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THE INFLUENCE OF PROTEIN SOURCE AND CROSSING SYSTEM OF LAMBS ON WOOL QUALITY PARAMETERS

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Abstract: The experiment included 30 lambs-crosses F1 generation: Pirot Pramenka (50%) x Württemberg (50%) and 30 crossbred F1 generations: Pirot Pramenka (12.5%) x Württemberg(37.5) x Ille de France (50%), weaned at 60 days of age, the average body weight of 18.0 kg. The mixtures varied in protein source: I - sunflower meal, II - soybean meal and III - fish meal. The share of undegradable protein was 43 : 51 : 58 %. The average diameter of the fibres in lambs on treatments I:II:III was 26.14 : 24.96 : 25.20 μm, and of two-breed (PxW) and three-breed (PxWxIDF) crosses: 25.38 and 25.49 μm. The average height of the wool fibre in lambs on treatments I:II:III was: 2.97 : 3.06 : 3.17 cm, and in two-breed (PxW) and three-breed (PxWxIDF) crosses 2.98 : 3.15 cm. The average length of the fibre in lambs on protein sources I:II:III was 4.62 : 5.08 : 5.11 cm and in two-breed (PXW) and three-breed (PxWxIDF) crosses 4.77 : 5.11 cm. Protein source in feed mixtures, and genotype of lambs significantly influenced the quality of wool expressed through diameter, height and length of the fibres.

Key words: lamb, protein source, wool, diameter, height length

Introduction

Wool is not a uniform biological product because its physical characteristics vary depending on sheep genetics, environment and management strategies (*Warn et al., 2006*; *Poppi and McLenan, 2010*).
Wool value is intrinsically linked to its characteristics and the ability to meet commercially pre-determined parameters (*Wood, 2003; Jones et al., 2004; Purvis and Franklin, 2005; Bidinost et al., 2008*).
The quality of wool has determined by the physical and mechanical properties: diameter (fineness), height, length, tortuosity, strength and ductility of the wool fibres (*Ružić-Muslić, 2006*). In addition, these properties have ascertained by

factors of genetic and paragenetic nature. The most important characteristic of wool is definitely diameter (fineness) fibres, which implies an average thickness or diameter of the cross section of fibre expressed in micrometres (μm). Fibre diameter (FD) refers to the average width of a single cross section of wool fibre (*Gillespie and Flanders, 2010*). It is measured in microns (μm) which equates to one thousandth of a millimetre (*Cottle, 1991; Cottle, 2010; Poppi and McLenan, 2010; Rowe, 2010*). FD is widely acknowledged as the most important wool characteristics when assessing wool quality and value (*Edriss et al., 2007; Kelly et al., 2007; Rowe, 2010*) accounting for approximately 75% of the total price of raw wool (*Jones et al., 2004; Mortimer et al., 2010*).

Growth of lamb wool fibre is a continuous process influenced by: a genetic basis, nutrition, general physiological status and different environmental factors. The potential of sheep for wool production was determined during their embryonic development. During intrauterine development of lambs, begins the formation of the hair, to the extent of which depends on the genetic potential of the animal. The number and size of wool fibres produced by follicles (structural units in the skin of sheep) determine the quantity of wool produced. Primary follicles occur in the skin of the foetus on the ninetieth day after fertilization, while the secondary follicles develop from that moment on until the birth of lambs (*Jovanović et al., 2001*). The volume of maturation of follicles and production of wool fibres have closely related to nutrition and intensity of lamb growth.

Because the wool fibre is a protein matter whose main ingredient is keratin, the presence and source of protein in the diet affect the yield and quality of fibre (*Zeremski et al., 1989*). According to the research results obtained by *Slen (1969)* increase of protein levels from 7 to 10 % in dry matter of isoenergy diet used for feeding sheep, has resulted in an increase in production of unwashed wool by 16 %. At the same time, influenced by the above nutrition treatment, in terms of length and thickness of wool fibre, improvement of 8-12 % was established. In order to investigate the optimal protein content in the diet for maximal growth of high-quality wool fibre, the author carried out a trial on Romney Marsh breed lambs fed diets to suit their basic requirements and rations for fattening with a high proportion of protein in dry matter. It was established that during the period of 6 months of the experiment the lambs fed fattening diets with a high proportion of protein realized by 343 % more of unwashed wool, superior tortuosity of fibre, by 172 % higher fibre, by 206 % stronger and slightly coarser fibre.

Researches by *Urbaniak (1994)* indicated that with the increase in protein levels of 9.3 to 15.9 % in the diets for sheep, a linear increase in the production of wool has recorded. In studies by *Pajak et al. (1992)* had found that the decrease in protein content in the diet for nutrition of lambs (17, 14 and 11 %) resulted in a decrease in wool production. Profile analysis of amino acids present in the wool showed that the protein of wool is significantly richer in cystine and serine and poor in lysine and methionine. *Jovanović et al. (2001)* point out that the amount of available amino acids containing sulphur is one of the most important nutritional factors that affect the production and quality of wool. Degradation of feed proteins in the rumen prevents supply the sheep organism with large quantities of mentioned amino acids. Proteins that avoid bacterial hydrolysis in the rumen (undegradable protein), increase the wool production through increase in supply of the organism with amino acids, especially cystine, which is a limiting factor for the production of wool. According to the same author, the infusion of cystine into abomasum or blood can double the growth of wool, while the infusion of methionine increases the wool growth by providing sulphur for the synthesis of cystine. Another method to protect proteins from degradation in the rumen is treatment with formaldehyde. *Zeremski et al. (1989)* showed that lambs fed diets supplemented with casein (previously treated with formaldehyde) realized by 70% more wool than those who received untreated casein.

Chalupa (1975) studied the impact of application of formaldehyde treated feeds on growth of wool. Comparing the effects of soybean meal (untreated and treated) as the protein source, the author found that the increase of wool in the use treated soybean meal of 117 % compared to untreated (100 %). The use of untreated meat meal as a source of undegradable protein in the sheep diet had a greater effect on the growth of wool (100 %) compared to treated meal (96%). A similar relationship has noted in the use of flax meal (100:92 %). *Kiljpa and Kravcov (1989)* studied the effect of different protein supplements on the productivity of four (4) groups of sheep. As a source of protein, the Group I used sunflower meal, Group II used peas, Group III soybean meal and Group IV cottonseed meal. Respectively, wool yield in animals at the age of two years was 4.75, 4.78, 5.20, 4.73 kg. Effect of different concentrations of dehydrated alfalfa (0, 5, 10, 15 and 20 %) as source of undegradable protein in the diets for feeding lambs from 17.0 to 36.0 kg on wool production, *Urbaniak (1994)* found that the greatest accumulation of proteins in wool fibres (4.11 g day^{-1}) was achieved by lambs fed concentrate mixture that contained 10 % of dehydrated alfalfa.

The aim of the present study was to investigate the effect of different sources of protein in feed mixtures used in feeding of two populations of crosses: Pirot Pramenka x Württemberg (PXW) and Pirot Pramenka x Württemberg x Ille de France (PxWxIDF), on some physical and mechanical properties of wool.

Material and methods

The experiment included 30 lambs -crosses F1 generation: Pirot Pramenka (50%) x Württemberg (50%) and 30 crosses F1 generation: Pirot Pramenka (12.5%) x Württemberg(37.5%) x Ille de France (50%), weaned at 60 days of age, the average body weight of 18.0 kg. Animals fed with feed mixtures and alfalfa hay, in- group and ad libitum. The structure and nutritive value of mixtures have presented in Table 1and Table 2, respectively. The mixtures varied concerning protein source: I-sunflower meal, II- soybean meal and III- fish meal and hence the share of undegradable protein was 43 : 51 : 58%, respectively.

Table 1. Structure of concentrate mixtures for fattening of weaned lambs, %

Feeds	Concentrate		
	I	II	III
Corn	73	79	82
Sunflower meal	23	5	7
Soybean meal	0	12	0
Fish meal	0	0	7
Livestock lime	2	2	2
Salt	1	1	1
Premix	1	1	1

Protein source: I - sunflower meal, II - soybean meal and III - fish meal

Table 2. Nutritional value of mixtures

Nutritional indices	Concentrate mixtures		
	I	II	III
*Dry matter, g kg^{-1}	870	860.5	860.8
*OFU	1.2	1.2	1.2
*NEM,MJ	7.51	7.98	7.91
**UFV	0.99	1.05	1.04
*Total protein,g kg^{-1}	142	137	141
RUP	43	51	58
**PDIN g animal^{-1} day^{-1}	102	103	107
**PDIE g animal^{-1} day^{-1}	102	112	118
*Ashes, g kg^{-1}	25	23	27
*Ca,g kg^{-1}	8.4	8.2	10.6
*P,g kg^{-1}	4.6	3.7	5.0

Protein source: I - sunflower meal, II - soybean meal and III - fish meal; RUP- rumen undegradable protein; PDIN - protein digested in small intestine depending on the fermenting nitrogen; PDIE - protein digested in small intestine depending on the fermenting organic matter **INRA (1988) *Obračevic (1990)

The experiment lasted 75 days. The average body weight of animals at the end of the experiment was about 35.0 kg. To test the quality of wool, samples have taken from all animals in the experiment from three different locations: the left shoulder, the last rib and rump. For each sample, 10 fibres from the said locations had measured, i.e. 30 per head, or 1800 measured fibred. Samples were taken/cut using shear, along the skin, 2-3 cm in thickness and put in a form with the entered data for the animal and the place where the sample had taken.

As an indicator of the quality of wool, the following characteristics were analysed: height, length and diameter of wool fibre. In this study, the results of the analysis of wool related to the first three traits have presented, as seen from the point of impact of the sources of protein and lamb population. Fibre height has measured from the bottom to the top in a natural position and the length from the base to the top in the corrected position. These measurements had made according to JUS.F.B1O11 and JUS.F.B1O12. Evaluation of the thickness or fineness of wool fibres was performed by the method of short segments taken from the base, middle and top of fibre according to the Reichert lanometer, with a coefficient of 2 (magnification 500 times). Samples of wool used for testing of wool fibre diameter have pre-washed in hot water and detergent, and then rinsed in ethyl ether in order to remove all impurities.

Statistical analysis of the obtained data has done by analysis of variance (according to plan 3x2 factorial experiment, where a source of protein is one, and lamb population, the other observed factor) and assessment of the significance of the obtained differences, using the adequate tests (Tukey honest significant difference test, *Statistica 6 (2003)*.

Results and Discussion

The results of measurements of wool fibre diameter in lambs (two-breed and three-breed crosses) fed different sources of protein have displayed in Table 3. The average diameter of the fibres in lambs on treatments I : II : III was 26.14 : 24.96 : 25.20 μm. Established difference of 2.45 μm in the diameter of rump wool fibres taken from three-breed crosses on the third and first treatment, and to the benefit of treatment III, was highly significant (P= 0.000172). Moreover, three-breed crossbreds of treatment II had smaller fibre diameter (measured at the rump) by 2.16 μm, compared with the same population on treatment I, which was statistically highly significant (P= 0.000484). Analysing the observed characteristic in terms of genotypes, we can conclude that the average fineness of the fibre of two-breed and three-breed crosses was 25.38 and 25.49 μm. The difference in fibre diameter (measured at the rump) between the two-breed and three-breed crosses fed the diet I was 2.08 μm and was highly statistically significant (P= 0.000729). At the same time, this population of crosses differed in terms of fibre diameter by 1.51 μm, in favour of the three-breed crosses, in treatment III, which was statistically confirmed (P=0.02). The difference in the fineness of fibres (rump) between the two-breed crosses fed diet with protein source II and three-breed crosses fed diet with source of protein I, was 2.06 μm and was highly statistically significant (P = 0.000875) as well as the difference of 1.62 μm, in diameter of back fibres.

Table 3. Average diameter of wool fibre, µm.

Protein source	Crosses	Location	Indicators Average	CV
		Shoulder	25.61±1.56	6.08
		Back	26.11±1.73	6.62
	2	Rump	25.41±1.08***	4.24
		Average	25.71	
I		Shoulder	25.87±0.53	2.07
		Back	26.37±1.64*	6.24
	3	Rump	27.49±1.08***	3.94
		Average	26.57	
Average I			26.14	
		Shoulder	24.66±1.39	5.64
		Back	24.70±1.49*	6.05
	2	Rump	25.43±1.68*	6.60
		Average	24.93	
II		Shoulder	24.72±0.38	1.55
	3	Back	24.97±0.42	1.69
		Rump	25.33±0.53***	2.11
		Average	25.00	
Average II			24.96	
		Shoulder	24.82±2.34	9.43
	2	Back	25.12±0.47	1.88
		Rump	26.55±0.90*	3.38
		Average	25.50	
III		Shoulder	24.54±1.16	4.74
		Back	25.12±0.66	2.65
	3	Rump	25.04±0.60***	2.41
		Average	25.20	
Average III			26.14	

Protein source: I - sunflower meal, II - soybean meal and III - fish meal; 2-two-breed crosses (PxW); 3-three-breed crosses (PxWxIDF); *(P<0,05); ** (P<0,01); ***(P<0,001)

The results of the measurements of this property in experimental lambs have shown in Table 4. The highest average height of fibre has found in treatment III and it was 3.17 cm and the lowest in treatment I (2.97cm), while the animals on food type II had height of fibres of 3.06 cm. The value of the studied trait in two-breed and three-breed crosses was 2.98 and 3.15 cm. Difference between crosses, fed the source of protein II, in regard to the height of fibres measured at the shoulder was 0.37 cm in favour of the three-breed crosses and was statistically highly significant (P = 0.005) as well as difference in the above said trait measured at the rump (P = 0.003). Also, the established difference in the height of wool fibre between two-breed crosses on the type of diet I and three-breed crosses on II treatment, measured at the shoulder or rump was also confirmed at the level of statistical significance (P = 0.04) and (P = 0 .01), respectively.

Table 4. Average height of wool fibre, cm

Protein source	Crosses		Indicators	
		Location	Average	CV
		Shoulder	3.03±0.22*	7.46
	2	Back	2.85±0.37	12.88
		Rump	2.96±0.19**	6.43
I		Average	2.95	
		Shoulder	3.02±0.22	7.24
	3	Back	3.01±0.19	6.49
		Rump	2.98±0.23	7.84
		Average	3.00	
Average I			2.97	
		Shoulder	2.91±0.24**	8.17
	2	Back	2.88±0.22	7.62
		Rump	2.88±0.19**	6.56
II		Average	2.89	
		Shoulder	3.28±0.22**	6.58
	3	Back	3.14±0.24	7.73
		Rump	3.26±0.30**	9.28
		Average	3.23	
Average II			3.06	
		Shoulder	3.20±0.20	6.16
	2	Back	3.03±0.09	3.01
		Rump	3.09±0.18	5.75
III		Average	3.11	
		Shoulder	3.45±0.10	2.90
	3	Back	3.15±0.11	3.49
		Rump	3.10±0.10	3.22
		Average	3.23	
Average III			3.17	

Protein source: I - sunflower meal, II - soybean meal and III - fish meal; 2-two-breed crosses (PxW); 3-three-breed crosses (PxWxIDF); *(P<0,05); ** (P<0,01); ***(P<0,001)

Length of wool fibre is the distance between the ends of straightened fibre (without extension). Wool fibre staple length is becoming an increasingly important determinant of wool quality and value (*Edris et al., 2007; Valera et al., 2009; Gillespie and Flanders, 2010*), and is expressed in millimetre (mm) (*Thompson et al. 1988*). In Table 5, the results of measurements of this trait in experimental lambs are exposed.

The average length of the fibre in lambs on protein sources I : II : III was 4.62 : 5.08 : 5.11 cm, respectively. Established difference in fibre length, measured at the shoulder and rump, between two-breed crosses on source of protein III and I was a statistically significant (P = 0.02) and (P = 0.01).

Also, the difference between the two-breed crosses on treatments II and I in the length of the fibres measured on the back, was statistically confirmed (P = 0.03). Established fibre length of the three-breed crosses was 5.11 cm, and it was by 0.34 cm higher than in the two breed crosses.

Table 5. Average length of wool fibre, cm

Protein source	Crosses		Indicators	
		Location	Average	CV
		Shoulder	4.37±1.09**	28.61
	2	Back	4.10±1.27*	41.5
		Rump	4.27±1.07*	25.20
I		Average	4.25	
		Shoulder	5.02±0.25	26.88
	3	Back	4.95±0.17*	27.88
		Rump	5.01±0.22*	4.38
		Average	4.99	
Average I			4.62	
		Shoulder	5.02±0.33**	21.57
	2	Back	4.95±0.20*	26.70
		Rump	4.90±0.18*	3.76
II		Average	4.96	
		Shoulder	5.27±0.20	18.97
	3	Back	5.08±0.29*	16.50
		Rump	5.24±0.29**	5.51
		Average	5.20	
Average II			5.08	
		Shoulder	5.17±0.18*	25.41
	2	Back	5.01±0.09*	30.86
		Rump	5.09±0.19*	3.74
III		Average	5.09	
		Shoulder	5.21±0.28	21.45
	3	Back	5.15±0.24	30.24
		Rump	5.03±0.025	0.49
		Average	5.13	
Average III			5.11	

Protein source: I - sunflower meal, II - soybean meal and III - fish meal; 2-two-breed crosses (PxW); 3-three-breed crosses (PxWxIDF); *(P<0,05); ** (P<0,01); ***(P<0,001)

The studied populations of crosses on treatment I and about this trait measured on the back differed by 0.85 cm, which was statistically significant at P = 0.03, and measured on the rump by 0.74cm, which was also statistically significant (P = 0.03).

Comparing the ratio of the length and height of wool fibres, we concluded that, on the protein sources I : II : III it was 155.55 : 166.01 : 161.20 %, and in two-breed and three-breed genotypes 160.07 and 162.22 %. This relationship is consistent with the already known fact that in animals with finer wool there is significant difference between the length and the height of fibre.

During intrauterine development of lambs begins the formation of wool follicle, the extent of which depends on the genetic potential of animals. The yield and quality wool have influenced by genetic factors and environmental conditions within which the most important are nutrition and seasonal influences (*Zeremski et al., 1994*).

Comparing our results with data obtained by *Mitić (1984)* who examined the effect of genotype on some qualitative wool indicators in Württemberg breed of sheep, and found fibre fineness of 24-26 microns, we can state a certain agreement, given that the values obtained ranged from 24.96 - 26.14 micrometres.

By studying the phenotypic variability of wool of Merinolandschaf population, *Petrović et al. (1995)* found that the average height of fibre was 9.13 cm, fibre fineness 28.38 microns, strength 12:51CN / tex and extensibility 25.62 %, which is not fully consistent with our results. Furthermore, in the study of sheep wool quality of Ile de France breed, *Mitić (1984)* found the diameter of the fibres of 23-27 microns, and the average length was about 8.0 cm *Mekić et al. (1998),* found that the diameter of wool fibres in animals of Ile de France breed was on average 25.27 microns (rams) and 24.43 microns (sheep). Height of fibres amounted to 6.85 and the length of 10.30 cm. *Ćeranić (1970)* studied the impact of two-breed and three-breed crosses of domestic Merino on improvement of some fibre properties. The experiment involved the following genotypes: F_2 (domestic Merino X Precose); F_2 (domestic Merino x Stavropol); F_1 (domestic Merino X Precose) x Caucasian and F_1 (domestic Merino x Stavropol) x Caucasian. The average thickness of the fibres was 23.02 : 21.85 : 19.73 : 20.66 micrometres, respectively.

In terms of the impact of nutrition on yield and quality of wool, *Jovanović et al. (2001)* point out that the amount of available amino acids containing sulphur is one of the important nutritional factors that affect the quality of the wool. Protein degradation in the rumen prevents food supply to the sheep organism with more of the above-mentioned amino acids. Proteins that avoid bacterial hydrolysis in the rumen (undegradable protein) increase the growth and quality of wool, by increasing the supply of amino acids to the organism, especially cystine, which is a limiting factor for the production of wool. This conclusion is fully consistent with our results, since the best results in terms of quality of lamb's wool were obtained on treatment III which included fish meal as a protein source and the highest share of undegradable protein (58 % of the total), and thus the optimal content of amino acids necessary for the production and quality of wool. In addition to this, the study results by *Jovanović et al. (2001)* show that lambs fed diets supplemented with casein (previously treated with formaldehyde) reported a 70 % more wool than those who received untreated casein.

Also, *Chalupa (1975),* has studied the impact of the application of formaldehyde treated feeds on growth of wool. Comparing the effects of soybean meal (untreated and treated) as the protein source, the author found an increase in wool by 117% when used treated soybean meal compared to untreated (100 %). The use of untreated meat meal as a source of undegradable protein in the sheep diet had a greater effect on the growth of wool (100 %) compared to treated meal (96 %). A similar relationship noted in the use of flax meal (100 : 92 %).

In order to investigate the optimal protein content in the diet for maximal growth of high-quality wool fibre, *Slen (1969)* performed a trial on Romney Marsh breed lambs fed diets to suit their maintenance requirements and rations for fattening with a high proportion of protein in dry matter. It has found that during the period of 6 months of the experiment, the lambs fed fattening diets with a high proportion of protein had by 343 % more of unwashed wool, superior fibre tortuosity, by 172 % increase in the height of fibre and by 206 % stronger and slightly coarser fibre.

Generally feed protein containing a high level of sulphur-containing amino acids that is less degradable in the rumen would favour increased wool production. For example, canola (rapeseed) meal and lupin seed both contain similar and high levels of crude protein, but canola meal is less degraded in the rumen (*AFRC, 1993*). Merino lambs fed a diet containing canola meal grew 7-64 % more wool than sheep fed a lupin seed diet (*Masters and Mata, 1996; White et al., 2000*) and the response depends on the level of intake and the proportion of canola meal in the diet. When ruminal degradation of protein is avoided, substantial increase in wool growth rate can be obtained with protein, and only small responses are associated with energy *(Allden, 2001). Reis (2000)* showed that very high rates of wool growth could be obtained with moderate energy intakes when casein was given through the abomasum.

Conclusion

It is determined the quality of wool by the physical and mechanical properties: diameter (fineness), height, length, tortuosity, strength and ductility of wool fibres.

Diameter (fineness) of fibres implies an average thickness or diameter of the cross section of fibre expressed in micrometres (μm). The average diameter of the fibres in lambs on treatments I : II: III was 26.14 : 24.96 : 25.20 μm, and in two-breed (PxW) and three-breed crosses (PxWxIDF): 25.38 and 25.49 μm.

The average height of the wool fibre in lambs on treatments I: II: III was 2.97 : 3.06 : 3.17 cm, and in two-breed (PxW) and three-breed crosses (PxWxIDF) 2.98 : 3.15 cm.

Length of wool fibre is the distance between the ends of straightened fibre (without extension). The average length of the fibre in lambs on protein sources I : II: III was 4.62 : 5.08 : 5.11 cm, and in two-breed (PxW) and three-breed crosses (PxWxIDF) 4.77 : 5.13 cm.

Protein source in feed mixtures, and genotype of lambs significantly influenced the quality of wool expressed through diameter, height and length of the fibres, with the best results achieved in lambs on treatment with fish meal as a protein source, while the superior genotype were three-breed crosses (PxWxIDF).

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Uticaj izvor proteina i sistema ukrštanja jagnjadi na parametre kvaliteta vune

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Rezime

Eksperimentom je obuhvaćeno 30 jagnjadi-meleza F1 generacije pirotska pramenka (50%) x virtemberg (50%) i 30 meleza F1 generacije: pirotska pramenka (12,5%) x virtemberg (37.5) x Il de frans (50%), odbijenih na 60 dana starosti, prosečne telesne mase 18,0 kg. Smeše su se razlikovale u izvoru proteina: I – suncokretova sačma, II - sojina sačme i III – riblje brašno. Udeo nesvarljivih proteina je 43: 51: 58%. Prosečan prečnik vlakana u jagnjadi na tretmanima I: II: III je bio 26.14: 24.96: 25.20 µm, a kod dvorasnih (PxW) i trorasnih meleza (PxWxIDF): 25.38 i 25.49 µm. Prosečna visina vune u jagnjadi na tretmanima I: II: III je bila: 2.97: 3.06: 3.17 cm, a kod dvorasnih (PxW) i trorasnih (PxWxIDF) meleza: 2.98: 3.15 cm. Prosečna dužina vlakana u jagnjad na proteinskim izvorima I:II:III je bila 4.62: 5.08: 5.11 cm, a kod dvorasnih (PxW) i trorasnih (PxWxIDF) meleza 4.77: 5.11 cm. Izvor proteina u smešama hrane, kao i genotip jagnjadi, značajno su uticali na kvalitet vune izražen kroz prečnika, visinu i dužinu vlakana.

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