Journal of Elementology ISSN 1644-2296

Kawęcka A., Radkowska I. 2018.
Meat quality and slaughter traits of native Świniarka lambs depending on a housing system.
J. Elem., 23(4): 1423-1435. DOI: 10.5601/jelem.2017.22.4.1550

RECEIVED: 26 October 2017
ACCEPTED: 24 April 2018

ORIGINAL PAPER

MEAT QUALITY AND SLAUGHTER TRAITS OF NATIVE ŚWINIARKA LAMBS DEPENDING ON A HOUSING SYSTEM*

Aldona Kawęcka[1], Iwona Radkowska[2]

[1]Department of Sheep and Goat Breeding
[2]Department of Cattle Breeding
National Research Institute of Animal Production, Balice, Poland

Abstarct

The Świniarka, an old indigenous breed of sheep, is very well adapted to local environmental conditions and limited food sources, resistant to disease, and tolerant of unfavourable housing conditions. Świniarka sheep perform well in extensive production systems, on pasture, and on set-aside land and are successfully used for landscape management. The carcass quality of lambs is not very high, but the lamb meat of this race is highly popular among consumers owing to its special taste. The aim of the study was to characterize the carcass and meat quality in lambs of the Świniarka breed, kept indoors and on pasture. The study involved 20 ram-lambs, which were divided at 120 days of age into two feeding groups with 10 animals per group. Control ram-lambs (G_K) were kept in a sheep house, where they received meadow hay and straw *ad libitum* as well as around 0.3 kg/lamb of crushed oats. Animals from the second group (G_P) remained on pasture throughout the fattening period (3 months) and were supplemented with crushed oats. When the animals reached 7 months of age, they were slaughtered, their carcasses were subjected to slaughter analysis, and the chemical composition of the entrecote muscle was determined. It was found that a rearing system (indoor vs. pasture) had no effect on the final weight and dressing percentage of the lambs. Pasturing of the lambs had a beneficial effect on most carcass parameters and their meat was richer in proteins and minerals. The content of hypocholesterolemic fatty acids was also higher in the meat of lambs from this group.

Keywords: lambs, native breed, housing system, meat quality.

Aldona Kawęcka, PhD DSc, Department of Sheep and Goat Breeding, National Research Institute of Animal Production, 32-083 Balice, Poland, email: aldona.kawecka@izoo.krakow.pl.
* The study was financed from a research project of the Ministry of Science and Higher Education.

INTRODUCTION

Native sheep breeds are very well adapted to local environmental conditions and limited food resources, resistant to disease, and tolerant of unfavourable housing conditions. One such breed is the Świniarka, an old indigenous breed of sheep. Once abundant all over Poland, it became practically extinct after being replaced by other breeds. The current Świniarka population consists of more than 2,000 breeding ewes and has been included in the genetic resources conservation programmes. Świniarka sheep perform well in extensive production systems and are successfully used for landscape management, including environmentally valuable areas (Lipiec et al. 2015). Although the Świniarka's carcass quality is not very high, their lamb meat is highly popular among the consumers owing to its special taste. Lamb carcasses, known as *Jagnięcina ze świniarki,* have been included on the List of Traditional Products by the Polish Ministry of Agriculture and Rural Development.

The aim of the study was to evaluate and compare the quality of slaughter material (carcasses and meat) obtained from Świniarka ram-lambs kept indoors and on pasture.

MATERIAL AND METHODS

The experiment was carried out at a Świniarka sheep farm located in the Subcarpathian region. For evaluation of meat performance depending on the management system, 20 ram-lambs at the age of 4 months were divided into two feeding groups (10 lambs in group) Control ram-lambs (G_K) were kept in a sheep house, where they received meadow hay and straw *ad libitum* as well as around 0.3 kg/lamb of crushed oats. Animals from the second group (G_p) remained on pasture throughout the fattening period (3 months) and were supplemented with crushed oats.

The pasture area was 0.4 ha. The average forage intake of free grazing sheep was around 5-6 kg per day. During the plant growing period, the botanical composition of the sward was estimated according to Klapp and the pasture yield was determined using the method of Różycki. During the evaluation, samples of sward were collected for chemical analyses according to the AOAC procedures (2007). When animals reached 7 months of age, they were slaughtered and their carcasses were subjected to slaughter analysis according to the procedures used by the National Research Institute of Animal Production (NRIAP, 2009). The evaluation of meat performance included post-slaughter carcass evaluation and determination of the proportion of carcass cuts and leg tissue composition. The chemical composition was determined on the *longissimus dorsi* muscle, which was dissected from entrecote during the lamb carcass dissection using standard methods according to AOAC (2007). Fat was extracted based on the method of Folch (1975). The composition of fatty acids was analysed using a VARIAN 3400 gas chromatograph (Varian, Walnut Creek Instrument Division, USA) with a column Rtx 2330 (105 m × 0.32 mm × 0.2 μm). The column temperature was maintained at 60°C for 10 min, increased to 120°C at a rate of 20°C min^{-1} and to 240°C at a rate of 3°C min^{-1}; the time of analysis was 60 min. Other parameters included the injector temp. 250°C, detector temp. 250°C; helium as the carrier gas, 3 ml min^{-1}, 1.0 mcl injection. The cholesterol content was determined on a GC-2010 Shimadzu gas chromatograph (Shimadzu Corp., Japan) with an FID detector (Flame Ionization Detector) and a column Zebron ZB-5 (30 m×0.25 mm×0.5 μm). The column temperature was maintained at 100°C for 2 min, increased at a rate of 30°C min^{-1} to 150°C, and at a rate of 15°C min^{-1} to 360°C. The time of analysis was 60 min, injector temp. 250°C, detector temp. 300°C, helium as the carrier gas, 1.7 ml min^{-1}, 1.0 mcl injection.

The results were statistically analysed with STATISICA ver. 10 using Student's *t*-test. All analyses were conducted at a $p \leq 0.05$ and $p \leq 0.01$ level of significance.

RESULTS AND DISCUSSION

Grassland feeds are a valuable source of nutrients, mainly protein, carbohydrates, macro- and microelements, and vitamins. In turn, herbs which make up pasture sward increase the palatability of feed, improve the efficiency of its utilization, contribute to better metabolism, and influence the performance and health of grazed animals (Hashemzadeh-Cigari et al. 2014, Radkowska, Herbut 2014).

Analysis of the botanical composition of pasture sward grazed by sheep (Gp) showed that the largest group of plants were grasses, which accounted for almost 72% (Table 1), mainly perennial ryegrass (*Lolium perenne* L.), red fescue (*Festuca rubra* L.) and smooth-stalked meadow-grass (*Poa pratensis* L.). Legumes constituted 19% and dicotyledons 9% on average. Sheep tend to graze sward selectively and prefer high quality plant parts such as shoots, flowers and pods (Rook et al. 2004). Based on the analysis of the botanical composition of pasture sward, it was concluded that the percentage of different plant fractions was optimal for pastures intended for ruminant grazing. The chemical composition and nutritional value of the roughages and oat grain are presented in Table 2. These values corresponded to the parameters of medium or good quality feeds (Strzetelski et al. 2014).

The chemical composition of pasture sward depends on the botanical composition of the component plants, as well as on factors such as habitat conditions, fertilization, harvest time, and management system (Kulik 2009).

Table 1

Floristic composition of the pasture (%)

Grasses	72
Red fescue (*Festuca rubra* L.)	16
Cocksfoot (*Dactylis glomerata* L.)	3
Couch-grass (*Agropyron repens*)	2
Smooth-stalked meadow-grass (*Poa pratensis* L.)	15
Rough-stalked meadow-grass (*Poa trivialis* L.)	5
Perennial ryegrass (*Lolium perenne* L.)	31
Papilionaceae	19
White clover (*Trifolium repens* L.)	16
Red clover (*Trifolium pratense* L.)	2
Lucerne (*Medicago x varia Martyn.*)	1
Dicotyledons	9
Ribwort plantain (*Plantago lanceolata* L.)	+
Great plantain (*Plantago maior* L.)	1
Tall buttercup (*Ranunculus acris* L.)	1
Red dead-nettle (*Lamium purpureum* L.)	+
Yarrow (*Achillea millefolium* L.)	1
Dandelion (*Taraxacum officinale* F. H. Wigg.)	2
Common nettle (*Urtica dioica* L.)	+
Germander speedwell (*Veronica chamaedrys* L.)	+
Hedge bedstraw (*Galium mollugo* L.)	+
Brook thistle (*Cirsium rivulare* (Jacq.) All.	1
Common sorrel (*Rumex acetosa* L.)	1

Comparison of the crude protein content of pasture sward with the optimal values for ruminants showed that it fell within the normal range. The crude fibre content of roughages for ruminants ranges from 200 to 250 g kg^{-1} d.m. and should not exceed 280 g kg^{-1} d.m. (PAWLAK 1990). In the analysed pasture sward, the average crude fibre content was optimal and fell within the normal range for ruminant feeds. The crude fat content of forage, which depends on the developmental stage of grazed vegetation, should be 35-65 g kg^{-1} d.m. and was too low in our study. The protein value of feed is significantly affected by the percentage of different grass and clover species in the sward. A study by GAWEŁ (2008) confirmed the close relationship between protein value and a high proportion of legumes in the mixture sward. We evaluated the feeding value of pasture sward to be appropriate and its composition similar to the values specified in feeding standards.

Table 2

Chemical composition and nutritional value of the feeds

Item	Forage	Meadow hay	Straw	Oats
Chemical composition				
Dry matter (g kg^{-1})	225.1	906.7	919.1	889.0
on a DM basis (g kg^{-1})				
crude ash	71.7	59.0	64.7	28
crude protein	208.7	83.8	40.6	127
crude fat	30.7	17.9	16.4	46
crude fibre	220.4	293.1	424.9	118
NDF	521.9	630.5	784.8	144
ADF	287.2	386.9	527.1	315.5
Nutritional value (kg of DM)				
UVF	0.90	0.61	0.34	0.85
PDIE (g)	131	62	24	76
PDIN (g)	104	72	46	72
SFU	1.04	1.20	2.05	-

Explanatory notes: PDIN – protein truly digestible in the small intestine when N limits microbial protein synthesis, PDIE – protein truly digestible in the small intestine when energy limits microbial protein synthesis, UFV – feed unit for meat production, SFU – fill unit for sheep

Pasture sward is an important source of the precursors of linolenic acid and conjugated linoleic acid (CLA) in ruminant milk and meat. According to Bauchart et al. (1984), grasses are a source of five major fatty acids such as linolenic ($C_{18:3}$), linoleic ($C_{18:2}$), oleic ($C_{18:1}$), stearic ($C_{18:0}$) and palmitic acids ($C_{16:0}$). Their concentration varies according to plant species, stage of growth, temperature, light intensity, and season of the year. Pasture forage (Table 3) is dominated by unsaturated fatty acids, which form an average of 70-90% of the fatty acids, predominantly linoleic and linolenic acids (Harfoot, Hazlewood 1997). Morand-Fehr and Tran (2001) showed the plant's development stage to significantly influence the concentration of fatty acids. Clapham et al. (2005) demonstrated that the development of plants is paralleled by a decrease in the content of C_{18} fatty acids, in particular $C_{18:3}$. Some grass spe-

Table 3

Fatty acid content of the feeds (% in total amount of fatty acids)

Kind of feed	Fatty acid										
	C_{12}	C_{14}	C_{15}	C_{16}	$C_{16:1}$	C_{18}	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	C_{20}	$C_{20:1}$
Pasture sward	1.14	0.91	2.62	18.61	1.40	2.26	5.34	14.41	41.41	0.29	0.03
Oat grain	-	0.27	-	17.90	0.22	1.30	37.70	39.40	1.37	0.18	0.84

cies contain fairly large amounts of linolenic acid (Dewhurst et al. 2001) and most lipids are concentrated in leaf tissue (Harfoot 1981). Therefore, the content of fatty acids in feed depends on plant leafiness, which can be a species-specific trait and depends on plant maturity, habitat conditions and the fertilization used (Boufaied et al. 2003).

Meat performance

Despite their excellent adaptation to local environmental conditions, native breeds of sheep are often characterized by low meat performance parameters. The dressing percentage of free-range Świniarka sheep (7-8 months old), kept in environmentally valuable areas of the landscape park, was only 36% (Gruszecki et al. 2013). Numerous studies have shown that pastured lambs, compared to those fed intensively, had a lower dressing percentage (Klewiec et al. 2000). Karaca et al. (2016) found the group fed concentrate and hay *ad libitum* to be superior to pastured animals in terms of final weight and dressing percentage. Similar observations were made by Priollo et al. (2002) and Sauer et al. (2014), where the animals supplemented with concentrate showed higher weight gains and final body weight regardless of a genotype (native breed vs. crossbred). For four different rearing systems of Kivircik lambs, Ekiz et al. (2013) observed the lowest weight gains in lambs that used only pasture. No effect of the production system on the

Table 4

Fattening results of rams (kg), dressing percentage (%) and measurements of half-carcasses (cm) $\bar{x} \pm SD$

Item	G_K		G_P	
	$\bar{x}$	SD	$\bar{x}$	SD
Initial weight	16.70	0.70	16.30	0.96
Final weight	24.74	2.31	26.22	0.75
Dressing percentage	38.08	1.52	39.16	1.41
Cold carcass weight	8.85*a*	0.68	9.68*b*	0.63
Right half-carcass	4.36*a*	0.36	4.72*b*	0.31
Left half-carcass	4.46*A*	0.33	4.92*B*	0.33
Width of front	21.95*a*	0.68	22.67*b*	0.66
Length of half-carcass	55.1*A*	1.68	52.3*B*	2.09
Length of loin	27.1*A*	1.10	25.17*B*	1.14
Length of leg	30.95	0.89	31.05	1.04
Length of shank	15.00	0.10	15.38	0.77
Leg circumference	32.20*a*	1.60	34.33*b*	2.30

Explanatory notes:
Feeding group: G_K – control, G_P – experimental, $\bar{x}$ – mean value, SD – standard deviation, n = 10;
Means in rows and denoted using different letters differ statistically significantly: *a*, *b* – $p \leq 0.05$, *A*, *B* – $p \leq 0.01$.

growth of lambs was reported by DIAZ et al. (2002). Likewise, MAJDOUB-MATHLOUTH et al. (2015) found no differences in the final weight of lambs, while dressing percentage was higher when animals were fed hay and concentrate.

In our study, the rearing methods (confinement vs. pasture) had no effect on the final weight of the lambs and dressing percentage, although these parameters were observed to be higher in the pastured group (Table 4). Dressing percentage in the control group was 38.2% compared to 39.2% in the pastured group. The final body weight of pastured lambs was 26.2 kg and those reared indoors were 1.5 kg lighter. According to EKIZ et al. (2013), the carcasses of lambs on pasture were the lightest and their dressing percentage the lowest of all rearing systems under analysis. In Skudde lambs, NUERNBERG et al. (2005) found higher daily gains in the group maintained on pasture. ZAHARIA et al. (2012), who compared the effect of rearing system on the growth of the native Romanian Turcana breed under similar conditions as in our study, also observed much higher parameters for pastured compared to confined lambs, with the same supplement of concentrate (grain and wheat bran) given to both groups. According to these authors, lambs fed semi-intensively on pasture had 2.5-fold higher gains than those reared indoors and fed hay, which was decisive for the higher final body weight and translated into higher carcass weight.

The results of postslaughter evaluation (Table 5) indicate that the group reared on pasture was superior in terms of carcass weight and leg circumference, whereas carcass and loin length were greater in confined lambs.

Table 5

Weight of carcass cuts (g) and tissue composition of leg (g), $\bar{x}$ ± SD

Item	G_K		G_P	
	$\bar{x}$	SD	$\bar{x}$	SD
Scrag	314.50	64.99	356.67	50.99
Middle neck	361.00	45.08	326.11	47.48
Entrecote	284.00	44.15	314.44	42.24
Rump	323.00	49.84	323.88	36.97
Shoulder	537.50*A*	33.27	666.67*B*	59.47
Breast and brisket	866.50	91.68	941.11	123.56
Leg	1145.50*A*	80.54	1331.67*B*	107.56
Fore shank	151.00	13.70	143.33	23.45
Hind shank	261.50*A*	18.86	289.22*B*	17.83
Meat	836.00*A*	83.09	993.33*B*	74.46
Fat	106.50	31.72	81.67	37.42
Bones	213.50*A*	33.00	253.88*B*	25.10

Meanings of group symbols as in Table 4.

The slaughter analysis showed that lamb carcasses differed in the weight of cuts. In group G_p, the weight of leg, hind shank and shoulder was higher than in the control group (by 186.2 g, 27.7 g and 129.2 g respectively), with highly significant differences. KARACA et al. (2016), despite the differences found in the weight of half-carcass subjected to detailed dissection, found no such differences between the cuts except for fore shank, the proportion of which was higher in lambs reared on pasture. In the evaluation of leg tissue composition, the weight of meat and bones was found to be higher in pasture-fed lambs. MAJDOUB-MATHLOUTH et al. (2015) reported a higher bone percentage in the leg of pastured lambs.

Quality of świniarka meat

The quality of meat is determined by its chemical composition, which depends on several factors such as breed, age, preslaughter weight of lambs, and feeding. The results of the chemical analysis of entrecote muscle are shown in Table 6. A similar content of dry matter, fat and cholesterol was

Table 6

Chemical composition of lamb meat *(m. longissimus dorsi)*

Item	G_k		G_p	
	$\bar{x}$	SD	$\bar{x}$	SD
Dry matter (g kg^{-1})	238.9	1.88	234.7	0.97
Fat (g kg^{-1})	37.8	2.16	22.8	1.07
Protein (g kg^{-1})	190.3*A*	0.96	204.3*B*	0.84
Ash (g kg^{-1})	10.9*a*	0,05	11.3*b*	0,04
Cholesterol (mg 100 g^{-1})	72.00	4.83	71.46	2.49

Meanings of group symbols as in Table 4.

found in both groups. Protein and ash content was higher in the meat of pastured lambs. KARACA et al. (2016) found the meat of concentrate-fed lambs to have a higher component content. ONENC et al. (2015) did not find any differences in the basic composition of meat from traditionally and intensively fed Chios ram-lambs.

The cholesterol content of food products is important for human nutrition, especially of people with disturbances in lipid metabolism, which are associated with the risk of coronary heart disease. In our study, the level of cholesterol was 71.46-72.0 mg 100 g^{-1}. No statistically significant differences were found in the content of cholesterol between the groups. In the *M. l. lumborum* of 6-month-old crossbred lambs from Texel rams, kept extensively on pasture, it was around 76 mg 100 g^{-1} (FARIA et al. 2012).

The dietary value of animal products is also determined by the composition of fatty acids, which is influenced by a number of factors, including animal nutrition. Many studies in this area mainly compared the pasture (extensive) system with other feeding systems. According to MILEWSKI (2006), forage-fed animals produce meat with a lower fat content and a more beneficial profile of fatty acids, including a higher content of PUFA and conjugated dienes of linoleic acid, compared to those fed intensively with a high proportion of concentrates.

In the meat of both groups, palmitic acid ($C_{16:0}$) and stearic acid ($C_{18:0}$) dominated among saturated fatty acids (SFA), and oleic acid ($C_{18:1}$) was prevalent among unsaturated fatty acids (UFA). In the meat fat of G_K lambs, $C_{16:0}$ fatty acids were significantly higher than in the muscles of G_P lambs, which, in turn, contained twice as much $C_{20:0}$ arachidonic acid. The muscles of G_P lambs had a much higher content of unsaturated fatty acids oleic ($C_{18:1}$), linoleic ($C_{18:2}$) and arachidonic ($C_{20:4}$). Linolenic acid ($C_{18:3}$) was abundant in the intramuscular fat of control lambs. In general, however, the proportion of UFA in the meat of both groups was similar and accounted for more than half of the total pool of fatty acids. The meat of G_K lambs contained more monounsaturated (MUFA), and the meat of G_P lambs had more polyunsaturated fatty acids (PUFA), with highly significant differences. The high content of *n-6* linoleic and arachidonic acids contributed to a higher proportion of the *n-6* PUFA fraction in the group fed with forage. The content of *n-3* PUFA was the same in both groups (1.35%) – Table 7. The content of DFA was higher in group $G_{P.}$ The DFA/OFA, PUFA/SFA and PUFA *n-6* to PUFA *n-3* ratios differed significantly among the groups. ONENC et al. (2015) found CLA to be higher in the intramuscular fat of *m.l.d.* from traditionally fed Chios ram-lambs and this value was similar to that in the muscles of Świniarka lambs from both groups (0.6%).

GRUSZECKI et al. (2001) reported that the fat of pastured lambs contained less MUFA but almost 3 times as much C18:2, compared to concentrate-fed lambs. CIVIDINI et al. (2008), who compared the meat of lambs from mountain pastures and those fed indoors with hay and concentrate, concluded that pasture feeding contributes to lower SFA and MUFA concentrations and a higher concentration of PUFA, both *n-6* and *n-3*. For this reason, in the meat of these lambs, the *n-6/n-3* fatty acids ratio was higher than in lambs fed indoors. PARAPONIAK et al. (2012) also found this parameter to be higher in Pomeranian and Suffolk sheep despite pasture management. Both JOY et al. (2008) and EKIZ et al. (2013), who used different systems of feeding native breed lambs, did not find significant differences in the proportions of fatty acids between the groups.

Considering the recommendations of the World Health Organisation (WHO), it is difficult to clearly state which of the lamb management systems is responsible for a more beneficial fatty acid profile of meat from the human health perspective. According to the WHO nutritional recommendations, the PUFA to SFA ratio should be >0.4 and PUFA *n-6/n-3* around 4:1 (FARIA et al. 2012).

Table 7

Fatty acid composition of lamb meat (%)

Item	G_k		G_p	
	$\bar{x}$	SD	$\bar{x}$	SD
$C_{10:0}$	0.144	0.106	0.061	0.074
$C_{12:0}$	0.292	0.083	0.224	0.089
$C_{14:0}$	3.446	0.852	2.374	0.721
$C_{16:0}$	23.243*A*	0.813	20.288*B*	1.446
$C_{16:1}$	2.091*A*	0.301	1.485*B*	0.080
$C_{18:0}$	19.594	3.032	22.034	3.211
$C_{18:1}$	42.063*a*	2.598	38.913*b*	2.758
$C_{18:2;\,n\text{-}6}$	3.951*A*	0.921	6.664*B*	2.482
$\text{gama}_{18:3}$	0.031	0.014	0.037	0.031
$C_{18:3;\,n\text{-}3}$	0.861*A*	0.151	0.593*B*	0.216
$C_{20:0}$	0.045*A*	0.013	0.105*B*	0.062
CLA c9-t11	0.555	0.112	0.519	0.190
CLA t10-c12	0.019	0.011	0.011	0.017
CLA c9-c11	0.014	0.017	0.006	0.019
CLA t9-t11	0.045*a*	0.015	0.069*b*	0.024
$C_{20:4;\,n\text{-}6}$	3.112*A*	1.588	5.853*B*	3.194
$C_{20:5;\,n\text{-}3}$	0.386	0.251	0.573	0.319
$C_{22:6;\,n\text{-}3}$	0.105	0.076	0.185	0.103
SFA	46.765	2.561	45.089	4.247
UFA	53.234	2.561	54.911	4.247
MUFA	44.155*a*	2.832	40.399*b*	2.823
PUFA	9.080*a*	2.715	14.511*b*	6.061
PUFA-6	7.093*A*	2.389	12.556*B*	5.680
PUFA-3	1.352	0.449	1.351	0.587
DFA	72.829*A*	1.595	76.945*B*	1.725
OFA	27.170*A*	1.595	23.054*B*	1.725
UFA/SFA	1.144	0.117	1.237	0.231
DFA/OFA	2.691*A*	0.215	3.361*B*	0.363
MUFA/SFA	0.948	0.097	0.901	0.080
PUFA/SFA	0.196*a*	0.063	0.336*b*	0.182
PUFA 6/3	5.261*A*	0.869	9.6328*B*	2.044
CLA	0.633	0.133	0.605	0.201

Meanings of group symbols as in Table 4.

CONCLUSION

It is important for the breeder to use a lamb rearing system that minimizes the costs and ensures optimum results. Rearing native breed lambs on pasture had a beneficial effect on most carcass parameters. The meat of lambs on forage was richer in protein and minerals. The content of beneficial hypocholesterolemic acids was also higher in the meat of lambs from this group.

REFERENCES

AOAC. *Official Methods of Analysis of AOAC Int.*, 18th ed., USA, 2007.

Bauchart D., Vérité R., Rémond B. 1984. *Long-chain fatty acid digestion in lactating cows fed fresh grass from spring to autumn.* Can. J. Anim. Sci, 64: 330-331. DOI: org/10.4141/cjas84-285

Boufaied H., Chouinard P. Y., Tremblay G. F., Petit H. V., Michaud R. Belanger G. 2003. *Fatty acids in forages. I. Factors affecting concentrations.* Can. J. Anim. Sci., 83: 501-511. DOI: org/10.4141/A02-098

Cividini A., Levart A., Zgur S. 2008. *Fatty acids composition of lamb meat as affected by production system, weaning and sex.* Acta Agric. Slovenica, 2: 47-52.

Clapham, W.M., Foster, J.G., Neel, J.P.S., Fedders, J.M. 2005. *Fatty acid composition of traditional and novel forages.* J. Agric. Food Chem., 53(26): 10068-10073. DOI: 10.1021/jf0517039

Dewhurst R. J., Scollan N. D., Youell S. J., Tweed J. K. S., Humphreys M. O. 2001. *Influence of species, cutting date and cutting interval on the fatty acid composition of grasses.* Grass Forage Sci., 56: 68-74. DOI: 10.1046/j.1365-2494.2001.00247.x

Díaz M.T., Velasco S., Cañeque V., Lauzurica S., Ruiz de Huidobro F., Pérez C., González J., Manzanares C. 2002. *Use of concentrate or pasture for fattening lambs and its effect on carcass and meat quality.* Small Rumin. Res., 43(3): 257-268. DOI: org/10.1016/S0921--4488(02)00016-0

Ekiz B., Demirelb G., Yilmaz A., Ozcan M., Yalcintan H., Kocak O., Altinel A. 2013. *Slaughter characteristics, carcass quality and fatty acid composition of lambs under four different production systems.* Small Rumin. Res., 114(1): 26-34. DOI: org/10.1016/j.smallrumres.2013.05.011

Faria PB., Bressan MC., Vieira JO., Vicente-Neto J., Ferrão SP., Rosa FC., Monteiro M., Cardoso MG., Gama LT. 2012. *Meat quality and lipid profiles in crossbred lambs finished on clover-rich pastures.* Meat Sci., 90(3): 733-738. DOI: 10.1016/j.meatsci.2011.11.004

Folch J., Lees M., Sloane-Stanley G.H. 1975. *A simple method for the isolation and purification of total lipids from animal tissues.* J. Biol. Chem., 226: 497-509.

Gaweł E. 2008. *The effect of the way and frequency of utilization of lucerne-grass mixtures on their yield, botanical composition and quality.* Water – Environment – Rural Areas, 8(24): 5-18. (in Polish)

Gruszecki T., Klewiec J., Lipiec A., Lipecka C., Junkuszew A., Baranowski A. 2001. *Composition of lipid fraction in lamb muscle fattened according to the feeding system.* Rocz. Nauk. Zoot., 11: 133-138. (in Polish)

Gruszecki T. M., Bojar W., Junkuszew A., Szymanowski M., Ciesielczuk M. 2013. *Slaughter value of domestic breed of lambs managed under free-range system on valuable natural areas.* Rocz. Nauk. Stow. Ekon. Rol. Agrob., 15(5): 94-96. (in Polish)

Harfoot C.G. 1981. *Lipid metabolism in the rumen.* In: *Lipid metabolism in ruminant animals.* Christie W.W., (ed.). Perg. Press, Oxford, UK, 21-55.

Harfoot, C.G., Hazlewood, G.P. 1997. *Lipid metabolism in the rumen.* In: *The rumen microbial ecosystem.* Second edition. Hobson P.N (ed). Els App Sci, London, 382-426.

Hashemzadeh-Cigari F., Khorvash M., Ghorbani G.R., Kadivar M., Riasi A., Zebeli Q. 2014. *Effects of supplementation with a phytobiotics-rich herbal mixture on performance, udder health, and metabolic status of Holstein cows with various levels of milk somatic cell counts.* J Dairy Sci., 97(12): 7487-7497. DOI: 10.3168/jds.2014-7989

Joy M., Ripoll G., Delfa R. 2008. *Effect of feeding system on carcass and non-carcass composition of Churra Tensina light lambs.* Small Rumin. Res., 78: 123-133, DOI: org/10.1016/j.smallrumres.2008.05.011

Karaca, S., Yilmaz, A., Kor, A., Bingöl, M., Cavidoğlu, İ., Ser, G. 2016. *The effect of feeding system on slaughter-carcass characteristics, meat quality, and fatty acid composition of lambs.* Arch. Anim. Breed., 59: 121-129. DOI: 10.5194/aab-59-121-2016

Klewiec J., Gruszecki T., Baranowski A., Markiewicz J., Gabryszuk M. (2000). *Evaluation of the slaughter value of lambs kept indoor and in pasture systems.* Prz. Hod, 8: 49-50. (in Polish)

Kulik M. 2009. *Effect of different factors on chemical composition of grass-legumes sward.* J. Elem., 14(1): 91-100.

Lipiec A., Gruszecki T.M. , Warda M., Bojar W., Junkuszew A., Kulik M., Greguła-Kania M. 2015. *Nutritional well-being of sheep under free-range grazing system on natural dry grasslands.* Med. Wet., 71(1): 41-45.

Majdoub-Mathlouthi, L., Saïd, B., Kraiem, K. 2015. *Carcass traits and meat fatty acid composition of Barbarine lambs reared on rangelands or indoors on hay and concentrate.* Animal, 9 (12): 2065-2071. DOI: 10.1017/S1751731115001731

Milewski S. 2006. *Health benefits of sheep products.* Med. Wet., 62(5): 516-519. (in Polish)

Morand-Fehr P., Tran G. 2001. *La fraction lipidique des aliments et les corps gras utilisés en alimentation animale.* INRA Prod. Anim., 14(5): 285-302.

NRIAP. 2009. *Evaluation of meat performance of lambs against the background of the requirements and methods used in EU countries.* Praca zbiorowa. Wyd. IZ PIB. Kraków, ss. 32. (in Polish)

Nuernberg K., Nuernberg G., Ender K., Dannenberger D., Schabbel W., Grumbach S., Zupp W., Steinhart H. 2005. *Effect of grass vs. concentrate feeding on the fatty acid profile of different fat depots in lambs.* Eur. J. Lipid Sci. Technol., 107: 737-745. DOI: 10.1002/ejlt.200501141

Onenc S., Ozdogan M., Aktumsek A., Taskin T. 2015. *Meat quality and fatty acid composition of chios male lambs fed under traditional and intensive conditions.* Emir. J. Food Agric., 27(8): 636-642. DOI: 10.9755/ejfa.2015.04.068

Paraponiak P., Kaczor A., Wieczorek - Dąbrowska M. 2012. *Comparison of fattening and slaughter parameters in meat and native breed sheep raised on an organic farm.* Rocz. Nauk. Zoot., 39(2): 203-216. (in Polish)

Pawlak T. 1990. *Feed value of grassland feeds on the basis of assessment (analysis) of the quality of organic and mineral substances.* Mat. KUR PAN, Sekcja Łąkarstwa, 8-65. (in Polish)

Priolo A., Micol D., Agabriel J., Prache S., Dransfield E. 2002. *Effect of grass or concentrate feeding systems on lamb carcass and meat quality.* Meat Sci., 62(2): 179-85. DOI: org/10.1016/S0309-1740(01)00244-3

Radkowska I., Herbut E. 2014. *Hematological and biochemical blood parameters in dairy cows depending on the management system.* Anim. Sci. Pap. Rep., 32(4): 317-326.

Rook A. J., Dumont B., Isselstein J., Osoro K., Wallis de Vries M.F., Parente G., Mills J. 2004. *Matching type of livestock to desired biodiversity outcomes in pastures: a review.* Biol. Conserv., 119: 137-150. DOI: org/10.1016/j.biocon.2003.11.010

Sauer M., Padeanu I., Sauer W-I., Gavojdian D., Voia S-O. 2014. *Comparative study on growth performance in lambs reared under organic and conventional systems.* Sci. Papers: Anim. Sci. Biotech., 47(1): 296-299.

Strzetelski J.A., Brzóska F., Kowalski Z.M., Osięgłowski S. 2014. *Feeding recommendation for ruminants and feed tables*. IZ PIB, Kraków, 214-234.

Zaharia R., Pascal C., Zaharia N., Lazăr R., Salamon S. 2012. *The influence of the fattening system on growth rate and dressing percentage of the Turcana lambs bred in mountain area in the north-east of Romania*. Lucr. Ştiinţ., Ser. Zooteh., 57(17): 190-195.