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FOOD TECHNOLOGY

Meat quality of the Berrichon du Cher lambs and its cross-breeds with a native breed

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ABSTRACT: *This study evaluated the meat of lambs from crossbreeding of Polish lowland sheep, heather and rams of the Berrichone du Cher breed (B). The lambs were kept in a medium-intensive feeding system. During fattening, they received haylage and grass hay with the addition of clover, and a mixture of cereal grains with the addition of minerals and vitamins. During the fattening period, all feeds were given at will. The slaughter and cutting of the carcasses were performed in accordance with the technology applicable in the meat industry. In the longissimus lumborum muscle, the content of dry matter, total protein, total fat and ash was determined. In addition, the pH value of 45 minutes and 24 hours after slaughter, as well as the parameters of colour and tenderness of the meat were measured. The content of collagen protein, cholesterol and selected fatty acids was also determined. As a result of the conducted analyzes, the influence of the Berrichone du Cher breed on the improvement of quantitative parameters related to the slaughter value and some parameters related to the physicochemical composition of the hybrid meat was reported.*
Key words: *lambs, local sheep breeds, collagen, chemical composition, muscle fibre diameter.*

Qualidade da carne dos cordeiros Berrichon du Cher e seus cruzamentos com raça nativa

RESUMO: *O objetivo deste estudo foi avaliar como o cruzamento da raça Berrichon du Cher com raças nativas de ovelhas polonesas de baixa altitude e ovelhas de charneca polonesa afeta os parâmetros qualitativos da carne .O maior teor de proteína (19,86 ± 0,36%, P <0,05) em cordeiros foi encontrado no grupo Berrichon du Cher e no grupo de cordeiros ovinos (19,23 ± 0,67%, P <0,05). Por outro lado, o maior teor de colágeno total (1,10 ± 0,21%) e a maior sensibilidade do tecido muscular (10,69 ± 0,74 N cm-2), que também apresentaram o menor diâmetro das fibras musculares (24,01 ± 4,62 µm, P < 0,01) foi encontrado nos cordeiros mestiços Berrichon du Cher e Polish Heath Sheep. Tanto a raça quanto o gênero afetaram significativamente o teor de colesterol na carne de cordeiro e o maior teor de colesterol foi encontrado na carne dos cordeiros Berrichon du Cher. Seu menor teor foi demonstrado na carne de Ovinos da Baixada Polonesa com a diferença de 9,1 mg 100g-1 de tecido muscular. Um dos níveis mais baixos do isômero CLA (C 18: 2 cis-9 trans-11) também foi encontrado no grupo dos cordeiros Berrichon du Cher. Este isômero evita a formação de colesterol. Dependência semelhante em relação ao gênero também foi observada. Os resultados obtidos indicam que as raças nativas são utilizadas em cruzamentos com a raça Berrichon du Cher destinada à engorda, principalmente para melhorar parâmetros quantitativos relacionados ao valor de abate e parâmetros selecionados de propriedades físicas e químicas da carne ovina.*
Palavras-chave: *cordeiros, qualidade da carne, colágeno, composição química, diâmetro da fibra muscular.*

INTRODUCTION

Present meat industry faces a number of problems connected with the quality of raw material obtained. There is still an increasing demand for high quality meat characterized not only by parameters related to taste, but also its qualities affecting consumer health. An understanding about factors shaping high quality meat is key in order to obtain it. Among these determinants are, for example, chemical composition, glycolytic metabolism occurring in the muscle tissue, fatty acids content as well as the structure of muscle fibres. Lamb meat can be characterized not only by its distinctive taste and smell, but also health benefits, which a contemporary consumer is most often guided by (DE ANDRADE et al., 2016; JOO et al., 2013; PONNAMPALAM et al., 2019). A vast variety of the quality of lamb meat entails the need for prospecting for a specially designed fattening scheme in various age and weight categories (STANISZ & GUT, 2005). The application of different fattening schemes as well as the way animals are fed to improve the quality of

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the derived muscle tissue has been repeatedly proven by numerous studies. However, lamb meat as a great raw material intended for processing is still a way underrated and neglected in a number of countries.

This study evaluated how cross-breeding of native lamb breeds with the Berrichon du Cher meat breed affects qualitative parameters of the meat (including CLA and cholesterol contents) obtained from lambs fattened to 35 kg live body weight.

MATERIALS AND METHODS

The study group comprised 40 lambs (ten per each group- 5 males and 5 females in each group) of the following breeds: the Berrichon du Cher (B), the Polish Lowland Sheep (PON), F1 cross-breeds of the Polish Lowland Sheep ewes with the Berrichon du Cher rams (BxPON) and F1 cross-breeds of the Polish Heath Sheep ewes with the Berrichon du Cher rams (BxW). During the rearing of lambs, mothers were fed with grass haylage and hay from the same plants. They also received an addition of concentrated feed - about 0.4 kg / head / day. The concentrated feed included ground grains of cereals (wheat, barley, rye and oats). Lambs were reared with their mothers until they were 56 days old, during this time they used their mothers' milk and were fed with solid fodder by their mothers. After After weaning, eight weeks of age lambs were kept in uniform conditions. A medium intensity lamb fattening scheme was applied until the live body weight of 35±2 kg was reached. During fattening, they received haylage and grass hay with the addition of clover and a mixture of cereal meal with the addition of minerals and vitamins. During the fattening period, all feeds were given at will.The lambs were slaughtered and their carcasses were cut and boned in accordance with technologies applied in the meat industry. In the longissimus lumborum muscle certain contents were indicated and these were: dry matter content determined by the oven-drying method (PN-ISO 1442:2000), total protein content determined by the Kjehdahl method (PN-75/A-04018), free fatty acids content determined by the Soxhlet method (PN-ISO 1444:2000). In the freeze-dried meat and fat samples, the fatty acid content was determined by extracting them with a solution of chloroform and methanol according to the methodology of FOLCH (1957) Fatty acid methyl esters were prepared according to ISO 12966-2: 2011. The fatty acid profile of the respective methyl esters was determined by gas chromatography using a VARIAN 3400 gas chromatograph, with a flame ionization detector FID, dispenser temperature 250 °C, using an Rtx 2330 column with parameters 105 m x 0.32 mm x 0.2 μ. 3 ml / min helium was used as the carrier gas, 0.7 mcl injection. The Lardon Fine Chemicals AB acid standards were used to determine CLA, and the Sigma - Aldrich standards were used for the remaining acids. Ash content determined by the combustion method (PN-ISO 936:2000). The pH values (pH_1 and pH_2) were measured with the CP-315M pH meter 45 minutes and 24 hours post-slaughter respectively. Additionally, collagen protein content was also indicated based on hydroxyproline content determined by the PN-ISO method 3496:2000. The colour of the muscle tissue was determined 24 hours following slaughter using a Minolta Chroma Meter CR 310 colourimeter, thus identifying meat colour parameters L* (metric lightness) in three replications. A sensor was calibrated on a test plate N^0 20933050 with the calibration data of Y=92.80, x=0.3160, y=0.3319 (Konica Minolta, Japan). The fatty acids profile and cholesterol content analysis were performed in the accredited Food and Environment Research Laboratory in Warsaw (N^0 AB 553; PN-EN ISO/IEC 17025:2006). Block-shaped samples of a cross section of $1000mm^2$ and a length of 50mm (5 per each sample) were collected to determine lamb meat tenderness (boiled meat), which was measured using a TA-XT texture analyser by Stable Micro System. Muscle samples for histological analysis were collected from freshly slaughtered lambs. The samples were cut into blocks of a cross section of $1000mm^2$ and a length of 10mm parallel to the muscle fibre structure and frozen in liquid nitrogen (at -80 ^0C) prior to initiating analyses. Then, they were cut into shreds of 10 μm length on a cryostat according to the methodology provided by WEGNER et al. (1993) and mean muscle fibre diameter of the prepared specimen was measured. The obtained tests results were processed using Statistica 12 PL software. A two-way ANOVA was used (gender and genotype). The Turkey's range test was used to identify any statistical differences between the mean values of the lamb quality parameters.

RESULTS AND DISCUSSION

Chemical composition and properties of meat is one of the determinants of nutritional value of meat (Table 1). Among other things, it can be affected by animal gender, age, growth rate and muscle tissue type and its function. There is also a wide scope for modification of its composition through, for example, feeding methods and diets or tissue handling while processing. One of the key components of meat is

Table 1 - Chemical composition (%) of purebred and crossbred lamb meat (Means ± SEM).

Parameter	B	PON	BxPON	BxW	---------------Gender-----------------	
					♀	♂
Dry Matter	24.60±0.29	24.23±0.20	24.54±0.25	22.97±0.17	24.01±0.17	24.15±0.72
Protein	19.86±0.36a	18.41±0.20b	19.42±0.31c	18.84±0.07d	18.84±0.07*	19.23±0.67*
Fat	3.58±0.23b	3.73±0.04	4.54±0.12a	3.65±0.49b	3.65±0.49	3.85±0.55
Ash	1.36±0.30	1.34±0.05	1.34±0.05	1.45±0.25	1.45±0.25	1.41±0.14

B - Berrichon du Cher lambs; PON- Polish Lowland Sheep; BxPON- Berrichon du Cher lambs x Polish Lowland Sheep; BxW- Berrichon du Cher lambs x Polish Heath Sheep.
a,b,c,d P ≤ 0,05; * significance of differences at P ≤ 0,05.

protein which is an indispensable part of healthy human nutrition. Its main function is to supply our body with essential amino acids. An informed consumer is increasingly seeking a produce of the highest quality parameters. The highest protein content was observed in the group of the Berrichon du Cher lambs and it was higher by 0.44% compared to the cross-breeds of the Berrichon du Cher with the Polish Lowland Sheep. It was 1.02% when compared to the cross-breeds of the Berrichon du Cher and the Polish Heath Sheep and 1.45% when compared to the Polish Lowland Sheep - $P < 0.05$. Furthermore, the meat of rams contained more protein compared to the meat of ewe lambs by 0.39% - $P < 0.05$. The highest fat content, i. e. 4.54% compared to the other groups of lambs, was recorded in the Berrichon du Cher and the Polish Lowland Sheep cross-breeds, and that difference proved to be statistically significant ($P < 0.05$). Moreover, a statistical pattern in fat content was observed in the cross-breeds with the Berrichon du Cher individuals ($P < 0.05$). The other chemical composition parameters analysed in the study were similar both in rams and ewe lambs. KAWĘCKA et al. (2016) pointed to differences in the way fat is stored depending on age and gender. In young females, fat was observed mainly in the body cavity, while in males it was accumulated around the thigh and on the neck. While studying the sensory quality and chemical composition of the meat from lambs fed feeds enriched with rapeseed oil, fish oil and carnosic acid, JAWORSKA et al. (2016) identified circa 22% protein content of the muscle tissue. No impact of the feeding methods and diets on the parameter studied was found either. When quercetin was fed to fattening lambs, ANDRÉS et al. (2013) identified a similar protein content, yet a much higher fat content. In the experiment conducted by BHATT et al. (2011), coconut oil feed additive did not affect significantly the carcass quality change. The findings concerning the chemical composition were in line with those of own research. While analysing the effects of a genotype of lambs on the physical properties of the quadricep muscle, KUCHTIK et al. (2012) found it impacted significantly dry matter and fat content.

Whether the meat is fit for processing is determined not only by its chemical composition but also its collagen content and muscle fibre quality (Table 2). The studies of the semimembranosus muscle in the group of lambs showed the highest collagen content in the Berrichon du Cher and the Polish Heath Sheep cross-breeds (1.10±0.21%), whereas the lowest collagen content was observed in the Berrichon du Cher lambs (0.79±0.04%) – $P < 0.01$. The results demonstrated that collagen content is higher in the meat of rams and that the meat of native breeds is more tender. The meat from ewes was also more tender than that of rams. In his study concerning the relationship between collagen content and some selected technological meat quality parameters, DOMARADZKI et al. (2010) indicated there were some differences as for collagen content in the muscle tissue depending on a role and a type of work muscles performed. In the study of the muscle tissue of calves they that collagen content was approximately 0.95% in the longissimus lumborum muscle and 1.20% in the semitendinosus muscle. In the meat of lambs slaughtered at 32 kg live body weight OKEUDO & MOSS (2005) showed total collagen content which was approximately 0.30%. Moreover, their further study showed explicitly that there was a correlation between collagen content and the muscle tissue tenderness. While analysing collagen content and the longissimus muscle tenderness depending on animal age at slaughter, VEISETH et al. (2004)

Table 2 - Selected post-slaughter parameters of the meat of purebred and crossbred lambs (Means ± SEM).

Parameter	B	PON	B x PON	B x W	-------------Gender-------------	
					♀	♂
pH_1	6.28±0.06	6.27±0.07	6.33±0.07	6.33±0.03	6.25±0.05	6.35±0.03
pH_2	5.80±0.05	5.80±0.05	5.69±0.09	5.62±0.14	5.67±0.13	5.79±0.07
T_1	36.92±0.63	36.86±0.68	37.56±0.53	36.61±0.46	36.54±0.51	37.43±0.50
T_2	8.43±0.38	8.58±0.26	8.43±0.45	8.23±0.35	8.51±0.37	8.45±0.38
L^*	41.22±3.54	44.07±2.20	41.53±3.84	42.54±4.97	39.78±3.27**	44.90±2.47**
Tenderness (N cm^{-2})	20.11±0.34A	12.65±0.31C	12.54±0.38C	10.69±0.74D	13.73±3.74	14.27±3.61
Collagen (%)	0.79±0.04A	0.95±0.04	0.80±0.03	1.10±0.21B	0.89*±0.21	0.93*±0.12
Mean muscle fibre diameter (μm)	25.30±3.52A	24.00±2.96	23.87±1.93B	24.01±4.62C	21.93±1.65**	26.67±3.00**

B - Berrichon du Cher lambs; PON- Polish Lowland Sheep; BxPON- Berrichon du Cher lambs x Polish Lowland Sheep; BxW- Berrichon du Cher lambs x Polish Heath Sheep.
T_1 –post-slaughter carcass temperature; T_2 carcass temperature at day 1 post-slaughter; L^*-color; Tenderness (N cm^{-2}); Collagen (%); Mean muscle fibe diameter (μm); pH_1 – pH value at 45 minutes post-slaughter; pH_2 – pH value at day 1 post-slaughter.
A,B,C,D $P < 0.01$; * significance of differences at $P<0.05$ level; ** significance of gender-specific differences at $P < 0.01$ level.

proved collagen concentration to amount of 3.80 mg $100g^{-1}$. MAIORANO et al. (2009) demonstrated there was a relationship between a feeding method or diet followed and collagen content in a raw muscle. Morphological characteristics of muscle fibres, which include, for example, the surface of fibres, can also determine muscle mass and its quality. With regard to a muscle fibres microstructure, the muscle tissue of the Berrichon du Cher lambs had the thickest muscle fibres compared to the other groups of the Berrichon du Cher and the Polish Lowland Sheep cross-breeds. In the Berrichon du Cher and the Polish Heath Sheep cross-breeds and in the Polish Lowland Sheep lambs, the differences in thickness were 5.37%, 5.99% and 5.42% respectively. Furthermore, the muscle fibres of the Berrichon du Cher rams were thicker than those of ewes by up to 21.61% ($P < 0.01$). The mean muscle fibre diameter in this group amounted to 25.30 µm. The Berrichon du Cher and the Polish Lowland Sheep cross-breeds demonstrated the lowest value of the parameter studied (23,87 µm). One of the physico-chemical measurements illustrating glycolytic metabolism in meat is the pH measurement. The acidity of meat at 45 minutes post-slaughter was comparable both in purebred and crossbred lambs, and a uniform pH decline at 24 hours post-slaughter in particular study groups proved the processes occurring in the muscle tissue after slaughter to be correct. The differences in the level of acidity of meat did not show statistically significant differences. There was also no detectable dependency of the tissue pH value on gender. When the cardiopulmonary system ceases to function after slaughter, the removal of heat from deeper parts of muscles is difficult. Therefore, the temperature of this muscle tissue can rise shortly after slaughter, which is due to accelerated glycolysis. The duration of slaughter, the temperature in a slaughterhouse as well as post slaughter carcass handling can affect the temperature of the tissue and the rate of temperature decline (JACOB & HOPKINS, 2014; WARNER et al., 2014). The carcass temperature straight after slaughter and 24 hours after being chilled at 4 ^{0}C did not show any relevant differences, which can prove the cooling process occurring in the muscle tissue to be correct. While analyzing the dependence of lamb meat qualitative parameters on various feeding methods and diets, KARACA et al. (2016) obtained similar results. Studying the muscle tissue of lambs fed with oats-based feed 24 hours post-slaughter, MAJDOUB-MATHLOUTHI et al. (2013) indicated the pH value to be 6.19. Meat color is a qualitative parameter which is the most significant to consumer acceptance of products. The color that meat takes is partly determined by the degree of oxidation of the myoglobin and the heme iron. Fresh muscle tissue is normally dark red, but then it darkens as the iron in the myoglobin oxidizes from the ferrous iron to the ferric state to the point of the metmyoglobin stage (JEONG et al., 2009; SUMAN & JOSHEP, 2013). The dependence of meat color on breed and animal gender was also observed. The muscle tissue of the purebred Berrichon du Cher ewes was much lighter compared to that of cross-breeds. The meat colour

L^* of the Berrichon du Cher rams was similar to that of the ewes and amounted to 44.98 and 45.50. While comparing animal gender, a lighter meat color was observed in rams, which could have resulted from higher intramuscular fat content in this group, and consequently, lower muscle tissue content. The studies of PIENIAK-LENDZION et al. (2011) demonstrated that the 10% addition of flax seeds to the kid feed significantly affected lighter meat colour (L^* 42.60). However, when RIPOLL et al. (2013) enriched a lamb feed with vitamin E, they obtained much lighter muscle tissue – L^* from 49.54 to 51.99. While studying the factors regarding duration and storage temperature of lamb carcasses, VIEIRA (2014) and FERNÁNDEZ (2014) obtained normal meat colour of L^* 47.10 (slow cooling) and dark meat colour of L^* 45.8 (rapid cooling). A consumer choosing a meat species very often pays close attention not only to its taste, but also to its tenderness. According to HOPKINS et al. (2006), the tenderness of lamb meat should be below 27 N cm^{-2}. Analysing the relationship between meat storage and its tenderness, SCHMIDT et al. (2013) observed meat tenderness can differ significantly depending on meat storage and its time. Their findings were significantly higher compared to those of own research. In the study conducted by BOND et al. (2004), shear force at day 1 post-slaughter amounted to 67.4 N cm^{-2}. FRANCISCO (2020) conducted the studies of lambs fed a feed enriched with dried alfalfa, which demonstrated a significant dependence of meat tenderness on animal nutrition and the tenderness of the muscle tissue ranged from 29.3 to 49.6 N cm^{-2}.

The muscle tissue in the Berrichon du Cher lamb group r and the Polish Lowland Sheep contained the most cholesterol, which amounted to; 72.74, 65.49 and 67.51 mg $100g^{-1}$ respectively (Table 3). In hybrids of Berrichon du Cher with native breeds, the cholesterol content was lower by about 8 mg / 100g. Gender differences were also observed.

Furthermore, higher cholesterol content by 4.52% ($P < 0.01$) was observed in the meat of rams compared to that of ewes. BURIN et al. (2016) proved that the nutrition of lambs affected cholesterol content which ranged from 75.54 to 81.01 mg $100g^{-1}$. But then, average cholesterol content in the muscle tissue of lambs fed a feed enriched with flax seeds amounted to 1.79 g $100g^{-1}$ (LUCIANO et al., 2013). Modification of the fatty acid profile may improve the nutritional value of the raw meat as the quantity and quality of fat in the carcass considerably depends on the composition of the feed components in the diet

Changing the fatty acids composition by the use of vegetable oils and various herbal additives, VASTA et al. (2013) and GUERREIRO et al. (2020) obtained the results regarding fatty acids content in line with those of their own research. They claimed that Rosemary and Artemisia pallens essential oil supplementation did not affect changes in the composition of fatty acids significantly, but it enhanced the other health properties of meat. But then, the replacement of carbohydrates in lamb nutrition with calcium salts resulted in a significant change in the structure of fatty acids without affecting the dressing percentage (SEABROOK et al., 2011). VALENTIA et al. (2018) indicated that the addition of dried tomatoes in lamb fattening resulted in an increase in polyunsaturated fatty acids content without affecting the dressing percentage and qualitative parameters

Table 3 - Cholesterol and selected fatty acid content in lamb meat (Means ± SEM).

Parameter	B	PON	B x PON	B x W	--------------Gender----------------	
					♀	♂
Cholesterol mg/100 g	72.74±4.91A	63.64±1.65B	65.49±1.08C	67.51±1.13D	65.86±1.88**	68.84±5.47**
C15:0	0.52±0.04A	0.51±0.09B	0.55±0.09C	0.64±0.04D	0.51±0.07	0.59±0.08
C17:0	0.96±0.05A	1.13±0.14B	1.50±0.25C	1.38±0.77D	1.36±0.57**	1.12±0.25**
C18:0	15.69±0.31	15.81±0.73	17.02±0.71A	16.37±0.29B	15.96±0.72**	16.49±0.70**
C18:1	1.40±0.06A	1.38±0.07A	1.82±0.39B	2.47±0.11C	1.68±0.45**	1.85±0.51**
C18:2	8.37±0.23A	4.00±0.56B	5.54±0.85B	7.90±1.11C	5.92±1.92*	6.98±1.82*
CLA	0.41±0.05A	0.50±0.11B	0.35±0.07C	0.93±2.01D	0.67±1.43**	0.43±0.08**

B - Berrichon du Cher lambs; PON- Polish Lowland Sheep; BxPON - Berrichon du Cher lambs x Polish Lowland Sheep; BxW- Berrichon du Cher lambs x Polish Heath Sheep.
a,b,c,d – the significance of differences at P < 0.05 level; A,B,C,D – the significance of differences at P<0.01 level; ** significance of differences at P < 0.01 level; * significance of differences at P < 0.05 level.

of meat. Produce derived from ruminants is a natural source of CLA. In the study above, the dependence of CLA content (P < 0.01) on gender and breed was demonstrated. Thanks to enriching a lamb diet with some CLA addition to a lamb feed, TERRÉA et al. (2011) obtained the results regarding the average CLA content which were in line with those of their own research. They also observed that feeding lambs with feed mix enriched with CLA and up to 10 g kg^{-1} of a concentrate feed added does not affect carcass dressing percentage significantly.

CONCLUSION

Summing up, it is necessary to prove the beneficial effect of crossing the Berrichone du Cher breed with native breeds. The hybrids were characterized by a high level of physicochemical parameters. The use of this type of crossing will enable the production of wholesome slaughter material.

BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

The study was carried out in strict compliance with the recommendations in Directive 63/2010/EU and the Journal of Laws of the Republic of Poland of 2015 on the protection of animals used for scientific or educational purposes. The study was approved by the Polish Local Ethics Committee, Warsaw, Poland (Number: 51/2015) and by the Polish Laboratory Animal Science Association (Numbers 3235/2015; 4466/2017).

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

DECLARATION OF CONFLICT OF INTEREST

The authors declare that there is no conflict of interest between them and other people or organizations that could inappropriately bias the results. These authors contributed equally to this work.

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