al.*, 2020). Goats mating is seasonal, the start and duration of the breeding season depends on various factors such as latitude, climate, breed, physiological status, buck effect, type of mating (natural mating or artificial insemination) and specifically the photoperiod (Simões, 2015). It is due to this seasonality that its reproductive activity has important annual variations (Gatica *et al.*, 2012). For this reason, regular monitoring of the reproductive efficiency is essential to determine the effectiveness of reproductive programs (Mellado *et al.*, 2008). From this perspective, buck fertility plays a crucial role in goat reproduction, considering that a single male can mate with several females (Chaudhari *et al.*,2018). The analysis of the buck reproductive potential is carried out through the evaluation of reproductive capacity (Breeding Soundness Evaluations), where mating ability, physical examination, testicular conformation, scrotal circumference, seminal parameters (motility and spermatozoa morphology) and zoometry, all are data that are taken into account (Hoflack *et al*., 2006). Moreover, social position affects reproduction (Šárová *et al*., 2017), according to Alvarez *et al*., (2003) and Côté, (2000) goats´ reproduction are influenced by their social status, given that the dominant females enter in estrous before the subordinate ones and, therefore, the former maintain contact with the bucks first, or in the opposite case, dominant bucks have access to the receptive females. Likewise, Côté (2000) also mentions that factors such as weight, corpulence, and age influence the social hierarchy in goats. In accordance Zuñiga-Garcia *et al.*(2020b),social dominance, aligned to morphological and growth related traits, modulates and even determines out-of-season reproductive success. The physiological and ethological development in goats is influenced by the social structure of the herd, and in consequence, the animal frequency of courtship and copulation are modified by this factor (Pérez-Muñoz, 2020). In this regard, Chaudhari *et al.* (2018) mentioned that the establishment of measurable criteria allows judging the buck's reproductive capacity that guides their selection. Through zoometric evaluation the racial biotype could be determined, allowing genetic improvement The phenotypic attributes that are suitable for genetic improvement are selected based on the effectiveness in reproductive program, thereby reducing costs. Therefore, the objective of this work was to associate body weight, conformation, testicular, semen characteristics, and sexual behavior of young Creole bucks with high (HSH), medium (MSH), and low (LSH) social hierarchy (SH).

MATERIALS AND METHODS

Ethical statement: Animal handling procedures were approved by the Bioethics Committee of the Autonomous University of Tamaulipas, Mexico, with approval reference number CBBA_26_2021.

Localization, Animals, and Installations: The present study was conducted in the experimental area of the Faculty of Veterinary Medicine and Zootechnics of the Autonomous University of Tamaulipas, Mexico. It is located W 99°06´41´´ and N 23°41´16.8´´at an altitude of 340 meters above sea level with a semi-dry climate with summer rain (BS1hw), an average annual temperature of 22.1°C, and an average annual rainfall of 887 mm (INEGI, 2010).

Fifteen three-month-old Creole goat bucks (14.66± 3.3 kg liveweight) were used. The study was carried out from July to November 2022. Bucks were housed in 28 ×12 m (336 m^2) pens with concrete floor, with a gable roof of 3.90 m high. During the adaptation period (15 d), bucks were kept in a 40 m^2 pen (2.6 m^{2}per buck). They only had contact with females during semen collection. Upon arrival, bucks were vaccinated against pneumonic pasteurellosis, clostridiasis, and enterotoxemia (Bobact 8® MSD Animal Health, 2.5 mL IM). Additionally, bucks were dewormed with Levamisole 12 mg/kg BW (Vermizol L® Aranda).

Feed: The diet consisted of 35% sorghum grain, 35% *Medicago sativa*, 14% sorghum straw, 7% molasses, 8% soybean meal, 0.9% mineral mix, and 0.1 % salt. This diet was served twice daily in a standard feed bunk. Total diet (13.9% crude protein and 10.5 MJ/kg; the amount was supplied based on 3% of their body weight) was offered considering the average body weight (NRC, 2007).

Social hierarchy: Social behavior recordings began for ten days, twice daily (09:00and 18:00 hours), for 60 minutes during feeding time in the fifteen Creole goat bucks. The main interactions between the Creole bucks were monitored for 120 min/day with a total of 1200 min. The behavioral interactions recorded were aggression with contact (SBAC, Butting and Biting), contact assault (SBCA, Threatening and Pursuing), affiliative with contact (SBAFC, Grooming, Attempting to mount, and Mounting), and contactless affiliative (SBCAF, Sniff, and Flehmen)(Miranda de la Lama, 2005). "An interaction of aggressiveness is defined when an individual goat displayed dominant behaviors towards a goat that withdrew from the interaction, namely the subordinated goat". This definition was coined by Zuñiga-Garcia *et al.*(2020b).The individual success rate (IE) was calculated considering the following formula: IE = number of individuals able to displace/(number of individuals able to displace + number of individuals displaced) and were classified into three social hierarchies: high (HSH, IE: 0.67 to 1), medium (MSH, IE: 0.34 to 0.66), and low (LSH, IE: 0 to 0.33)(Zuñiga-Garcia *et al*., 2020a)

Body measurements: Body weight (BW) was measured every 30 days and was calculated using a digital scale with 150 kg capacity (L. Noval SA de CV). Bucks were weighed in the morning before feeding. The body condition score (BCS) was assessed according to FAO (2012).Linear body measurements (LBM)recorded were heart girth (HG), body length (BL), withers height (WH), rump width (RW), rump height (RH), chest width (CW), horn length (HL), and ear length (EL), according by FAO (2012). The compactness index (COM) and the anamorphosis index (ANA) were obtained as described by Zuñiga-Garcia *et al*., (2020b). The scrotal circumference (SC) was determined according to Ashraf *et al.*(2021); meanwhile, left testicular length (LTL), right testicular length (RTL), left testicle width (LTW), and right testicle width (RTW) were measured following the technique of Jiménez-Severiano *et al.*(2010). All measures were recorded once a month for five months.

Sexual Behavior: The reaction time, sexual aggressiveness (SA), and mating capacity of bucks were evaluated every fifteen days for four months (a total of 17 weeks). Every buck was exposed for20 minutes to estrous does to determine sexual performance, according to Ángel-García *et al.*, (2015). This test consists of exposing each buck to estrogenized female (2 mg of Zoetis© estradiol cypionate). The events were scored as indicated by Valle-Moysen *et al.*(2018)as appetitive behaviors (ABS), consummation (CSB), and non-sexual interest (NSIB). The libido (LI), mating ability (MAS), and sexual behavior score (SBS) were recorded following the procedure described by Ashraf *et al.*(2021).Sexual odor intensity was obtained by smelling the area posterior to the horn's base at a distance of 15 cm, as described by Fernández *et al.*(2022). Sexual odor intensity was score assigned (0-3), where 0= neutral scent equal to female or castrated buck scent, 1= slight sexual odor, 2= moderate boar taint, and 3= strong sexual odor like lanolin.

The semen was evaluated macroscopically and microscopically by traditional non-computerized methods. For semen volume (SV), bucks were trained under the use of an artificial vagina for semen collection. For training an estrogenized goat female (2 mg of Zoetis© estradiol cypionate) was used. The training was performed every week for one month (20 min. of exposure) as described by Ángel-García *et al.*(2015). After training period, semen collection was achieved as indicated by Calderón-Leyva *et al.*(2017) each 15 days for 17 weeks. Finally, semen volume was obtained by direct reading of the collection tube scale (14 ml graduated conical). Mass spermatozoa motility (MM) was determined through the deposition of a 5 µl of semen on a tempered slide at 37 °C. The speed of seminal waves and spermatozoa movement vigor were evaluated microscopically. The spermatozoa movement vigor was assigned in a range of 0-5, where 0= no movement, 1= some move from their site, 2= motile spermatozoa but do not form waves; 3= presence of waves or very slow eddies (50-70% of motile spermatozoa), 4= the waves or eddies form quickly (70-90% motile spermatozoa), and 5= progressive movement, waves form very quickly (<90%). Spermatozoa concentration (SCON) was calculated using a Neubauer hematocytometer chamber as follows. A semen aliquot was diluted with saline (1:400) to a total volume of 4 ml. From this dilution a 10 µl was taken for the hematocytometer filling. A humid chamber was made moistening the edges of the hematocytometer and allowing an incubation of 5 minutes at room temperature. SCON was made as described by Ax *et al.*(2013). Spermatozoa count in the ejaculate is the result of the product between seminal volume and sperm concentration per ml as describe Jo *et al.*(2019).

Blood samples without anticoagulant were taken through jugular venipuncture between 07:00-07:30 in the morning before feeding. Specimens were taken every 30 days for four months, and were centrifuged for 10 minutes at 1,000 g to separate clot from the blood serum. The serum was frozen at -20 °C. The samples were processed under laboratory conditions. Serum testosterone concentration was measured using a solid phase competitive chemiluminescent enzyme immunoassay following the manufacturer's instructions (Immulite/Immulite1000 Total Testosterone, Siemens Medical Solutions Diagnostics, Los Angeles, CA). The sensitivity of the assay was 15 ng/ml. The intra- and inter-assay coefficients of variation were 6.8 % and 9.2 %, respectively.

Statistical analysis: A Shapiro-Wilk and Kolmogorov-Smirnov test were used to examine the data normality. Parametric tests were performed if the data were normally distributed ($p > 0.05$) and non-parametric tests if this condition was not accomplished. Homoscedasticity was also analyzed using the Bartlett test. The frequency of each social behavior (SBCA, SBAC, SBAFC, SBCAF, IE) was calculated individually (10 d period, Table 1), and analyzed by chi-square test (SAS Institute Cary, version 9.0) (SAS, 2010). Differences were declared significant at $p < 0.05$.

BW, BCS, LBM, COM, ANA, and testosterone were ANOVA evaluated for repeated measurements (mixed procedure). The model included the SH, period (30 d period, Table 2), and the interaction between SH and time as fixed effects. The random effects were the buck and residual. Least square mean separation considered the PDIFF option and Tukey's least significant difference. The covariance structure that yielded the smallest Schwarz´s Bayesian information criterion was considered the most desirable analysis.

The semen characteristics (spermatozoa concentration, odor, mass motility, volume) and sexual behaviors (ABS, CBS, NSIB, MAS, SBS, and libido) were evaluated with ANOVA analysis for repeated measurements (mixed procedure). The model included the SH, period (15 d period, Table 3), and the interaction between SH and period as fixed effects. The random effects were the buck and residual. In the event of a significant effect, least square mean separation considered the PDIFF option and Tukey's least significant difference. The means presented in table 3 correspond to non-transformed data, and SEM and p-values correspond to the ANOVA analyses of the transformed data. These data were transformed into natural logarithms plus 1to achieve a normal distribution.

BW, LBM, ANA, COM, testicular and semen characteristics, sexual behavior, and social hierarchy were analyzed using the PROC CORR of SAS to obtain the Pearson correlation coefficients. According to the correlation coefficient, the magnitude of association was declared as moderate (r >0.4 – 0.6), high (r >0.6 – 0.8) or very high (r >0.8 – <1.0). The p values < 0.05 were considered statistically significant.

RESULTS

Social hierarchy: Contact assault (SBCA actor) was performed more frequently (P≤0.05) by HSH bucks, followed by MSH and, to a lesser extent, by LSH goats (Table 1). Aggression with contact (SBAC actor) was observed more frequently in HSH. Therefore, differences were observed between the three groups (P≤0.05). Regarding affiliative with contact (SBAFC actor), LSH bucks showed the highest frequency (P≤ 0.05) followed by the MSH bucks and with minimal expression in the HSH bucks (Table 1). LSH bucks showed the highest expression of contactless affiliative (SBCAF actor), followed by the MSH and HSH bucks, with no difference between groups. Reactor social hierarchy were significantly to SH, SBCA, SBAC, SBAFC and SBAFC between SH groups (P≤0.05; Table 1), it was observed more frequency reactions to LSH in contrast to MSH or HSH. The individual success rate shows that HSH bucks (IE: 0.79) was observed in four individuals, while five showed medium dominance (IE: 0.49) and six had low dominance (IE: 0.12). Therefore, there was a difference (P≤0.05; Table 1) in dominance between the three groups.

Table 1. Frequency and percent (%) values of social behavior in young Creole bucks of northeastern Mexico with high, medium, and low social hierarchy.

Behavior	Social hierarchy[1]			c2	P-value
	HSH	MSH	LSH		
Actor					
SH	1833 (64)[a]	784(27)[b]	249(9)[c]	250.82	0.000
SBCA	575 (68)[a]	211 (25)b	60 (7)[c]	497.07	0.000
SBAC	1238 (65)[a]	540 (28)b	139 (7)[c]	968.07	0.000
SBAFC	1 (3)[c]	8 (86)a	19 (11)[b]	17.64	0.000
SBCAF	19 (25)	25 (42)	31 (33)	2.88	0.236
Reactor					
SH	464(16)[c]	836(29)[b]	1566(55)[a]	16.98	0.009
SBCA	131 (15)[c]	253 (30)[b]	462 (55)[a]	198.73	0.000
SBAC	325 (17)[c]	540 (28)[b]	1052 (55)[a]	436.56	0.000
SBAFC	0 (0)	9 (32)[b]	19 (68)[a]	3.57	0.058
SBCAF	8 (11)[b]	34 (45)[b]	33 (40)[a]	17.36	0.000
IE	0.79[a]	0.49[b]	0.12[c]	12.37	0.002

[1] HSH: High social hierarchy; MSH: medium social hierarchy; LSH: low social hierarchy. SH: all social behavior; SBAC: aggression with contact (Butting, and Biting); SBCA: contact assault (Threatening and Pursuing); SBAFC: affiliative with contact (Grooming, attempting to mount, and Mounting;); SBCAF: contactless affiliative (Sniff, and Flehmen). Sexual behavior score. IE: Individual success rate.

[abc]Means with different superscript letters in the same row differ (*P*< 0.05).

Body weight, linear body measurements, indexes, and testicular biometry: BW of HSH and MSH bucks were higher (P≤ 0.05) than LSH bucks. A difference was observed over time, with no SH × time interaction. On the other hand, BCS was not affected by SH; there was no SH × time, although there were differences in time. HSH and MSH bucks were superior in LBM than LSH bucks with exception RW (P≤ 0.05). HSH bucks were superior to HL bucks compared to MSH and LSH bucks (P≤ 0.05). Again, differences were evident in time evaluated; however, there was no time × SH interaction, except for BL. The COM and ANA indexes for HSH and MSH bucks were higher than that of LSH bucks (P≤ 0.05). Testicular biometry was generally higher for HSH and MSH bucks than LSH bucks (P≤ 0.05). Additionally, differences were observed only for evaluation time (P≤ 0.05; Table 2).

Testosterone, semen characteristics, and sexual behavior: Serum testosterone did not differ between the SH groups(P³0.05). While odor was higher (P≤0.05) in HSH and MSH bucks than LSH bucks. HSH and MSH bucks had a higher SCON compared to LSH bucks. Further, HSH bucks had higher (P<0.05) MM than the other groups. Differences in SV were only observed between HSH and LSH bucks (P≤0.05). Regarding sexual behavior, HSH bucks had higher mount latency, CSB, and libido (P≤0.05). Differences in the sexual behavior variables were also observed across time, except ABS and NSIB. Interaction effect was observed for CSB (P≤0.05; Table 3).

Table 2. Body weight, linear body measurements, indexes, and testicular biometry in young Creole bucks of northeastern Mexico with high, medium, and low social hierarchy.

	Social Hierarchy[1]			SEM[3]	p-Value[2]		
	HSH	MSH	LSH		SH	T	SH × T
BW (kg)	22.51^{a}±4.52	20.65^{a}±4.19	16.74^{b}±4.36	1.218	0.001	0.000	0.897
BCS	1.83±0.45	1.88±0.48	1.72±0.40	0.080	0.223	0.000	0.169
HG (cm)	66.01^{a}±4.64	65.08^{a}±4.43	59.16^{b}±5.55	1.314	0.000	0.000	0.100
BL (cm)	55.16^{a}±4.93	49.21^{b}±6.15	54.37^{a}±4.82	1.177	0.000	0.000	0.000
WH (cm)	59.89^{a}±4.52	57.40^{a}±4.54	53.23^{b}±5.59	1.127	0.000	0.000	0.441
CW (cm)	16.18^{a}±2.24	15.20^{ab}±1.66	14.37^{b}±1.91	0.394	0.001	0.000	0.116
RW (cm)	10.33±1.26	10.75±1.45	9.70±1.33	0.408	0.110	0.000	0.169
RH (cm)	61.93^{a}±5.03	60.46^{a}±4.96	55.53^{b}±5.55	1.373	0.001	0.000	0.722
EL (cm)	19.12^{a}±2.61	19.24^{a}±1.99	17.08^{b}±2.90	0.521	0.156	0.001	0.744
HL (cm)	13.30^{a}±2.99	8.58^{b}±5.31	9.73^{b}±4.13	0.881	0.143	0.000	0.176
COM	37.37^{a}±5.30	35.70^{a}±5.01	31.08^{b}±5.61	1.644	0.009	0.000	0.657
ANA	72.94^{a}±6.24	73.91^{a}±5.67	65.93^{b}±32.23	2.273	0.009	0.000	0.598
RTL (cm)	3.70^{a}±0.76	3.29^{a}±0.90	2.59^{b}±0.81	0.204	0.000	0.000	0.362
LTL (cm)	3.68^{a}±0.87	3.36^{a}±0.93	2.69^{b}±0.83	0.208	0.001	0.000	0.303
RTW (cm)	1.69^{a}±0.41	1.52^{ab}±0.50	1.28^{b}±0.49	0.113	0.020	0.000	0.711
LTW (cm)	1.73^{a}±0.48	1.55^{ab}±0.49	1.25^{b}±0.49	0.114	0.005	0.000	0.223
SC (cm)	21.64^{a}±5.61	20.41^{a}±4.94	17.36^{b}±4.81	0.944	0.001	0.000	0.926

[1] HSH: High social hierarchy; MSH: medium social hierarchy; LSH: low social hierarchy. BW: Body weight; BCS: body condition score (0 -5); HG: head girth; BL: body length; WH: withers height CW: chest width; RW: rump width; RH: rump height; EL: ear length; HL: horns length; COM: compactness index; ANA: anamorphosis index. RTL: right testicular length; LTL: left testicular length; RTW: right testicular width; LTW: left testicular width; SC: scrotal circumference

[2] SH: social hierarchy; T: time effect (period 30 d); SH × T: social hierarchy by time interaction effect

[3] SEM: standard error of the mean. Means with different superscript letters in the same row differ: ($P < 0.05$).

Table 3. Testosterone, semen characteristics and sexual behavior in young Creole bucks with high, medium, and low social hierarchy.

	Social hierarchy[1]				p-Value[2]		
	HSH	MSH	LSH	SEM[3]	SH	T	SH × T
Testosterone (ng/mL)	5.17±7.27	4.12±6.43	4.29±4.66	0.153	0.528	0.001	0.174
Odor	2.59^{a}±0.75	2.55^{a}±0.90	2.06^{b}±0.95	0.880	0.010	0.000	0.294
Semen characteristics							
Volume (mL)	0.52^{a}±0.40	0.34^{ab}±0.39	0.18^{b}±.0.32	0.073	0.006	0.000	0.051
SCON (million/mL)	1.06^{a}±0.59	1.33^{a}±1.09	0.35^{b}±0.39	0.450	0.005	0.030	0.051
MM	2.30^{a}±1.88	1.36^{b}±1.67	0.68^{b}±1.39	0.210	0.007	0.000	0.882
Sexual behaviour							
Libido (%)	34.93^{a}±26.97	27.71^{ab}±26.47	21.10^{b}±21.39	0.210	0.052	0.000	0.119
Mount latency (s)	68.75^{a}±117.05	46.87^{ab}±80.89	40.50^{b}±126.54	0.475	0.006	0.000	0.187
Response time (s)	56.59^{a}±186.14	39.53^{ab}±134.46	13.60^{b}±54.92	0.393	0.050	0.000	0.207
ABS (%)	56.78±17.89	63.37±23.58	56.78±26.87	0.397	0.544	0.219	0.641
CSB (%)	36.56^{a}±20.49	27.22^{ab}±20.95	20.33^{b}±21.21	0.368	0.007	0.000	0.022
NSIB (%)	6.71^{b}±11.19	6.97^{b}±17.85	19.77^{a}±29.87	0.385	0.009	0.089	0.090
MAS (%)	10.65±8.08	11.72±8.85	7.15±7.87	0.263	0.065	0.00	0.797
SBS (%)	30.00±27.81	23.21±24.73	19.86±20.71	0.218	0.257	0.000	0.385

[1] HSH: High social hierarchy; MSH: medium social hierarchy; LSH: low social hierarchy. SCON: spermatozoa concentration; MM: mass motility. ABS: Appetitive sexual behavior; CSB: Consummatory sexual behavior; NSIB: Non-sexual interest behavior; MAS: Mating ability score, SBS: Sexual behavior score.

[2] SH: Social hierarchy effect; T: Time effect (period of 15 d) with exception testosterone (period of 30 d); SH × T: Social hierarchy by time interaction effect.

[3] SEM: standard error of the mean (log-transformed data). Means with different superscript letters in the same row differ: ($P < 0.05$).

Table 4. Correlation of social hierarchy, body weight, body condition score, and linear body measurements in young Creole bucks of northeastern Mexico.

	BW	BCS	HG	BL	WH	CW	RH	RW	EL	HL	COM	ANA
SH	0.48^{***}	0.11^{NS}	0.49^{***}	0.41^{***}	0.48^{***}	0.35^{***}	0.20^{***}	0.44^{*}	0.32^{**}	0.26^{**}	0.44^{***}	0.42^{***}
BW		0.57^{***}	0.93^{***}	0.89^{***}	0.88^{***}	0.85^{***}	0.74^{***}	0.89^{***}	0.72^{***}	0.65^{***}	0.96^{***}	0.80^{***}
BCS			0.53^{***}	0.55^{***}	0.46^{***}	0.55^{***}	0.51^{***}	0.46^{***}	0.28^{**}	0.45^{***}	0.56^{***}	0.48^{***}
HG				0.86^{***}	0.89^{***}	0.80^{***}	0.75^{***}	0.89^{***}	0.76^{***}	0.62^{***}	0.87^{***}	0.90^{***}
BL					0.87^{***}	0.83^{***}	0.76^{***}	0.85^{***}	0.69^{***}	0.63^{***}	0.83^{***}	0.68^{***}
WH						0.76^{***}	0.66^{***}	0.89^{***}	0.75^{***}	0.60^{***}	0.75^{***}	0.63^{***}
CW							0.77^{***}	0.77^{***}	0.60^{***}	0.64^{***}	0.82^{***}	0.68^{***}
RH								0.69^{***}	0.61^{***}	0.55^{***}	0.81^{***}	0.72^{***}
RW									0.85^{***}	0.54^{***}	0.73^{***}	0.69^{***}
EL										0.41^{***}	0.63^{***}	0.63^{***}
HL											0.62^{***}	0.52^{***}
COM												0.83^{***}

SH: social hierarchy BW: body weight; BCS: body condition score; HG: head girth; BL: body length; WH: withers height CW: chest width; RW: rump width; RH: rump height; EL: ear length; HL: horns length; COM: compactness index; ANA: anamorphosis index; SH: social hierarchy. *P< 0.05; **P< 0.01; ***P< 0.001, and NS no significant.

Table 5. Correlation of social hierarchy and testicular characteristics in young Creole bucks of northeastern Mexico.

	SC	LTL	RTL	LTW	RTW	SCON	MM	SV
SH	0.28^{**}	0.43^{***}	0.43^{***}	0.37^{***}	0.34^{**}	0.12^{NS}	0.37^{***}	0.38^{***}
SC		0.87^{***}	0.92^{***}	0.89^{***}	0.86^{***}	0.32^{*}	0.59^{***}	0.50^{***}
LTL			0.96^{***}	0.93^{***}	0.92^{***}	0.32^{*}	0.68^{***}	0.61^{***}
RTL				0.91^{***}	0.87^{***}	0.40^{**}	0.66^{***}	0.58^{***}
LTW					0.93^{***}	0.27^{*}	0.63^{***}	0.54^{***}
RTW						0.27^{*}	0.66^{***}	0.61^{***}
SCON							0.14^{NS}	0.25^{NS}
MM								0.67^{***}

SH: social hierarchy SC: scrotal circumference; RTL: Right testicular length; LTL: left testicular length; RTW: right testicle width; LTW: left testicle width; SCON: spermatozoa concentration; MM: mass motility; SV: semen volume. *P< 0.05; **P< 0.01; ***P< 0.001, and NS no significant.

Table 6. Correlation of social hierarchy and sexual behavior in young Creole buck goats of northeastern Mexico.

	Odor	**SA**	**LI**	**MAS**	**SBS**	**ABS**	**CSB**	**NSIB**	**ML**
SH	0.24^{**}	0.23^{**}	0.21^{*}	0.16^{NS}	0.15^{NS}	0.03^{NS}	0.29^{***}	-0.24^{***}	0.09^{NS}
Odor		0.57^{***}	0.59^{***}	0.14^{NS}	0.56^{***}	0.12^{NS}	0.41^{***}	-0.39^{***}	0.06^{NS}
SA			0.56^{***}	0.46^{***}	0.48^{***}	0.19^{*}	0.53^{***}	-0.55^{***}	0.21^{***}
LI				0.10^{NS}	0.97^{***}	-0.09^{NS}	0.46^{***}	-0.26^{**}	-0.007^{NS}
MAS					-0.012^{***}	0.0^{NS}	0.44^{***}	-0.40^{***}	0.18^{*}
SBS						-0.12^{NS}	0.39^{***}	-0.22^{**}	-0.4^{NS}
ABS							-0.31^{***}	-0.46^{***}	0.034^{NS}
CSB								-0.48^{***}	0.18^{*}
NSIB									-0.16^{NS}

* SH: social hierarchy; SA: social aggression; LI: libido; MAS: mating ability; SBS: sexual behavior score; ABS: appetitive; CSB: consummation; NSIB: non-sexual interest behavior; ML: mount latency. *P< 0.05; **P< 0.01; ***P< 0.001, and NS no significant.

Correlations: Sixty-six correlations were made for SH, for BW, BCS, ANA, and COM, where 65 were significant with exception BCS to SH. (P≤0.05; Table 4). Additionally, it was observed a significant correlation between SH and testicular characteristics (P≤0.05; Table 5) except for SCON (i.e., SCON were non-significant to MM and SV). Also,45 correlations were made between SH, semen characteristics, and sexual behavior. In these correlations SH were significant correlated with odor, SA, LI, CBS, and NSBIB (P≥0.05; Table, 6). Meanwhile, SA had a significant correlation with all variables analyzed (P≤0.05; Table 6)

DISCUSSION

The HSH bucks had more SBCA and SBAC frequency compared to MSH and LSH bucks, which agrees Çakmakçı *et al.*(2021)**,** whose found that HSH bucks had a more significant number of events with contact and a lower number of events without contact compared to LSH bucks. Barroso *et al*. (2000) and Flota-Bañuelos *et al*. (2019) illustrate similar results. In the present research, we observed that MSH bucks had more affiliative with contact and contactless behaviors than LSH bucks. Çakmakçı *et al.* (2021) results are similar with our study. Meanwhile, Miranda de la Lama (2005) observed that dominant female goats performed more frequently affiliative behaviors, mainly grooming. It is possible that males require more aggressive behavior to establish a high hierarchy and achieve mating with high-ranking females, while females do not need to be as aggressive as males, given that it is common that goat females of all social hierarchy mate. Ungerfeld and González-Pensado (2008) showed that HSH bucks were more active in affiliative events like buck mounting that increased with the buck´s age. However, our research was with young Creole goats and it is possible that HSH need to be aggressive to food access for faster growth and reach puberty first to mate with females. Our results showed that the increase in aggression events is in accordance to social hierarchy (i.e., the higher the SH, more aggression events). The contrary phenomena are observed for affiliative behaviors, where less affiliative performances are observed in bucks with HSH. These behaviors could be due to the natural development of young Creole bucks, where social hierarchy is being established, as it was mentioned by Zuñiga-Garcia *et al.* (2020b).

BW is an important indicator of goat production since it is associated with better feed efficiency, puberty, and physiological status (Canaza-Cayo *etal.*, 2017). Our results showed that young Creole bucks had an increase in aggression events when BW was higher. According to this parameter, HSH and MSH bucks had higher aggression events than LSH bucks, which aligns with observations of Zuñiga-Garcia *et al.*(2020b) and Fiol *et al.*(2017), who worked with female goats and heifers, respectively. Sánchez-Dávila *et al.*(2018a) found no BW differences between dominant and subordinate bucks. In our study the increasing BW of HSH may have been positively correlated to glucose level. In agreement with this notion Bica *et al.* (2020) observed that LSH females grazed more and eat less grain supplement than HSH or MSH heifers. in rotational grazing systems.

HSH and MSH bucks had higher LBM values than LSH bucks, except RW. These results align with Zuñiga-Garcia *et al.*(2020b) who observed that LSH female goats had low LBM (WH, HG, and BL) values. However, Fiol *et al.*(2017) observed relationships between HG and WH measures in dairy heifers, regardless of SH. The different animal species could partially explain these differences. Additionally, growth in small ruminants is faster compared to bovines. It is possible that HSH and MSH bucks had better availability of food resources than LSH bucks; due to more aggression with contact behavior that displaces MSH and LSH bucks out of food. The ANA and COM indexes were higher in HSH and MSH bucks than LSH bucks. Zuñiga-Garcia *et al.* (2020b) showed that the percentage of dominance and BW are positively related to COM and ANA indexes. Remarkably, biometric measurements (considered productive parameters) are highly heritable, so it can be assumed that characteristics of HSH and MSH bucks could be inherited. Some studies (Chacón *et al.*, 2011; Peña-Avelino *et al.*, 2021) have reported that HG and BL can be used to estimate BW in goats. In the present study, it was observed that there are high correlations between the ANA and COM indices with HG and BL LBM´s, therefore it could be inferred that animals with HSH acquire high ANA and COM indices as a consequence of greater corpulence and conformation.

The SC was associated with SH; LSH bucks had less scrotal than the other groups, which agrees with Ortíz *et al.*(2001). Ungerfeld and González-Pensado (2008), in sheep, also observed that SC was higher in HSH lambs. In contrast, Sánchez-Dávila *et al.* (2018a) did not observe differences in SC and stated that SC is associated with age and BW of the bucks.SC represents one of the main buck selection variables because testicular size is correlated with the reproductive capacity (Espitia-Pacheco *et al.*, 2018), which is a highly heritable trait (Barrozo *et al.*, 2012). Górecki *et al.* (2020) indicate that animals with the highest number of aggressive events have the highest dominance index, which is related to testicular size. Our results showed positive influence of SH over SC, partially explained by experimentation time. These results were also observed by Ungerfeld and González-Pensado (2008), whose experiment lasts forty weeks with differences in BW, and SC. In contrast, Sanchez Davila *et al.* (2018a) assessed the reproductive behaviors in eight weeks and did not find differences in BW and SC. In this context, our 24weeks experiment had a positive effect on BW by SH in young Creole bucks. It was reported that high-ranked lambs maturated earlier than low-ranked rams. This ability was reflected by the increase in body weight, scrotal circumference, semen production, and exploring sexual behavior (Ungerfeld and González-Pensado (2008).

Serum testosterone concentration did not differ between SH groups, which agrees with Ungerfeld and González-Pensado (2008) and Sánchez-Dávila *et al.*(2018a)**,** whose observed that testosterone secretion was similar between dominant and subordinate individuals. Ungerfeld and González-Pensado, (2008), suggests that testosterone levels in young animals exerts moderate effect, and differences are pronounced in mature animal, concerning SH. Additionally, our experiment was carried out under tropical climate. Mukasa-Mugerwa *et al.* (2002), demonstrate that goats breeding in tropical conditions are non-seasonal or exhibit only a weak seasonality of reproduction. This observation is related to food supply, according to rainfall distribution. Also, growth rate and BW are decisive factors for puberty onset in the tropics (Rouatbi *et al.*, 2022). In adult animals, domination and aggressiveness are influenced by testosterone (Giammanco *et al.*, 2005). The aggressiveness increases during the mating season with increased testosterone. Still, fewer confrontations are registered during the pre-rut, even though similar testosterone concentrations occur during the mating season and pre-rut (Shargal *et al.*, 2008).

Odor was more pungent in HSH and MSH bucks than LSH bucks. Bucks practice self-marking, i.e., the urine is brought to the muzzle and raises the upper lip (flehmen). In line with our results, Russell (2014) indicates that bucks in close contact promote urination concomitant with increased territorial behaviors, suggesting a direct role in setting dominance status. In addition, odor indicates the start of puberty (Chasles *et al.,* 2018), and possibly odor indicates that HSH and MSH bucks could reach puberty earlier than LSH bucks.

Semen characteristics evaluated as volume, SCON, and MM were influenced by the SH, where the HSH bucks showed better values than LSH bucks. In contrast, Sánchez-Dávila *et al.* (2018a) did not find differences in SV and SCON in a eight week experimental period. They observed MM differences, where HSH bucks had a better value than low-ranking bucks. Interestingly, MM decreased as HSH animals were regrouped with other dominant bucks. On the other hand, Pérez-Muñoz (2020) did not detect differences for SV, SCON, and MM between subordinate and dominant bucks. In our work we observed better seminal characteristics in HSH, and this could be due to better nutrition. This had a positive impact on puberty onset.

SH influenced libido, mount latency, and response time. HSH bucks were more sexually active than LSH bucks. Again, similar results were observed by Sánchez-Dávila *et al.*, (2018a) and Pérez-Muñoz (2020)**.** In our work, SH affected CSB and NSIB; HSH bucks had more CSB events than LSH bucks. On the contrary, NSIB events were outnumbered in LSH bucks compared to MSH and HSH bucks. In agreement with this observation, Sánchez-Dávila *et al.*(2018a) found sexual behavior-dominance differences, with more frequent mounting and appetitive behaviors in the dominant bucks. On the other hand, Ungerfeld and González-Pensado (2009) observed that sexual behavior was correlated with age and not with SH.

Pérez-Muñoz (2020) observed that HSH goats expressed sexual appetitive behaviors more frequently than LSH goats and carried out consummation behaviors in a greater proportion. In our study, the consummation behaviors recorded were affected by the individual success rate of bucks, which was higher as the range increased. In contrast, appetitive behaviors were not affected by individual success rates. In a competitive environment, dominant bucks tend to carry out more consummation acts due to the stimulation of other competing bucks (Sánchez-Dávila *et al.*, 2018b). On the other hand, subordinate animals tend to develop opportunistic strategies (decrease courtship activities and increase the frequency of consummation behaviors), thus ensuring the service of bucks to females (Lacuesta *et al.*, 2018), which could explain these results.

Most of the LBM, BW, and testicular biometry had a significant correlation with SH. Semen characteristics and sexual behavior had significant correlation with SH. In the present study, correlations between these variables were higher than those reported by Zuñiga-Garcia *et al.*(2020). These differences may be due to the difference in bucks' age, time of study, and gender. Alvarez *et al.* (2003) and Zuñiga-Garcia *et al.*(2020) indicated that HSH females ovulated and conceived earlier than LSH goats, probably due to the more intense stimulation that results from their close association with bucks. Biometric parameters, such as scrotal circumference and testicular length, are essential in andrological evaluation (Gore *et al*., 2020). Cardoso da Luz *et al.*(2013) indicated that SC had a high correlation with BW and reproductive capacity (libido and spermatozoa production); in agreement with the latter, SC had a high correlation with the testicular biometric measures, MM, and SV.

Conclusion: The social behavior of Creole goat bucks of northeastern Mexico is decisive in establishing and maintaining the social hierarchy. The hierarchy positively influenced body weight, linear zoometric measurements, compactness and the anamorphosis indexes, and testicular biometry. Young bucks with high social hierarchy showed greater capacity for mounting, response time to estrous does, consumption, libido, and odor. In addition, the greater the social hierarchy of bucks, the better the semen characteristics are observed.

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