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DIFFERENCES IN BODY MEASUREMENTS, WOOL AND SEMEN QUALITY TRAITS BETWEEN TWO SLOVENIAN AUTOCHTHONOUS SHEEP BREEDS

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Summary

The aim of the study was to indicate significant differences in body measurements, wool and semen quality traits between two Slovenian autochthonous sheep breeds, Jezersko-Solčava (JS) sheep and Improved Jezersko-Solčava (JSR) sheep. Forty-four rams of JS sheep and 43 rams of JSR sheep from the same test station in the year 2020 were included in the study. In each ram, body length, wither height, chest circumference, ear and tail length, as well as body weight, were recorded. In addition, ultrasound measurement of rib eye muscle depth was performed. Wool samples were analysed in the laboratory where several wool quality traits were determined. The concentration of the semen, progressive motility and morphological changes of sperm cells were analysed as well. After analysis of variance, we found that JSR rams had shorter body, lower wither height, higher chest circumference, as well as shorter ears and tails compared to JS rams. A comparison of wool quality traits showed that JSR rams had lower wool fibre diameter, lower spinning fineness, and higher comfort factor than JS rams. JSR rams had higher progressive motility of sperm cells compared to JS rams. According to many differences, especially in body measurements, it could be concluded that JS and JSR are two different breeds which could be genetically different as well.

Keywords: Jezersko-Solčava sheep, Improved Jezersko-Solčava sheep, body measurements, wool quality, semen quality

Introduction

In Slovenia, five autochthonous sheep breeds are reared mainly for meat production (Jezersko-Solčava sheep, Improved Jezersko-Solčava sheep, and Bela Krajina Pramenka) or milk production (Bovec sheep and Istrian Pramenka). The highest population size have two related breeds, Jezersko-Solčava (JS) sheep (5,100 breeding animals) and Improved Jezersko-Solčava (JSR) sheep (4,500 breeding animals). JS sheep is widespread throughout the entire territory of Slovenia but most of the flocks are located in the Alpine area (Žan Lotrič et al., 2013). This breed origins from the primitive Zaupel sheep and improved with Bergamasca and Paduan sheep. Zaupel sheep was white sheep of small body frame which was widespread throughout the area of Eastern Alps in the ancient times. JS sheep has finer wool due to upgrading with Paduan sheep while the most notable consequence of upgrading with Bergamasca sheep is a convex nose profile. JS sheep has a lop, relatively long ears, and a long tail which ends under the tarsal joint. Sheep are commonly completely white. However, some animals had black spots under the eyes (called "tear") and on the tips of the ears which are desirable traits. Animals with black

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coat are rare. JS sheep is polled breed. JS ewes weigh 65 – 70 kg, while rams could achieve a weight of 100 kg (Birtič et al., 2015). JS sheep has year-round lambings with an average of 1.18 lambs per litter (Savšek et al., 2021). On the other hand, JSR sheep is the most geographically widespread breed in Slovenia (Žan Lotrič et al., 2013). This breed is the result of improving JS sheep with Romanov sheep which started in the year 1982. The main goal of improving was to achieve higher litter size of ewes. JSR sheep has erected, relatively short ears, and a short tail which ends above the tarsal joint. The tail length should depend on the percentage of Romanov breed within an animal. The head profile is narrow or slightly convex but not as much as in JS sheep. The most common coat colour of JSR sheep is white. However, animals with Romanov coat colour pattern (black head with white face and grey wool) are also common. JSR sheep is polled breed as well. JSR ewes weigh 65 – 75 kg while rams could achieve a weight of more than 90 kg (Cividini et al., 2015). JSR sheep has year-round lambings with an average of 1.50 lambs per litter (Savšek et al., 2021), which means that the goal of improving litter size was achieved.

So far, no study about phenotypic differences between JS sheep and JSR sheep was prepared, despite such studies should identify and differentiate breeds. Nevertheless, studies about morphological differences between breeds could be the basis for further genetic studies (Yunusa et al., 2013). In Slovenia, one study about phenotypic differences among related sheep breeds was already conducted. Marković et al. (2019) included six breeds of the Pramenka group – two Slovenian breeds (Bela Krajina Pramenka and Istrian Pramenka) and four Montenegrin breeds (Bardoka, Pivska Pramenka, Sjenička Sheep, and Zeta Žuja). They found significant differences in the majority of body measurements and morphometric indices between Bela Krajina Pramenka and Istrian Pramenka.

The aim of the current study was to indicate significant differences in body measurements and some morphometric indices between JS sheep and JSR sheep. Additionally, it was also investigated if there are any significant differences in wool and semen quality traits between breeds.

Material and methods

Animals

Forty-four rams of JS sheep and 43 rams of JSR sheep that finished the performance test for growth traits on the same test station in the year 2020 were included in the study. There were uniform housing conditions. The feed ratio consisted of hay *ad libitum* and concentrates up to 1 kg. Rams originated from 24 different flocks which are included in Slovenian National Breeding Programs for Jezersko-Solčava sheep and Improved Jezersko-Solčava sheep, respectively.

Body measurements and indices

Rams were measured at an average age of 249 ± 23 days. Wither height and body length were measured with a measuring stick while ear and tail length were measured with an angle ruler. For the measuring of chest circumference, a measuring tape was used. All rams were weighed with an electronic balance. Based on these measurements, some morphometric indices were calculated to detect possible differences in body proportions between sheep breeds. Indices were calculated as follows.

1. *Index of body frame (IBF)* $= \frac{body\ length}{wither\ height}$ *x 100.*
2. *Index of thorax development (ITD)* $= \frac{chest\ circumference}{wither\ height}$ *x 100.*
3. *Index of body weight (IBW)* $= \frac{body\ weight}{wither\ height}$ *x 100.*

Measurement of rib eye muscle depth

Rams were 246 ± 23 days old at measuring, on average. Rib eye muscle depth was measured using an ultra-sound scanner Mindray DP-50Vet and ultrasonic probe 75L38LA. All measurements were taken on the left side of the body between the 12th and 13th rib, approximately 45 mm lateral from the spinous process of thoracic vertebrae. Measurements were performed perpendicularly to the skin surface and in parallel with the ribs.

Wool sampling and analysis

The average age of rams at shearing was 255 ± 22 days. Each ram was sheared according to Bowen's method. After shearing, the fleece of each ram was weighed and the wool sample was taken for laboratory analyses. A wool sample was taken from the left side in the middle of the body, on an area between the 30th and 31st cut according to Bowen method. All wool samples were individually packed in plastic bags, marked and sent to the laboratory Art of fibre (https://artoffibre.com/) in Finland or Great Britain, respectively. There is implemented and certificated method for determination of wool quality traits. These traits are fibre diameter, comfort factor, spinning fineness, fibre length, and fibre curvature.

Semen quality analysis

On average, rams were 257 ± 36 days old at semen collection. At first, the scrotal circumference of each ram was measured with a measuring tape. Then semen samples were taken using an electro-ejaculator. The concentration of the semen, progressive motility of sperm cells and morphological changes of sperm cells were determined as an average of two measurements.

Statistical analysis

Data were analysed with the GLM procedure using SAS/STAT® (SAS, 2014). The statistical model for all traits included breed of ram as a fixed effect while age at recording was included as a linear covariate.

Results

Differences in body measurements and morphometric indices between JS and JSR rams are presented in Table 1. JS rams had significantly higher wither height (55.74 ± 0.43 cm) compared to JSR rams (53.10 ± 0.44 cm). JS rams also had significantly longer bodies (67.97 ± 0.50 cm), tails (44.18 ± 0.63 cm) and ears (14.74 ± 0.19 cm) compared to JSR rams (66.41 ± 0.51 cm, 28.54 ± 0.61 cm and 12.51 ± 0.19 cm, respectively). On the other hand, JSR rams had significantly higher chest circumference (81.22 ± 0.42 cm) in comparison with JS rams (79.57 ± 0.42 cm). All morphometric indices (IBF, ITD and IBW) were significantly higher in JSR rams (125.30 ± 1.03, 153.34 ± 1.28 and 92.69 ± 1.05, respectively) than in JS rams (122.09 ± 1.02, 143.04 ± 1.27, and 88.01 ± 1.04, respectively). The breed of rams did not affect body weight and rib eye muscle depth.

Table 1 Body measurements and morphometric indices of JS and JSR rams (LSM ± SE)
Tablica 1. Tjelesne mjere i morfometrijski indeksi JS i JSR ovnova (LSM ± SE)

Trait	Breed of ram (LSM ± SE)		p-value
	JS	JSR	
Body weight (kg)	49.06 ± 0.63	49.13 ± 0.63	0.9361
Wither height (cm)	55.74 ± 0.43	53.10 ± 0.44	<0.0001
Body length (cm)	67.97 ± 0.50	66.41 ± 0.51	**0.0309**
Chest circumference (cm)	79.57 ± 0.42	81.22 ± 0.42	**0.0065**
Tail length (cm)	44.18 ± 0.63	28.54 ± 0.61	**<0.0001**
Ear length (cm)	14.74 ± 0.19	12.51 ± 0.19	**<0.0001**
IBF	122.09 ± 1.02	125.30 ± 1.03	0.0292
ITD	143.04 ± 1.27	153.34 ± 1.28	**<0.0001**
IBW	88.01 ± 1.04	92.69 ± 1.05	**0.0022**
Rib Eye muscle depth (cm)	2.26 ± 0.03	2.27 ± 0.03	0.7659

IBF – index of body frame; ITD – index of thorax development; IBW – index of body weight; the p-values shown in bald are lower than a significant threshold value (0.05) LSM - least squares means, SE- standard error

Pearson correlation coefficients between body measurements of JS and JSR rams are presented in table 2. Body weight was positively correlated with wither height, body length, chest circumference and rib eye muscle depth with correlation coefficients of 0.384, 0.644, 0.605 and 0.460, respectively. Wither height was positively correlated with body length, tail length and ear length with correlation coefficients of 0.457, 0.424 and 0.399, respectively. Body length was positively correlated with tail length (0.246) and ear length (0.248). Chest circumference was negatively correlated with tail length (-0.350) and positively correlated with rib eye muscle depth (0.524). Tail length was positively correlated with ear length (0.615).

Table 2 Pearson correlation coefficients among body measurements of JS and JSR rams
Tablica 2. Pearsonovi koeficijenti korelacije između tjelesnih mjera JS i JSR ovnova

	BW	WH	BL	CC	TL	EL	RD
BW	1	0.384***	0.644***	0.605***	0.012^{NS}	0.051^{NS}	0.460***
WH		1	0.457***	0.062^{NS}	0.424***	0.399***	0.057^{NS}
BL			1	0.192^{NS}	0.246*	0.248*	0.207^{NS}
CC				1	-0.350**	-0.190^{NS}	0.524***
TL					1	0.615***	-0.081^{NS}
EL						1	-0.098^{NS}
RD							1

BW – body weight; WH – wither height; BL – body length; CC – chest circumference; TL – tail length; EL – ear length; RD – rib eye muscle depth; ^{NS} - not significant; *P < 0.05; **P < 0.01; ***P < 0.001

The effect of the breed on wool quality traits and fleece weight is shown in Table 3. JSR r ams had significantly lower fibre diameter (26.70 ± 0.36 µm), lower spinning fineness (26.52 ± 0.38 µm) and higher comfort factor (76.01 ± 2.03%) compared to JS rams (30.28 ± 0.35 µm, 29.98 ± 0.37 µm and 55.86 ± 1.99%, respectively) while JS rams had significantly higher fleece weight (1.62 ± 0.05 kg) than JSR rams (1.47 ± 0.05 kg). There were no significant differences in fibre curvature and fibre length between breeds.

Table 3 Wool quality traits and fleece weight of JS and JSR rams (LSM ± SE)
Tablica 3. Kvaliteta vune i težina runa JS i JSR ovnova (LSM ± SE)

Trait	Breed of ram (LSM ± SE)		p-value*
	JS	JSR	
Fibre diameter (µm)	30.28 ± 0.35	26.70 ± 0.36	**<0.0001**
Comfort factor (%)	55.86 ± 1.99	76.01 ± 2.03	**<0.0001**
Spinning fineness (µm)	29.98 ± 0.37	26.52 ± 0.38	<0.0001
Fibre curvature (degree/mm)	48.88 ± 1.23	48.07 ± 1.26	0.6457
Fibre length (cm)	81.81 ± 2.07	79.29 ± 2.12	0.4007
Fleece weight (kg)	1.62 ± 0.05	1.47 ± 0.05	**0.0303**

*p-values shown in bold are lower than a significant threshold value (0.05)

Differences in semen quality traits and scrotal circumference between JS and JSR rams are presented in Table 4. JSR rams had significantly higher progressive motility of sperm cells (70.93 ± 2.38%) compared to JS rams (57.64 ± 2.48%) while the breed of ram did not affect semen concentration, morphological changes of sperm cells and scrotal circumference.

Table 4 Semen quality traits and scrotal circumference of JS and JSR rams (LSM ± SE)
Tablica 4. Kvaliteta sjemena i opseg skrotuma JS i JSR ovnova (LSM ± SE)

Trait	Breed of ram (LSM ± SE)		p-value*
	JS	JSR	
Semen concentration (10^9/ml)	1.78 ± 0.16	2.16 ± 0.16	0.1056
Progressive motility (%)	57.64 ± 2.48	70.93 ± 2.38	**0.0003**
Morphological changes (%)	14.19 ± 0.76	12.72 ± 0.73	0.1746
Scrotal circumference (cm)	29.86 ± 0.31	30.57 ± 0.31	0.1070

*p-values shown in bold are lower than significant threshold value (0.05)

Discussion

Phenotypic traits are affected by several different effects. The most reported effects which influence body measurements and morphometric indices are sex (Mavule et al., 2013; da Costa et al., 2014; Sabbioni et al., 2016) and age of an animal (Shrestha, 1984; Mavule et al., 2013; Megdiche, 2022). Some researchers reported that body measurements are affected by rearing technology as well (Riva et al., 2004; Mustefa et al., 2022) and even by birth period and litter

size in the case of animals younger than 10 months (Shrestha, 1984). Several researchers reported that apart from sex and age, the breed of sheep also affects the body measurements in a significant way (Searle et al., 1989; Carneiro et al., 2010; Mustefa et al., 2022). In a current study, JS and JSR rams differed in almost all body measurements with an exception of body weight and rib eye muscle depth. As expected, JSR rams had shorter ears and shorter tails than JS rams. Furthermore, JSR rams had shorter bodies, lower wither height, and higher chest circumference compared to JS rams. All morphometric indices – IBF, ITD and IBW were significantly higher in JSR rams in comparison with JS rams which means that JSR rams had more elongated body frames, better thorax development and relatively higher body weight according to the wither height. Comparison of absolute body measurements between breeds from different studies in most cases is not reasonable due to differences in age, sex and rearing conditions of animals. However, a comparison of morphometric indices of animals from different studies could be more appropriate because morphometric indices indicate the body proportions of each animal. If morphometric indices of JS and JSR rams are compared with Slovenian breeds belonging to Pramenka group (Marković et al., 2019) it could be noticed that Istrian Pramenka (IBF = 114.13 ± 0.56) and Bela Krajina Pramenka (IBF = 110.89 ± 0.56) had more square body frame than JS rams (IBF = 122.09 ± 1.02) and JSR rams (IBF = 125.30 ± 1.03). Further comparison shows that JS rams had a similar ITD (143.04 ± 1.27) to Bela Krajina Pramenka (145.07 ± 0.89) and a similar IBW to Istrian Pramenka (IBW = 88.01 ± 1.04 for JS rams and 87.95 ± 1.45 for Istrian Pramenka, respectively). On the other hand, JSR rams had quite higher ITD (153.34 ± 1.28) and IBW (92.69 ± 1.05) than both breeds in the Pramenka group. However, it must be considered that sheep from the study of Marković et al. (2019) were adult animals, 3.0 to 5.5 years old while the average age of JS and JSR rams from the current study was around eight months. This means that rams were still growing and it could be expected that not only absolute body measurements but also morphometric indices changed in JS and JSR rams when they achieved a full-size of body frame. Nevertheless, da Costa et al. (2014) reported in the population of Santa Ines sheep that sheep with increasing age become more compact and less high which is a consequence of a higher deposition of muscle and fat and at the same time lower bone growth. Body measurements of both breeds could be indirectly compared with related breeds such as Bergamasca sheep which was used for creating JS sheep. Consequently, there is also a genetic link between Bergamasca sheep and JSR sheep. In the study of Riva et al. (2004), young Bergamasca rams had larger body frame than JS and JSR rams. The largest difference was in wither height, which was 83.1 ± 4.4 cm in Bergamasca rams, while in the current study wither height was 55.74 ± 0.43 cm in JS rams and 53.10 ± 0.44 cm in JSR rams. Body length was also higher in Bergamasca rams (80.0 ± 3.1 cm) than in JS rams (67.97 ± 0.50 cm) and JSR rams (66.41 ± 0.51 cm). The proportion between body length and wither height was 0.962 (96.2%) in Bergamasca rams, as opposed to JS and JSR rams where IBF was 122.09 ± 1.02 and 125.30 ± 1.03, respectively. This means that Bergamasca rams had short body frame while JS and JSR rams had rectangular body frame. Rams in the study of Riva et al. (2004) were 12-24 months old while rams in the present study were younger (average age was eight months) but even if this fact is considered results of both studies clearly indicate that Bergamasca sheep have larger body frame than JS and JSR sheep. Considering this fact, it could be concluded that larger and more square body frame of JS rams in comparison with JSR rams might be a consequence of a

higher percentage of Bergamasca sheep in JS sheep than in JSR sheep. Body measurements of Bergamasca sheep were also investigated in a study of Carneiro et al. (2010) where 11 different breeds were included. Apart from some measurements of body frame, ear length of sheep was also included. Bergamasca sheep had significantly the longest ears (19.98 cm) while in other breeds ear lengths were from 12.21 cm to 16.98 cm. This indicates that longer ears in JS rams (14.74 ± 0.19 cm) than in JSR rams (12.51 ± 0.19 cm) could also be a consequence of a higher percentage of Bergamasca sheep in JS sheep compared to JSR sheep. The strong positive correlation between body weight and all body measurements (wither height, body length, and chest circumference) was in agreement with Shrestha et al. (1984) and Marković et al. (2019). In the present study, body length was positively correlated with wither height which was also in accordance with the results of Shrestha et al. (1984) and Marković et al. (2019). Both authors found that chest circumference was positively correlated with body length and wither height, as opposed to the results of the present study where there was no correlation between chest circumference and body length nor between chest circumference and wither height. The reason for this is probably the fact that JSR rams had shorter and lower body frame and at the same a little higher chest circumference than JS rams. There were some correlations between body frame measurements and tail length and ear length, respectively. Tail length, as well as ear length, were positively correlated with wither height and body length. Additionally, tail length was negatively correlated with chest circumference. This means that breeding based on the ear length and tail length where differences between both breeds are most evident had an indirect effect on the body frame measurements of breeding animals within each breed. Animals with long ears and tails have also longer bodies, higher wither height and lower chest circumference which are the characteristics of JS sheep. By contrast, animals with short ears and tails have shorter bodies, lower wither height and higher chest circumference which are the characteristics of JSR sheep.

The sheep breed could affect several wool quality traits as well, especially the most important fibre diameter. In the study of Francis et al. (2000) genotype of lambs affected fibre diameter, fibre length and fleece weight. Similarly, Woolliams and Wiener (1980) reported significant differences in fibre diameter and fibre length between different sheep breeds and their crossbreeds while in the study of Plowman et al. (2020) breed affected fibre diameter and fibre curvature. In the current study, JSR rams had a significantly lower fibre diameter than JS rams. Consequently, spinning fineness (a highly correlated value to fibre diameter) was also significantly lower in JSR rams while a value for comfort factor (the proportion of fibres thinner than 30 μm) was significantly lower in JS rams. Due to differences in sampling and determining wool quality traits, the results of different studies could not be compared directly. However, if the results of the current study are indirectly compared with the results of Plowman et al. (2020) JSR rams had a similar fibre diameter (26.52 ± 0.38 μm) to Bordaleiro sheep (27.2 ± 5.0 μm). On the other hand, Churro sheep in the study of Plowman et al. (2020) had quite larger fibre diameter (43.8 ± 13.4 μm) compared to both JSR rams (26.52 ± 0.38 μm) as well as JS rams (29.98 ± 0.37 μm). However, it must be considered that the sampling method could influence the results of determining wool quality traits even within the same study. In the present study, a wool sample was taken from the left side of the ram, in the middle of the body, on an area between the 30th and 31st cut according to Bowen method. Regarding the experiences that JSR

sheep often have more coarse wool on some other parts of the body than JS sheep (especially on the neck and the chest), it could be expected that wool sampling on several different parts of the body would not result in better wool quality traits of JSR rams. Apart from fibre diameter, comfort factor and spinning fineness, fleece weight was also affected by the breed. JS rams had higher fleece weight than JSR rams which could be a consequence of the larger body frame of JS rams in comparison with JSR rams. Some semen quality traits could also be affected by the breed. In the present study, JSR rams had significantly higher progressive motility of sperm cells compared to JSR rams, Similarly, Kahwage et al. (2018) found that Morada Nova rams in all climate seasons had significantly higher progressive motility of sperm cells than Santa Ines rams. In this study, JSR rams had a higher semen concentration, higher scrotal circumference, and a lower percentage of morphological changes of sperm cells compared to JS rams although these differences were not significant. Based on these findings, in further studies could be investigated if there is any correlation between the relatively high fertility traits of JSR ewes and the relatively high fertility traits of JSR rams.

Conclusion

The result of this study clearly showed that JS rams and JSR rams differed in the majority of body measurements. JSR rams had shorter and lower body frame, higher chest circumference, and shorter ears and tails compared to JS rams. JSR rams had a lower wool fibre diameter and lower fleece weight than JS rams. Progressive motility of sperm cells was higher in JSR rams compared to JS rams. Based on all phenotypic differences in body measurements, wool and semen quality traits could be concluded that JS sheep and JSR sheep are two different breeds which could be genetically different as well.

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RAZLIKE U TJELESNIM MJERAMA, OSOBINAMA KAKVOĆE VUNE I SJEMENJA IZMEĐU DVIJE SLOVENSKE AUTOHTONE PASMINE OVACA

SAŽETAK

Cilj istraživanja bio je ukazati na značajne razlike u tjelesnim mjerama, svojstvima kvalitete vune i sjemena između dviju slovenskih autohtonih pasmina ovaca, jezersko-solčavske (JS) ovce i poboljšane jezersko-solčavske (JSR) ovce. U istraživanje je uključeno 44 ovna JS ovaca i 43 ovna JSR ovaca iz iste pokusne stanice tijekom 2020. godine. Za svakog ovna izmjerena je tjelesna dužina, visina do grebena, opseg prsa, duljina ušiju i repa, kao i tjelesna težina. Osim toga, učinjeno je ultrazvučno mjerenje promjera dugog leđnog mišića. Uzorci vune analizirani su u laboratoriju pri čemu je utvrđeno nekoliko svojstava kvalitete vune. Također je analizirana koncentracija sjemena, progresivna pokretljivost i morfološke promjene spermija. Nakon analize varijance, otkrili smo da JSR ovnovi imaju kraće tijelo, nižu visinu grebena, veći opseg prsa, kao i kraće uši i repove u usporedbi s JS ovnovima. Usporedba svojstava kvalitete vune pokazala je da JSR ovnovi imaju manji promjer vunenih vlakana, manju finoću predenja i viši faktor udobnosti od JS ovnova. JSR ovnovi imali su veću progresivnu pokretljivost spermija u usporedbi s JS ovnovima. Na osnovu rezultata istraživanja može se zaključiti da su JS i JSR dvije različite pasmine koje bi mogle biti i genetski različite.

Ključne riječi: jezersko-solčavska ovca, poboljšana jezersko-solčavska ovca, tjelesne mjere, kvaliteta vune, kvaliteta sjemena

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