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Productive performance of lambs born in different seasons of the year

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Abstract

Background: The seasonality in lamb supply challenges the development of sheep production. Increasing the duration of the breeding season, aimed at distributing births throughout the year, enables a constant supply of lambs. However, the birth season can influence their productive performance.

Aim: The objective was to evaluate the effect of birth season on birth live weight (BW), daily live weight gain from birth to weaning (DWGBW), weaning live weight (WW), and daily live weight gain from weaning to 150 days (DWGW-150) slaughter age, as well as the influence of ewe age and body condition score (BCS), sex of the lamb, and type of pregnancy (single or twin) on these productive indices.

Methods: The study analyzed production data comprising ten breeding seasons (from 2015 to 2019), 643 matings, and 531 lambs, using binary logistic regression, ANOVA, Tukey's, and *t* tests.

Results: Lambs born in summer exhibited lower productive performance, as evidenced by lower DWGBW (0.22 ± 0.08 kg), WW (18.88 ± 7.82 kg), and DWGW-150 (0.13 ± 0.07 kg). Ewes with prepartum BCS between 3 and 4 gave birth to heavier lambs. After birth, lambs from ewes with BCS between 3 and 4 had a higher DWGBW, while lambs from ewes with postpartum BCS of 1.5 and 2 had a lower WW. Ewes aged 2 to 8 years gave birth to heavier lambs, and ewes aged ≥8 years weaned lambs at a lower weight. After weaning, the weight gain was similar among all age groups. Male lambs had higher DWGBW and WW than female lambs. Lambs from twin pregnancies had lower BW (3.95 ± 1.27 kg), lower DWGBW (0.21 ± 0.08 kg), and lower WW (17.59 ± 8.18 kg). The average lamb mortality rate between lambing and weaning was 12.5%, ranging from 9.8% to 13.9%, with no significant variations between birth seasons. Lambs born in spring and summer needed more anthelmintic treatments than those born in autumn and winter.

Conclusion: The production of lambs outside the traditional season is possible; however, the productive performance of lambs born in the summer is lower than that in the other seasons of the year.

Keywords: Birth season, Finishing lambs, Live weight gain.

Introduction

The demand for quality sheep meat has been increasing in recent years; however, despite the Brazilian herd having approximately 20,628,699 heads (IBGE, 2020), national production cannot meet the domestic market demand (AGROSTAT, 2021).

An effective method of expanding production revenue is increasing the number of lambs produced per ewe each year throughout the year, circumventing also the irregular supply of this meat (Brasil, 2017). But reproductive seasonality can hamper the structuring of the sheep production chain and sustainable development of sheep farming, as it affects the seasonality of supply, especially of lamb meat.

To guarantee a constant supply of lambs, increasing the period of the ewes' breeding season is necessary, enabling births outside conventional times. However, different birth times across the year may affect important aspects of production, such as birth weight, mortality rate, daily weight gain, and susceptibility to parasites (Sušić *et al.*, 2005; Yilmaz *et al.*, 2007). Sen *et al.* (2013) described birth-season-influenced differences in meat quality, pre-and post-weaning growth patterns, and carcass yield.

Considering the possible influence of birth season on productive aspects, it is essential to determine its impact at different stages of lamb production to guide management, minimize losses, and enable production throughout the year. Therefore, the objective was to evaluate the effect of birth seasons on birth weight, weight gain from birth to weaning, weaning weight, and weight gain from weaning to slaughter age, as well as the influence of age and body condition score (BCS) of the mother, sex and breed of the lamb, and type of pregnancy (single or twin) on the aforementioned productive indices. In addition, the mortality rate

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and need for anthelmintic treatment of lambs born in different seasons were also analyzed.

Materials and Methods

Description of data origin

The data on the reproductive control and performance of lambs used in the present observational and retrospective study were obtained from the sheep sector of the Gralha Azul Experimental Farm (FEGA), comprising 10 breeding seasons (between 2015 and 2019), 643 matings and 531 lambs. FEGA is located in the municipality of Fazenda Rio Grande, Paraná, southern Brazil (latitude −25.66114429S, longitude −49.27262198W, 904 m above sea level). The climate in the region is temperate, with a mild summer, without a dry season with evenly distributed rainfall, but with severe and frequent frosts, classified as Cfb according to the Köppen-Geiger climate classification (Caviglione *et al.*, 2000).

The herd was composed of Texel, Ile de France, and Suffolk ewes, and ewes that were crossed between these breeds (crossbreeds). The rams used in the different years were purebreds of Texel, Ile de France, Hampshire Down, and Suffolk breeds.

Reproductive management

The reproductive management in the farm aimed at the birth of lambs throughout the year but did not use an accelerated lambing system. No male effect or hormones were used to induce estrus in the evaluated breeding seasons. The breeding seasons, with a mean duration of 45 days, using 30–40 females per sire, were distributed throughout the year, not just in the traditional reproductive season (from January to June). On average, the pregnancy rate was 83% (winter), 91% (autumn), and 89% (summer), with no differences between them, and 77% in spring. The complete reproductive data were published elsewhere (Heinzen *et al.*, 2023). Lambs were born in different seasons (winter, spring, summer, and autumn) under supervision and assistance in case of need.

Nutritional management

The adopted production system was semi-intensive. During the day, the animals were kept in paddocks formed by native pasture and Pensacola pasture (*Paspalum notatum*) in summer and annual winter pastures of oats (*Avena sativa*) and ryegrass (*Lolium multiflorum*), with a stocking rate of 30–40 ewes/ha; at night, they remained in the pen. They received forage supplementation with hay and corn silage, throughout the year. Ewes in late gestation and lactation and growing lambs were also supplemented with concentrate, with an average crude protein (CP) content of 16%, varying in quantity according to the category, to reach the sheep requirements according to NRC (1995). Lambs and their mothers only had access to pasture paddocks 15 days after birth, when the lambs started to have access to creep feeding, which occurred until weaning (approximately 60 days). In the creep feeding, lambs had *ad libitum* access to concentrate (16% CP). During this period, lambs were weighed weekly. After weaning, the lambs were fed through a semi-intensive system (pasture during the day and in the pen at night). They were also supplemented with concentrate (16% of CP) in a ratio of 1 to 1.5% of their live weight until they were ready for sale at approximately 35 kgs. After weaning, animals were weighed fortnightly or monthly.

Sanitary management

The animals were vaccinated against clostridiosis. Ewes in the final third of gestation and lambs, after the first dose at weaning, received a vaccine booster in 30 days. The other animals received booster vaccination annually. Anthelmintic treatment was performed selectively, and the animals were evaluated using the Famacha and BCS methods (Sotomaior and Cintra, 2018). For lambs, mean daily live weight gain (DWG) was also considered a treatment criterion (Cintra *et al.*, 2019).

Database

For data analysis, the following variables were considered:

I. Ewe data: identification number, date of birth, breed, and pre- and postpartum BCS.
II. Ram data: breed of sire used in each batch of ewes in breeding seasons.
III. Lamb data: identification number, date of birth, birth season (summer, December 21 to March 20; autumn, March 21 to June 20; winter, June 21 to September 22; spring, September 22 to December 20), whether born alive or not, presence of dystocia at birth, birth live weight (BW), weaning live weight (WW), daily live weight gain from birth to weaning (DWGBW), daily live weight gain from weaning to 150 days (DWGW-150), breed, number of anthelmintic treatments, and mortality between birth and weaning.

The pre- and postpartum BCS corresponded to the score observed at a maximum interval of 15 days before or after parturition since the ewes were evaluated weekly or fortnightly.

The breed was determined based on phenotypic traits and pedigree information. Ewes with a phenotypic pattern of a particular breed, although not pure, were considered to belong to this breed. Those that did not show racial standardization were considered crossbreeds. The rams were pure breed, with complete pedigree information. The breed of lambs was determined by the breed of the father and mother if they were the same or half-blood (1/2) of the father's breed if the mother was crossbred. The lamb breeds included Ile de France (ile), Texel (tex), Suffolk (suf), 1/2 Ile de France (1/2ile), 1/2 Texel (1/2tex), and 1/2 Suffolk (1/2suf), and 1/2 Hampshire Down (1/2hd).

The DWGBW was calculated using the following formula, age is considered in days:

$$\text{DWGBW} = \frac{\text{live weight at weaning-live weight at birth}}{\text{age at weaning}}$$

For DWGW-150, the last weighing closest to 150 days of age (WEIGHT150) was considered (approximate age at which the animals were sold). Only live weights between 135 and 165 days of age were used to calculate this index. The DWGW-150 was calculated using the following formula, age is considered in days:

$$DWGW-150=\frac{WEIGHT150-\text{live weight at weaning}}{\text{age}}$$

The number of anthelmintic treatments was based on the number of times that anthelmintic was administered to a lamb. The need for treatment was assessed using FAMACHA and the average DWG (Cintra *et al.*, 2019). For the lamb mortality rate (in which born and weaned represent the number of born and weaned lambs, respectively) between lambing and weaning, the formula used was:

$$\text{Mortality }\%=\frac{\text{born}-\text{weaned}}{\text{born}}\ 100$$

The factors and variables evaluated in this study (season of birth, BCS of the ewe before and after parturition, breed of the mother and father, age of the mother, single or twin pregnancy, BW, DWGBW, WW, DWGW-150, and the number of anthelmintic treatments) were those available in the database. This explains the absence of relevant variables, such as the parity number of ewes and birth weight of stillborn lambs, as well as the difference in the number of observations between the various variables. For statistical analysis, all available data from each lamb were used so that the number of observations for each factor was different.

Statistical analysis

For the statistical analysis, the following tests were adopted.

i. Analysis of variance was used to determine the effect of the season of birth, BCS of the ewe before and after lambing, breed, and age of the ewe, breed, and sex of the lamb, and type of pregnancy (single or twin) on the following variables: BW, DWGBW, WW, DWGW-150, and the number of anthelmintic treatments. Variance homogeneity was analyzed using the Levene test, normality by the Shapiro–Wilk test, and the means were compared using analysis of variance Type III, followed by the Tukey test if homoscedasticity was observed; otherwise, the Bonferroni test was used.
ii. To compare BW between dystocic and non-dystocic deliveries, the *t*-test was used for independent samples, assuming homoscedasticity, according to Levene's test.
iii. The interactions of BW, WW, DWGBW, and DWGW-150 were analyzed by generalized linear model, with the following factors: type of gestation, birth season, sex, and lamb breed, as well as their interactions up to the fourth order. Only the significant interactions are presented in the results.
iv. The level of significance considered for all analyzes was 5%. The analyzes were performed using SPSS V. 25 (IBM Corp, 2017).

Ethical approval

This study was evaluated and approved by the Research Ethics Committee on the Use of Animals at PUCPR (registration number 01620).

Results

The number of observations and averages of the analyzed characteristics are shown in Table 1. The averages for BW and WW were 4.59 and 21.15 kg, respectively. In this herd, the mean age was 64 (± 6.12) days at weaning.

The birth season did not influence the mean BW; however, the effect of the year's season on the productive performance of lambs after birth was observed (Fig. 1). Lambs born in the summer showed lower productive performance than those born in the other seasons, as evidenced by lower DWGBW (0.22 ± 0.08 kg), lower WW (18.88 ± 7.82 kg), and lower DWGW-150 (0.13 ± 0.07 kg).

Regarding the factors linked to the mother (Table 2), ewes with a prepartum BCS between 3 and 4 gave birth to heavier lambs. Offspring of ewes with postpartum BCS between 3 and 4 had a higher DWGBW, while lambs of ewes with BCS of 1.5 and 2 had a lower WW compared to the other lambs, ranging from 13.57 kg (±7.36) to 17.62 kg (±7.77), respectively. After weaning, maternal BCS did not influence lamb weight gain, indicating that post-weaning lamb development was unrelated to the mother.

Regarding the age of the ewes (Table 2), females between 2 and 8 years old gave birth to lambs with an average weight of 4.68 kg (±2.26 kg), which was higher than that of the other age groups; however, the weaning weight of lambs from these females was similar to that of lambs from ewes less than 2 years old. After weaning, the DWG between all ages was similar, implying that lamb development until weaning is closely linked to

Table 1. Number of observations (*n*), mean and SD for the variables of productive performance of lambs born between 2015 and 2019 at Fazenda experimental Gralha Azul.

Variable	*n*	Mean ± SD
BW (kg)	481	4.59±1.17
DWGBW (kg)	465	0.26±0.08
WW (kg)	396	21.15±5.09
DWGW-150 (kg)	250	0.16±0.09
Registered births	531	-
Registered deaths	72	-

(BW): birth live weight; (DWGBW): average daily live weight gain from birth to weaning; (WW): weaning live weight; (DWGW-150): average daily live weight gain from weaning to 150 days of age; (SD): standard deviation.

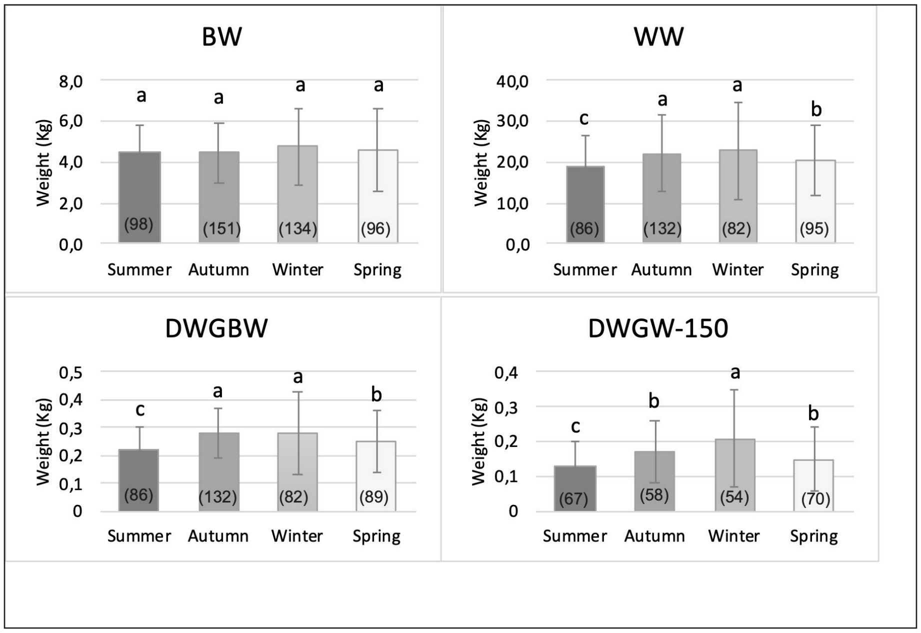

Fig. 1. Lamb productive performance parameters (mean and SD) as a function of the birth season (summer, autumn, winter, and spring). (BW): birth live weight; (DWGBW): average daily live weight gain from birth to weaning; (WW): weaning live weight; (DWGW-150): average daily live weight gain from weaning to 150 days of age. The number of observations (*n*) in each column is in parentheses. Different letters above the columns indicate differences according to Tukey or Bonferroni test ($p < 0.05$).

Table 2. Mean (±SD) of the lambs' productive performance parameters as a function of maternal factors (pre and postpartum BCS, age, and breed of the ewe).

		BW (kg)	DWGBW (kg)	WW (kg)	DWGW-150 (kg)
Ewe BCS prepartum (for BW) and postpartum (for DWGBW, WW and DWGW-150)	1,5	(4) 3.2 ± 0.42[c]	(3) 0.15 ± 0.06[b]	(3) 13.57 ± 7.36[d]	(1) 0.18 ± 0.09[a]
	2	(9) 3.77 ± 1.66[c]	(16) 0.22 ± 0.08[bc]	(17) 17.62 ± 7.77[cd]	(8) 0.13 ± 0.07[a]
	2,5	(94) 4.23 ± 1.67[bc]	(104) 0.24 ± 0.08[b]	(104) 20.42 ± 8.65[b]	(74) 0.14 ± 0.09[a]
	3	(221) 4.65 ± 1.88[a]	(171) 0.28 ± 0.12[a]	(177) 22.16 ± 10.42[a]	(106) 0.17 ± 0.10[a]
	3,5	(106) 4.81 ± 1.8[a]	(64) 0.27 ± 0.12[a]	(67) 21.35 ± 10.25[ab]	(53) 0.18 ± 0.13[a]
	4	(18) 4.73 ± 1.67[ab]	(8) 0.28 ± 0.12[ab]	(8) 21.24 ± 10.07[abc]	(5) 0.16 ± 0.09[a]
Age of the ewe	<2 years	(41) 4.25 ± 2.17[b]	(29) 0.24 ± 0.12[ab]	(29) 19.97 ± 10.27[a]	(19) 0.17 ± 0.10[a]
	2–8 years	(384) 4.68 ± 2.26[a]	(315) 0.27 ± 0.14[a]	(321) 21.5 ± 11.16[a]	(213) 0.16 ± 0.10[a]
	>8 years	(25) 3.91 ± 1.93[b]	(22) 0.20 ± 0.1[b]	(23) 16.9 ± 8.63[b]	(10) 0.14 ± 0.07[a]
Breed of the ewe	Ile de France	(106) 4.70 ± 2.22[a]	(82) 0.24 ± 0.13[b]	(82) 20.26 ± 10.77[b]	(53) 0.18 ± 0.11[a]
	Suffolk	(44) 4.10 ± 2.20[b]	(38) 0.26 ± 0.15[ab]	(39) 20.73 ± 11.19[b]	(23) 0.14 ± 0.07[ab]
	Texel	(132) 4.96 ± 2.44[a]	(106) 0.29 ± 0.15[a]	(108) 22.81 ± 11.74[a]	(73) 0.14 ± 0.07[b]
	Crossbred	(156) 4.39 ± 1.95[b]	(134) 0.25 ± 0.12[b]	(138) 20.53 ± 10.12[b]	(85) 0.16 ± 0.1[ab]

In parentheses in each column is the number of lambs (*n*). (BW): birth live weight; (DWGBW): average daily live weight gain from birth to weaning; (WW): weaning live weight; (DWGW-150): average daily live weight gain from weaning to 150 days of age; (BCS): body condition score. Different letters in the columns indicate differences according to Tukey or Bonferroni tests ($p < 0.05$) for each maternal factor (BCS, age, breed of the ewe).

the maternal condition. It is worth mentioning that the number of lambs born to ewes younger than 2 years or older than 8 years was lower than that in the group aged 2–8 years.

Maternal breed influenced BW, with lambs of Ile de France and Texel ewes having the highest average weights, 4.70 kg (±2.22) and 4.96 kg (±2.44), respectively. DWGBW was higher in offspring of Texel and Suffolk females, with Texel offspring being the heaviest weaners, with 22.81 kg (±11.74). However, after weaning, the offspring of Texel ewes had a DWGW-150 lower than the offspring of Ile de France ewes.

Regarding the variables inherent to the lambs, male lambs had higher DWGBW and WW than females, although sex did not influence BW and DWGW-150 (Table 3). There was an interaction between the sex of the lamb and the type of gestation for the DWGW-150, and male lambs from twin gestation had less weight gain after weaning compared to males from single births, 0.15 ± 0.13 kg and 0.19 ± 0.16 kg, respectively.

Lambs from twin pregnancies had a lower mean BW (3.95 ± 1.27 kg) than lambs from single gestation (5.01 ± 1.6 kg). Twin lambs also had lower DWGBW (0.21 ± 0.08) and were weaned with a lower average weight (17.59 ± 8.18); however, after weaning, DWG was similar in both groups (Table 3).

Regarding the lamb breed, BW ranged from 3.77 kg (±1.88) to 5.07 kg (±2.58), and weaning weight ranged from 19.21 kg (±9.94) and 23.56 kg (±12.11), with differences between breeds (Table 3).

There was an interaction between breed and pregnancy type for BW and DWGW-150 (Table 4). Although Suffolk lambs had lower BW in single births, the same was not observed when these lambs were from twin pregnancies, with BW equivalent to that of the other breeds. After weaning, the weight gain of lambs from Ile de France was higher in twin pregnancies.

Considering the mortality rate of lambs between lambing and weaning, the average mortality rate between the years was 12.5%, ranging from 9.8% to 13.9%. In this study, there were no significant variations in mortality rate between birth seasons, BCS of the prepartum ewes, type of pregnancy, and age of the mother. However, there was an interaction between birth season and the age of the ewe for mortality rate, and lambs from ewes aged 2–8 years had a lower mortality rate (9%) in the winter period compared to ewes under 2 (31%) and over 8 years of age (50%) ($p < 0.05$).

The influence of BW on lamb survival could not be evaluated because lambs that were stillborn or died on the day of delivery were not weighed. However, regarding peripartum complications, it was possible to observe that the birth weight of lambs in dystocic deliveries (5.37 ± 1.34 kg) was higher ($p < 0.05$) than in non-dystocic deliveries (4.54 ± 1.14 kg). Dystocia and myiasis were identified as the leading causes of mortality in lambs until weaning. Although the difference was not statistically significant, the highest deaths from myiasis occurred in summer (5/10, 50%) and autumn (4/10, 40%). Regarding deaths from

Table 3. Mean (±SD) of the lambs' productive performance parameters as a function of the evaluated factors inherent to the lamb (sex, type of pregnancy, and lamb breed).

		BW (kg)	DWGBW (kg)	WW (kg)	DWGW-150 (kg)
Sex of the lamb	Male	(244) 4.64 ± 1.60^{a}	(202) 0.27 ± 0.11^{a}	(207) 21.72 ± 10.00^{a}	(120) 0.17 ± 0.11^{a}
	Female	(235) 4.53 ± 1.36^{a}	(186) 0.25 ± 0.10^{b}	(188) 20.53 ± 9.49^{b}	(129) 0.15 ± 0.10^{a}
Pregnancy type	Single	(293) 5.01 ± 1.60^{a}	(239) 0.29 ± 0.11^{a}	(245) 23.33 ± 10.38^{a}	(149) 0.17 ± 0.11^{a}
	Twin	(186) 3.95 ± 1.27^{b}	(149) 0.21 ± 0.08^{b}	(150) 17.59 ± 8.18^{b}	(100) 0.15 ± 0.09^{a}
Lamb breed	½ hd	(12) 4.42 ± 2.15^{bc}	(11) 0.29 ± 0.15^{ab}	(12) 21.63 ± 10.66^{ab}	(1) 0.16 ± 0.05^{ab}
	½ ile	(61) 4.58 ± 2.09^{bc}	(47) 0.27 ± 0.13^{abc}	(48) 21.28 ± 11.01^{ab}	(29) 0.21 ± 0.14^{a}
	½ suf	(43) 4.30 ± 1.72^{c}	(41) 0.23 ± 0.10^{c}	(43) 19.75 ± 9.00^{b}	(36) 0.14 ± 0.08^{b}
	½ tex	(80) 4.74 ± 2.35^{ab}	(61) 0.25 ± 0.14^{abc}	(61) 20.89 ± 11.14^{ab}	(33) 0.13 ± 0.07^{b}
	suf	(20) 3.77 ± 1.88^{c}	(17) 0.23 ± 0.13^{bc}	(18) 19.21 ± 9.94^{ab}	(17) 0.14 ± 0.07^{b}
	tex	(93) 5.07 ± 2.58^{a}	(75) 0.30 ± 0.15^{a}	(77) 23.56 ± 12.11^{a}	(51) 0.14 ± 0.08^{b}
	ile	(62) 4.42 ± 1.90^{c}	(48) 0.25 ± 0.14^{c}	(48) 20.23 ± 10.90^{b}	(32) 0.21 ± 0.13^{a}

In parentheses in each column is the number of lambs (*n*). (BW): birth live weight; (DWGBW): average daily live weight gain from birth to weaning; (WW): weaning live weight; (DWGW-150): average daily live weight gain from weaning to 150 days of age; (hd): Hampshire Down; (ile): Ile de France; (suf): Suffolk; (tex): Texel. (½): means half-blood of the described breeds. Different letters in the columns indicate differences according to Tukey or Bonferroni test ($p < 0.05$) for each factor (sex, type of pregnancy, and lamb breed).

Table 4. Mean (±SD) of BW, in kg and average of age DWGW-150, in kg for interaction between lamb breed and type of pregnancy (single or twin).

	BW (kg)		DWGW-150 (kg)	
Lamb breed	**Single**	**Twin**	**Single**	**Twin**
½ hd	(22) 4.95 ± 2.48 ^{aAB}	(12) 3.45 ± 0.79 ^{bA}	(2) 0.14 ± 0.03^{aC}	(3) 0.17 ± 0.08^{aAB}
½ ile	(53) 4.77 ± 2.37^{aB}	(32) 4.11 ± 1.10^{bA}	(28) 0.25 ± 0.16^{aA}	(15) 0.15 ± 0.08^{aB}
½ suf	(35) 4.24 ± 2.06^{aC}	(35) 4.12 ± 1.01^{aA}	(30) 0.15 ± 0.08^{aBC}	(24) 0.14 ± 0.07^{aB}
½ tex	(65) 5.26 ± 2.69^{aA}	(48) 4.04 ± 1.29^{bA}	(26) 0.14 ± 0.06^{aC}	(20) 0.13 ± 0.07^{aB}
suf	(6) 3.40 ± 2.01^{aC}	(114) 3.68 ± 0.65^{aA}	(5) 0.14 ± 0.07^{aC}	(12) 0.14 ± 0.06^{aB}
tex	(76) 5.19 ± 2.68^{aA}	(17) 4.03 ± 2.03^{bA}	(40) 0.14 ± 0.07^{aC}	(11) 0.15 ± 0.08^{aB}
ile	(36) 4.97 ± 2.55^{aAB}	(26) 3.65 ± 1.21^{bA}	(18) 0.21 ± 0.11^{aAB}	(14) 0.21 ± 0.14^{aA}

In parentheses in each column is the number of lambs (*n*). (BW): birth live weight; (DWGW-150): average daily live weight gain from weaning to 150 days of age; (hd): Hampshire Down; (ile): Ile de France; (suf): Suffolk; (tex): Texel. (½): means half-blood of the described breeds. Different lowercase letters in the lines indicate differences in BW or DWGW-150 between pregnancy types in the same breed. Different capital letters in the columns refer to differences in BW or DWGW-150 among different breeds for the same type of pregnancy, according to Tukey or Bonferroni test ($p < 0.05$).

Table 5. Mean (±SD) of the number of anthelmintic treatments to which the lambs were submitted, from birth to slaughter, as a function of the evaluated factors (lamb breed, type of delivery, birth season).

		n	**Number of anthelmintic treatments Mean ± SD**
Lamb breed	½ hd	41	0.00 ± 0.00^{d}
	½ ile	22	0.49 ± 1.11^{c}
	½ suf	38	1.54 ± 1.72^{a}
	½ tex	23	0.38 ± 0.96^{cd}
	suf	17	1.37 ± 1.43^{a}
	tex	34	0.53 ± 1.13^{c}
	ile	27	0.69 ± 1.33^{b}
Type of delivery	Single	112	0.67 ± 1.22^{b}
	Twin	84	1.06 ± 1.56^{a}
Birth season	Summer	62	1.12 ± 1.17^{a}
	Autumn	44	0.79 ± 1.80^{b}
	Winter	20	0.18 ± 0.52^{c}
	Spring	70	1.33 ± 1.26^{a}

(*n*): Tthe number of lambs; (hd): Hampshire Down; (ile): Ile de France; (suf): Suffolk; (tex): Texel. (½): means half-blood of the described breeds. Different letters in the column indicate a significant difference between the groups for each factor (lamb breed, type of delivery, birth season), according to the Tukey or Bonferroni test ($p < 0.05$).

dystocia, a higher incidence was observed in autumn (17/41, 41.5%) and winter (14/41, 34.1%).

With regard to anthelmintic treatments (Table 5), the greater susceptibility to parasites in this study is related to lamb breed, birth season, and type of pregnancy. The lambs that most needed treatment was suf or 1/2 suf, born in spring or summer from twin pregnancy ($p < 0.05$).

Discussion

Although no difference was observed in the average BW of lambs born in different seasons in this study, Sormunen-Cristian and Suvela (1999) and Yilmaz *et al.* (2007) reported that lambs born in winter were heavier than lambs born in spring, whereas Sušić *et al.* (2005) observed higher BW in lambs born in spring and summer. In addition to the influence of food availability and climatic conditions, differences in growth patterns, and body composition of lambs born in different seasons may be related to the nutritional status of mothers during pregnancy (Kuran *et al.*, 2007, 2008; Ensoy *et al.*, 2008). During pregnancy, nutritional changes to which the mother may be exposed will potentially influence fetal development and may alter the development of muscle, adipose, and connective tissue, as competition for stem cells may occur between these tissues (Bonnet *et al.*, 2010; Du *et al.*, 2010) in cases of inadequate nutrition. Yilmaz *et al.* (2007) also suggested that seasonal differences in birth weight may be due to environmental conditions, which influence the quantity and quality of forage available, thus impacting the ewe's condition during pregnancy. The supplementation with concentrate provided to the ewes in this study, in the final third of gestation, may have contributed to the similar weights at birth, regardless of the season, since it allowed the animals to be kept in a good BCS, which, as reported in Table 2, significantly influenced birth weight.

Meanwhile, the postpartum parameters were influenced by the birth season, with summer being the season where the lowest productive performance was observed in all phases. The quality of ewe milk is essential for the performance of lambs from birth to weaning, and weight gain is directly related to the quality of the diet provided to lambs. The variations in the parameters in the postpartum period may be related to the dry matter consumption of both mothers, which will impact the production and quality of the milk, as well as the consumption of the lamb, which would be higher in the winter period and lower in the warmer seasons (Yilmaz *et al.*, 2007; Gbangboche *et al.*, 2008). The nutritional inferiority of summer grasses, especially in terms of protein content, will also likely play a role (Hoveland and Monson, 1980; Moore, 1980).

Several studies have reported a relationship between the BCS of the ewe before lambing and the BW of lambs (Maurya *et al.*, 2009; Sejian *et al.*, 2010; Oldham *et al.*, 2011). Low BCS during pregnancy, caused by malnutrition in mid-to-late pregnancy, can reduce fetal growth and BW (Kenyon *et al.*, 2007). At the end of gestation, the nutritional demand for ewes, especially those with twin gestations, increases significantly (Nicol and Brookes, 2007). Under conditions where sheep cannot meet the increased nutritional demand via ingestion, they must utilize body reserves. Therefore, the impact of BCS on fetal growth and lamb BW can be expected to be greater toward the end of gestation, especially in situations where maternal nutrition is limited.

The pre-and postpartum body conditions can affect the productive performance of ewes and lambs until weaning since they directly influence the quality and efficiency of colostration, interfering with the transfer of passive immunity, and milk production during lactation (Karakuş and Atmaca, 2016). Al-Sabbagh (2009) reported that ewes with a BCS between 2.5 and 3.5 produced more colostrum than ewes with a score less than 2.5 and greater than 3.5, and Karakuş and Atmaca (2016) observed that ewes showing good body condition ensured a quality colostrum production, weaning heavier lambs. At the beginning of lactation, up to a third of the milk produced by a ewe is obtained through the mobilization of fat and protein stores (Cannas, 2002); therefore, ewes with higher BCS tend to produce more milk, especially under conditions where they have lost weight during lactation. Therefore, BCS monitoring is important for identifying ewes with low lambing scores and feeding them strategically during lamb suckling, benefiting growth rates (Mathias-Davis *et al.*, 2013).

An increase in BW with the advancing age of the ewe has been reported in the literature (El-Karim and Owen, 1988; Ali *et al.*, 2006). Ali *et al.* (2006) argued that it results from physiological phenomena, in which the size of the ewes increases with advancing age, up to a peak. Moreover, younger ewes are still developing in size and weight and therefore use energy for their own growth, which can affect the BW of their lambs. In contrast, older sheep, reaching full growth, can divert all their energy toward productivity (Ali *et al.*, 2006). Therefore, adult ewes are likely to produce the heaviest lambs at birth; however, in this study, this result was not observed in ewes older than 8 years.

Regarding the influence of maternal breed on the productive parameters of lambs, it is known that the growth of mammals during the suckling period is influenced by their genes as well as by environmental influences. Some of them can be attributed to the mother's genotype, as the growth rate of young infants can be considerably influenced by the lactational performance of the mother and varies between different breeds (Tosh and Kemp, 1994).

With respect to performance differences between male and female lambs, the growth advantage of male lambs is attributed to the presence of testicular hormones, particularly testosterone (Schanbacher *et al.*, 1980). The literature also states that lambs from twin births present lower development than lambs from single births, as there is intrauterine competition for nutrients and, after birth, by maternal milk (Yilmaz *et al.*, 2007; Mohammadi *et al.*, 2010). Twin lambs consume smaller amounts of milk because, despite the higher milk production of ewes with multiple fetuses, this increase is not sufficient to meet the demand for suckling lambs (Carneiro *et al.*, 2004; Allah *et al.*, 2011; Castro *et al.*, 2012). However, despite the lower productive performance, a twin pregnancy is desirable from the point of view of meat production.

Considering the interaction between breed and type of pregnancy for BW and DWGW-150 (Table 4), it can be observed that there are breeds that present a superior productive performance before weaning, such as the Texel breed, whereas others stand out after weaning, like the Ile de France breed. Improving lamb weight gain, in addition to reducing slaughter age and improving meat and carcass quality, is possible with the use of breeds specialized in meat production (Cameron and Drury, 1985; Cunha *et al.*, 2000). However, there may be productive differences between the breeds used and within the breeds in different production systems (Crouse *et al.*, 1981; Cameron and Drury, 1985; Kempster *et al.*, 1987). These breed variations must be considered to establish which breed corresponds to the objectives of each production system.

No significant variations were observed in this study for mortality rate, in the factors studied. Although the extent of perinatal mortality mainly depends on the management system, the main factors that affect lamb survival include lamb BW, type of gestation (single or multiple), nutrition, ewe parity, and the birth season (Notter *et al.*, 1991; Gatenby *et al.*, 1997). Sušić *et al.* (2005) observed higher mortality rates in the winter and summer months, and the negative effects of maternal malnutrition on lamb survival are well documented (Hinch and Brien, 2014). It is also known that the poor survival of low-birth-weight lambs may be associated with a lower thermoregulatory capacity in relation to size and energy reserves (Robinson, 1981; Dwyer and

Morgan, 2006), and there is evidence that they are relatively less mobile (vigorous) than larger lambs (Hinch *et al.*, 1985; Nowak and Poindron, 2006).

The observed mortality rates, varying from 9.8% to 13.9% between years, demonstrate that the property management was efficient in minimizing the risks (confined animals, sheltered and protected from low temperatures, continuous veterinary monitoring of the pregnant ewes and newborn lambs). In temperate climate regions, mortality rates of 15% to 32% have been described in Uruguay (Azzarini and Ponzoni, 1971), and in the Rio Grande do Sul State, Brazil, a mortality rate of 15% to 40% (Riet-Correa and Méndez, 2001), with the starvation/hypothermia complex being responsible for 56%–78% of deaths.

From the analysis of the number of anthelmintic treatments (Table 5), a relationship was observed between breed, birth season, and type of pregnancy. Different studies have addressed resistance to parasitic gastrointestinal infections among different breeds, and among these studies, lower resistance was observed in the Suffolk breed (Amarante *et al.*, 2004; Good *et al.*, 2006). In addition to the racial aspect, environmental factors directly influence the composition and regulation of parasite populations, mainly during the larval stages in the environment (Stromberg, 1997). In this way, the increase in relative humidity and temperature, and characteristics of the spring and summer months in the study region favor the development of infective larvae, and lambs born in these seasons find a more challenging environment, corroborating the results found, which show a greater number of treatments in these seasons. Some factors may explain the greater susceptibility of lambs to twin births. First, the greater energy demand in twin pregnancies can result in greater maternal susceptibility to parasites; thus, at birth, lambs will be in contact with an environment with a greater parasite load (Hayward *et al.*, 2010).

This study suggests that the production of lambs outside the traditional season is possible; however, it should be noted that the productive performance of lambs born in the summer is inferior to that of the year's other seasons. Despite these limitations, it is possible to recommend the adoption of breeding distributed in different seasons of the year, especially for producers who want an accelerated lambing system or the production of lambs throughout the year.

Conflict of interest

The authors declare that there is no conflict of interest.

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Data availability

The data that support the findings of this study are available on request from the corresponding author.

Author contributions

Bruna Cristina Heinzen: conceptualization, investigation, formal analysis, writing—original draft**;** Saulo Henrique Weber: methodology, formal analysis, writing—review and editing; Dhéri Maia—writing—review and editing; Cristina Santos Sotomaior: conceptualization, methodology, writing—review and editing, resources, supervision, project administration.

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