The level of nutrition received during the post-weaning development period influences the reproductive behavior of Pelibuey rams in adulthood

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Citation: Vargas-Velázquez, A. D., Espinosa-Martínez, M. A., Basurto-Gutiérrez, R., Vera-Ávila, H. R., Rosales-Nieto, C. A. & Jiménez-Severiano, H. (2025). The level of nutrition received during the post-weaning development period influences the reproductive behavior of Pelibuey rams in adulthood. *Agro Productividad*. https://doi.org/10.32854/cts1wx55

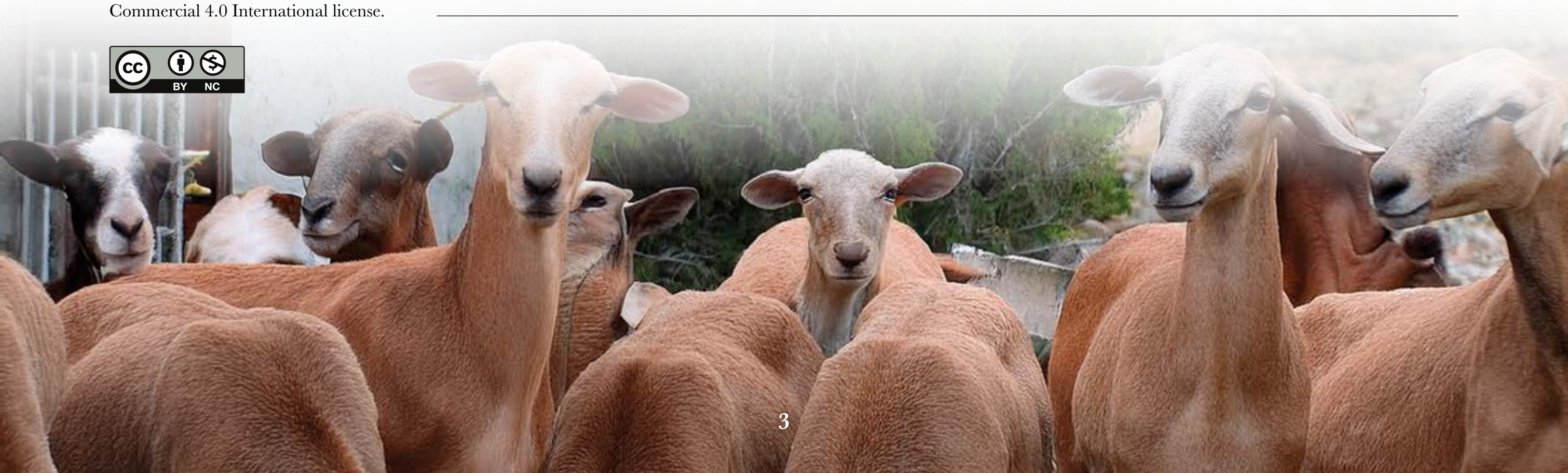
Academic Editor: Jorge Cadena Iñiguez
Associate Editor: Dra. Lucero del Mar Ruiz Posadas
Guest Editor: Daniel Alejandro Cadena Zamudio

Received: June 25, 2025.
Accepted: August 11, 2025.
Published on-line: October 24, 2025.

Agro Productividad, 18(9). September. 2025. pp: 3-16.

ABSTRACT
Introduction: Post-weaning nutrition plays a pivotal role in the reproductive development of sheep; however, its long-term effects during adulthood remain insufficiently studied.
Objective: To assess the long-term impact of post-weaning diets that induced varying average daily gains (ADG) on the reproductive performance of adult Pelibuey rams.
Design/Methodology/Approach: Twenty-eight Pelibuey rams were evaluated after being subjected to nutritional regimens aimed at achieving high (240 g/d), medium (209 g/d), or low (144 g/d) ADG during the post-weaning development phase (up to 40 weeks of age). Thereafter, all animals were maintained on a standardized diet from 18 to 30 months of age. Evaluations included body measurements, testicular and seminal characteristics, sexual behavior, and seminal plasma concentrations of zinc, α-glucosidase, and fructose.
Study Limitations/Implications: The lack of hormonal profiling constrains the physiological interpretation of the mechanisms involved and limits extrapolation to field scenarios.
Results: Rams with low ADG were able to recover body and testicular dimensions and exhibited seminal quality comparable to their counterparts; nonetheless, they demonstrated reduced mating efficiency, requiring a greater number of attempts per ejaculation. Conversely, rams with high ADG exhibited lower progressive motility, potentially associated with testicular oxidative stress.
Findings/Conclusions: Post-weaning undernutrition may exert lasting effects on sexual behavior in adulthood, despite the eventual normalization of body and seminal parameters. Promoting post-weaning ADG within the range of 200–240 g/d is recommended to optimize reproductive performance in hair sheep production systems.

Keywords: Sexual behavior, seminal plasma, reproductive performance, Pelibuey sheep, post-weaning nutrition



INTRODUCTION

Sheep production in Mexico is carried out under intensive, semi-intensive, and extensive systems, with marked differences in feed availability and quality. In intensive systems, specialized breeds are kept in confinement and fed high-energy diets designed to accelerate weight gain and growth. In semi-intensive systems, grazing is combined with limited supplementation, while in extensive systems (the most common), grazing with poor supplementation often leads to nutritional deficiencies and undernutrition (Herrera-Haro *et al.*, 2019; Secretaría de Agricultura y Desarrollo Rural, 2024). In this context, the reproductive efficiency of rams becomes a critical factor, as in extensive systems a single male can service numerous females, thus determining the productivity of the flock and, consequently, the economic profitability of producers (Macedo & Arredondo, 2008; Notter, 2012).

The use of efficient rams is essential to ensure a high number of effective matings, optimal semen quality, and sustained fertility. In hair breeds such as Pelibuey, which is widely distributed in Mexico, males represent a strategic genetic resource due to their hardiness, heat adaptability, and productive relevance in meat systems (Aguilar-Martínez *et al.*, 2017; Chay-Canul *et al.*, 2019; García-Chavez *et al.*, 2020; Castañeda-Hidalgo *et al.*, 2021). Understanding the factors that affect their reproductive performance is therefore a priority to optimize productivity in these systems. Among the most influential factors is nutrition during the post-weaning period, a stage during which growth rate, gonadal maturation, and the onset of puberty are determined. The availability and quality of nutrients modulate the secretion of metabolic and reproductive hormones that directly impact gonadal function (Castellano *et al.*, 2011; Kenny *et al.*, 2018). Recent studies confirm that both early undernutrition and overfeeding can have persistent effects on testicular morphology, semen quality, and sexual behavior in ruminants (Nazari-Zonouz *et al.*, 2022; Masudul *et al.*, 2024; Imik *et al.*, 2024; Keogh *et al.*, 2025; Giaretta *et al.*, 2025). The physiological mechanism by which early undernutrition impacts adult sexual behavior has been linked to neuroendocrine programming of the hypothalamic-pituitary-gonadal axis, reducing the secretion of GnRH and LH, which may alter testosterone production (Cardoso *et al.*, 2015; 2020) and the activation of hypothalamic circuits involved in the expression of libido and sexual behavior (Duittoz & Kenny, 2023). These early modifications may persist into maturity, conditioning reproductive behavior even after body recovery. In a previous study with Pelibuey lambs, it was observed that a high post-weaning average daily gain (ADG; 240 g/d) advanced puberty and improved testicular parameters compared to a low ADG (144 g/d) (Vargas *et al.*, 2018). However, it is still unknown whether these post-weaning nutritional differences exert a residual long-term effect, particularly on semen quality and sexual behavior in adult rams, two variables of high practical relevance for extensive systems. The aim of this study was to evaluate the long-term effects of three post-weaning nutritional plans, which generated high, medium, and low ADG, on body and testicular characteristics, semen quality, and sexual behavior in adult Pelibuey rams. The hypothesis proposed that low post-weaning ADG compromises reproductive performance in adulthood, while medium or high ADG allows for adequate reproductive development.

MATERIALS AND METHODS

General conditions

The study was conducted with the approval of the Institutional Subcommittee for the Care and Use of Experimental Animals (SICUAE) of the National Autonomous University of Mexico (SICUAE.DC-2020/2-2, 06/22/2020).

The study took place at the facilities of the National Research Center for Physiology and Animal Breeding, INIFAP (Colón, Querétaro, Mexico, 20° 43"N, 100° 15"W). A total of 28 Pelibuey rams (initial age: 18 months; initial weight: 78.4±0.4 kg) were used, originating from a previous study (Vargas *et al.*, 2018), in which they had been randomly assigned to three ADG treatments: high (240 g/d), medium (209 g/d), and low (144 g/d). Briefly, from weaning (60 days of age) until 40 weeks of age, they were offered diets formulated to achieve the target ADG, adjusting the levels of metabolizable energy and crude protein (Table 1).

Table 1. Experimental diets offered to male Pelibuey lambs from weaning to 40 weeks of age. Initial requirements[1] and diet characteristics.

Group	Expected ADG (g)	DM (kg)	Mcal/kg	CP[2] (%)	ADG obtained (g)
High	' >250	0.80	2.89	15.5	240
Medium	150 a 200	0.72	2.83	14.3	209
Low	<100	0.64	2.75	12.8	144

[1] Estimated requirements for male lambs weighing 15 to 20 kg of live weight (LW).
[2] Containing 40% bypass protein.
ADG=Average daily gain, DM=Dry matter, Mcal=Megacalories, CP=Crude protein.

The present study focused on the evaluation of animals from 18 to 30 months of age. This age range was selected because it corresponds to the reproductive adult stage in hair sheep, when rams have already reached stability in sperm production and full sexual capacity (Notter, 2012). During this stage, all rams were offered a maintenance diet (11.1% CP and 2.54 Mcal ME/kg DM), consisting of a concentrate (73% sorghum grain, 7.8% DDGS, 7.9% oat hay, 7.8% molasses, 2.2% calcium carbonate, and 1.3% microminerals) and corn silage, supplied at 700 g and 4 kg/animal/day, respectively, with ad libitum access to water. The content of microminerals (especially zinc, copper, and selenium) was not determined, although it was assumed to be adequate based on the composition tables of the ingredients used. It is worth noting that the number of animals (n=28) was defined by the availability of the experimental herd, and the groups continued to be designated as High (n=9), Medium (n=9), and Low (n=10), referring to the treatment received during the post-weaning stage. Prior to the start of the experiment, a basic clinical and reproductive examination was performed to rule out reproductive or infectious diseases that could interfere with the results.

Body and testicular morphometry

Every two months, live weight and body measurements were recorded, including height at the rump and height at the withers, using a somatometric ruler or measuring tape (Teletape, Ketchum, Ontario, Canada), as well as body length and thoracic perimeter, measured with a flexible tape. Scrotal circumference (SC) was assessed using a flexible measuring tape, and testicular diameter and length were measured with a Vernier caliper. Additionally, the body mass index (BMI) was calculated (Tanaka *et al.*, 2002; 2012).

Evaluation of semen samples

Semen evaluation was conducted at 22, 25, 28, and 30 months of age, using samples collected via artificial vagina and analyzed by microscopy in their fresh state. Prior to each sampling, one semen sample per day was collected over three consecutive days to deplete and homogenize the sperm reserves in the extratesticular duct system. The following parameters were assessed: ejaculate volume (ml), sperm concentration (spermatozoa/ml), mass motility (MM; scale 0 to 4), and the percentages of progressive motility (PM), live spermatozoa, and morphologically normal spermatozoa, following WHO guidelines adapted for sheep (Ávalos *et al.*, 2018).

Determination of seminal plasma components

At 22 months of age, after two consecutive days of semen collection using an artificial vagina, a semen sample was obtained, centrifuged at 1,000 g for 10 minutes at 5 °C. The sperm-free seminal plasma was decanted and stored at −20 °C until analysis.

The methods used to measure zinc, fructose, and neutral α-glucosidase in seminal plasma followed the procedures documented by the World Health Organization (Lu *et al.*, 2010). Zinc measurement was based on the formation of a complex between zinc and 2-(5-bromo-2-pyridylazo)-5-(N-propyl-N-sulfopropylamino)-phenol (5-Br-PAPS), which absorbs light at a wavelength of 560 nm; a commercial zinc kit (catalog number MAK032, Sigma-Aldrich) was used for this determination. Fructose was measured by heating the sample to 50 °C at a low pH (2.8), allowing the formation of a complex with indole that absorbs light at 470 nm. Neutral α-glucosidase activity was determined by its ability to convert synthetic glucopyranoside into p-nitrophenol, which, upon reaction with sodium carbonate, absorbs light at a wavelength of 405 nm (Lu *et al.*, 2010). The content of these components was expressed as concentration per milliliter and total per ejaculate.

Sexual behavior and mating capacity

Sexual behavior was evaluated every three months by presenting estrus-induced females, treated with estradiol benzoate (0.02 mg/kg; Forestro) three days prior to testing. The ethogram was conducted during a 5-minute observation period and included courtship variables: number of foreleg elevations, anogenital sniffing events, and Flehmen responses, as well as copulatory variables: latency to first mounting attempt, frequency of mounts without ejaculation, latency to first ejaculation, and refractory period (time from first ejaculation to the next mounting interaction). These parameters were used to calculate indicators of copulatory efficiency: mating capacity (frequency of mounts with ejaculation) and mating efficiency (total number of mounting interactions [attempts, mounts with and without ejaculation] divided by the number of ejaculations). This description is provided to facilitate interpretation, even though the ethogram has been previously validated (Price *et al.*, 1991; Perkins & Roselli, 2007). All observations were performed by evaluators who were blinded to the treatment of the animals.

Statistical analysis

The response variables measured at different ages were analyzed using a completely randomized design (CRD), applying the MIXED procedure of SAS (SAS Institute Inc., Cary, NC, USA) for repeated measures over time, with the "repeated" statement, the option sub=animal (group), and an autoregressive (1) covariance structure within the animal. Seminal plasma variables were analyzed as a CRD using the GLM procedure of SAS, which included the fixed effect of treatment. The assumptions of normality and homoscedasticity were verified using the Shapiro-Wilk and Levene tests, respectively.

To meet the assumptions of ANOVA, semen quality variables (volume and sperm per ejaculate) and sexual behavior variables measured in time units (seconds) were transformed using $\log N(y+1)$ and/or $\log N(y)$. For mass motility and the number of courtship and copulatory behaviors, the transformation $\sqrt{y+0.5}$ was applied. Percentage variables, expressed as proportions (p), were transformed using the arcsine $\sqrt{p}$ function. After analysis, data were back-transformed to real values for tables and figures. Mean comparisons were performed using Tukey's test, with statistical differences considered at $P<0.05$ and trends at P-values between 0.05 and 0.1.

RESULTS AND DISCUSSION

Body measurements

Daily weight gain and body weight

Data in Table 2 and Figure 1 show a significant group × age interaction for ADG (P=0.01) and body weight (P=0.001). At 18 months, the High group had a greater weight (82.5 kg) than the Medium (76.6 kg) and Low (74.2 kg) groups. Between 20 and 24 months, no significant differences were detected among groups, suggesting a stabilization phase. From 26 months onward, the High group again showed an advantage over the Low group (P=0.03). Thus, the group effect was significant at early and late stages, but not during the intermediate period; the age effect showed a progressive recovery pattern across all groups. At 30 months, body weights were: High 89.0 kg, Medium 82.7 kg, and Low 84.2 kg. Between 18 and 22 months of age, ADG was higher in the Low group, but from 24 months onward, it was similar among all three groups.

Table 2. Evolution of average daily gain (g) from 18 to 30 months of age in adult Pelibuey rams subjected to different post-weaning nutritional levels.

Nutritional level	Age (months)						
	18	**20**	**22**	**24**	**26**	**28**	**30**
High	12 ± 2^a	7 ± 2^a	3 ± 2^a	3 ± 2^a	54 ± 2^a	39 ± 2^a	53 ± 2^a
Medium	6 ± 2^a	7 ± 2^a	3 ± 2^a	3 ± 2^a	26 ± 2^a	55 ± 2^a	70 ± 2^a
Low	68 ± 2^b	48 ± 2^b	10 ± 2^b	4 ± 2^a	36 ± 2^a	30 ± 2^a	43 ± 2^a

[a, b] values within the same column without a common letter differ significantly (P<0.05).

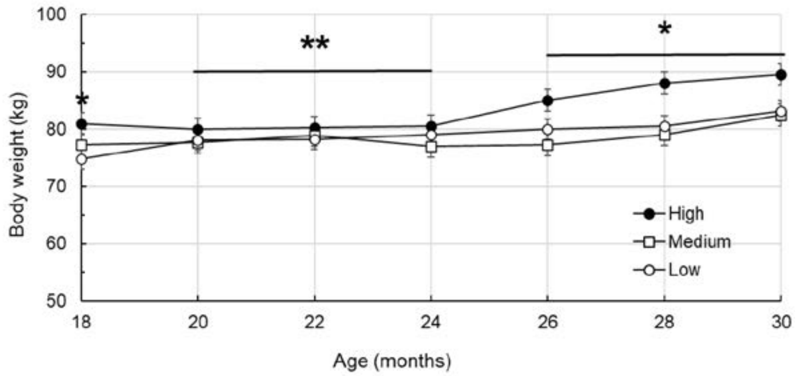


Figure 1. Evolution of body weight in adult Pelibuey rams subjected to different post-weaning nutritional levels. *Months in which Low and Medium are not different from each other (P>0.05) but differ from High (P<0.05). **High, Medium and Low do not differ from each other (P>0.05).

Body morphometry and body mass index

The group × age interaction tended to be significant for body length (P=0.07). Initially, the High and Medium groups showed greater values than the Low group; however, this difference disappeared by 26 months of age. Table 3 presents the results of body measurements. The group effect was significant for rump height (P=0.003), thoracic perimeter (P=0.04), height at the withers (P=0.001), and body length (P=0.025), while BMI showed no differences among groups. The age effect was not significant for these variables, indicating stability during adulthood, except for the compensatory adjustment observed in the Low group.

Testicular measurements

The group × age interaction was not significant for any of the testicular variables, while the group effect was significant for testicular diameter, which was greater in the Low group compared to the High group (P=0.03), and showed a trend for scrotal circumference (P=0.07; Table 3). However, this finding may be attributed to a compensatory effect in

Table 3. Average body and testicular measurements of Pelibuey rams from 18 to 30 months of age, which experienced three levels of average daily gain during the post-weaning stage (High, Medium, and Low; means ± SE, across the age).

	Nutritional level			P
	High	**Medium**	**Low**	
Rump height (cm)	79.2±0.6[a]	76.1±0.6[b]	77.0±0.6[b]	0.012
Thoracic perimeter (cm)	100.9±0.9[a]	97.4±0.9[b]	99.6±0.9[ab]	0.032
Height at the withers (cm)	79.5±0.6[a]	76.5±0.6[b]	78.2±0.6[a]	0.027
Body length (cm)	80.9±0.7[a]	79.4±0.7[ab]	78.1±0.7[b]	0.010
Body mass index	13.0±0.2	12.7±0.2	12.9±0.2	0.71
Scrotal circumference (cm)	33.5±0.5[b]	34.1±0.5[ab]	35.1±0.5[a]	0.042
Testicular length (cm)	12.2±0.2	12.0±0.2	12.1±0.2	0.98
Testicular diameter (cm)	6.6±0.1[b]	6.8±0.1[ab]	7.0±0.1[a]	0.045

[a,b] Different letters in the same row indicate significant differences (P<0.05).

gonadal growth following nutritional recovery, although it does not necessarily reflect improvements in semen quality or sexual behavior.

The age effect was significant for both testicular length ($P<0.001$) and diameter ($P=0.02$), which increased with sexual maturation.

Semen quality

The group × age interaction tended to be significant for sperm concentration ($P=0.06$; Table 4). Regarding the group effect (Figure 2), progressive motility was lower in the High group (57.2%) compared to the Medium (67.5%) and Low (68.5%) groups ($P=0.05$). Progressive motility increased with age (67.0% at 18 months *vs*. 73.7% at 30 months; $P<0.001$). Figure 2 shows that the percentage of normal spermatozoa was slightly but significantly higher in the Low group (99.3%) compared to the High (98.7%) and Medium (98.9%) groups ($P=0.03$). Thus, the group effect revealed relevant differences in motility and morphology, while the age effect indicated a progressive improvement in motility.

Table 4. Sperm concentration (millions/ml; means ± SE) of Pelibuey rams that experienced three levels of average daily gain during the post-weaning stage (High, Medium and Low; means ± SE).

Age (months)	Nutritional level		
	High	Medium	Low
22	$^{x}3,080\pm320^{b}$	$^{x}2,580\pm320^{b}$	$^{y}3,940\pm330^{a}$
25	$^{x}2,780\pm320$	$^{xy}3,070\pm320$	$^{x}3,030\pm330$
28	$^{xy}3,370\pm320^{ab}$	$^{x}2,850\pm320^{b}$	$^{y}3,730\pm300^{a}$
30	$^{y}3,380\pm320$	$^{y}3,560\pm320$	$^{y}3,440\pm300$

Group × age interaction ($P=0.063$).
^{a,b} Values within a row without a common letter indicate significant differences ($P<0.06$).
^{x,y} Values within a column without a common letter indicate differences ($P<0.06$).

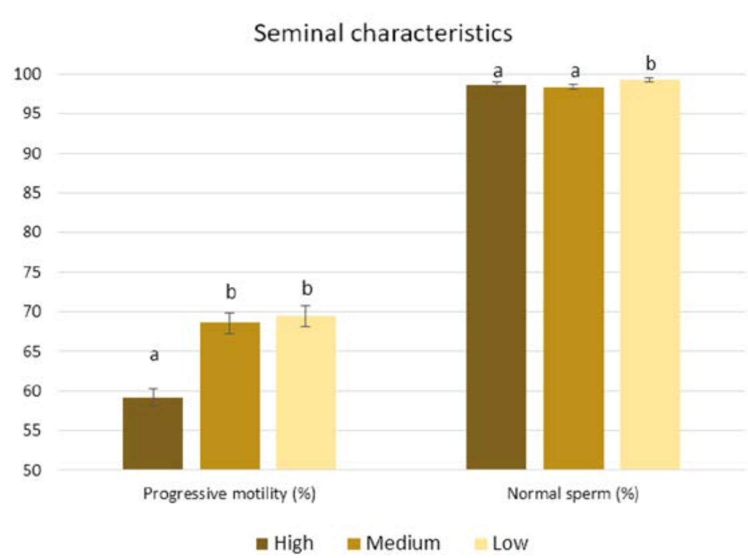


Figure 2. Progressive motility and normal spermatozoa in Pelibuey rams that experienced three levels of average daily gain during the post-weaning stage (High, Medium and Low; mean ± SE).

Concentration of seminal plasma components

No group × age interaction was detected. There were also no significant differences among groups in seminal plasma concentrations of zinc, fructose, or α-glucosidase, nor in total semen volume (Table 5). The relatively low zinc values may be related to the fact that the maintenance diet was not specifically formulated to optimally meet zinc requirements, which limits interpretation.

The age effect was not analyzed since measurements were performed at a single time point (22 months).

Sexual behavior and service capacity

Table 6 presents the results of sexual behavior. No group × age interaction was observed. Regarding the group effect, the High group recorded fewer mounting attempts than the

Table 5. Concentrations of zinc, fructose, and α-glucosidase in seminal plasma of Pelibuey rams that experienced three levels of average daily gain during the post-weaning stage (High, Medium, and Low; means ± SE).

	Nutritional level			**P**
	High	**Medium**	**Low**	
Seminal plasma concentration				
Zinc (mg/ml)	0.49±0.02	0.54±0.02	0.48±0.02	0.12
Fructose (mg/ml)	6.2±2.3	7.2±2.1	5.4±2.8	0.26
Neutral α-glucosidase (μmol/ml)	90.3±30.8	79.6±30.1	72.2±30.8	0.34
Total content in ejaculate				
Zinc (mg)	0.40±0.05	0.37±0.05	0.33±0.05	0.64
Fructose (mg)	5.6±2.1	5.7±2.0	4.3±2.6	0.46
Neutral α-glucosidase (μmol)	71.2±11.8	61±50.1	50.6±33.1	0.46

Table 6. Sexual ethogram variables of Pelibuey rams that experienced three levels of average daily gain during the post-weaning stage (High, Medium, and Low; means ± SE).

	Nutritional level		
	High	**Medium**	**Low**
Courtship behaviors			
Flehmen (n)	0.8±0.2	0.7±0.2	1.2±0.3
Forelimb elevations (n)	3.0±0.8	3.6±0.8	3.9±0.9
Anogenital sniffing (n)	7.2±0.8	8.1±0.8	8.1±0.8
Copulatory behaviors			
Mount attempts (n)	2.1±1.0 [a]	3.5±1.0 [ab]	5.2±1.1 [b]
Mounts without ejaculation (n)	2.1±0.3 [a]	1.7±0.4 [a]	3.2±0.4 [b]
Service capacity (Mounts with ejaculation, n)	2.5±0.3	2.3±0.3	2.6±0.3
Latency to first copulatory interaction (s)	32.8±7.3	30.0±7.2	17.1±7.7
Latency to first ejaculation (s)	48.5±11.2	54.8±11.1	44.7±11.8
Refractory period (s)	86.7±11.6	104.1±11.5	71.6±12.1
Mount/ejaculation ratio (n)	3.3±0.8 [a]	4.3±0.8 [ab]	6.4±0.8 [b]

[a,b] Values within a row without a common letter indicate differences ($P<0.05$). n: number of events, s: seconds.

Low group (P=0.03), while the Low group showed more mounts without ejaculation than the High and Medium groups (P=0.01). The High group had fewer interactions per ejaculation compared to the Low group (P=0.05). The age effect was not significant for these variables, indicating stable behavior during adulthood.

Our hypothesis was that male sheep receiving three post-weaning diets that produced high, medium, and low ADG during growth and development would exhibit compromised long-term reproductive performance in adulthood. The results of this study showed that differences in body weight and morphometry associated with post-weaning nutritional management tended to diminish in adulthood, reflecting a partial recovery capacity in animals that had lower ADG (Low group). However, this recovery was not complete across all reproductive variables, as sexual behavior and certain seminal parameters still bore traces of early nutritional management.

The higher body weight observed in the group with greater post-weaning ADG confirms that a high nutritional plane promotes somatic growth, as previously reported by López *et al.* (2010) and Lourençon *et al.* (2023) in hair sheep breeds. Nevertheless, the fact that the Low group reached similar body values to the High group by 26 months of age indicates the presence of compensatory growth mechanisms, which are highly correlated with body weight and ADG (De Jesús *et al.*, 2013; da Silva *et al.*, 2015; da Silva-Souza *et al.*, 2019). In this regard, it is noteworthy that despite its disadvantage during development, the Low group was able to recover body dimensions within a normal range once nutritional conditions improved. This plasticity suggests that animals can partially restore body size under improved conditions, although such recovery does not necessarily translate into equivalent improvements in reproductive efficiency, as reflected by subsequent limitations in sexual behavior.

In testicular morphometry, the greater diameter observed in the Low group should be interpreted cautiously, as lower ADG during sexual development does not necessarily indicate superior gonadal development. Recent studies have shown that testicular response to nutrition depends on the interaction between dietary plane and body condition (Ghorbankhani & Souri, 2014; Rosales-Nieto *et al.*, 2021). Moreover, scrotal circumference has been shown to correlate highly with body weight (r=0.83; Espitia-Pacheco *et al.*, 2018; Chacon *et al.*, 2019), and findings in Pelibuey sheep by Campos-Frías *et al.* (2023) report a strong positive correlation (r=0.89). Therefore, the variations in ADG and weight observed in the Low group during the evaluated period likely contributed to the restoration and enlargement of their testicular size. Although this may reflect compensatory growth following nutritional recovery, the increase did not represent a clear reproductive benefit, as it was not accompanied by improvements in sexual behavior or seminal characteristics.

In semen quality, the High group exhibited lower progressive motility, classified as "regular" (40-59% of spermatozoa with progressive motility; Ávalos *et al.*, 2018), whereas sperm from the Low and Medium groups showed "good" values (60-79%). The reduced progressive motility in the High group could be associated with potential testicular oxidative stress induced by a more energy-rich diet during sexual development, consistent with findings by Johnson *et al.* (2020) in bulls subjected to enhanced prepubertal nutrition, as well as studies reporting damage to the sperm membrane (Xu, 2025) and reduced progressive movement (Pintus, 2021; Wang, 2025). Conversely, the higher proportion of morphologically normal sperm in the Low group may be related to a more balanced and efficient metabolism, despite their initial growth disadvantage. Additionally, motility has been shown to increase gradually and linearly with SC size (Avellaneda *et al.*, 2006; Pabón-Quevedo & Pulido-Medellín, 2021), and in both cattle and sheep, SC has been positively correlated ($r=0.51$, $P<0.04$) with the percentage of progressively motile sperm (Pérez-Osorio *et al.*, 2014). Thus, the better motility observed in the Low and Medium groups may be due to their larger testicular size compared to the High group.

In seminal plasma, zinc concentrations in all three groups were low relative to values reported in other breeds (0.56 to 1.79 mg/ml; Juyena & Stelletta, 2012), which may have affected sperm motility, given the positive correlation between seminal zinc and sperm motility (Mahsud *et al.*, 2013). These zinc levels likely reflect deficiencies in the maintenance diet, as it was not formulated to optimize micromineral intake, limiting the interpretation of its impact on fertility. As for fructose concentrations in seminal plasma, the High and Medium groups showed higher values than those reported by Juyena & Stelletta (2012). These elevated levels may have contributed to reduced motility, as fructose concentrations have been negatively correlated with motility (Lewis-Jones *et al.*, 1996). Additionally, fructose synthesis is stimulated by testosterone (Juyena & Stelletta, 2012), and it has been suggested that seminal fructose concentration may depend on the spermatozoa's ability to utilize it (Giaretta *et al.*, 2025). Therefore, as reproductive hormones such as testosterone or LH were not measured, the results do not allow for a direct link between this metabolite and the endocrine regulation of spermatogenesis and sexual behavior. Future studies should include hormonal profiling to strengthen conclusions.

Sexual behavior was the variable most sensitive to post-weaning nutritional plane. Differences among groups suggest that post-weaning ADG can influence libido and mating efficiency, as reported by Kumar *et al.* (2015), Joshi (2022), and Zaobi *et al.* (2025). Despite recovering body and testicular size, the Low group exhibited lower copulatory efficiency, requiring more attempts to achieve ejaculation compared to the High group, which required fewer interactions. There are very few reports on the effect of nutrition on sexual behavior in sheep; existing studies indicate that undernutrition or feed restriction compromises libido (Parker & Thwaites, 1972; Zaobi *et al.*, 2025) and mating capacity (Kumar *et al.*, 2015). Although sexual behavior is complex and influenced by various factors (Petherick, 2005), the effect of nutrition during postnatal stages has been studied in animal models such as rodents (Laus *et al.*, 2011), showing that inadequate diets and consequently low ADG during early life compromise proper brain development and function, leading to behavioral alterations (Dorantes-Barria, 2021). This may explain how post-weaning nutritional plane affects the neuroendocrine programming of the hypothalamic–pituitary–gonadal axis, which regulates libido expression and mating capacity (Martin *et al.*, 2010; Gurule *et al.*, 2024). These effects are long-lasting and severe, as previously reported (Neu *et al.*, 2007; Laus *et al.*, 2011; Dorantes-Barria, 2021). Thus, even though nutritional recovery in the Low group allowed for compensation in body dimensions, sexual function remained impaired, which has a more substantial practical impact on fertility than morphological differences.

Overall, the results suggest that in extensive systems, where supplementation is often limited, implementing post-weaning feeding strategies that ensure gains of 200 to 240 g/d in lambs may enhance reproductive performance in males without incurring the risks associated with overfeeding.

The present study was conducted under controlled feeding and management conditions, which allowed for the isolation of the effect of the post-weaning nutritional plane. However, these conditions may differ from the practices of extensive production systems, which could influence the observed responses. Additionally, the sample size and duration of follow-up limit the extrapolation of results to other sheep breeds or different agroclimatic environments. Future research is recommended to include evaluations under field conditions and across various production systems, as well as to incorporate a greater racial diversity and longer follow-up periods. This would allow for validation and broader applicability of the findings, taking into account the genetic, environmental, and management variations present in sheep production at the regional and national levels. Overall, the results highlight that post-weaning nutrition has differential and persistent effects on the reproductive biology of Pelibuey sheep. While body variables tend to recover with age, sperm motility and copulatory efficiency are more susceptible to the effects of early nutritional restriction or excess. Thus, a moderate nutritional plane that ensures ADG between 200 and 240 g/d emerges as the most effective strategy for optimizing semen quality and sexual behavior, contributing to improved reproductive efficiency in extensive systems, where ram fertility determines production profitability.

ACKNOWLEDGMENTS

To MVZ. Miriam Sánchez Pérez, MVZ. Daniel Mijail Porta Vega, and MVZ. Ximena B. Arcos Romo for their collaboration in the activities of this experiment. This research was funded by the National Institute of Forestry, Agricultural and Livestock Research (INIFAP), SIGI 1581734139. We also thank CONACYT (now SECIHTI) for the scholarship granted, and the Graduate Program in Animal Production and Health Sciences at UNAM for the academic training provided.

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