

The effect of genotype and sex on growth and carcass traits of lambs

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The objective of the present study was to investigate the effect of genotype and sex on growth and carcass traits of grazing lambs. A total of 32 lambs (16 Improved Jezersko-Solčava - JSR and 16 crossbreds with Texel - JSRT, 8 males and 8 females within each genotype) were included in the study. The lambs were grazed together with their dams from the beginning of the grazing period and had free access to commercial concentrate from the age of 10 days. Lambs were weaned at the average body weight of 22.9 kg. Feeding with a concentrate was finished when lambs achieved 35 kg of body weight and were slaughtered. Daily gains from birth to slaughter and from weaning to slaughter were calculated. Several carcass traits were determined. JSRT lambs had significantly higher daily gain from birth to slaughter, hot and cold carcass weights, and dressing percentages compared to JSR lambs. Carcass conformation was higher in JSRT than JSR carcasses. Also, carcasses of JSRT were shorter and wider than JSR carcasses. Rib eye muscle areas of JSRT lambs were significantly larger, and the colour was significantly lighter. Males had significantly higher average daily gain from birth to slaughter and from weaning to slaughter than females. Females had higher dressing percentages and subcutaneous and internal fatness scores than males. Females had significantly higher amount of kidney fat. The colour of males' meat was significantly lighter than that of females. Crossbreeding with Texel rams improved growth and carcass traits of lambs, and males had better growth performance and several carcass traits than females.

Keywords: lambs, commercial crossbreeding, sex, growth, carcass traits

1 Introduction

Commercial crossbreeding in sheep production is widespread worldwide. Through the adoption of this reproductive system, breeders want to improve growth and carcass traits of lambs. To achieve this goal, ewes of local breeds are crossbred with rams of terminal breeds, such as Suffolk, Poll Dorset, Dorper, Oxford Down, Ile de France, and Texel. The latter is one of the most widespread terminal breeds used for commercial crossbreeding. Some studies have reported that crossbreeding with Texel rams significantly improved growth performance (Cardoso et al., 2013, Blasco et al., 2019, Freitas-de-Melo et al., 2019) and several carcass traits, such as carcass weight and dressing percentage (Scales et al., 2000), carcass conformation (Scales et al., 2000, Blasco et al., 2019), and subcutaneous and internal fatness (Blasco et al., 2019). According to the literature, crossbreeding different local breeds with Texel rams apparently improves the growth and carcass traits of lambs, so we assumed that Texel could also be used as a terminal breed for commercial crossbreeding with Improved Jezersko-Solčava sheep (JSR), a Slovenian sheep breed reared mainly for lamb production. This breed originates from the breeding of the local Slovenian breed Jezersko-Solčava sheep with the Romanov sheep. The main goal of breeding was to increase the litter size, and this goal was achieved. Nowadays, JSR is a locally adapted breed with relatively high fertility, and it seems to be a good maternal breed choice for commercial crossbreeding with terminal breeds, such as Texel.

The objective of our research was to investigate how genotype (JSR and JSRT) and sex affect growth and carcass traits of grazing lambs.

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2 Material and methods

A total of 32 grazing lambs of two genotypes were included in the study. A group of 16 JSR lambs (8 males, 8 females) and 16 JSRT lambs (8 males, 8 females) were grazed together on the same pasture. All lambs were born and reared on the same farm. They were born between March 10, 2019 and April 4, 2019. Lambs had free access to commercial concentrate from the age of 10 days. Before the grazing season started on April 5, 2019, lambs were kept in a barn together with ewes. From the beginning of the grazing season, lambs were grazed with their dams on natural pasture and had free access to concentrate. Lambs were weaned at an average age of 96.7 ± 11.7 days, and an average body weight of 22.9 ± 2.1 kg. Subsequently, all lambs were moved into the same paddock and fed with commercial concentrate *ad libitum*. The concentrate contained 18% crude protein, 8.4% crude fibre, 4.5% crude fat, and 7.2% crude ash. On average, the daily consumption of concentrate per lamb was 1,056 g. To monitor daily gains, lambs were weighed at 10-day intervals.

2.1 Slaughter and sampling

Lambs were slaughtered in the abattoir located on the farm where the lambs were reared. Lambs were slaughtered at a body weight of 35.5 ± 2.0 kg on three consecutive dates using the same procedure. Lambs were not fasted before slaughter. On the slaughter line, hot carcass weights and pH were recorded 45 min after bleeding.

Following 24 h of cold storage, the cold carcass weight and carcass pH were recorded. Both pH recorded 45 min and 24 h after slaughter were measured on the right side of the carcass in the Longissimus dorsi muscle behind the last rib, using a pH-meter equipped with a penetrating electrode. The EUROP carcass conformation (E - excellent, U - very good, R - good, O - fair, and P - poor) was evaluated by a specialist and given a score from 15 for E+ (excellent) to 1 for P- (poor). Subcutaneous and internal carcass fatness degrees were scored subjectively on a scale from 1- (very low) to 5+ (15, very high) of the fatness classification system (1 – low, 2 – slight, 3 – average, 4 – high, and 5 – very high). The hanging carcasses were measured for carcass length, from the cranial edge of the symphysis pelvis to the cranial edge of the first rib, leg width, and shoulder width. Carcasses were dissected into commercial cuts: shoulder, neck, chuck, rib with flank, back, loin, and leg. Each cut was weighed and expressed as a percentage of cold carcass weight. After dissection, kidney weight and kidney fat were recorded. The areas of the right and left Longissimus dorsi muscle between the 12th and 13th thoracic vertebrae were determined using a polar planimeter. A 200 g sample of loin (Longissimus dorsi muscle) was taken for total intramuscular fat content determination. A sample of muscle was vacuum-packed and frozen at -20°C until analysis. Total intramuscular fat content in the Longissimus dorsi muscle was determined in homogenized samples using 4 M HCl per hydrolysis unit (SoxCap™ 2047). Meat colour was measured as a triplicate on the Longissimus dorsi muscle's cross-section after 30 min of exposure to air using a colourimeter YS3010 and expressed in CIE $L^*a^*b^*$ values.

The daily gain from birth to slaughter was calculated as the difference between birth and slaughter weight divided by the age at slaughter. Daily gain from weaning to slaughter was calculated as the difference between weaning and slaughter weight divided by the number of days between them. The dressing percentage was determined as the quotient between the hot carcass weight and the animal's slaughter weight of the animal, expressed as a percentage.

2.2 Statistical analysis

Growth performance and carcass traits were analysed using the GLM procedure of the SAS package (SAS, 2014). The statistical model included genotype (JSR, JSRT), sex (male, female), and fattening period (36 days, 50 days, 76 days) as categorical fixed effects, and age at slaughter as linear covariate. Statistical significance between genotypes and between sexes for the investigated traits was declared at $P < 0.05$.

3 Results and discussion

3.1 Results

Least squares means of growth performance and carcass traits for the genotype effect are reported in Table 1.

Crossbred lambs had significantly higher daily gain from birth to slaughter (219.3 ± 2.8 g/d) than JSR lambs (205.7 ± 2.7 g/d). On the other hand, there was no significant difference in daily gains from

weaning to slaughter between genotypes (Table 1). Consequently, JSRT lambs had higher hot and cold carcass weights than JSR lambs. In addition, JSRT lambs had higher dressing percentage compared to JSR lambs. Carcass conformation was higher in JSRT carcasses (10.02 ± 0.33 ; U-) than in JSR carcasses (7.12 ± 0.31 ; R-). The difference between them was one class. The carcasses of crossbred lambs were shorter and wider than JSR carcasses. The areas of JSRT lambs' rib eye muscles were significantly larger in comparison with JSR lambs. The colour of JSRT lamb meat was significantly lighter (41.62 ± 0.50) than the meat of JSR lambs (40.07 ± 0.49), while there was no difference in the redness (a^*) nor the yellowness (b^*) of the meat. There were no significant differences in subcutaneous and internal fatness of carcasses, total fat content, and kidney fat content between genotypes.

Table 1 Growth performance and carcass traits (least squares means \pm standard error) of Improved Jezersko-Solčava (JSR) lambs and crossbreds with Texel (JSRT)

Trait	Genotype		Significance
	JSR	JSRT	
Daily gain from birth to slaughter (g/d)	205.7 ± 2.7	219.3 ± 2.8	**
Daily gain from weaning to slaughter (g/d)	240.5 ± 9.9	255.8 ± 10.5	ns
Hot carcass weight (kg)	15.72 ± 0.28	17.23 ± 0.29	**
Cold carcass weight (kg)	15.14 ± 0.27	17.06 ± 0.29	***
Dressing percentage (%)	45.70 ± 0.44	47.07 ± 0.47	*
Carcass conformation, EUROP (1-15)	7.12 ± 0.31	10.02 ± 0.33	***
Subcutaneous fatness (1-15)	7.51 ± 0.24	7.60 ± 0.25	ns
Total intramuscular fat (g/100g of muscle)	1.68 ± 0.11	1.90 ± 0.12	ns
Kidney fat (kg)	0.25 ± 0.02	0.22 ± 0.02	ns
pH ₄₅	6.66 ± 0.09	6.72 ± 0.09	ns
pH ₂₄	5.53 ± 0.01	5.49 ± 0.01	*
Carcass length (cm)	59.54 ± 0.38	57.46 ± 0.41	**
Leg width (cm)	19.52 ± 0.22	20.45 ± 0.23	**
Shoulder width (cm)	17.06 ± 0.23	18.61 ± 0.24	***
Internal fatness of carcass (1-15)	8.92 ± 0.30	8.53 ± 0.31	ns
Right rib eye muscle area (cm ²)	12.22 ± 0.36	15.04 ± 0.41	***
Left rib eye muscle area (cm ²)	11.42 ± 0.32	14.02 ± 0.37	***
L	40.07 ± 0.49	41.62 ± 0.50	*
a*	17.48 ± 0.29	17.24 ± 0.29	ns
b*	5.65 ± 0.24	6.02 ± 0.24	ns

pH₄₅ - pH of meat 45 min after slaughter; pH₂₄ - pH of meat 24 h after slaughter; L - lightness of meat; a* - redness of meat; b* - yellowness of meat; ns - not significant; * - $P < 0.05$; ** - $P < 0.01$; *** - $P < 0.001$

Least squares means of growth performance and carcass traits for the sex effect are in Table 2. Male lambs had significantly higher daily gain from birth to slaughter (219.6 ± 2.7 g/d) as well as higher daily gain from weaning to slaughter (264.8 ± 10.2 g/d) than female lambs (205.4 ± 2.9 g/d and 231.5 ± 10.8 g/d, respectively) (Table 2). Female lambs had higher dressing percentage ($47.57 \pm 0.48\%$), subcutaneous fatness (8.04 ± 0.26), and internal fatness (9.56 ± 0.32) than male lambs ($45.20 \pm 0.46\%$, 7.07 ± 0.24 and 7.89 ± 0.31 , respectively). Female lambs also had significantly higher amount of kidney fat (0.27 ± 0.02 kg) than male lambs (0.20 ± 0.02 kg). The meat of male lambs was significantly lighter (41.71 ± 0.48) than the meat of female lambs (39.98 ± 0.53), while there was no significant difference in the redness (a^*) and yellowness (b^*) of meat. Likewise, no significant differences between sexes in hot and cold carcass weight, carcass conformation, total fat content, carcass length, leg width, shoulder width, and rib eye muscle areas were found.

Table 2 Growth performance and carcass traits (least squares means \pm standard error) of male and female lambs of Improved Jezersko-Solčava breed and crossbreds with Texel

Trait	Sex		Significance
	Male	Female	
Daily gain from birth to slaughter (g/d)	219.6 \pm 2.7	205.4 \pm 2.9	**
Daily gain from weaning to slaughter (g/d)	264.8 \pm 10.2	231.5 \pm 10.8	*
Hot carcass weight (kg)	16.44 \pm 0.29	16.51 \pm 0.30	ns
Cold carcass weight (kg)	16.01 \pm 0.28	16.19 \pm 0.30	ns
Dressing percentage (%)	45.20 \pm 0.46	47.57 \pm 0.48	**
Carcass conformation, EUROP (1-15)	8.38 \pm 0.32	8.77 \pm 0.34	ns
Subcutaneous fatness (1-15)	7.07 \pm 0.24	8.04 \pm 0.26	*
Total intramuscular fat (g/ 100 g of muscle)	1.67 \pm 0.12	1.91 \pm 0.13	ns
Kidney fat (kg)	0.20 \pm 0.02	0.27 \pm 0.02	*
pH ₄₅	6.87 \pm 0.09	6.51 \pm 0.10	*
pH ₂₄	5.52 \pm 0.01	5.50 \pm 0.01	ns
Carcass length (cm)	58.65 \pm 0.39	58.34 \pm 0.42	ns
Leg width (cm)	19.85 \pm 0.22	20.12 \pm 0.24	ns
Shoulder width (cm)	17.99 \pm 0.24	17.68 \pm 0.25	ns
Internal fatness (1-15)	7.89 \pm 0.31	9.56 \pm 0.32	**
Right rib eye muscle area (cm ²)	13.63 \pm 0.38	13.63 \pm 0.40	ns
Left rib eye muscle area (cm ²)	12.87 \pm 0.34	12.57 \pm 0.36	ns
L	41.71 \pm 0.48	39.98 \pm 0.53	*
a*	17.21 \pm 0.28	17.51 \pm 0.31	ns
b*	5.86 \pm 0.23	5.81 \pm 0.25	ns

pH₄₅ - pH of meat 45 min after slaughter; pH₂₄ - pH of meat 24 h after slaughter; L - lightness of meat; a* - redness of meat; b* - yellowness of meat; ns - not significant; * - P < 0.05; ** - P < 0.01; *** - P < 0.001

3.2 Discussion

The effect of genotype on the growth performance and carcass traits of lambs has been investigated in several studies. Do Prado Paim et al. (2013) compared growth and carcass traits of purebred Santa Ines lambs and Santa Ines x Texel crossbreds. They also used Texel rams as a terminal breed for commercial crossbreeding. In accordance with our results, do Prado Paim et al. (2013) did not detect significant difference in average daily gains from weaning to slaughter between purebred lambs and crossbreds with Texel.

Contrary to our results, they found no significant difference in the average daily gain from birth to slaughter between the two studied genotypes. In this study, the crossbreds with Texel grew faster compared to purebred JSR lambs and reached significantly higher average daily gain from birth to slaughter. Do Prado Paim et al. (2013) found that crossbreds had significantly longer carcasses than purebred Santa Ines lambs, opposed to the results of our study, where crossbreds with Texel had shorter carcasses than purebred JSR lambs. In their study, there were no significant differences in hot and cold carcass weights or dressing percentages, while in the present study, it was found that Texel crossbreds had significantly higher values for all examined traits compared to purebred JSR lambs.

Growth performance and certain carcass traits of purebred Santa Ines lambs and Santa Ines x Texel crossbreds were also compared by Nunes et al. (2019). Compared to the present study, they also found that Texel crossbreds had significantly higher daily gain than purebred Santa Ines lambs. As in the study of do Prado Paim et al. (2013), Nunes et al. (2019) did not report significant difference in hot and cold carcass weight nor in the dressing percentage between both genotypes, while in the present study crossbreds with Texel had significantly higher values for all the above-mentioned traits compared to purebred JSR lambs. In conformity with results of the current study, Nunes et al. (2019) found that crossbreds with Texel had significantly higher carcass conformation scores than purebred

lambs, while no difference was found in the fatness of carcasses between the considered genotypes. Nunes et al. (2019) found no difference in rib eye muscle area nor leg width, while our research revealed that crossbreds with Texel had significantly larger rib eye muscles and wider legs than purebred JSR lambs.

Scales et al. (2010) studied the effect of commercial crossbreeding of Merino ewes with rams of several breeds (including Texel) on growth and carcass traits. They found that crossbreds with Texel had a significantly higher daily gain from birth to slaughter as well as a significantly higher hot carcass weight and dressing percentage than purebred lambs, which is in agreement with our results. Scales et al. (2010) found that crossbreds with Texel had larger rib eye muscle area than purebred lambs, which is consistent with our findings. In their study, most Texel crossbreds were classified into two best grades (E and U) of carcass conformation, while these two grades categorized none of the purebred lambs. These results are similar to findings of the present study, where crossbreds with Texel were ranked in the U- class, while purebred lambs were categorized in class R-.

Claffey et al. (2018) also used Texel rams as the terminal breed for commercial crossbreeding. They compared growth and carcass traits of purebred Scottish Blackface lambs and crossbreds with Texel. Purebred lambs had significantly lower daily gains compared with Texel crossbreds which agrees with results of this study. As in our study, Claffey et al. (2018) observed that crossbreds with Texel had significantly higher carcass weights, dressing percentages, and carcass conformation scores than purebred lambs. In their study, Texel crossbreds had significantly lower carcass fat scores than purebred Scottish Blackface lambs, while the present study found no difference in subcutaneous fat and internal fat between purebred JSR lambs and crossbreds with Texel.

Blasco et al. (2019) compared the growth performance and a number of carcass traits of purebred Segurena lambs and their Texel crossbreds. The average Texel crossbred daily gain from birth to slaughter was significantly higher compared to purebred lambs, which is in agreement with our study. In the present study, crossbreds with Texel had significantly heavier carcasses and higher dressing percentages than purebred JSR lambs, while Blasco et al. (2019) did not observe differences in cold carcass weight and dressing percentage between genotypes. In concordance with our results, Blasco et al. (2019) reported that crossbreds with Texel had significantly shorter carcasses and significantly higher carcass conformation. Crossbreds had significantly lower fatness than purebred Segurena lambs, while the subcutaneous and internal carcass fatness scores were not affected by genotype in present study. The meat of the crossbreds with Texel, in the present work, was significantly lighter than the meat of purebred JSR lambs, while Blasco et al. (2019) found that none of the meat colour parameters was affected by the lambs' genotype.

However, the use of Texel rams for commercial crossbreeding with JSR ewes has improved the carcass quality and growth performance of JSRT lambs, compared to purebred JSR lambs, which could be economically justifiable for farmers.

The effect of sex on the carcass traits of four different lamb genotypes was investigated by Perez et al. (2007). Male lambs had significantly higher hot carcass weight than female lambs, while there was no significant difference in dressing percentage between sexes. In the present study, contrary to the results of Perez et al. (2007), female lambs had significantly higher dressing percentage than male lambs, probably due to significantly higher subcutaneous and internal carcass fatness, as concluded by Facciolongo et al. (2018). The latter study found similar results with female lambs having significantly higher dressing percentages compared to male lambs. In their study, male lambs had significantly higher daily gains than female lambs, which is in agreement with results of the present study. The higher dressing percentage of female lambs in our study could explain why higher daily gains of male lambs did not cause a difference in hot carcass weights between males and females. In agreement with Facciolongo et al. (2018), the meat of male lambs in our study was significantly lighter than the meat of female lambs, while redness of meat was not affected by sex. In our research, no difference in the yellowness of meat was observed, while the study of Facciolongo et al. (2018) showed that male lambs' meat had significantly higher values of yellowness than female lambs. Both studies found that sex did not affect the content of total intramuscular fat.

4 Conclusions

The genotype of lambs affected the majority of growth and carcass traits, such as daily gains from birth to slaughter, hot and cold carcass weights, dressing percentages, carcass conformation, carcass length, leg and shoulder width, rib eye muscle area, and meat colour. The results of our study clearly indicate that crossbreeding with Texel improves the growth performance and carcass traits of lambs.

Sex affected daily gains from birth to slaughter and daily gains from weaning to slaughter, dressing percentages, subcutaneous and internal carcass fatness, kidney fat, and meat colour. The comparison of growth traits between both sexes in this study showed that male lambs grew faster than females. When carcass traits were compared, female lambs had significantly higher subcutaneous and internal fatness along with higher amounts of kidney fat than male lambs. These results indicate that the carcasses of females had higher amounts of total carcass fat than males when they were slaughtered at 35 kg of slaughter weight. Thus, it can be concluded, that female lambs of both genotypes (JSR and JSRT) should be slaughtered earlier than male lambs. On the other hand, male lambs could be fattened to a higher body weight due to their higher average daily gains and lower carcass fatness.

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