

The effects of using the biofuel co-products in semi-intensively fattening of lambs Part II. Yield of culinary cuts and meat quality

Bronisław Borys¹, Eugenia Grześkowiak², Andrzej Borys², Dariusz Lisiak²

¹National Research Institute of Animal Production, Experimental Station in Koluda Wielka
ul. Parkowa 1, 88-160 Janikowo

²Institute of Agricultural and Food Biotechnology
ul. Rakowiecka 36, 02-532 Warszawa

In part II of the study, the effects of using by-products from biofuels' production in semi-intensive fattening of lambs on yield of culinary meat from the half-carcass, chemical composition and physicochemical characteristics of meat were investigated. Ram lambs were fattened to 35 kg (± 3 kg) body weight in 5 groups, and 6 from each group were slaughtered. Each group included 50% of the prolific-dairy Koluda sheep (OK) and 50% of F₁ Ile de France rams \times OK ewes (If \times OK). The lambs were fed concentrates (3% of body weight) + grass hay *ad libitum* or pasture grazing for 5-6 h/day. The control group received a standard diet + hay, and experimental groups had a diet with rapeseed meal or maize DDGS (50%), linseed (5%) and vitamin E (0.2%). The yield of culinary meat was determined for the right half-carcasses, and its chemical composition, physicochemical properties and organoleptic characteristics were determined using samples of raw and/or grilled leg meat. Neither dietary factors nor breed origin of the lambs had a significant effect on the yield of culinary meat. The analyzed factors did not influence the basic chemical composition of meat and its physicochemical characteristics. Feeding the diet with 50% DDGS, regardless of the type of roughage used, had no significant effect on the organoleptic scores of grilled meat, while feeding the diet with 50% rapeseed meal and pasture grazing adversely affected these scores.

KEY WORDS: lamb / fattening / biofuel co-products / meat quality / meat yield

One of the major directions in research in animal science and related disciplines is connected with the identification of conditions determining dietary and health-promoting value of animal origin products (primarily meat and milk) and methods of their potential modification [5, 6, 19, 27]. Numerous studies on the subject conducted on practically all farm animal species have indicated the most important factors determining the dietary value of meat and milk along with a number of methods ensuring their beneficial modification in

terms of their health-promoting properties. It was found that among the many genetic and environmental factors nutrition-based methods proved to be most effective in the modification of dietary quality of these products. In relation to ruminants, the most effective methods consist in the application of vegetable fats in various forms. Basic aspects of these problems have also been investigated in meat of slaughter lambs [7, 10, 31]. However, new research directions have been suggested in this respect. One of them is to determine the effects of by-products of biofuel production in fattening of lambs. In Poland these products include primarily rapeseed meal and rape cake as well as dried distillers' grain with solubles (DDGS). In view of the dynamic development of biofuel component production using oil crop seeds and cereal grain, large amounts of by-products have become commercially available and they should be rationally managed first of all as feed for farm animals [6, 9]. Effects of their application in various feeding systems adopted for slaughter lambs need to be investigated both in terms of their effect on the growth rate and slaughter value of these lambs [8] and the yield of sub-primal cuts and meat quality, including the chemical composition, physico-chemical parameters, organoleptic properties as well as dietary value and health benefits provided by such meat.

Most studies conducted in this area within the scope of animal science research concern individual muscles or storage fat, typically analysed in the raw form. Only recently research results have been reported in world literature sources, which analysed the effect of various factors on the quality of whole cuts, both raw and following various processing operations, which may cause extensive changes in parameters affecting dietary value and health benefits of meat [3, 18, 27, 30]. Such a research approach is crucial from the point of view of consumers, who focus on the eating quality of meat dishes, i.e. meat products ready to be served.

The aim of the presented study was to determine the effect of high proportions of by-products generated in biofuel production (50% rapeseed meal or DDGS + 5% linseed and 0.2% vitamin E) in a concentrate mixture used in semi-intensive fattening of lambs, administered feed rations supplemented with hay or pasture grazing, on the yield of sub-primal cuts from the half-carcass as well as the chemical composition, physico-chemical properties and sensory attributes of meat.

Material and methods

The experimental material comprised right half-carcasses of 30 lambs (tup lambs) fattened in a semi-intensive system until body weight of 35 kg (± 3 kg). Lambs were fattened in 5 groups, from each of which 6 animals were selected at random for analyses of yield and meat quality, including 3 tup lambs of the prolific-dairy Koluda sheep line (OK) and 3 F_1 cross-breds of rams of the mutton Ile de France breed and OK ewes (If x OK).

Lambs were fed in lots using concrete mixtures provided in the amount equivalent to approx. 3% body weight and grass hay *ad libitum* (S groups) or grazed on the pasture for 5-6 hours a day (P groups). In the control (K) the standard mixture was used based on cereal components (50.5%) and rapeseed meal (20%), while in the experimental groups – on

rapeseed meal (SR, 50%) or dried distillers' grains with solubles (DDGS, 50%) and linseed (5%) + vitamin E (0.2%). The composition of concrete mixtures as well as their nutritive value and feed intake levels for lambs in the compared groups are given in Part I of this study [8].

Lamb slaughter and carcass division into half-carcasses followed guidelines of the Institute of Animal Science NRI [20]. Yields of sub-primal cuts from right half-carcasses were determined as recommended by the Institute of Agricultural and Food Biotechnology [12].

Analyses of the basic chemical composition and physico-chemical parameters were conducted on samples of raw and/or grilled leg cuts. Deboned leg meat (DLM) was formed in nets with an addition of 2% salt and ripened for 24 h at a temperature of +4°C. Representative slices of 1.5 cm in thickness were cut from such prepared deboned leg meat and they were grilled on both sides (for 5 minutes each side) in an electric grill Expo Sernice GR 100.

In samples of raw and grilled DLM water content was determined by the gravimetric method at a temperature of 105°C to establish constant mass [22], protein content – according to Kjeldahl in a Tecator apparatus [21] and fat content according to Soxhlet [23].

In raw DLM samples electrical conductivity (EC_{24}) was measured with a PQM-1 KOM-BI apparatus; pH (pH_{24}) – using a Radiometer PHM 80 Portable pH-meter with a coupled electrode; water holding capacity (WHC) was determined according to Grau and Hamm [13] as modified by Pohja and Niinivaara [24]; colour parameters (L^* , a^* and b^*) were measured with a Minolta CR 400 camera in the CIE system. Moreover, organoleptic evaluation of marbling was performed in a 5-point scale using intramuscular fat deposition reference standards (from invisible – 1 point to very strong – 5 points).

Following thermal processing (grilling) of DLM the percentage cooking loss was recorded, while shear force was determined in the Warner-Bratzler shear test using a Zwick shear testing machine. Organoleptic evaluation of aroma, juiciness, tenderness and palatability was conducted by a 5-person trained panel applying a 5-point score scale [4].

Results were analysed statistically using the STATISTICA 8.0 software package applying the two-way analysis of variance (feeding system, lamb breed) in the orthogonal system and the model with interactions. Significance of differences between the feeding groups was estimated using Duncan's test.

Results and discussion

Yield of sub-primal cuts. The statistically confirmed ($P \leq 0.01$) effect of the feeding system on the percentage yield of sub-primal cuts was found only for loin (saddle) chops, which lowest share was found in carcasses of lambs from the control (K) – Table 1. Differences between groups SR+S, SR+P and DDGS+P and group K amounted to 1.9, 2.3 and 2.2 percentage points (pp). Additionally, within the experimental groups a trend was observed for a greater yield of chops from carcasses of lambs which had been grazing on the pasture in comparison to the corresponding groups of lambs fed hay indoors. At the

Table 1
Yield of selected culinary cuts from the half-carass

Culinary elements	K	Feeding group				Breed origin		SEM
		SR+S	SR+P	DDGS+S	DDGS+P	OK	If x OK	
n	6	6	6	6	6	15	15	
Weight of half-carass (kg)	6.89 ^a	6.99 ^b	7.35	7.39	7.56 ^{ab}	7.17	7.30	0.826
Yield of culinary meat from the half-carass (%):								
culinary elements ¹ in total	64.5	64.7	66.3	64.3	64.8	64.9	65.0	0.401
share:								
shoulder roulade	12.1	12.0	12.1	11.8	11.5	11.8	12.0	0.136
cervical roulade	8.5	8.8	9.1	9.4	9.0	8.9	8.9	0.135
breast roulade	9.3	8.9	9.0	8.8	8.6	9.1	8.7	0.160
loin chops	11.5 ^{ABC}	13.4 ^C	13.8 ^{AA}	12.5 ^A	13.7 ^B	12.6	13.3	0.240
leg roast meat:								
– with the bone	21.3	21.0	21.7	21.3	21.6	21.3	21.5	0.240
– boneless	19.9	18.3	18.9	18.5	18.8	19.1	18.7	0.370
hind shank boneless	3.3	3.3	3.4	3.3	3.3	3.3	3.3	0.020

Feeding groups: K – control, SR+S – mixture with rapeseed meal + grass hay, SR+P – mixture with rapeseed meal + pasture grazing, DDGS+S – mixture with DDGS + grass hay, DDGS+P – mixture with DDGS + pasture grazing

Breed origin: OK – Koluda Sheep, If x OK – crossbreeds F₁ Ile de France x OK

¹Total: shoulder roulade + cervical roulade + breast roulade + loin chops + leg roast meat boneless + hind shank boneless

SEM – standard error of arithmetic mean; AA, BB, CC – P≤0.01; aa, bb – P≤0.05

generally slight and uncharacteristic differences in the yields of the other analysed cuts group SR+P turned out to be best in terms of the total yield of sub-primal cuts from the half-carcass, as it exceeded group K by 1.8 pp and the other experimental groups by 1.8 and 1.7 pp, respectively.

The effect of both investigated feeding-related factors on the percentage yield of sub-primal cuts obtained from the half-carcass was generally non-significant, except for loin chops. Similarly, studies by Borys et al. [11] and Grześkowiak et al. [15] on lambs fattened in the intensive system to high body weight levels showed no effect of feeding a diet including oil crop components (rapeseed and linseed, rape cake) on yields of sub-primal cuts.

Lamb breed was found to have no significant effect on the yield of analysed sub-primal cuts.

A lack of a significant effect of breed on the percentage yield of sub-primal cuts from the half-carcass was also indicated by earlier studies [11, 28, 29], in which similar commercial crossbreeding systems were used. In turn, a study by Grześkowiak et al. [16] on purebred lambs fattened in an intensive system to high body weight levels showed significant differences in yields of sub-primal cuts between the prolific Finnsheep breed or the dairy East Friesian breed and the mutton Texel and Suffolk breeds, at a lack of differences in the case of the Ile de France breed.

Chemical composition and meat quality. The tested fattening systems and the breed group had no significant effect on the basic chemical composition of raw leg meat from sub-primal cuts (Table 2). Following heat processing by grilling meat from sub-primal cuts contained less water (on average by 19.5%), while it contained more protein and fat (on average by 57.0 and 59.8%, respectively), at a lack of significant differences depending on the feeding system and lamb breed. Greater differences in contents of protein and fat were recorded in grilled meat depending on the feeding system used in lamb fattening. Meat of lambs from all the experimental groups contained more protein in comparison to that from the control (K). Differences for groups SR+S, SR+P and DDGS+S were statistically significant and amounted to 12.9 and 11.1% ($P \leq 0.01$) and 8.4% ($P \leq 0.05$), respectively. Moreover, a reduced fat content (on average by 16.8%; $P \leq 0.05$) was recorded in grilled meat of lambs fattened with a mixture containing a high proportion of rapeseed meal (SR+S and SR+P) in comparison to the meat of lambs from the K group or lambs fed a mixture containing a high share of dried distillers' grains with solubles (DDGS+S and DDGS+P).

Numerous studies concerning the effect of various feeds and applied feeding systems as well as the breed of lambs on the basic chemical composition of raw muscles and sub-primal cuts indicate that it depends on many simultaneously interacting factors [2, 10, 11, 25, 26]. In view of the increasingly common application of components rich in vegetable oils in fattening of farm animals, including lambs, we may observe growing interest on the part of researchers in problems related with supplementation of feed rations with green forage and other components exhibiting antioxidant properties (e.g. vitamin E, garlic), which are to protect meat with a modified fatty acid profile against oxidation processes [1, 25]. In this study nutrition-related factors and the breed of lambs did not have a significant effect on the basic chemical composition of raw meat. The lack of an effect of oil crop components (rapeseed and linseed) on the basic chemical composition of the longissimus dorsi muscle

Table 2
Chemical composition of raw and grilled culinary leg meat (g/100 g)

Component	Feeding group						Breed origin		SEM
	K	SR+S	SR+P	DDGS+S	DDGS+P	Breed origin			
						OK	If x OK		
Raw meat:									
water	73.4	74.3	74.5	73.2	73.8	74.1	73.5	0.286	
protein	20.2	19.3	19.4	20.1	19.2	19.7	19.6	0.228	
fat	5.2	5.2	4.9	5.5	5.8	5.0	5.7	0.255	
Grilled meat:									
water	60.7	59.1	59.8	58.3	59.0	59.9	58.9	0.515	
protein	28.7 ^{ABa}	32.4 ^A	31.9 ^B	31.1 ^a	30.2	30.4	31.3	0.382	
fat	9.4	7.3	7.1	9.4	9.6	8.5	8.6	0.470	

Feeding groups: K – control, SR+S – mixture with rapeseed meal + grass hay, SR+P – mixture with rapeseed meal + pasture grazing, DDGS+S – mixture with DDGS + grass hay, DDGS+P – mixture with DDGS + pasture grazing

Breed origin: OK – Kolumbia Sheep, If x OK – crossbreeds F, Ile de France x OK

SEM – standard error of arithmetic mean; AA, BB – $P \leq 0.01$; aa – $P \leq 0.05$

(LD) was also reported in a study by Grzeškowiak et al. [15]. Similarly, Borys et al. [11] also found no effect of feeding rapeseed meal on DLM composition. Moreover, Kaczor et al. [17] showed that an identical commercial crossbreeding system as that applied in this study caused no differences in the basic chemical composition of raw LD muscle. In contrast, in lambs fed ad libitum with a concrete mixture and additionally grazing on the pasture in comparison to those, which diet was supplemented with grass hay provided indoors, the cited authors observed a significantly higher content of intramuscular fat (by 21.6%).

Thermal processing of meat alters its basic chemical composition, while the scale and character of these changes depend mainly on the applied heat processing method and the meat cut [3, 7, 11, 18, 29, 30]. In these investigations the meat grilling process reduced water content (by almost 20%) and increased the contents of protein and fat (by almost 60%). However, these changes varied both for the meat of lambs from the individual feeding groups and in terms of the analysed nutrients. Grilled meat of lambs fed concentrate mixtures with oil crop components, irrespective of the type of forage in their feed ration, contained more protein than meat of lambs from the control. Additionally, in the meat of lambs fed a concentrate mixture with a high proportion of rapeseed meal a trend towards reduced fat content was observed. These differences are difficult to explain based on the conducted observations or available literature sources. It needs to be stressed here that feed rations for lambs in all the groups were similar in terms of digestible protein contents, while those in the experimental groups contained much higher levels of fat: in the groups with a 50% share of SR in the feed mixture it was on average 2.6-fold greater, while in the groups with a 50% share of DDGS in the mixture it was 5.3-fold greater [8]. However, a thesis may be proposed here that the reported differences in the contents of protein and fat in grilled DLM may be related with resistance of complexes of these nutrients with other components of the analysed meat cuts to the action of high temperature they are exposed to during thermal processing.

No significant effect of either of the two factors was observed in the DLM physico-chemical parameters (Table 3). More marked trends were found for shear force in the Warner-Bratzler test, which was greater in meat of lambs from the experimental groups than in the control (on average by 11.4%, $P>0.05$). Marked trends were also observed in the point scores for meat marbling, which for lambs from the groups grazing on the pasture was lower than in the other groups (on average by 21.0%; $P>0.05$). No significant differences were recorded in the values of colour lightness L^* . In contrast, a trend towards an increased share of the red colour a^* (on average by 8.6%) in meat of lambs fed a mixture with a high DDGS content (DDGS+S and DDGS+P) and a trend towards a decreased share of the yellow colour b^* (on average by 23.5%) in meat of lambs grazing on the pasture (SR+P and DDGS+P) were found in comparison to the other groups (Table 3). Greater shear force in the Warner-Bratzler test (by 11.5%), greater marbling (by 14.6%), a greater share of the red colour a^* (by 7.0%) and a lower share of the yellow colour b^* (by 9.4%) were recorded in meat of If x OK crossbreds, in comparison to meat of OK tup lambs.

In a paper by Borys et al. [11], similarly as in this study, no evident effect of the applied oil crop components on the analysed quality attributes of lamb was reported. The effect of pasture grazing of lambs was only manifested in the downward trend for meat marbling

Table 3
Physicochemical characteristic of leg culinary meat

Trait	Feeding group					Breed origin		SEM
	K	SR+S	SR+P	DDGS+S	DDGS+P	OK	If x OK	
EC ₂₄ (mS)	2.7	3.0	3.8	3.0	3.9	3.2	3.3	0.166
pH ₂₄	5.71	5.79	5.70	5.80	5.75	5.73	5.77	0.027
Water holding capacity (%)	30.0	29.8	29.7	28.9	28.5	28.7	30.1	0.402
Shear force WB (N)	59.6	66.9	68.2	66.5	64.1	61.5	68.6	1.834
Grilling losses (%)	28.3	27.5	26.4	29.5	27.0	28.1	27.4	0.770
Marbling (pts)	1.75	1.62	1.35	1.90	1.42	1.50	1.72	0.077
Colour:								
L*	44.4	44.4	43.4	42.8	42.2	44.1	42.8	0.442
a*	12.9	12.9	12.7	14.0	13.7	12.8	13.7	0.248
b*	3.5	3.2	2.5	3.4	2.7	3.2	2.9	0.176

Feeding groups: K – control, SR+S – mixture with rapeseed meal + grass hay, SR+P – mixture with rapeseed meal + pasture grazing, DDGS+S – mixture with DDGS + grass hay, DDGS+P – mixture with DDGS + pasture grazing

Breed origin: OK – Kolluda Sheep, If x OK – crossbreeds F₁ Ile de France x OK

SEM – standard error of arithmetic mean

scores in relation to lambs fattened indoors and receiving grass hay in their feed rations. In a study by Strzelecki et al. [28] a limited effect of green forage used in the intensive fattening of lambs was observed in the case of colour lightness and LD muscle marbling, as well as shear force in the Warner-Bratzler test for meat after boiling as the adopted thermal processing method. This effect was varied by the fact whether lambs received the green forage addition indoors or they grazed on the pasture. Most frequently no significant effect of the commercial crossbreeding system on this group of parameters was reported [11, 14, 16]. In contrast, a significant variation was reported [16] in selected physico-chemical parameters of meat depending on the breed and its utilisation, i.e. meat purpose (Suffolk, Ile de France, Texel), dairy purpose (East Friesian sheep) or prolific (Finnsheep).

Grilled meat of lambs from group SR+P received worse scores in organoleptic assessment than meat from the other feeding groups (Table 4). The total scores for aroma, juiciness, tenderness and palatability of meat were higher in the case of lambs from groups K, SR+S and DDGS+S than in group SR+P on average by 6.4% ($P \leq 0.05$). Meat of tup lambs from group SR+P received higher scores for all organoleptic attributes, but significant differences in relation to the other feeding groups were observed for aroma and juiciness, for both these attributes being on average by 6.5% lower.

The breed of lambs had no significant effect on the results of sensory examination of the cooked meat (Table 4).

Deterioration of scores for all organoleptic attributes recorded in the case of meat of lambs from group SR+P may not be verified, since no studies conducted in a comparable experimental system could be found in available literature sources. However, generally it may be stated that the application of quality green forage in fattening of lambs (provided indoors and particularly when the animals are grazing on a quality pasture) is considered advantageous, as it tends to improve the dietary value and organoleptic attributes of meat [25, 26, 31]. Also studies on the use of rapeseed meal and/or other oil crop components in feed mixtures for fattened lambs showed no adverse effect on the organoleptic attributes of their meat [11]. It may not be excluded that the use of a concentrate mixture with a high share of rapeseed meal (50%) in combination with pasture grazing had a disadvantageous effect on the organoleptic quality of meat. Further studies need to be conducted to verify this thesis.

Based on the results recorded in this part of the study it may be stated that the effect of the analysed nutrition-related factors and the breed of lambs on the yield of sub-primal cuts from the carcass was generally slight. A higher yield of loin chops was recorded in the case of carcasses of lambs receiving feeds containing both oil crop components. It was more evident in lambs fattened with access to pasture grazing than in those fed hay provided indoors. The applied feeding systems and the breed of lambs did not significantly differentiate the basic chemical composition of raw meat. In contrast, in grilled leg meat at generally higher contents of protein and fat both used oil crop components were found to affect protein content, while at the application of rapeseed meal a trend was observed towards a decreased fat content. Neither of the two factors investigated in this study had a significant effect on physico-chemical parameters of meat. In the semi-intensive fattening system feeding lambs with a concentrate mixture containing a 50% share of DDGS, irrespective of the type of forage in the feed ration (hay vs. pasture grazed forage), and

Table 4
Organoleptic scores of grilled leg culinary meat (pts)

Evaluation parameter	Feeding group					Breed origin		SEM
	K	SR+S	SR+P	DDGS+S	DDGS+P	OK	IfxOK	
Total score (max 20 pts)	18.2 ^b	18.2 ^c	17.1 ^{abc}	18.2 ^a	17.8	17.8	18.0	0.135
in that (1-5 pts):								
aroma	4.7 ^b	4.7 ^a	4.3 ^{ABa}	4.6 ^a	4.5	4.6	4.5	0.041
juiciness	4.6 ^a	4.7 ^a	4.3 ^{Abbc}	4.5 ^c	4.6 ^b	4.5	4.6	0.042
tenderness	4.3	4.3	4.1	4.4	4.2	4.2	4.3	0.048
palatability	4.7	4.6	4.4	4.7	4.5	4.5	4.6	0.040

Feeding groups: K – control, SR+S – mixture with rapeseed meal + grass hay, SR+P – mixture with rapeseed meal + pasture grazing, DDGS+S – mixture with DDGS + grass hay, DDGS+P – mixture with DDGS + pasture grazing

Breed origin: OK – Kolumbia Sheep, Ifx OK – crossbreeds F₁ Ile de France x OK

SEM – standard error of arithmetic mean; AA, BB – P≤0.01; aa, bb, cc – P≤0.05

with a 50% share of rapeseed meal and hay had no significant effect on the results of organoleptic assessment of grilled meat. In contrast, feeding a concentrate mixture with a 50% share of rapeseed meal and pasture grazing resulted in a deterioration of scores for all individual sensory attributes as well as the total scores.



The study was conducted within project "BIOFOOD – innovative, functional animal origin products" no. POIG.01.01.02-014-090/09 co-financed by the European Union from the European Regional Development Fund within the Operational Programme Innovative Economy 2007 – 2013

REFERENCES

1. AMAGASE H., PETESCH B.L., MATSUURA H., KASUGA S., ITAKURA Y., 2001 – Recent advances on the nutritional effects associated with the use of garlic as a supplement: Intake of garlic and its bioactive components. *Journal of Nutrition* 22, 955-962.
2. ANDERSON J.M.L., 2001 – Sheep meat: can we adapt to forthcoming demands? *Option Mediterraneennes. Serie A: Seminaires Mediterraneens* 46, 11-17.
3. BADIANI A., MONTELLATO L., BOCHICCHIO D., ANFOSSI P., ZANARDI E., MARRANESI M., 2004 – Select nutrient contents, fatty acid composition, including conjugated linoleic acid, and retention values in separable lean from lamb rib loins as affected by external fat and cooking method. *Journal of Agricultural and Food Chemistry* 52, 5187-5194.
4. BARYŁKO-PIKIELNA N., 1975 – Zarys analizy sensorycznej żywności. WNT, Warszawa.
5. BAS P., MORAND-FEHR P., 2000 – Effect of nutritional factors on fatty acid composition of lamb fat deposits. *Livestock Production Science* 64, 61-79.
6. Biofuels: implications for feed industry. 2007 – Edited by: Doppenberg J. and Piet van der Aar, Wageningen Academic Publishers, The Netherlands.
7. BORYS A., BORYS B., GRZEŚKOWIAK E., STRZELECKI J., BORZUTA K., 2006 – Effect of some factors on the yield and culinary quality of roasted and grilled lamb meat. *Archiv für Tierzucht* 49, 174-180.
8. BORYS B., BORYS A., LISIAK D., 2013 – Efekty stosowania produktów towarzyszących produkcji biopaliw w półintensywnym tuczu jagniąt. Cz. I. Wyniki tuczu i wartość rzeźna. *Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego* 9 (2), 35-43.
9. BORYS B., PIETRAS M., 2010 – Produkty uboczne wytwarzania biodiesla – wykorzystanie w żywieniu małych przeżuwaczy. Konferencja Naukowo-Techniczna w Cieszynie. Rolnictwo XXI wieku – nowe aspekty gospodarowania (red. K. Węglarzy). Kraków – Grodziec Śląski, 277-290.
10. BORYS B., PISULEWSKI P.M., 2001 – Jakość oraz możliwości kształtowania prozdrowotnych właściwości spożywczych produktów owczarskich. *Roczniki Naukowe Zootechniki*, Supl. 11, 67-86.
11. BORYS B., STRZELECKI J., GRZEŚKOWIAK E., 2008 – Wstępne badania nad wpływem stosowania makuchu rzepakowego i nasion lnu bez lub z suplementacją witaminą E na uzysk

- i jakość elementów kulinarnych jagniąt z uwzględnieniem metody obróbki termicznej. *Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego* 4 (4), 97-110.
12. BORZUTA K., STRZELECKI J., 2001 – Możliwość produkcji dobrej jakości mięsa kulinarnego z jagniąt. *Roczniki Naukowe Zootechniki*, Supl. 11, 13-21.
 13. GRAU R., HAMM R., 1952 – Eine einfache Methode zur Bestimmung der Wasserbindung in Fleisch. *Fleischwirtschaft* 4, 295-297.
 14. GRZEŚKOWIAK E., BORYS B., STRZELECKI J., BORZUTA K., BORYS A., LISIAK D., 2009 – Podstawowy skład chemiczny oraz wybrane parametry fizykochemiczne mięsa jagniąt tuczonych paszami suchymi lub z udziałem zielonek. *Żywność. Nauka. Technologia. Jakość* 2 (63), 28-39.
 15. GRZEŚKOWIAK E., STRZELECKI J., BORYS B., BORYS A., BORZUTA K., LISIAK D., 2004 – Wpływ stosowania nasion rzepaku i lnu w tuczu jagniąt na uzysk wyrębów i mięsa kulinarnego oraz wybrane parametry jakości mięsa. *Zeszyty Naukowe Przeglądu Hodowlanego* 72, z. 3, 69-78.
 16. GRZEŚKOWIAK E., STRZELECKI J., BORZUTA K., BORYS B., BORYS A., LISIAK D., 2003 – Wpływ rasy owiec na uzysk wyrębów kulinarnych i jakość mięsa jagniąt tuczonych intensywnie do wysokich standardów wagowych. *Zeszyty Naukowe Przeglądu Hodowlanego* 68, z. 3, 81-91.
 17. KACZOR U., BORYS B., PUSTKOWIAK H., 2010 – Effect of intensive fattening of lambs with forages on the fatty acid profile of intramuscular and subcutaneous fat. *Czech Journal of Animal Science* 55 (10), 408-419.
 18. KOSULWAT S., GREENFIELD H., BUCKLE K.A., 2003 – True retention of nutrients on cooking Australian retail lamb cuts of differing carcass classification characteristics. *Meat Science* 65, 1407-1412.
 19. MCNEILL S., VAN ELSWYK M.E., 2012 – Red meat in global nutrition. *Meat Science* 92, 166-173.
 20. NAWARA W., OSIKOWSKI M., KLUZ I., MODELSKA M., 1963 – Wycena tryków na podstawie badania wartości potomstwa w Stacjach Oceny Tryków Instytutu Zootechniki za rok 1962. Wydawnictwa własne IZ Kraków, No. 166.
 21. PN-A-04018. 1975 – Produkty rolniczo-żywnościowe. Oznaczenie azotu metodą Kjeldahla i przeliczanie na białko.
 22. PN-ISO 1442. 2000 – Mięso i przetwory mięsne. Oznaczenie zawartości wody i suchej masy.
 23. PN-ISO 1444. 2000 – Mięso i przetwory mięsne. Oznaczenie zawartości tłuszczu wolnego.
 24. POHJA N.S., NIINIVAARA F.P., 1957 – Die Bestimmung der Wasserbindung des Fleisches mittels des Konstantdruck Methods. *Fleischwirtschaft* 9, 193-195.
 25. ROWE C., MACEDO F.A.F., VISENTAINER J.V., SOUZA N.E., MATSUSHITA M., 1999 – Muscle composition and fatty acid profile in lambs fattened in drylot or pasture. *Meat Science* 51, 283-288.
 26. SANUDO C., SANCHES A., ALFONSO M., 1998 – Small ruminant production system and factors affecting lamb meat quality. *Meat Science* 49 (1), Supl., 29-64.
 27. SCHMID A., COLLOMB M., SIEBER R., BEE G., 2006 – Conjugated linoleic acid in meat and meat products: A review. *Meat Science* 73, 29-41.
 28. STRZELECKI J., BORYS B., GRZEŚKOWIAK E., BORYS A., BORZUTA K., LISIAK D., 2002 – Uzysk elementów kulinarnych z jagniąt rzeźnych w zależności od genotypu i wieku. *Zeszyty Naukowe Przeglądu Hodowlanego* 63, 91-99.

29. STRZELECKI J., BORZUTA K., GRZEŚKOWIAK E., BORYS B., BORYS A., LISIAK D., 2008 – Wpływ tuczu jagniąt paszami suchymi lub z udziałem zielonek na uzysk elementów kulinarnych oraz podstawowy skład chemiczny i cechy sensoryczne mięsa. *Roczniki Instytutu Przemysłu Mięsnego i Tłuszczowego* 46 (3), 59-71.
30. VICENTI A., COLONNA M.A., RAGNI M., TOTEDA F., 2004 – Effect of type of suckling and polyunsaturated fatty acid use on lamb production. 2. Chemical and fatty acid composition of raw and cooked meat. *Italian Journal of Animal Science* 3, 81-91.
31. WOOD J.D., ENSER M., FISHER A.V., NUTE G.R., SHEARD P.R., RICHARDSON R.I., HUGHES S.I., WHITTINGTON F.M., 2008 – Fat deposition, fatty acid composition and meat quality: A review. *Meat Science* 78, 343-358.