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REGULAR ARTICLES

The effect of sex and genotype on growth performance, feed efficiency, and carcass traits of local sheep group Pantaneiro and Texel or Santa Inês crossbred finished on feedlot

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Abstract This study aimed to assess and compare the growth performance, feed efficiency, and carcass traits of Pantaneiro sheep and their Texel and Santa Inês crossbreds. Ninety-six lambs, fifty-one males, and forty-five females, with a mean weaning weight of 15.21±1.25 kg and 78±13 days of age, were slaughtered at a 32-kg body weight. The results showed better production efficiency from males compared with females. Texel-crossed lambs had a better growth performance than the other genotypes. The Texel×Pantaneiro lambs were more efficient with a better feedlot performance, higher ribeye muscle area, and better carcass characteristics with an adequate amount of fat cover. Pantaneiro lambs and their crosses with meat breeds could be useful in meat production systems under Savanna environmental conditions.

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Keywords Animal performance · Breed crosses · Carcass · Pantaneiro

Introduction

The development of specialized sheep breeds has been causing growing concerns regarding the erosion of genetic resources (FAO, 2007). In sheep meat production systems, it is essential to maintain the genetic diversity of the adapted breeds as well as the pure breeds and their crosses with recognized meat breeds. In Brazil, particularly in the Mato Grosso do Sul region, a genetic group designated “Pantaneiro” is very well adapted to the tropical conditions (Gomes et al. 2007). This has led to an increasing interest in the breed from research institutions as well as from farmers as a solution for meat production systems and for complementing meat production by beef producers in Pantanal.

Some studies on the performance of the Santa Inês breed in tropical conditions have been carried out by Pedrosa et al. (2010) and Paim et al. (2013). However, the performance of the local Pantaneiro sheep and their crosses with the most abundant breeds, Santa Inês and Texel, has not yet been studied.

Considering the natural importance of using native breeds on the productive efficiency of meat production systems, the objective of the present work was to evaluate and compare the feedlot performance, carcass traits, and production of non-carcass components of the native lambs Pantaneiro, in relation to crossbred lambs of Texel and Santa Inês with Pantaneiro.

Materials and methods

The experiment was performed at the Sheep Technological Centre on the Três Barras Experimental Farm of the University for the Development of the State and the Region of Pantanal (UNIDERP, Campo Grande, Mato Grosso do Sul, Brazil). The climate of the region, using the Köppen classification, is tropical savanna or a tropical wet and dry climate with a monthly mean temperature above 18 °C (64 °F) in every month of the year, typically a pronounced dry season and with the driest month having precipitation of less than 60 mm.

Animal sampling and diets

A total of 96 lambs, 51 males and 45 females, with a mean weaning weight of 15.21±1.25 kg and 78±13 days of age, of Pantaneiro, Texel×Pantaneiro, and Santa Inês×Pantaneiro crossbreds were used. The distribution of lambs according to sex or genotype is given in Table 1.

Lambs were housed according to sex in pens, three animals to each pen and fed with rations formulated to provide an average daily gain (ADG) of 250 g following NRC (2007) requirements. Lambs were fed twice a day at 8:30 a.m. and 16:00 p.m., with quantities adjusted daily to yield 10 and 20 % of the total feed offered which was weighed to determine the daily dry matter intake (DMI, kg day^{-1}). The dry matter in the diet consisted of 60 % concentrate and 40 % roughage in the form of corn silage. The formulation of the concentrate included 47.88 % ground corn, 32.92 % soybean meal, 15 % wheat bran, 0.1 % probiotic (Biosaf®, *Saccharomyces cerevisiae*, Lesaffre, France), 2 % mineral salts, 2 % calcium carbonate, and 0.1 % vitamins A, D, and E. Animals were weighed every 21 days after a 12-h fasting, until slaughter. During the feedlot period, the following data were recorded: number of days on the feedlot (DF, days), initial and final body weights (IBW and FBW, respectively, kg), ADG (g day^{-1}), DMI (kg day^{-1} and %), and feed conversion (FC, kg DM kg^{-1}).

Carcass and non-carcass components

When lambs reached a body weight of approximately 32 kg, they were slaughtered after a 12-h fasting, and the body weights were recorded (BW, kg). The contents were removed from the digestive tract, weighed, and subtracted from BW before slaughter to obtain empty body weight (EBW, kg). The hot carcass weight (HCW, kg) was recorded. Carcasses were then cooled at 4 °C for 24 h, and the cold carcass weights (CCW, kg) were also recorded. The carcass shrinkage during chilling (CS, %), hot dressing percentage (HDP, %), and cold dressing percentage (CDP, %) were calculated. The true dressing percentage (TDP, %) was calculated as TDP=(HCW/EBW)×100. Omental, mesenteric, perinephric, and retroperitoneal fats were removed, weighed, and recorded as internal fat. The gut, lungs, trachea, diaphragm, heart, liver, kidneys, and other viscera were separated and weighed as non-carcass components. The blood, pelt, head, and feet were removed and weighed as body components. The ribeye area (REA, cm^2) and the subcutaneous fat thickness (SFT, mm) were obtained by cutting the carcass between the 12th and 13th thoracic vertebrae then measuring the area of the exposed *Longissimus dorsi* muscle surface using a planimeter and AutoCAD R14 software and using a caliper, respectively.

Table 1 Lamb distribution according to sex and genotype

Sex	Genotype			Total
	P	TP	SIP	
Male	17	16	18	51
Female	12	13	20	45
Total	29	29	38	96

P Pantaneiro, *TP* Texel×Pantaneiro, *SIP* Santa Inês×Pantaneiro

Statistical analysis

Statistical analyses were performed using the SAS package version 9.2 (SAS Institute, Cary, NC, USA). A fully randomized factorial design was implemented with three genotypes (Pantaneiro, Texel×Pantaneiro, and Santa Inês×Pantaneiro) and two sexes (male and female). The normality of data was verified using the Shapiro-Wilk test (Shapiro and Wilk 1965) and the homogeneity of variances using the Bartlett test (Bartlett 1937). The significance of differences between genotype and sex as well as the interactions was verified using the *t* test for levels of $P<0.05$ and $P<0.01$.

Results

The means and standard deviations of the variables of growth performance for the different genotypes as a function of sex are shown in Table 2. No significant differences between genotypes were found for the IBW and FBW, all animals having started and finished the feedlot with the same body weight, thus allowing comparisons between groups in the same experimental conditions. However, the Texel×Pantaneiro lambs needed 16 fewer days to reach the body weight for slaughter ($P<0.01$) and consequently exhibited a better ADG 217 vs. 177 and 175 g day^{-1} ($P<0.01$) and also a better FC 4.48 against 5.28 and 5.62 kg DM kg^{-1} for Pantaneiro and Santa Inês×Pantaneiro ($P<0.05$), respectively.

For the FBW, DF, ADG, DMI, and FC growth performance variables, males exhibited significantly better results than females. Within each genotype, only the male Santa Inês×Pantaneiro lambs had significantly higher FBW and DMI, but for the other growth parameters, the males were significantly more efficient than females. No significant interactions between sex and genotype were found ($P>0.05$).

Table 3 shows the different carcass traits for each genotype according to sex. The HDP was significantly different

Table 2 Effect of sex (S) and genotype (G) on feedlot performance

Item	G			Mean	P		
	P	TP	SIP		S	G	S×G
IBW, kg					ns	ns	ns
Male	14.95±1.30	15.48±1.18	15.71±1.87	15.36±1.44			
Female	15.12±0.87	14.71±1.30	15.15±0.65	15.02±0.91			
Mean	15.02±1.11	15.19±1.24	15.45±1.42				
FBW, kg					*	ns	ns
Male	33.18±1.69	33.94±2.70	34.30^{A}±2.48	33.77±2.27			
Female	32.80±2.13	33.36±1.45	31.54^{B}±1.61	32.50±1.86			
Mean	33.02±1.84	33.72±2.27	33.00±2.49				
DF, days					**	**	ns
Male	94.73±9.47	79.17±10.29	92.00±6.93	88.72±11.20			
Female	113.43±12.29	98.63±7.67	113.61±9.62	109.46±11.88			
Mean	102.60^{B}±14.09	86.47^{A}±13.34	102.17^{B}±13.72				
ADG, g day^{-1}					**	**	ns
Male	192^{A}±14	234^{A}±13	202^{A}±14	209±22			
Female	157^{B}±21	190^{B}±15	145^{B}±15	161±25			
Mean	177^{B}±24	217^{A}±26	175^{B}±33				
DMI, kg day^{-1}					*	ns	ns
Male	0.93±0.09	0.98±0.15	1.03^{A}±0.15	0.98±0.13			
Female	0.91±0.13	0.94±0.11	0.89^{B}±0.08	0.91±0.11			
Mean	0.92±0.11	0.96±0.13	0.96±0.14				
DMI, %					ns	ns	ns
Male	3.87±0.31	3.95±0.55	4.13±0.44	3.98±0.44			
Female	3.80±0.51	3.91±0.47	3.81±0.41	3.83±0.44			
Mean	3.84±0.39	3.94±0.50	3.98±0.44				
FC, kg DM kg^{-1}							
Male	4.86^{A}±0.34	4.19^{A}±0.65	5.13^{A}±0.83	4.72±0.72	*	*	ns
Female	5.85^{B}±0.77	4.95^{B}±0.45	6.17^{B}±0.78	5.72±0.84			
Mean	5.28^{B}±0.74	4.48^{A}±0.68	5.62^{B}±0.95				

IBW initial body weight, *FBW* final body weight, *DF* days of feedlot, *ADG* allowed daily gain, *DMI* dry matter intake, *FC* feed conversion, *P* Pantaneiro, *TP* Texel×Pantaneiro, *SIP* Santa Inês×Pantaneiro, *ns* not significant

For sex within G, means with different capital, italic, and superscript letters differ significantly for *P<0.05, **P<0.01, and ***P<0.0001

For G, means with different capital and superscript letters differ significantly for *P<0.05, **P<0.01, and ***P<0.0001

For S×G, means with different lower case superscript letters differ significantly for *P<0.05, **P<0.01, and ***P<0.0001

between the three genotypes. The Santa Inês×Pantaneiro had the highest HDP value, while the Texel×Pantaneiro had the lowest compared with Pantaneiro which had an intermediate HDP value but was significantly different from both (P<0.01). Only the Santa Inês×Pantaneiro showed significant differences between sexes. The existence of a significant interaction (P<0.05) shows that the Santa Inês×Pantaneiro females had the highest HDP, while the lowest value was observed for the Texel×Pantaneiro males. The TDP was also significantly higher for the Santa Inês×Pantaneiro females, while the lowest value was for the Texel×Pantaneiro males and females because of the interaction between sex and genotype. No significant differences existed for this trait between Pantaneiro and Texel×Pantaneiro, but both had a significantly lower TDP value than the Santa Inês×Pantaneiro lambs, 56.25 and 55.11 % against 57.95 %, respectively. The CDP was significantly different between genotypes; 48.88, 46.19, and 50.2 % for Pantaneiro, Texel×Pantaneiro, and Santa Inês×Pantaneiro lambs, respectively. The females had higher CDP values than males except for Pantaneiro lambs which showed no significant differences between sexes. The REA observed for Texel×Pantaneiro lambs, 15.41 cm^2, was significantly higher than that for Pantaneiro and Santa Inês×Pantaneiro lambs which were 1.8 and 2.9 cm^2 less, respectively.

The effect of genotype and sex in the non-carcass components are shown in Table 4. The weight of body components

Table 3 Effect of sex (S) and genotype (G) on carcass traits

Item	G			Mean	P		
	P	TP	SIP		S	G	S × G
BW, kg					ns	ns	ns
Male	32.57±2.84	34.16±3.58	34.54±3.25	33.73±3.28			
Female	33.35±3.64	33.68±2.64	31.55±3.65	32.64±3.46			
Mean	32.88±3.15	33.94±3.15	32.92±3.74				
EBW, kg					ns	ns	ns
Male	28.71±2.72	29.23±3.61	30.65±3.30	29.52±3.26			
Female	29.83±3.09	29.49±1.97	28.18±3.34	29.00±2.97			
Mean	29.15±2.87	29.35±2.94	29.32±3.51				
HCW, kg					ns	ns	ns
Male	16.21±1.46	16.12±2.01	17.14±2.01	16.49±1.86			
Female	16.67±2.09	16.21±1.43	16.65±2.31	16.53±2.00			
Mean	16.39±1.72	16.16±1.75	16.87±2.16				
HDP, %					**	**	*
Male	$49.77^{b}\pm1.48$	$47.16^{d}\pm2.31$	$49.55^{bc}\pm2.30$	48.88±2.33			
Female	$49.97^{b}\pm2.55$	$48.11^{cd}\pm1.73$	$52.68^{a}\pm2.62$	50.64±3.05			
Mean	$49.85^{B}\pm1.94$	$47.59^{C}\pm2.09$	$51.24^{A}\pm2.91$				
TDP, %					ns	**	*
Male	$56.52^{b}\pm1.86$	$55.26^{b}\pm3.56$	$55.92^{b}\pm2.95$	55.93±2.83			
Female	$55.86^{b}\pm3.15$	$54.91^{b}\pm2.22$	$59.01^{a}\pm3.50$	56.99±3.55			
Mean	$56.25^{AB}\pm2.43$	$55.11^{B}\pm2.99$	$57.59^{A}\pm3.57$				
CCW, kg					ns	ns	ns
Male	15.85±1.54	15.52±1.96	16.79±2.03	16.06±1.89			
Female	16.36±1.96	15.90±1.49	16.30±2.16	16.20±1.90			
Mean	16.05±1.71	15.69±1.75	16.53±2.08				
CDP, %					**	**	ns
Male	48.64±1.79	$45.38^{\mathit{B}}\pm2.42$	$48.52^{\mathit{B}}\pm2.02$	47.58±2.53			
Female	49.25±2.56	$47.19^{\mathit{A}}\pm1.43$	$51.62^{\mathit{A}}\pm2.24$	49.71±2.82			
Mean	$48.88^{B}\pm2.11$	$46.19^{C}\pm2.20$	$50.20^{A}\pm2.63$				
CS, %					ns	ns	ns
Male	2.28±2.02	3.70±4.24	2.04±1.71	2.64±2.87			
Female	1.78±1.48	1.97±1.85	1.97±1.96	1.92±1.77			
Mean	2.08±1.81	2.92±3.45	2.00±1.82				
SFT, mm					ns	ns	ns
Male	3.32±1.20	3.44±1.45	2.94±0.97	3.23±1.21			
Female	4.10±1.24	3.66±1.03	3.34±1.29	3.61±1.22			
Mean	3.61±1.25	3.54±1.26	3.16±1.16				
REA, cm^2					ns	**	ns
Male	13.66±2.81	15.23±2.43	12.75±3.34	13.85±3.01			
Female	13.53±5.17	15.63±3.11	12.34±2.41	13.61±3.71			
Mean	$13.61^{B}\pm3.84$	$15.41^{A}\pm2.71$	$12.53^{B}\pm2.84$				

BW body weight, *EBW* empty body weight, *HCW* hot carcass weight, *HDP* hot dressing percentage, *TDP* true dressing percentage, *CCW* cold carcass weight, *CDP* cold dressing percentage, *CS* carcass shrinkage during shilling, *SFT* subcutaneous fatness thickness, *REA* ribeye area, *P* Pantaneiro, *TP* Texel×Pantaneiro, *SIP* Santa Inês×Pantaneiro, *ns* not significant

For sex within G, means with different capital, italic, and superscript letters differ significantly for $^{*}P<0.05$, $^{**}P<0.01$, and $^{***}P<0.000$

For G, means with different capital and superscript letters differ significantly for $^{*}P<0.05$, $^{**}P<0.01$, and $^{***}P<0.0001$

For S×G, means with different lower case superscript letters differ significantly for $^{*}P<0.05$, $^{**}P<0.01$, and $^{***}P<0.0001$

Table 4 Effect of sex (S) and genotype (G) on non-carcass components traits

Item	G			Mean	P		
	P	TP	SIP		S	G	S×G
BC, kg					**	**	ns[3]
Male	6.74 ± 0.88	7.37 ± 0.92	$6.85^{A}\pm1.13$	6.98 ± 1.00			
Female	6.68 ± 0.72	6.87 ± 0.51	$5.97^{B}\pm0.70$	6.42 ± 0.76			
Mean	$6.72^{\mathrm{AB}}\pm0.81$	$7.15^{\mathrm{A}}\pm0.79$	$6.38^{\mathrm{B}}\pm1.01$				
BC, %					**	**	ns
Male	23.50 ± 2.31	$25.29^{A}\pm2.08$	22.45 ± 3.32	23.71 ± 2.83			
Female	22.45 ± 1.76	$23.32^{B}\pm1.08$	21.28 ± 1.97	22.18 ± 1.88			
Mean	$23.08^{\mathrm{B}}\pm2.14$	$24.41^{\mathrm{A}}\pm1.95$	$21.82^{\mathrm{C}}\pm2.70$				
NCC, kg					**	ns	ns
Male	4.00 ± 0.41	$4.29^{A}\pm0.53$	$4.35^{A}\pm0.50$	4.21 ± 0.50			
Female	3.75 ± 0.49	$3.63^{B}\pm0.33$	$3.76^{B}\pm0.41$	3.72 ± 0.41			
Mean	3.90 ± 0.45	3.99 ± 0.56	4.03 ± 0.54				
NCC, %					**	ns	ns
Male	$13.96^{A}\pm0.95$	$14.71^{A}\pm1.21$	14.25 ± 1.43	14.29 ± 1.22			
Female	$12.58^{B}\pm1.02$	$12.33^{B}\pm1.18$	13.46 ± 1.72	12.90 ± 1.48			
Mean	13.41 ± 1.18	13.65 ± 1.69	13.82 ± 1.62				
IF, kg					**	**	*
Male	$1.08^{\mathrm{c}}\pm0.23$	$0.91^{\mathrm{c}}\pm0.32$	$1.35^{\mathrm{b}}\pm0.48$	1.12 ± 0.39			
Female	$1.93^{\mathrm{a}}\pm0.55$	$1.18^{\mathrm{bc}}\pm0.30$	$2.03^{\mathrm{a}}\pm0.42$	1.76 ± 0.56			
Mean	$1.42^{\mathrm{B}}\pm0.57$	$1.03^{\mathrm{C}}\pm0.34$	$1.72^{\mathrm{A}}\pm0.56$				
IF, %					**	**	**
Male	$3.78^{\mathrm{bc}}\pm0.73$	$3.10^{\mathrm{c}}\pm1.06$	$4.36^{\mathrm{b}}\pm1.22$	3.76 ± 1.12			
Female	$6.45^{\mathrm{a}}\pm1.64$	$4.01^{\mathrm{b}}\pm0.95$	$7.15^{\mathrm{a}}\pm0.97$	6.06 ± 1.77			
Mean	$4.85^{\mathrm{B}}\pm1.76$	$3.51^{\mathrm{C}}\pm1.10$	$5.87^{\mathrm{A}}\pm1.77$				

BC body components=blood + pelt + head + feet, *NCC* non-carcass components=gut + lungs + trachea + diaphragm + heart + liver and kidneys + other viscera; Internal fat (IF)=omental + mesenteric + the perinephric and retroperitoneal fats, *P* Pantaneiro, *TP* Texel×Pantaneiro, *SIP* Santa Inês×Pantaneiro, *ns* not significant

For sex within G, means with different capital and italic superscript letters differ significantly for *$P<0.05$, **$P<0.01$, and ***$P<0.0001$

For G, means with different capital and superscript letters differ significantly for *$P<0.05$, **$P<0.01$, and ***$P<0.0001$

For S×G, means with different lower case superscript letters differ significantly for *$P<0.05$, **$P<0.01$, and ***$P<0.0001$

was higher ($P<0.01$) in Texel×Pantaneiro than in Santa Inês×Pantaneiro lambs with Pantaneiro lambs being no different from the others. For Santa Inês×Pantaneiro lambs, males presented a higher weight of body components than females. When the body component data were expressed as a percentage of BW, the same differences were shown, but Texel×Pantaneiro lambs exhibited the highest value, followed by Pantaneiro and Santa Inês×Pantaneiro lambs. The non-carcass components of males were higher than those of females in Texel×Pantaneiro and Santa Inês×Pantaneiro lambs, but when this component was expressed as a percentage, the only genotype that showed sex differences was the Texel×Pantaneiro. The internal fat and internal fat percentage were significantly different ($P<0.01$) between genotypes. As a result of the interaction between sex and genotype, the Santa Inês×Pantaneiro females presented the highest internal fat and internal fat percentage content, 2.03 kg and 7.15 %, while the lowest was shown by the Texel×Pantaneiro males (0.91 kg and 3.10 %). Overall, female lambs presented a higher internal fat and internal fat percentage than male lambs.

Discussion

These results show that males have a better production efficiency compared with females agreeing with the work of Kremer et al. (2004) and Pérez et al. (2007) who worked with different genotypes. In the present study, the higher DF and FC and lower ADG values observed for females show a lower response; and taking into account the BW, females should be slaughtered earlier than males. According to Rodríguez et al.

(2011), the gender differences for ADG, FC, or carcass yields could be explained by differences in the composition of body weight gain since the development of adipose tissue occurs earlier in females than in males. Furusho-Garcia et al. (2004), working with Santa Inês purebreds and crossed with Bergamácia, also observed that from a 25-kg BW, females had a worse FC than males, indicating a higher fat deposition for females with a reduction in live weight gain.

The better growth performance results observed for the crossbred Texel lambs may be due to the effect of cross-breeding of a local breed with a specialized meat production breed, although Paim et al. (2013) have observed lower ADG values for Texel crossbred lambs compared with the present study. Souza et al. (2013) evaluating crossbred lambs (Doper×Santa Inês and Dorper×Somális) observed ADG values 50 % higher for the first cross, whereas in the present study, Texel×Pantaneiro lambs presented an ADG only 21 and 18 % higher than Pantaneiro and Santa Inês×Pantaneiro lambs, respectively.

The higher REA of Texel crossbred lambs is related to the recognized carcass conformation of the Texel breed. The other genotypes evaluated presented better REA values than those reported by Pires et al. (2011) and Cartaxo et al. (2011) with the same crossbred lambs. The lower HDP values observed in Texel×Pantaneiro males can be explained by their higher body components' weight and percentage compared with Santa Inês×Pantaneiro, where the females exhibited a lower weight of body components. However, the Texel×Pantaneiro lambs produced leaner carcasses compared with other genotypes as a result of less internal fat, reflecting the influence of the greater muscularity of Texel. Additionally, the Texel crossbred lambs in the present study had a higher HDP value (47.16 %) compared with lambs of the same crossbreed (44.9 %) in studies by Kremer et al. (2004) and Álvarez et al. (2013).

Recently, many studies have evaluated the use of local breeds and native or adapted crossbreds in sheep meat production systems. Abdullah et al. (2010, 2011) evaluated the effects of cross-breeding local with exotic sheep and concluded that the use of the Charolais breed in crosses with Awassi sheep improved performance and carcass traits in terms of muscularity. The authors observed a lower value for HDP (47.1 %) for Awassi crossbred with exotic breeds than that observed for the Pantaneiro breed (49.85 %) in the present study.

We also found that crossbred animals have better results compared with the local genotype. However, in some cases, the performance of local breeds can be equal or even superior to crossbreds, as the highest HDP and CDP values were exhibited by Pantaneiro lambs compared with Texel×Pantaneiro lambs. Santos-Silva et al. (2002) observed the same ADG for the local genotype as for the Ile de France crossbreed. Suarez et al. (2000) showed the similar HDP values for Corriedale, Corriedale×Pampita, and Pampita lambs in Argentina. Tsegay et al. (2013) compared the performance of two local genotypes (Blackhead Ogaden and Hararghe Highland) and their crosses with Dorper and observed similar ADG, HCW, HDP, and CL values.

The Texel×Pantaneiro lambs were more efficient and showed a better feedlot performance, higher REA, and better carcasses with an adequate amount of fat in spite of the worst carcass yield. The new group of native sheep, Pantaneiro, showed a similar performance to the Santa Inês×Pantaneiro crossed lambs. Pantaneiro lambs and their crosses with sheep meat breeds could be useful for meat production systems under savanna environmental conditions.

Conflict of interest The authors declare that they have no conflict of interest.

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