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Environmental effects in the formation of contemporary groups of Santa Inês lambs[1]

Fatores ambientais na formação de grupos de contemporâneos de cordeiros Santa Inês

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Abstract

The objective of this work was to study the influence of environmental effects, sex of the lamb, type of birth, year of birth, birth season, julian birth date, and lambing weight on the weights and biometric measurements of Santa Inês lambs from birth to weaning (70 days of age), and to define the best-adjusted statistical model. Data on weights, heights, body lengths, and thoracic perimeters obtained at birth and close to 28 and 70 days of age from 270 lambs were used. Three analyses were carried out considering different models; one with isolated environmental factors, one with animals grouped into contemporaries according to lamb sex, type of birth, year of birth, and season of birth (GC1), and one with animals gathered in groups of contemporaries according to lamb sex, type of birth, year of birth, season of birth, and the julian date of birth (GC2). Environmental factors influenced a large proportion of body weights and measurements from birth to weaning; the main factors were type of birth and year of birth. The GC2 evaluations presented higher determination coefficients and lower values for Akaike information criteria. However, many observations were discarded; 114, 111, and 103 compared with those rejected by the GC1 analysis, which included two, three, and four observations at birth, 28 days of age, and at weaning, respectively. This may lead to the exclusion of animals with genetic potential.
Keywords: Julian date. Biometric measures. Body weight.

Resumo

Objetivou-se com este trabalho avaliar a influência dos fatores ambientais, sexo do cordeiro, tipo de parto, ano de nascimento, época de nascimento, data juliana de nascimento e peso da mãe ao parto sobre os pesos e medidas biométricas de cordeiros da raça Santa Inês do nascimento ao desmame (70 dias de idade), e avaliar duas diferentes composições de grupos de contemporâneos. Foram utilizadas informações de peso corporal, altura de cernelha, comprimento corporal e perímetro torácico de 270 cordeiros ao nascimento e próximas aos 28 e aos 70 dias de idade. Foram realizadas três análises, utilizando-se diferentes modelos. Um modelo com efeitos de ano de nascimento, época de nascimento, sexo da cria e tipo de parto e o peso da mãe ao parto com efeitos linear e quadrático e a data juliana de nascimento. Outros dois modelos foram avaliados, com os animais reunidos em grupos de contemporâneos de acordo com sexo do cordeiro, tipo de parto, ano de nascimento e época de

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nascimento (GC1), e com os animais reunidos em grupos de contemporâneos de acordo com sexo do cordeiro, tipo de parto, ano de nascimento, época de nascimento e a data juliana de nascimento (GC2). Os fatores ambientais influenciaram grande parte dos pesos e medidas corporais do nascimento ao desmame, sendo que os principais efeitos foram o tipo de parto e ano de nascimento. As avaliações com GC2 apresentaram maiores coeficientes de determinação e menores critérios de informação Akaike, porém grande número de observações foi descartado, 114, 111 e 103, quando comparadas aos números de observações descartadas da análise com o GC1, que foram de 2, 3 e 4 observações ao nascer, aos 28 dias de idade e ao desmame, respectivamente, o que pode acarretar na exclusão de animais com bom potencial genético para as características analisadas.
Palavras-chave: Data juliana. Medidas biométricas. Peso corporal.

Introduction

Due to its adaptability, Santa Inês is the main breed of sheep raised in Brazil (MCMANUS et al., 2014), whose origin is still widely discussed (BIAGIOTTI et al., 2013). According to Paiva et al. (2005), the breed derives from successive crosses of Bergamácia with Rabo Largo, Somali and Morada Nova breeds. In tropical regions, Santa Inês sheep behave as non-seasonal polyestrous, i.e., with estrus throughout the year, which allows up to three parturitions in two years (OLIVEIRA et al., 2014). Therefore, the breed constitutes an interesting genotype in regions with tropical climate.

Growth characteristics are of high interest in sheep farming. Biometric measurements, such as thoracic perimeter, body length, and height at withers, vary according to body weight and have been used to evaluate growth and to characterize animals (MENEZES et al., 2008; SOWANDE; SOBOLA, 2008). Differences observed in performance among individuals can be due to genetic and environmental factors. Among the main environmental effects that influence the performance of Santa Inês sheep during pre-weaning are lamb sex, type of calving, year of birth, and maternal outcome (KORITIAKI et al., 2013). In this context, groups of contemporaries are an alternative to reduce the impact of the environment on the expression of characteristics of interest determined in a breeding program (BOURDON, 2000). The quality of the statistical model used for genetic evaluations is affected by the composition of contemporary groups, since this can eliminate deviations caused by environmental effects (VAN VLECK, 1987).

The objective of this study was to evaluate the influence of environmental factors on weight and biometric measurements from birth to weaning in Santa Inês lambs, and to compare different formations of contemporary groups to define the best-adjusted statistical model to compare individuals in order to minimize bias.

Material and Methods

The data used in this study were derived from the biometric measurements and weights of 270 Santa Inês lambs, born between 2008 and 2013 at the School Farm of the Londrina State University, Londrina, Paraná State, Brazil. The School Farm is located at 23° 23′S in latitude and 51°11′ W in longitude. It is characterized by two well-marked climatic seasons, one of abundant rainfall from October to March, and one of drought from April to September.

The animals were submitted to similar management conditions and kept in a pasture with Coast cross (*Cynodon dactylon[L.] Pers*) with mineral salt available in appropriate troughs and they received sorghum silage and concentrate as a supplement during the winter. Sanitary management was standard, and helminths were controlled based on the results of faeces tests. Lambs were weaned at approximately 70 days of age. Body weight and biometric measurements were measured weekly from birth to weaning. Three biometric measurements were performed with a tape measure, the height at withers was measured between the highest point of the interscapular region (withers) and the soil; the body length from the withers to the caudal part of the ischial tuberosity; and the thoracic perimeter was measured at the outer circumference of the thoracic cavity near the armpits.

A file was edited with weights and biometric measures at birth, adjusted to 28 and 70 days of age (weaning), as follows:

$$X_a = \left\{\left[\frac{(X_r - X_n)}{ID_r}\right] x\ ID_a\right\} + X_n$$

where:

X_a = weight or body size adjusted for the standard age;

X_r = weight or body mass observed at the considered age;

X_n = weight or body measurements observed at birth;

ID_r = age of the lamb at the time of the measurement;

ID_a = standard age.

The julian birth date was calculated using time of birth, represented by the birth date of the lamb considering the julian calendar, which varies from 1 to 365 days.

First, environmental factors were analyzed separately and subjected to analysis of variance, considering sex of the lamb, type of calving, year of birth, and lambing season as independent variables; and weight of mother at birth and the julian date of birth as covariates.

The method of generalized least square was used with the following fixed model to analyze the effects of environment on lamb performance:

$$Y_{ijklmno} = \mu + S_i + TP_j + A_k + E_l + b_1(PM_{ijklm}) + b_2(PM_{ijklm})^2 + b_3(DJN_{ijklmn}) + \varepsilon_{ijklmno}$$

where:

$Y_{ijklmno}$ = set of dependent variables (weight or body measurements of lambs);

μ = overall mean;

S_i = fixed effect of the i-th sex of the lamb (i= male or female);

TP_j = fixed effect of the j-th type of calving (j= singleton or twins);

A_k = fixed effect of the k-th year of birth (k= 2008, 2009, 2010, 2011, 2012, or 2013);

E_l = fixed effect of the l-th lambing season (l= dry or rainy seasons);

b_1 and b_2 = coefficients of linear and quadratic regression of the variable as a function of the weight of the mother at birth, respectively;

PM_{ijklm} = fixed effect of the m-th weight of the mother at birth;

b_3 = coefficient of linear regression of the variable according to the julian date of birth of the animal;

DJN_{ijklmn} = effect of the n-th julian date of birth;

$\varepsilon_{ijklmno}$ = random error associated with each observation.

Two other models considering the same effects as the previous model were evaluated, but with the effects grouped into two distinct groups of contemporaries. Thus, in the second model, the independent variable was Group of Contemporary 1 (GC1), which included the effects of year of birth, lambing season, sex of the lamb, and type of calving; weight of the mother at lambing (linear and quadratic) and julian date of birth (linear) were included as covariates.

In the third model evaluated, the independent variable was Group of Contemporary 2 (GC2), which included the effects of year of birth, lambing season, sex of the lamb, type of calving; in this case, the julian date of birth was considered in the definition of the group of contemporaries, and the weight of the mother at lambing (linear and quadratic) was treated as a covariate.

Groups of contemporaries with less than five animals were discarded from the analyses. Akaike information criterion (AIC) was used to determine the most appropriate model to analyze the performance of lambs for weight and morphometry from birth to weaning. Akaike (1973) developed the AIC to select the best models; the AIC originates from the minimization of information or Kullback-Leibler distance (K-L) based upon model selection. K-L information is a measure of the distance between the true model and the candidate model. Thus, the lower the AIC value, the better the candidate model.

Results and Discussion

Sex of the lamb influenced body weight at birth, at 28 days of age, and at weaning, the thoracic perimeter at birth (Table 1), and height at withers at 28 days of age and weaning (Table 2). The mean values for characteristics influenced by sex were higher for males than for females (Table 3).The type of calving affected all weight and biometric measurements from birth to weaning (Tables 1 and 2), where singleton calvings had higher mean weights and biometric measurements compared with lambs born from twin calvings (Table 3). Differences between males and females occur due to sexual dimorphism and the influence of hormones. Females exhibit a slower growth rate and reach a lower weight and size at maturity due to the effects of estrogen, which restricts the development of long bones (SOWANDE; SOBOLA, 2008).Testosterone has more significant action in males; this hormone has an anabolic effect, usually resulting in better growth performance (NUNES, 2008). In a study with Santa Inês lambs, Costa Junior et al. (2006) found differences between sexes in terms of weights and body measurements, with males being heavier and larger than females. Those authors concluded that these differences were accentuated with increasing age of the animals.

Lambs born from singleton calvings are larger and heavier at birth and weaning due to competition intrauterine and subsequent for breast milk (MOHAMMADI et al., 2010). According to Mexia et al. (2004), sheep that conceive lambs of twin calvings have higher but not double milk yields, so that the twin lambs consume less milk than lambs born from singleton calvings.

Ribeiro et al. (2002) found that twin lambs are lighter at birth and weaning than singleton lambs, but the sum of weights of twin lambs is higher than that of singleton lambs, both at birth and weaning. The authors concluded that, for sheep, a higher number of twin calvings is more advantageous, due to their greater contribution to the production system.

The year of birth influenced body weight and height at withers from birth to weaning, and body length and thoracic perimeter at 28 days of age (Tables 1 and 2).

The lambing season influenced body weight at 28 days of age and weaning, thoracic circumference at birth and weaning (Table 1), and height at 28 days of age (Table 2). For characteristics influenced by the time of birth, lambs born in rainy seasons presented higher mean values than those in dry lambing seasons (Table 3).

Table 1. Analysis of variance of body weight and thoracic perimeter at birth, 28 days of age, and weaning in *Santa Inês* lambs.

	At birth		At 28 days of age		At weaning	
Source of variation	DG	MS	DG	MS	DG	MS
Body weight						
Sex	1	3.92**	1	11.77*	1	46.35*
Type of calving	1	25.93**	1	417.54**	1	786.86**
Year of birth	5	2.64**	5	44.45**	5	93.68*
Lambing season	1	2.57ns	1	17.51*	1	143.92**
Julian date (L)	1	1.10ns	1	0.79ns	1	10.85ns
WMB (L)	1	7.17**	1	17.91**	1	4.83ns
WMB (S)	1	5.37**	1	6.98ns	1	0.13ns
Residue	245	0.40	238	2.32	221	8.38
R^2	0.39	-	0.64	-	0.53	-
CV (%)	16.20	-	17.29		20.83	-
AIC	480.3	-	898.6	-	1166.4	-
Thoracic perimeter						
Sex	1	35.11*	1	38.78ns	1	32.66ns
Type of calving	1	316.06**	1	1244.27**	1	1338.11**
Year of birth	5	12.56ns	5	270.96**	5	167.16**
Lambing season	1	32.77*	1	1.04ns	1	89.82*
Julian date (L)	1	4.39ns	1	23.32ns	1	3.13ns
WMB (L)	1	102.90**	1	125.31**	1	10.06ns
WMB (S)	1	78.96**	1	73.75**	1	0.01ns
Residue	245	6.21	238	10.28	221	17.53
R^2	0.30	-	0.60	-	0.55	-
CV(%)	6.62	-	6.67	-	7.37	-
AIC	1090.4	-	1248.3	-	1329.3	-

DG = degrees of freedom; MS = mean square; WMB = weight of the mother at lambing; L = linear; S = square; * = p<0.01; ** = p<0.05; ns= not significant; R^2 = coefficient of determination; CV = coefficient of variation; AIC =Akaike information criterion.

The covariate julian date of birth had a linear influence on height at withers at birth (Table 2). The weight of the mother at birth influenced all measurements at birth, thoracic perimeter, and body height at 28 days of age (Tables 1 and 2); quadratic behavior for weight of the mother at lambing was observed. The weight at 28 days of age had a linear behavior concerning the weight of the mother at lambing.

The year of birth can influence the growth characteristics of lambs, due to climatic and environmental changes such as temperature, thermal stress, amount and distribution of rainfall, and air humidity (SILVA et al., 2008; MOHAMMADI et al., 2010). Climatic variations also affect the availability and quality of the pastures, and consequently, the nutrition of animals raised in the field. Furthermore, the use of certain sires over the years may also influence the results due to variation in measurements depending on the year of birth. Variations in mean values for measurements were not observed according to the year of birth; therefore, comparisons between these values in each year were not justified in this study. However, this effect was considered in the formation of contemporary groups because of their importance.

Table 2. Analysis of variance of height at withers and body length at birth, at 28 days of age, and weaning in *Santa Inês* lambs.

	At birth		At 28 days of age		At weaning	
Source of variation	DG	MS	DG	MS	DG	MS
Height at withers						
Sex	1	49.69^{ns}	1	77.43**	1	63.15*
Type of calving	1	179.29**	1	555.49**	1	611.71*
Year of birth	5	6.68*	5	28.65**	5	87.63*
Lambing season	1	13.89^{ns}	1	40.08*	1	39.84^{ns}
Julian date (L)	1	0.61**	1	6.01^{ns}	1	11.74^{ns}
WMB (L)	1	26.76**	1	111.61**	1	6.28^{ns}
WMB (S)	1	18.48**	1	81.61**	1	0.42^{ns}
Residue	245	6.25	238	8.29	221	16.18
R^2	0.21	-	0.36	-	0.27	-
CV (%)	6.31	-	6.01		7.24	
AIC	1100.7	-	1177.3	-	1311.7	-
Body length						
Sex	1	0.01^{ns}	1	2.23^{ns}	1	0.01^{ns}
Type of calving	1	155.55**	1	639.42**	1	675.79**
Year of birth	5	71.75^{ns}	5	220.46**	5	705.87**
Lambing season	1	3.96^{ns}	1	16.28^{ns}	1	55.99^{ns}
Julian date (L)	1	53.76^{ns}	1	0.08^{ns}	1	19.36^{ns}
WMB (L)	1	86.31**	1	17.31^{ns}	1	4.51^{ns}
WMB (S)	1	75.21**	1	4.84^{ns}	1	17.46^{ns}
Residue	245	6.06	238	6.10	221	17.25
R^2	0.33	-	0.65	-	0.61	-
CV(%)	8.86	-	6.66	-	9.08	-
AIC	1093.3	-	1111.5	-	1325.8	-

DG = degrees of freedom; MS = mean square; WMB = weight of the mother at lambing; L = linear; S = square; * = $p<0.01$; ** = $p<0.05$; ns= not significant; R^2 = coefficient of determination; CV = coefficient of variation; AIC = Akaike information criterion.

Carneiro et al. (2007) and Mohammadi et al. (2010) reported differences between years of birth for weight and weight gain in small ruminants. Differences throughout years can be reduced by improving the available food and aspects relating to the general management of lambs, thus improving development and profitability for the producer (SOUZA et al., 2003).

The lambing season influences lamb performance due to variations in the quantity and quality of available dry matter, affecting the performance of mothers and breast feeding (QUESADA et al., 2002). Barros et al. (2004) stated that the lower weight of offspring born during dry seasons is strongly related to the nutrition of the mother in the final trimester of pregnancy and at the beginning of lactation when the lamb is highly dependent on breast milk.

Sheep weight is related to nutritional status. Thus, when females are well-nourished during the pre-parturition and pre-weaning periods, they tend to produce lambs with better performance (PACHECO; QUIRINO, 2008). According to Geraseev et al. (2006) and Castro et al. (2012), sheep subjected to food restriction conceive smaller and lighter lambs at birth and weaning.

Table 3. Means ± standard error of the mean for body weight (kg), body length (cm), thoracic perimeter (cm), and height at withers (cm) at birth, 28 days of age, and weaning according to sex, type of calving, and time of birth in *Santa Inês* lambs.

Characteristic	Sex of the lamb		Type of calving		Lambing season	
	Male	Female	Singleton	Twins	Rainy season	Dry season
Weight at birth	3.8 ± 0.1a	3.5 ± 0.1b	4.0 ± 0.1a	3.2 ± 0.1b	3.9 ± 0.1	3.4 ± 0.1
Weight at 28 days of age	8.5 ± 0.2a	7.9 ± 0.2b	9.9 ± 0.1a	6.6 ± 0.2b	8.9 ± 0.2a	7.6 ± 0.3b
Weight at weaning[1]	13.2 ± 0.4a	12.3 ± 0.3b	15.2 ± 0.3a	10.3 ± 0.5b	14.7 ± 0.4a	10.9 ± 0.6b
Length at birth	27.1 ± 0.3	27.1 ± 0.3	28.1 ± 0.2a	26.1 ± 0.4b	27.4 ± 0.4	26.8 ± 0.5
Length at 28 days of age	36.7 ± 0.3	36.4 ± 0.3	38.6 ± 0.2a	34.6 ± 0.4b	37.1 ± 0.4	35.9 ± 0.5
Length at weaning[1]	44.9 ± 0.5	44.9 ± 0.5	47.2 ± 0.4a	42.7 ± 0.7b	46.1 ± 0.7	43.7 ± 0.9
Thoracic perimeter at birth	37.4 ± 0.3a	36.7 ± 0.3b	38.4 ± 0.2a	35.6 ± 0.4b	37.9 ± 0.4a	36.1 ± 0.5b
Thoracic perimeter at 28 days of age	47.6 ± 0.4	46.6 ± 0.4	49.8 ± 0.3a	44.3 ± 0.5b	46.8 ± 0.5	47.3 ± 0.7
Thoracic perimeter at weaning	55.6 ± 0.5	54.8 ± 0.5	58.3 ± 0.4a	52.0 ± 0.7b	56.7 ± 0.7a	53.7 ± 0.9b
Height at birth	39.4 ± 0.3	38.5 ± 0.3	40.0 ± 0.2a	37.9 ± 0.4b	39.5 ± 0.4	38.4 ± 0.5
Height at 28 days of age	47.5 ± 0.3a	46.3 ± 0.3b	48.8 ± 0.3a	45.0 ± 0.5b	47.8 ± 0.5a	45.9 ± 0.6b
Height at weaning[1]	54.5 ± 0.5a	53.5 ± 0.5b	56.1 ± 0.4a	51.9 ± 0.7b	54.9 ± 0.6	53.6 ± 0.8

[1]Weaning = 70 days
Different letters on the same line, within each effect, differ statistically by the F test.

Few studies have investigated the julian date of birth in sheep. However, according to Dal-Farra et al. (2002), it is necessary to adjust or include this variable in the model evaluating growth measurements when aiming to perform a genetic assessment of the animals. Thus, more studies considering this effect in analysis models are necessary.

In the group of contemporaries without a Julian date of birth (GC1), we observed the formation of 27 groups, with two, three, and four observations discarded at birth, 28 days of age, and weaning, respectively. Julian date of birth in the model using GC1 was not an important source of variation, and was only significant for body length at birth (Table 4); as observed in the model that included the isolated effects, julian date of birth only affected height at withers at birth (Table 2).

When the julian date of birth was incorporated into the group of contemporaries (GC2), we observed the formation of 65 groups of contemporaries; However, more observations were discarded, from 114, 111, and 103 at birth, 28 days of age, and weaning, respectively (Tables 4 and 5).

The inclusion of several environmental effects in the formation of contemporary is desirable, since this better reflects the environmental conditions in which the animals were submitted, thus leading to a greater homogeneity; however, it removes a higher number of observations. Thus, the greater the number of environmental effects, the higher the number of contemporary groups with few animals and the higher the exclusion of information; in this way, the estimates may be less representative or accurate (LEGARRA et al., 2005; SANTANA JUNIOR et al., 2013).

Table 4. Analysis of variance of height at withers and body length at birth, 28 days of age, and weaningin *Santa Inês* lambs, using different Groups of Contemporaries.

	At birth		At 28 days of age		At weaning	
Source of variation	DG	MS	DG	MS	DG	MS
Height at withers						
GC1	26	21.61**	26	54.71**	26	62.32**
Julian date (L)	1	11.05ns	1	0.13ns	1	32.58ns
WMB (L)	1	39.43*	1	119.35**	1	2.16ns
WMB (S)	1	28.32*	1	82.50ns	1	0.37ns
Residue	225	6.40	217	7.45	199	16.11
R^2	0.34	-	0.53	-	0.38	-
CV (%)	6.37	-	5.69	-	7.21	-
AIC	1031.1	-	1067.5	-	1207.3	-
GC2	64	16.11**	62	20.73**	59	54.50**
WMB (L)	1	4.02*	1	5.95*	1	3.71ns
WMB (S)	1	4.31*	1	4.52ns	1	1.82ns
Residue	76	0.70	74	1.42	68	1.35
R^2	0.95	-	0.93	-	0.97	-
CV(%)	2.11	-	2.52	-	2.09	-
AIC	180.3	-	224.7	-	260.5	-
Body length						
GC1	26	38.68**	26	87.97**	26	190.68**
Julian date (L)	1	64.72**	1	1.67ns	1	5.40ns
WMB (L)	1	59.68**	1	28.01*	1	7.85ns
WMB (S)	1	47.92**	1	9.85ns	1	0.11ns
Residue	225	5.68	217	5.55	199	14.38
R^2	0.48	-	0.73	-	0.72	-
CV (%)	8.52	-	6.36	-	8.30	-
AIC	997.0	-	1007.8	-	1183.8	-
GC2	64	15.14**	62	21.67**	59	82.87**
WMB (L)	1	32.34**	1	6.92*	1	35.90**
WMB (S)	1	33.31**	1	5.51*	1	30.27**
Residue	76	0.78	74	1.09	68	0.94
R^2	0.95	-	0.95	-	0.99	-
CV(%)	3.19	-	2.87	-	2.13	-
AIC	167.2	-	204.9	-	237.9	-

DG = degrees of freedom; MS = mean square; WMB = weight of the mother at lambing; L = linear; S = square; * p<0,01; ** p<0,05; ns= not significant; R^2 = coefficient of determination; CV = coefficient of variation; AIC = Akaike information criterion.

In the model including GC1, the effect of the julian date of birth was significant only for body length at birth (Table 4) and thoracic perimeter at birth (Table 5). Although the effect of julian date of birth was not generally significant in analyses with isolated effects (Tables 1 and 2) and GC1 analyses (Tables 4 and 5), when this effect was included in GC2, there was an increase in the coefficient of determination (R^2), decrease in the coefficient of variation, and reduction in AIC, indicating better adjustment of the model. In addition to the environmental factors identified as important sources of variation, Oliveira (1995) suggested that interaction effects exist between two or more factors.That author reported that the formation of contemporary groups is the ideal way to compare animals when considering the factors and the interaction between them. Thus, although as an isolated effect, the julian date of birth was not a significant source of variation in this data set, it increased the accuracy of the evaluation when included in GC2. However, in this case, there was a significant loss of observations, which may have led to the exclusion of animals with good genetic potential for growth characteristics in sheep breeding programs. Thus, the model containing GC1 was selected for later genetic evaluations of this group of animals, which reconciled homogeneity with a low number of animals being discarded.

Table 5. Analysis of variance of body weight and thoracic perimeter at birth, at 28 days of age, and weaning in *Santa Inês* lambs, using different Groups of Contemporaries.

	At birth		At 28 days of age		At weaning	
Source of variation	DG	MS	DG	MS	DG	MS
Body weight						
GC1	26	2.21^{**}	26	34.10^{**}	26	75.23^{*}
Julian date (L)	1	0.01^{ns}	1	0.23^{ns}	1	64.82^{ns}
WMB (L)	1	6.80^{**}	1	16.23^{*}	1	6.29^{ns}
WMB (S)	1	5.00^{**}	1	5.23^{ns}	1	0.02^{ns}
Residue	225	0.40	217	2.32	199	7.86
R^2	0.46	-	0.71	-	0.65	-
CV (%)	16.36	-	17.24		20.21	-
AIC	461.9	-	839.7	-	1063.5	-
GC2	64	0.98^{*}	62	9.58^{**}	59	27.87^{**}
WMB (L)	1	1.14^{**}	1	4.71^{**}	1	1.93^{ns}
WMB (S)	1	1.05^{**}	1	3.51^{**}	1	0.67^{ns}
Residue	76	0.06	74	0.33	68	1.15
R^2	0.94	-	0.96	-	0.96	-
CV(%)	6.71	-	6.95	-	8.13	-
AIC	65.4	-	158.7	-	250.8	-
Thoracic perimeter						
GC1	26	22.89^{**}	26	141.62^{**}	26	137.71^{**}
Julian date (L)	1	21.91^{**}	1	1.21^{ns}	1	14.94^{ns}
WMB (L)	1	140.65^{**}	1	110.94^{**}	1	17.58^{ns}
WMB (S)	1	114.31^{**}	1	58.58^{*}	1	1.08^{ns}

continue

continuation

Residue	225	6.36	217	9.28	199	17.61
R^2	0.37	-	0.71	-	0.62	-
CV (%)	6.69	-	6.33	-	7.39	-
AIC	1026.4	-	1146.0	-	1225.5	-
GC2	64	11.47**	62	32.21**	59	81.63**
WMB (L)	1	15.93**	1	8.31*	1	16.67**
WMB (S)	1	15.46**	1	5.90*	1	11.92**
Residue	76	0.66	74	1.25	68	1.38
R^2	0.94	-	0.96	-	0.98	-
CV(%)	2.17	-	2.38	-	2.10	-
AIC	190.7	-	253.3	-	262.2	-

DG = degrees of freedom; MS = mean square; WMB = weight of the mother at lambing; L = linear; S = square; * = p<0.01; ** = p<0.05; ns= not significant; R^2 = coefficient of determination; CV = coefficient of variation; AIC = Akaike information criterion.

Conclusion

Environmental effects affected the growth performance of lambs from birth to weaning; thus, they should be considered in analysis models.

The model that used groups of contemporaries considering the year of birth, lambing season, sex of the lamb, and type of calving had good adjustment indicators with a low amount of information lost; it was, therefore, the model chosen in this study. Conversely, although the model containing the julian date of birth in the formation of contemporary groups presented better indicators for adjustment, much information was lost, which could lead to the loss of animals with good genetic potential.

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