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Effect of the genetic group on the productive performance of ewes subjected to intensified breeding in a semi-arid region in Brazil

Efeito do grupo genético sobre o desempenho produtivo de ovelhas submetidas à reprodução intensificada no semiárido

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Highlights

F1 ewes (Dorper x Santa Ines) demonstrate superior reproductive efficiency.
F1 ewes offered advantages in lamb production and economic performance.
The total weight of weaned lambs was influenced by the ewe's genetic group.
The BCS class ≤ 2.0 of the ewes at birth had greater prolificacy.

Abstract

This study evaluated the reproductive and productive effectiveness of an intensive meat sheep breeding program in the semi-arid region of Brazil. The research was conducted at the Paraíba State Farming Research Corporation (EMEPA-PB). A total of 120 ewes were used, 80 of the Santa Ines genotype and

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40 of the F1 Dorper x Santa Ines genotype, evaluated over three consecutive years. The characteristics assessed were fertility, prolificacy, total weight of offspring born per lambing ewe, and total weight of lambs weaned per lambing ewe. The F1 Dorper x Santa Ines ewes showed a higher fertility rate at lambing and a greater total weight of weaned offspring compared to the Santa Ines ewes. Body Condition Score (BCS) classes did not influence fertility rates for F1 Dorper x Santa Ines ewes. On the other hand, the BCS class ≤2.5 was superior to the other classes for Santa Ines ewes. However, prolificacy was not influenced by the genetic group. The F1 Dorper x Santa Ines ewes presented better reproductive and productive efficiency compared to the Santa Ines ewes. Hair sheep with a body condition score below 2.5 may exhibit high fertility and prolificacy rates.
Key words: Body condition. Weaning. Fertility. Sheep farming. Prolificacy.

Resumo

Este estudo avaliou a efetividade reprodutiva e produtiva de um programa intensivo de criação de ovinos de corte na região semiárida do Brasil. A pesquisa foi realizada na Empresa Estadual de Pesquisa Agropecuária da Paraíba (EMEPA-PB). Foram utilizadas 120 ovelhas, 80 foram do genótipo Santa Ines e 40 do genótipo F1 Dorper x Santa Inês, avaliadas durante três anos seguidos. As características avaliadas foram: fertilidade, prolificidade, peso total de crias nascidas por ovelha parida e peso total de cordeiros desmamados por ovelha parida. As ovelhas F1 Dorper x Santa Inês apresentaram maior taxa de fertilidade ao parto e peso total de crias desmamadas em relação as ovelhas Santa Ines. As classes de escore de condição corporal (ECC) não influenciaram a taxa de fertilidade para ovelhas F1 Dorper x Santa Inês. Por outro lado, a classe de ECC ≤2,5 foi superior as demais classes para ovelhas da raça Santa Ines. Entretanto, a prolificidade não foi influenciada pelo grupo genético. As ovelhas F1 Dorper x Santa Inês apresentaram melhor eficiência reprodutiva e produtiva em comparação as ovelhas Santa Ines. Ovelhas deslanadas com escore de condição corporal abaixo de 2,5 podem apresentar altas taxas de fertilidade e prolificidade.
Palavras-chave: Condição corporal. Desmame. Fertilidade. Ovinocultura. Prolificidade.

Introduction

The efficiency of sheep farming systems, both economically and biologically, plays a pivotal role in determining the productivity and reproductive performance of the flock. Traditional practices in extensive farming systems, such as using low-quality feed, neglecting genetic selection, and inadequate reproductive management, have led to extended calving intervals and overall inefficiency (Quadros & Cruz, 2017).

Such practices in sheep farming are often associated with reproductive losses, including low conception and prolificacy rates, poor weaning outcomes, and high mortality, all of which adversely affect herd productivity and the commercialization of lambs and meat throughout the year.

In lamb production systems, the herd's productive efficiency is linked to reproductive indices per cycle, including fertility (ratio of ewes lambing to those mated), prolificacy (number of lambs born per lambing ewe), and weaning rate (lambs weaned relative to those born). Low performance in these areas directly impacts the ewe's productivity, herd replacement, selection pressure, generational turnover, and overall herd productivity (Rego et al., 2014).

While the weaning rate is a common metric for evaluating sheep herds, it is insufficient alone, as it must be coupled with production quality. Hence, more effective indicators for assessing and guiding production systems include the weaning weight of lambs and the overall yield of lamb per ewe in the herd (Manzoni et al., 2017).

Understanding these reproductive parameters aids producers in tailoring reproductive, nutritional, and health strategies to their environmental context. It's vital to investigate the underlying causes of low herd productivity, considering genetic, environmental, and individual animal factors. These include genotype, sex, birth season, birthing type (single or multiple), ewe age, body condition, nutrition, and developmental potential (Sousa et al., 2006; Nóbrega et al., 2011; Souza et al., 2011).

Body condition score (BCS) is a widely used indirect measure for estimating body reserves in ruminants, showing a positive and significant correlation with subcutaneous fat levels (Mendizabal et al., 2007). These reserves at calving are crucial for maintaining satisfactory lactation levels, directly impacting lamb development and weight at birth and weaning (Rosa et al., 2007). Low BCS can hinder animal development and subsequent reproductive. There is a pressing need for comprehensive data on reproductive and productive indicators in meat sheep farming, especially for achieving three births within a two-year cycle. Understanding non-genetic factors related to lamb survival is crucial, particularly in semi-intensive systems aiming for enhanced reproductive and productive efficiency through reproductive management enabling three births every two years (Assan, 2020).

The objective of this study was to evaluate an intensified breeding system designed to achieving three lambing within a two-year period, under semi-arid conditions, which present significant challenges to reproductive and productive traits, focused on pure Santa Ines hair sheep and their crosses with the Dorper breed, aimed of optimizing meat production.

Materials and Methods

Ethics committee approval

This study received approval from the Ethics Committee for the Use of Animals of the Federal University of Paraíba (CEUA/UFPB), registered under CEUA number 2598200218.

Location

The study was conducted from 2014 - 2017 at the Benjamim Maranhão Experimental Station, part of the Paraíba State Farming Research Corporation (EMEPA-PB), situated in the semi-arid region of Paraíba State, Brazil (6°29'18" S, 35°38'14" W). The region experienced its highest rainfall during the autumn-winter period, from March to July, with average precipitation ranging from 17 mm to 154 mm throughout the study.

Production system (animals)

Initially, the system was comprised of 120 multiparous ewes and augmented each cycle with nulliparous females - 80 Santa Ines and 40 F1 Dorper x Santa Ines ewes (a 50/50 Dorper and Santa Ines mix) - alongside six breeding rams, two of which were Santa Ines and four Dorper, with more than 4 years of age.

The Santa Ines ewes were split into two groups of 40. One group was mated with Santa Ines rams, and the other with Dorper rams, resulting in two distinct genotypes: purebred Santa Ines and F1 Dorper x Santa Ines. The F1 Dorper x Santa Ines ewes were bred with Dorper rams to produce ¾ Dorper lambs.

The sheep were raised semi-intensively in caatinga vegetation, supplemented with buffel grass (*Cenchrus ciliaris* L.), and had access to water and multinutritional block supplements. Depending on the time of year, additional feed was provided, including sorghum silage (*Sorghum bicolor*) and forage palm (*Opuntia ficus-indica* L.).

Feed management

Prior to breeding, ewes underwent a flushing phase with 300g of concentrated feed per animal per day for 15 days leading up to and following the start of mating. Entering the final third of gestation, they received 300 g of a concentrated feed with approximately 16% crude protein and 3.05 Mcal/kg DM in metabolisable energy. During lactation, this increased to 500 g of feed with 20.7% crude protein and 3.01 Mcal/kg DM. The concentrate was comprised of crushed maize, soybean meal, livestock urea, and minerals (Table 1).

Table 1
Feed and chemical composition in dry matter of the concentrated feed for ewes and lambs during the production cycles

Feed composition	Mating/Final third	Lactation	Lambs
Tifton hay (g kg^{-1})	-	-	120.0
Ground maize (g kg^{-1})	800.0	675.0	480.0
Soybean meal (g kg^{-1})	180.0	300.0	360.0
Soybean oil (g kg^{-1})	-	-	20.0
Mineral salt* (g kg^{-1})	10.0	15.0	10.0
Calcitic limestone (g kg^{-1})	10.0	10.0	10.0
Chemical composition			
Dry matter (g kg^{-1})	886.0	882.4	886.3
Crude protein (g kg^{-1})	160.0	207.0	233.7
Metabolisable energy (Mcal kg^{-1} DM)	3.0	3.0	2.9
Total digestible nutrients (g kg^{-1})	844.7	833.5	818.5
Ethereal extract (g kg^{-1})	35.6	32.6	47.9
Mineral matter (g kg^{-1})	43.8	54.4	61.5
Ca (g kg^{-1})	6.0	7.9	8.0
P (g kg^{-1})	3.6	4.0	4.2

Composition of mineral salt per kilogram: Na 147 g; Ca 120 g; P 87 g; S 18 g; Zn 3,800 mg; Fe 3,500 mg; Mn 1,300 mg; Fl 870 mg; Cu 590 mg; Mo 300 mg; I 80 mg; Co 40 mg; Cr 20 mg; Se 15 mg; Vit. A (IU) 250 mg; Vit. D (IU) 100 mg; Vit. E (IU) 500 mg.

Reproductive management

An intensified reproductive management strategy was implemented to facilitate three calvings within two years, with an eight-month calving interval and a 42-day mating period. A 'male effect' practice was used: two with sexually mature rams, introduced to the herd 14 days before mating to stimulate oestrus. To monitor mating, coloured grease was applied to the wethers' collars.

Every 28 days, the entire herd was weighed. Approximately 40 days post-mating, ultrasound scans confirmed pregnancies. Non-pregnant ewes were separated with the replacement ewe lambs. The intensive reproductive schedule aimed for three births within two years, employing a 90-day cycle period, divided into 42 days of breeding season and 48 days of lactation period.

Post-birth, lambs underwent various procedures were carried out, including colostrum intake monitoring, tagging with plastic earrings, weighing, and umbilical cord treatment with a 10% iodine solution. At 15 days old, lambs were moved to native pasture paddocks with their mothers and received a high-protein diet (~23% crude protein) ad libitum in a creep-feeding system.

Lambs were weighed biweekly until an average weaning age of 48 days, after which they were weaned, weighed, assessed for BCS, and separated from the ewes to minimize stress.

Sanitary management

Animals Health management included regular eye mucous membrane checks using the Famacha® method, deworming, and annual vaccinations against rabies and clostridiosis, administered 30 days pre-calving to ewes and at 45 days for lambs.

Variables assessed

Ewes' BCS was determined through visual and tactile examination of the lumbar region, rated on a scale of 1 to 5 (1 = very thin, 5 = very fat or obese), as per Russel et al. (1969).

The study's focus was on key reproductive and productive traits: fertility (ratio of ewes lambing to those exposed to the ram), prolificacy (number of lambs born per lambing ewe), total weight of lambs born (TWLB), and total weight of lambs weaned (TWLW). Given the minor variation in lambs' weaning age (48 to 53 days), TWLW was adjusted to a 60-day standard following the methodology of Mariani et al. (2009).

Data was collated from 120 ewes across five production cycles, yielding 437 fertility observations, 391 prolificacy observations, 366 TWLB observations, and 312 TWLW observations.

Experimental design and statistical analysis

A completely randomized design was employed with varying numbers of replicates. Ewe reproductive performance data were analysed using the General Linear Model (GLM) approach in SAS version 9.2. Statistical Analysis System Institute [SAS Institute] (2024). The mathematical models for examining ewes' reproductive and productive traits incorporated fixed effects of genetic group, productive cycles, body condition score (BCS) at mating (categorized into ≤2.5; 2.5 > BCS ≤3.5; >3.5) and at lambing (categorized into ≤2.0; =2.5; 2.5 > BCS ≤3.5; >3.5), as well as the age and weight of ewes at lambing as covariates, including all potential interactions. Preliminary analyses utilizing the full model highlighted inconsistencies and confounding among some variables, which were then excluded from the initial model. Statistical significance of various effects in the models was determined using the F test ($P<0.05$), with mean comparisons conducted via the Tukey test at a 5% probability level. The specific mathematical models were as follows:

Fertility $y_{ijkl} = \mu + c_i + g_j + a_k + b(I_{ijkl} - \bar{I}) + (g * a_{jk} + e_{ijkl}$

Prolificacy $y_{ijfl} = \mu + c_i + g_j + h_f + b(I_{ijfl} - \bar{I}) + d(P_{ijfl} - \bar{P}) + (g * h)_{jf} + e_{ijfl}$

Total Weight of Offspring Born (TWOB) $y_{ijkfl} = \mu + c_i + g_j + a_k + h_f + b(I_{ijkfl} - \bar{I}) + (g * a)_{jk} + (g * h)_{jf} + e_{ijkfl}$

Total Weight of Lambs Weaned (TWLW) $y_{ijkfl} = \mu + c_i + g_j + a_k + h_f + b(I_{ijkfl} - \bar{I}) + d(P_{ijfl} - \bar{P}) + (g * a)_{jk} + (g * h)_{jf} + e_{ijkfl}$

where: Y_{ijkfl} = value of the dependent variable referring to the l-th animal, in the i-th productive cycle, in the j-th genotype, in the k-th score at mating and f-th score at calving; μ = general average; c_i = effect of the i-th productive cycle; g_j = effect of the j-th genetic group of the ewe; a_k = effect of the k-th BCS of the ewe at mating; h_f = effect of the f-th BCS of the ewe at calving; b = linear regression coefficient of the variable Yijkfl I in relation to the age of the ewe at calving, with b ≠ 0; d = linear regression coefficient of the variable Yijkfl in relation to the ewe's weight at calving, with d ≠ 0; I_{ijkfl} = value of the first auxiliary variable (covariable) of the l-th animal, in the i-th productive cycle, in the j-th genotype, in the k-th score at mating and f-th score at calving; P_{ijkfl} = value of the second auxiliary variable (covariate) of the l-th animal, in the i-th production cycle, in the j-th genotype, in the k-th score at mating and f-th score at calving; I^- = mean of the first auxiliary variable (covariate); P^- = mean of the second auxiliary variable (covariate); $(g*a)_{JK}$ = effect of the interaction between the factors ewe genotype j and BCS at mating k; $(g*h)_{Jf}$ = effect of the interaction between the factors ewe genotype j and BCS at calving f; e_{ijkfl} = random error associated with the observations Y_{ijkf} considering independent and normally distributed, with mean zero and variance σ^2.

Results and Discussion

Table 2 summarises the variance analysis for the reproductive and productive characteristics of F1 Dorper x Santa Ines and Santa Ines ewes. The fertility of the ewes was significantly influenced ($p < 0.05$) by all variables included in the model. Notable differences ($p < 0.05$) in prolificacy were observed across production cycles, BCS at calving (BCSC), and ewe weight at calving.

Table 2
Summary of the analysis of variance (significance and mean squares) as a function of the ewe's genetic group, production cycles and BCS at mating and at calving

Sources of variation	DF	Mean square			
		FERT	PROL	TWLB	TWLW
Genetic group of the ewe = g	1	0.8873*	0.0014	3.9718	631.4300*
Production cycle = c	4	0.7995**	0.9625*	7.6136*	33.4253
Ewe’s BCS at mating = a	2	0.4330*	-	3.1808	22.5220
Ewe’s BCS at calving = h	2	-	2.4571*	1.1638	20.5320
Ewe's age at calving = I	1	0.4758*	0.1359	5.9454	1.6416
Ewe’s weight at calving = P	1	-	4.0346*	-	43.5420
g x a	2	0.8842*	-	5.8072	27.7370
g x h	2	-	0.1737	0.8192	9.1969
Experimental error		0.1128 (452)	0.3057 (381)	2.7378 (377)	45.1490 (319)
Interactions breakdown					
g x 1st class of a	1	0.0130	-	-	-
g x 2nd class of a	1	2.2184**	-	-	-
g x 3rd class of a	1	0.2043	-	-	-
a x gD	2	0.0158	-	-	-
a x gSI	2	1.2722**	-	-	-
CV (%)		39.37	37.21	31.71	31.88

** Significant at 1% probability by the F test; *Significant at 5% probability by the F test;
DF = Degree of freedom; Mean in brackets represents the DF of the experimental error;
FERT (Fertility: ratio of ewes lambing to those exposed to the ram); PROL (Prolificacy: number of lambs born per lambing ewe); TWLB (total weight of lambs born); TWLW (total weight of lambs weaned).
gD = Dorper genotype; gSI = Santa Ines genotype; CV = Coefficient of variation.

For the productivity characteristics, TWLB was significantly influenced ($p < 0.05$) by production cycle, whereas TWLW was significantly influenced ($p < 0.05$) by the ewe's genetic group. For the assessed interactions, a significant response was noted in the fertility interaction (F test) between genetic group and BCS at mating. When evaluating all interactions, a significant effect ($p < 0.05$) was observed for BCS in coverage in the category 2.5 > BCS ≤ 3.5 and BCS > 3.5 between the genetic groups, with the highest fertility rates for F1 Dorper x Santa Ines ewes (Tables 2 and 4).

The third production cycle presented the lowest ($p < 0.05$) fertility rate at 66.46%, which represented a 22.18% lower level than the average fertility rates of the other production cycles (85.41%). This resulted in an overall average fertility rate of 81.62% for the herd’s production cycles (Table 3).

Table 3
Least squares means and standard errors (SE) for fertility, prolificacy, total weight of lambs born and total weight of lambs weaned according to the ewe's genetic group, production cycles, BCS class at mating and at calving of ewes subjected to eight-month lambing intervals

	FERT (%)		PROL		TWLB (kg)		TWLW (kg)	
Effects	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE
Genetic group								
1/2 Dorper	182	88.99a±2.32	162	1.46±4.10	162	5.58±14.24	148	24.80±59.79a
Santa Ines	383	74.25b±1.89	317	1.42±3.33	316	5.18±9.53	268	19.55±39.08b
Production cycle*								
1st	91	92.56±3.69a	91	1.29±6.43ab	90	4.36±18.23b	73	22.94±91.15
2nd	114	81.33±3.09a	100	1.54±5.91a	100	5.76±17.89a	88	21.13±70.74
3rd	121	66.46±3.98b	90	1.60±5.94a	90	6.03±19.33a	83	22.66±74.83
4th	119	87.65±3.22a	100	1.24±5.19b	100	5.17±14.29ab	88	22.89±77.37
5th	120	80.09±3.48a	98	1.53±5.56a	98	5.59±16.30a	84	22.26±77.39
BCS class at mating								
BCS ≤ 2.5	366	88.70±1.78	--	--	315	5.08±9.91	278	21.55±40.39
2.5 > BCS ≤ 3.5	144	77.30±3.39	--	--	113	5.51±16.11	96	21.42±74.52
BCS > 3.5	28	78.85±6.73	--	--	23	5.56±28.05	19	23.55±91.46
BCS class at calving								
BCS ≤ 2.0	--	--	169	1.75±4.62a	168	5.52±13.36	138	22.00±63.20
2.0 > BCS ≤ 2.5	--	--	141	1.44±4.63b	141	5.19±14.56	119	21.27±60.53
2.5 > BCS ≤ 3.5	--	--	96	1.39±5.73b	96	5.52±18.03	85	22.84±78.92
BCS > 3.5	--	--	70	1.18±5.35b	70	5.30±19.33	64	22.58±88.38

Period between the mating and weaning; N = number of observations.
Different letters in the column indicate a significant difference ($p<0.05$) between the means of the effects evaluated.
FERT (Fertility: ratio of ewes lambing to those exposed to the ram); PROL (Prolificacy: number of lambs born per lambing ewe); TWLB (total weight of lambs born); TWLW (total weight of lambs weaned).

Genetic group did not significantly influence prolificacy ($p > 0.05$). However, the study found significant effects ($p < 0.05$) from the production cycle and the BCS class at calving (Table 3). The fourth production cycle exhibited the lowest prolificacy rate of 1.24 lambs per lambing ewe ($p < 0.05$), a decrease compared to other cycles, except for the first cycle, which had a similar prolificacy rate of 1.29 lambs per lambing ewe.

With regard to the BCS class at calving, ewes with a BCS of ≤ 2.0 showed the highest prolificacy ($p < 0.05$), with an average of 1.75 lambs per lambing ewe, outperforming the other BCS classes.

There were significant effects between the TWLB and TWLW classes in relation to genetic group, production cycle, and BCS class. The genetic group notably impacted TWLW, with increase by 5.15 kg the F1 Dorper x Santa Ines group compared to the Santa Ines ewes, resulting in a 26.85% increase in the weaning weight of the lambs, while the production cycle influenced TWLB, as indicated in Table 3

A significant variation ($p<0.05$) in TWLB was observed across different production cycles. The lowest average values were recorded in the 1st and 4th cycles (4.36 kg and 5.17 kg, respectively), whereas the 2nd, 3rd, and 5th cycles exhibited statistically similar average TWLBs, ranging from 5.59 kg to 6.03 kg. Notably, the 3rd cycle showed the highest average TWLB at 6.03 kg, a substantial 38.3% increase compared to the 1st cycle.

The detailed breakdown of ewe fertility, as influenced by genetic group and BCS at mating, is presented in Table 4. The F1 Dorper x Santa Ines ewes displayed consistent fertility rates ($p > 0.05$) across all BCS classes at mating. In contrast, the fertility rate for Santa Ines ewes was different in BCS classes 2 (2.5 > BCS ≤ 3.5) and 3 (BCS > 3.5) compared to class 1 (BCS ≤2.5), showing a decrease of 25.42% in fertility rate.

Table 4
Least squares means of the interaction breakdown between ewe genetic group and BCS at mating as a function of ewe fertility

Genetic group	Ewe's BCS at mating (Score of 1 to 5)		
	Class 1	Class 2	Class 3
	BCS ≤2.5	BCS > 3.5	2.5 > BCS ≤ 3.5
F1 Dorper	88.03 aA	90.85 aA	87.90 aA
Santa Ines	89.45 aA	63.78 bB	69.64 bB

Lowercase letters differentiate the genetic group and uppercase letters differentiate the body condition classes (BCS). Means followed by equal lowercase letters in the columns and equal uppercase letters in the rows do not differ significantly by the Tukey test at 5%.

For ewes in BCS class 1 (BCS ≤2.5) at mating, the genetic group did not significantly affect fertility rates ($p > 0.05$). However, in BCS classes 2 and 3, Santa Ines ewes exhibited lower fertility rates compared to F1 Dorper x Santa Ines, with reductions of 29.8% and 20.8%, respectively.

Fertility

The variation in fertility at calving between F1 Dorper x Santa Ines and Santa Ines ewes (Table 2) might not solely be attributable to the genetic lineage of the ewes but could also be linked to the intensive reproductive management they underwent. Consequently, reproductive intensification might have induced greater reproductive stress in Santa Ines ewes, leading to fewer fertile ovulations and increased embryonic losses compared to F1 Dorper x Santa Ines ewes. Moreover, a contributing factor to the fertility disparity could be the older age of the Santa Ines ewes relative to those of the F1 Dorper x Santa Ines genotype, potentially impacting their fertility rate. Thus, age is a crucial factor to consider for an accurate evaluation of these differences.

The fertility advantage of the F1 Dorper x Santa Ines genotype over the Santa Ines breed is primarily due to non-additive genetic effects such as heterosis and breed-specific traits. Heterosis denotes an improvement in offspring performance or characteristics beyond that of their parents, while breed effect implies inherent genetic differences of a particular breed. Hence, it's plausible to assert that the superiority of crossbred sheep stems from non-additive genetic factors, particularly heterosis (Petrović et al., 2011; Abebe et al., 2023a). This is supported by Tesema et al. (2020) study, which examined reproductive traits in Dorper x Tumele genetic groups. These researchers noted differences in reproductive efficiency, such as fertility, and attributed the crossbred ewes' superiority to heterosis. These findings bolster the present study's conclusion that heterosis plays a pivotal role in enhancing fertility in crossbred genotypes.

Additionally, the implementation of feed supplementation strategies appears to have positively impacted the outcomes. Research indicates that using sorghum silage and forage palm as roughage, alongside concentrates based on maize and soybean meal, and employing multinutritional blocks during all reproductive phases, particularly in dry spells with limited forage availability and quality, benefits the females' body condition. Inadequate energy intake is closely associated with poor female reproductive performance, delayed puberty, extended intervals from first ovulation to post-calving oestrus, and lower conception and pregnancy rates. A diet deficient in protein can reduce amino acid levels in the bloodstream, decreasing pulsatile LH secretion and, consequently, fertility (Randel, 1990; Santos & Sá, 2006).

The utilisation of multinutritional blocks, as emphasised by Ramos et al. (2019) and Syarifuddin et al. (2022), has also proven effective. These blocks, combining macro and micronutrients strategically, fulfil the nutritional requirements of females, especially during dry periods with scarce high-quality forage. Additionally, they simplify feed management by providing consistent supplementation throughout the day.

Hence, the adoption of feed supplementation strategies, such as sorghum silage and forage palm, maize and soybean meal-based concentrates, and multinutritional blocks, has been effective in enhancing the females' body condition, ensuring ovulation and adequate conception, as well as improved fetal survival during production cycles.

Studies by Magaña-Monforte et al. (2013) and Soares et al. (2015) involving Pelibuey and Santa Ines sheep in Mexico's and Brazil's tropical climates, respectively, noted that reproductive parameters like fertility and prolificacy vary with breeding periods. These variations are directly linked to the annual availability and quality of forage, as well as management practices, particularly in nutrition.

Our results showed that Santa Ines ewes with a body condition score (BCS) of 2.5 to 3.5 had lower fertility compared to those with a BCS of up to 2.5 (Table 4), contradicting general literature where ewe fertility positively correlates with body condition and fat deposition.

According to studies by Haslin et al. (2023) and McLaren et al. (2023), high BCS in ewes can impair fertility due to excessive fat accumulation, particularly around the abdominal area and reproductive organs. This buildup can disrupt ovulatory processes and reduce embryo survival, increasing the risk of complications during gestation and lactation. Excess body reserves may also compromise energy balance and adaptation in low-nutrition regions, as stored energy can hinder metabolic adjustment and lower reproductive responses, especially in resource-scarce areas like Brazil's semi-arid regions.

Prolificacy

Prolificacy is a key indicator of reproductive performance in sheep, and understanding its influencing factors is pivotal for enhancing breeding programmes. Numerous studies have highlighted the significant impact of genetic group on prolificacy. Generally expressed as a decimal fraction, and when associated with fertility at birth, it is an important measure for determining reproductive and productive efficiency, as it is directly related to genetics and the viability of herd exploration (Sarmento et al., 2010).

This study's genetic groups displayed similar prolificacy levels, albeit higher than those reported by Silva and Araújo (2000) and Ximenes et al. (2009) for non-specific breed pattern sheep, Santa Ines, and Crioulas. These authors recorded average prolificacy of 1.09, 1.19, and 1.20, respectively, for sheep managed semi-intensively on native caatinga pasture in Ceará, Brazil. However, our study's values were lower than the 1.60 prolificacy for Santa Ines ewes supplemented during the final third of pregnancy reported by Torreão et al. (2014) in Piauí, Brazil.

The observed prolificacy variations between genetic groups may be due to the genetic traits of the ewes studied. Previous research has demonstrated that certain breeds display higher prolificacy, attributed to their reproductive characteristics. The Santa Ines breed, renowned for its high prolificacy, may explain the superior results observed by Torreão et al. (2014) in this breed's ewes.

Given the specifics of this production system, which entails reproduction intensification during adverse climatic periods in the region, the prolificacy values presented (Table 3) exceed the average for hair sheep herds raised semi-extensively on native pastures in northeastern Brazil of 1.09, according to results found by Ximenes et al. (2009). It's crucial to recognize that prolificacy averages can fluctuate between production cycles, and environmental factors, particularly nutrition, play a significant role (Abecia et al., 2006; Fitz-Rodríguez et al., 2009).

Ayele Abebe et al. (2023b) examined the reproductive and productive characteristics of local and Dorper crossbred ewes in a community management system, suggesting that pasture availability, influenced by climate, is crucial in lambing seasonality. They found prolificacy was affected by the lambing season, yet no significant differences were observed between genetic groups.

Therefore, in semi-arid tropical regions, neglecting to enhance feeding and management conditions is not advisable for achieving greater herd reproductive efficiency. Research indicates that this approach fails to boost productive efficiency (Magaña-Monforte et al., 2013). One method to mitigate the adverse impacts of intensive reproductive management on ewes is adjusting pre-calving feeding to maintain adequate weight and BCS at calving. This strategy aims to shorten the interval between calvings and ensure a favourable BCS in the next mating period, potentially leading to increased ovulation, fertility, and offspring numbers.

Regarding BCS at lambing, this study found an inverse relationship between BCS and prolificacy, echoing Bomfim et al. (2014). The authors suggest that this disparity in post-calving BCS is linked to the greater nutritional demands of ewes carrying multiple fetuses compared to those with a single birth, necessitating nutritional management in the final third of pregnancy to prevent a decline in BCS due to a higher rate of twin births.

It is vital to acknowledge that prolificacy is influenced by a myriad of factors, including nutrition, genetics, and reproductive management. Therefore, these elements must be considered when interpreting the results obtained.

Total weight of lambs at birth and at weaning

The similarity in the total weight of lambs born from crossbred ewes (F1 Dorper x Santa Ines) and Santa Ines ewes can be attributed to the neonatal period. During this period, new-born lambs are unable to express the genetic differences that come from their parents. As Mexia et al. (2004) emphasized, to achieve satisfactory outcomes in terms of total lamb birth weight, careful management of both lambing ewes and their offspring is crucial, particularly regarding birth weight. This is because lambs born small, and frail have a diminished survival chance due to difficulties in locating nourishment.

This study revealed that the genetic group of the F1 ewe (Dorper x Santa Ines) significantly impacts the Total Weight of Lambs Weaned (TWLW). This effect is likely due to the complementary nature of the Dorper breed, the expression of direct heterosis in the lambs, and the maternal heterosis of the F1 Dorper x Santa Ines ewes, all contributing positively to their progeny.

Other physiological and environmental factors also influence the increase in total weight of lambs born and weaned. The genetic quality of the rams and ewes involved in crossbreeding plays a significant role (Barbosa et al., 2010). According to Rocha et al. (2016), heterosis and complementarity between breeds were decisive in achieving higher average weight gain rates and, consequently, greater total weight gain in lambs.

Thus, it is evident that the genetic combination of the Dorper breed, along with direct and maternal heterosis in F1 Dorper x Santa Ines ewes, positively impacts the increase in the total weight of weaned lambs. This breed complementarity also contributes to a more rapid average weight gain, resulting in an overall increase in lamb weight gain (Barbosa et al., 2010; Rocha et al., 2016).

Barbosa et al. (2010) found that additive genetic differences between genetic groups from crossings involving Santa Ines, Brazilian Somalis, Dorper, and Poll Dorset breeds significantly influence weaning weight and weight gain from birth to weaning, directly related to TWLW. Essentially, the higher the proportion of genes from breeds specializing in meat production, the better these parameters perform due to non-additive genetic effects such as individual, maternal, and recombination heterosis.

F1 ewes (Dorper x Santa Ines), with their larger body structure throughout the reproductive period compared to Santa Ines ewes, can reach calving in conditions favorable for producing and sustaining more milk for their offspring. This may have led to better lamb performance until weaning, a phenomenon similarly observed by Aktaş and Doğan (2014) in a Turkish study, where it was noted that lambs' growth characteristics were influenced by the ewes' weight, as heavier ewes mobilized more body fat for milk production.

Zishiri et al. (2011) analyzed the genetic parameters of Dorper sheep and observed that direct selection for total weight of lambs weaned (TWLW) is more effective in improving the reproductive and productive efficiency of the herd.

The variation in the total weight of lambs weaned (TWLW) across production cycles can be attributed to fluctuating environmental conditions in the region. Factors like inadequate rainfall may not fulfil the nutritional needs of the ewes during gestation and post-calving phases, leading to poor fetal development and low milk production. Additionally, this forage scarcity could contribute to lamb mortality in the initial days of life, thereby reducing the total weight of lambs at birth.

To ensure optimal productivity throughout the production period, it is essential to implement effective feed planning and enhance the availability of quality forage in the field to meet all the sheep's nutritional requirements (Soares et al., 2015).

The variance analysis indicated no statistical significance (P>0.05) for the effect of Body Condition Score (BCS) at mating and calving on TWLB and TWLW under the conditions studied. However, it's important to note that in situations of low feed availability during fetal growth, ewes with low BCS might produce lower-weight lambs, adversely affecting their performance until weaning.

The results obtained for TWLB and TWLW, particularly in ewes with low BCS, can be credited to the proper implementation of nutritional management practices during the last third of gestation and the initial weeks of lactation, as well as the use of creep-feeding from the lambs' early weeks until weaning. These strategies provide the necessary conditions for lamb survival and growth, resulting in favourable ewe productivity in terms of kilograms of lambs weaned per ewe lambed.

In research by Corner-Thomas et al. (2014) in New Zealand, the impact of BCS of ½ Romney, ¼ New Zealand Texel, and ¼ Finn ewes on their offspring's performance was evaluated. Unlike this study's TWLB, no significant effects of BCS at mating on lambs' weight at birth and weaning were observed. However, when examining BCS at the end of gestation in relation to lamb birth weight, significant differences were noted among the evaluated scores. Ewes with a BCS ≤ 2.5 and =3.0 produced heavier lambs, averaging 5.3 kg and 5.2 kg, respectively. Conversely, ewes with BCS =3.5 and ≥ 4.0 had lambs with lower birth weights, averaging 4.9 kg and 4.7 kg, respectively.

According to Corner-Thomas et al. (2014), both live weight and body condition during mating and at calving exert minimal influence on lamb weight at weaning. These factors may not be reliable tools for producers to manipulate lamb birth and weaning weights. They also suggest that the ewe's BCS should not be the sole parameter for assessing the productive efficiency of ewes.

It's crucial to consider the impact of birth type and mortality on the total weight of weaned lambs. Lambs from multiple births typically have lower weights and reduced survival chances to weaning stage (Rocha et al., 2009; Koritiaki et al., 2012). This could explain the lower total weaning weight observed in the Santa Ines genetic group, as, irrespective of the ewes' body condition, this genotype recorded a higher incidence of multiple births and higher lamb mortality before weaning, resulting in reduced production of weaned lambs per ewe.

Conclusion

This study highlighted the need for further research on the reproductive and productive performance of hair sheep, especially regarding the influence of body condition scores on reproductive efficiency. The BCS observed in the Santa Ines breed in this study showed discrepancy when compared to the standards of wool breeds. The use of Santa Ines hair sheep ewes, either pure or crossed with Dorper, can be an effective strategy to enhance reproductive and productive efficiency in sheep production systems in semi-arid regions. Furthermore, the subjective analysis of the body condition score of the matrices may have influenced the data, since there is no concrete device to measure it, and it can be carried out in a human way, subject to underestimation or overestimation.

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