Comparison of carcass and meat quality traits of the native Polish Heath lambs and the Carpathian kids

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ABSTRACT
The aim of the study was to compare selected parameters of carcass and meat quality including testing of volatile compounds of male lambs and kids derived from Polish native breeds (Polish Heath Sheep and Carpathian Goat). For most of the slaughter parameters, no differences were found between the two species although the meat and bones weights in the legs of kids was higher than that found for lambs. The study shows differences in the chemical composition and quality characteristics of the meat. Drip loss was lower in kid meat, indicating better water binding capacity. In contrast, the roasted meat of Carpathian kids was less tender than that of lambs. There was more dry matter and protein in the muscle of the kids; the differences between species occurred between most fatty acids. The analysis of volatile compounds showed differentiation between the evaluated meat of lambs and kids. Despite the differences in the assessment of the physico-chemical and nutritional parameters of lamb and goat meat, both types of meat can be considered are a valuable component of the diet, while high values of the organoleptical assessment indicate a good reception of both products by consumers.

1. Introduction
The sheep meat market in Poland is a niche market and lamb consumption in Poland is five times lower than for the entire European Union, which is estimated at 1.9 kg per capita per year (Niżnikowski et al. 2017). Despite this not very optimistic data, lamb is becoming more and more popular in Poland, although it is still considered a delicatessen product. Lamb from native breeds of sheep is very popular among followers of this type of meat because of its exceptional taste. The goat meat market in Poland is practically non-existent and goat meat is a scarcely available product. The programmes for the conservation of genetic resources of sheep and goats, implemented consistently over many years with financial support within agri-environmental programmes of the agricultural policy of the EU, have made it possible to save numerous indigenous breeds and to achieve dynamic population growth within these breeds. Knowledge about the quality of raw materials from indigenous breeds can help to popularize and help to develop the market for sheep and goat products.

Sheep and goats provide valuable products that are appreciated by consumers who are looking for food that is not only tasty but also healthy, and lamb and goat meats are certainly one of these. Both lamb and goat meat is classified as red meat, but their organoleptical properties and nutritional composition differs. Lamb meat, due to higher fat content, is juicier than goat kid meat, and therefore more acceptable; it is characterized by valuable nutritional features: high biological quality protein, micro and macro elements, L-carnitine and conjugated linoleic acid (CLA) isomers that was associated with immunomodulating, anticarcinogenic and antiatherogenic properties, prevention of diabetes, and reduction of body fat (Ciliberti et al. 2021). In contrast, goat meat is considered as lean, with a similar nutritional value to sheep meat, but contains more protein, trace elements contents and less fat compared to lamb and mutton so more healthier compared to other types of red meat, advisable to consumers of a more sensitive health status like children, elderly, cardiovascular patients, convalescents (Ivanovic et al. 2014; Vnuček et al. 2020). The traditional production systems used for local breeds, with extensive grazing on natural pastures, also has particular importance to the quality of the meat obtained from these two species.

The study aim compare carcass and some meat quality parameters including volatile compounds of lambs and kids derived from native breeds fed the same diet.

2. Material and methods
2.1. Animal material, diet, and slaughter evaluation
For the experiment, ten male lamb of the native Polish Heath Sheep breed and ten male kids of the Carpathian breed were selected from flocks belonging to the National Research Institute of Animal Production (NRIAP). Lambs and kids on both farms were kept with their mothers until weaning at about 90 days of age, where they received supplementary crushed oats and hay. After weaning, they were placed in group pens and fed with good quality hay and given 300 g of concentrate mix containing: 52% barley, 20% oats, 5% wheat bran, 15%
soybean meal, 5% rapeseed expeller, with 3% of a mineral mixture; they had constant access to fresh water and mineral licks. Upon reaching 120 days of age, they were transported to the sheepfold of the NRIAP farm. The animals were kept in two group pens (4 × 4 m). The area of the pens was 1.5 m² for animal. After a period of 10 days of adaptation, the experimental/fattening period began. During the fattening period, which lasted from 130 days of age to slaughter on day 210, they received the same concentrate mixture at 400 g per animal. Procedures met the requirements of the Directive 2010/63/EU of the European Parliament and of the Council of 22 September 2010 on the protection of animals used for scientific purposes. The slaughter was performed at an EU-licensed abattoir, following the normal commercial procedure. After 24 h of chilling at 4°C, the basic slaughter parameters i.e. cold carcass weight, half-carcass weight and dressing percentage (cold carcass weight as a per cent of live weight), and the carcass weight, half-carcass weight and dressing percentage 24 h of chilling at 4°C, the basic slaughter parameters i.e. cold carcass weight, half-carcass weight and dressing percentage (cold carcass weight as a per cent of live weight), and the carcasses were separated into cuts (NRIAP 2009). A detailed dissection of the left leg into meat, fat and bone tissues was performed. Muscle samples were taken from the leg (m. biceps femoris) to determine chemical composition, physicochemical and sensory parameters.

2.2. Meat physicochemical properties

Twenty four hours after slaughter the pH was measured using a Hanna Instrument HI99163 pH meter equipped with a FC232D electrode. Meat colour (CIE 1986) was determined 48 h post-mortem on the muscle cross section using a Minolta Chroma Meter CR 400 device (Konica Minolta). L*a*b* parameters against the white standard: L* – 97.83; a* – 0.45; b* – 1.88. Colour measurements were made in three replicates 20 min after cutting of samples. Drip loss (%) was based on per cent loss of muscle mass during 24-hour storage of the meat at 4°C (Honikel 1998). The cooking loss (%) was determined from the difference in weight of the sample before and after a 60 minute thermal treatment in a water bath at 70°C. The samples were placed in a thin-walled transparent plastic bag and placed in a bath with continuously boiling water. After boiling, the plastic bags were cooled in a bath of ice-cold water and then chilled and stored at 4°C for 12 h. After 12 h of storage, the meat samples were removed from the bags, blotted dry and weighed (Honikel 1998). The maximum shear force was measured with a Warner–Bratzler V slot blade (shearing blade thickness of 1.016 mm; V-shaped cutting blade with a 60 degree angle) on texture analyzer Model TA-XT2 plus equipped with a 1 kN cutting head (Stable Micro Systems, Godalming, Surrey, England). Meat samples were cut from the cooked muscles into 10 mm × 10 mm × 40 mm cubes (minimum of 3 per sample). Each sample was cut into the half, parallel to muscle fibre orientation on Heavy Duty Platform (HDP/90) (2 mm/s test speed).

The samples of leg meat collected after slaughter were analyzed to determine the chemical composition using standard methods according to AOAC (2007): moisture, total protein, ash, and fat were determined. Vitamins were analyzed using HPLC (Merck-Hitachi, Germany, Japan) with UV-Vis detection (324 nm) for vitamin A and fluorescence detection (Ex295 nm, Em350 nm) for vitamin E (Eltenmiller and Landen 1999). The sample was saponified (70°C, 60 min) in the presence of 60% KOH and ethanol, followed by extraction with ethyl acetate; hexane (1: 9). After evaporation of the solvents under nitrogen (40°C), the residue was dissolved in ethanol and determined by reversed-phase HPLC using a LiChroCART™ 250-4 Super- spher™ 100 RP-18 (4 µ) column (Merck, Germany) and solvents (methanol:water, 96:5:3.5, v/v) for elution (1 mL/min). Before analysis, calibrated external vitamin standards (Sigma, St. Louis, Mo., USA) were used. The fatty acids were analyzed using a GC 2010 Plus gas chromatograph (Shimadzu, Japan). Samples were extracted with the chloroform/methanol mixture (2:1, v/v). Fatty acids were saponified (0.5 N NaOH in methanol, 80°C) followed by esterification with boron trifluoride/methanol. After extraction with hexane, the compounds were separated on the RTX-2330 column (105 m, 0.32 mm, 0.2 µ; flow rate 4 mL/min; injection 1 µL) using a flame ionization detector and autosampler AOC-20i (Shimadzu, Japan).

The temperature programme in the column oven was: 60°C to 120°C (at a rate of 20°C/min), and then 240°C (at a rate of 3°C/min). Fatty acids were identified by comparing their retention times to those of methylated FA standards (Supelco Inc., PA, U.S.). A gas chromatographic method (GC 2010 Plus, Shimadzu, Japan; FID detection; ZB-5, 30 m × 0.25 mm × 0.5 µ column; flow rate 2.6 mL/min; injection 1 µL) was used for cholesterol measurement. The temperature programme in column oven was: 100°C to 150°C (30°C/min), and then 350°C (15°C/min). The method involves ethanolic 60% KOH saponification (70°C, 60 min) of the sample material, homogeneous phase hexane extraction of the unsaponifiable material, derivatization of cholesterol with HMDS + TMCS + Pirydyne: 3:1:9, and quantification using 5α-cholestane as internal standard.

2.3. Sensory evaluation

The roasted leg meat was organoleptically evaluated for aroma, taste, juiciness, and tenderness according to the method of Barylko-Pikielna and Matuszewska (2014). A 5-point grading scale (5 = highest to 1 = lowest) was used: aroma: 1 – very undesirable, 5 – very desirable, typical for lamb; juiciness: 1 – very dry; 5 – very juicy; tenderness: 1 – very tough; 5 – very tender; taste: 1 – very undesirable, 5 – very desirable, typical for lamb. For each parameter, the scores were accurate to 0.5 point. The sensory panel consisted of five members trained in sensory profiling.

2.4. Sample preparation for volatile compounds analysis and chemometrics

For volatile compounds analysis, randomly selected 200 g leg muscles samples from 6 lambs and 6 kids were taken. Samples were taken and cut into smaller pieces and were vacuum-packed in 100 g portions into polyamide/polyethylene bags and stored at –80°C. Frozen, and previously cut 10 g sample was processed at a low temperature with liquid nitrogen and processed as described by Gąsior et al. (2020). Briefly, the meat sample was blended in liquid nitrogen, placed into a SPME vial (20 ml), tightly capped using a crimp cap with PTFE/silicone septum, before baking (170°C, 35 min).
and analyzed by headspace-solid phase microextraction – gas chromatography/mass spectrometry (HS-SPME-GC/MS) using the gas chromatograph mass spectrometer GCMS-QP 2010 Plus with the SPME autosampler Combi Pal System, AOC-5000 (Shimadzu, Duisburg, Germany). A 50/30 μm DVB/CAR/PDMS fibre (Supelco, Merck group, Poznań, Poland) and Zebron ZB-5MSi (30 m x 0.25 mm, 0.25 μm) column (Phenomenex; Shim-Pol, Izabelin, Poland) were used. The quadrupole electron ionization (70 eV) mass spectrometer was operated in full scan mode in a range of 35–450 m/z (416 ions). The same conditions for the chromatographic and mass spectrometer analysis were used as previously described (Gaśior et al. 2020).

Chemometric analysis for relative intensity spectral data was performed to analyze the possibility of determining the differences between the animal groups, based on volatile compounds analysis. A chromatogram from each sample was divided into 25 time ranges (from 1.4 to 51.0 min of a chromatographic analysis); 10,400 relative m/z ion intensities were the variables used in the chemometrics (416 relative intensities of mass spectrum ions × 25 times ranges).

2.5. Statistical analysis

The results are presented in tables as mean and standard deviation. The results were statistically processed using STATISTICA ver. 10 with one-way analysis of variance. Testing was conducted at the significance level of $P < 0.05$ and $P < 0.01$.

For chemometric classification, the spectral data from volatile compounds analysis were logarithmically transformed and the variables preselected using the F-ratio method, followed by the application of a principal component analysis (PCA), where the number of variables was reduced to the principal components using Cattell’s scree test (Gaśior et al. 2020). Finally, linear discriminant analysis (LDA) was executed, and the classification accuracy was calculated by cross validation. Statgraphics® Centurion XVI equipped with a multivariate statistics package (Statpoint Technologies, Inc.; Gambit, Kraków, Poland) was used for the PCA-LDA analyses. The F-ratio value was computed adopting statistical functions in Microsoft Excel®.

3. Results

3.1. Evaluation of slaughter performance

The fattening and carcass parameters of native breed lambs and kids are presented in Table 1. The initial weight of kids was 15.0 kg and of lambs 14.4 kg; the weight at the end of fattening period was 22.5 and 24.0 kg, respectively, none of these weights differed ($P > 0.05$) between the groups. In case of the other slaughter parameters, i.e. cold carcass weight, halfcarcass weight and dressing percentage, no statistically significant differences were found either. The results of leg dissection in lambs and goats showed differences ($P < 0.05$) in the meat and bone weights of the two species; the meat weight in the legs of goats was 829.16 g and was higher than that found for lambs (689.25 g). A similar relationship was found for bone, but no significant differences between groups were found for fat weight. The dressing percentage was 41.96% for kids and 38.04%, for lambs although the difference between these values was not statistically significant.

3.2. Lambs and kids meat physico-chemical characteristics

Lamb and kid meat (Table 2) did not differ significantly in terms of pH values and oscillated between 6.27 and 6.32. In the evaluation of meat colour, differences were found in colour lightness (L*) and yellowness (b*). Kid meat was darker than lambs meat; lamb, on the other hand, was characterized by a more yellow colouration of the muscle. The proportion of the redness (a*) did not differ between groups. Dripp loss was lower in kid meat, indicating better water binding capacity. In contrast, the heat-treated meat of Carpathian goats was less tender than that of lambs, and the difference was highly significant; the cutting force for the leg muscles of kids was significantly higher (73.66 N) than that found for lambs (43.45N). There were no differences between groups in cooking loss; it was 33.11% on average.

The chemical composition of the meat of the two species is shown in Table 3. There was less moisture and more protein in the leg muscle of the goats: 76.31% and 20.67% v. 77.28% and 19.23%, respectively in the sheep, no statistically significant differences were found for the fat content, which varied between 2.37% and 2.88%. The content of ash, cholesterol and vitamins did not differ between the groups (Table 3). The differences between groups occurred in most of the fatty acids (Table 4). In the intramuscular leg fat of both groups, there were more unsaturated acids than saturated ones, although their share in goat meat was higher (63.926% v. 54.605%) compared to meat from Polish Heath Sheep. The proportion of PUFA n-3 fractions was higher in the ram group; the proportion of C18:3 acid belonging to this category was more than twice as high in this

| Table 1. Some slaughter and carcass characteristics of kids and lambs |
|-----------------------------|-----------------------------|
| Item* | Kids (mean ± SD) | Lambs (mean ± SD) |
| Initial weight (kg) | 15.0 ± 1.02 | 14.4 ± 0.93 |
| Final weight (kg) | 22.51 ± 2.51 | 24.0 ± 3.24 |
| Cold carcass weight (kg) | 9.43 ± 0.96 | 9.13 ± 1.17 |
| Right half-carcass (kg) | 4.62 ± 0.51 | 4.49 ± 0.58 |
| Left half-carcass (kg) | 4.64 ± 0.45 | 4.58 ± 0.6 |
| Dressing percentage (%) | 41.89 ± 1.23 | 38.04 ± 1.12 |
| Leg tissue composition (g) | | |
| Meat | 829.16 ± 113.24 | 689.25 ± 110.06 |
| Fat | 80.83 ± 11.58 | 70.00 ± 21.38 |
| Bones | 282.33 ± 39.96 | 246.87 ± 24.48 |

*SD: standard deviation; A, B: different letters denote statistically significant differences. |
The ratio of PUFA n-6/PUFA n-3 was lower in the intramuscular fat of both groups, while no CLA t9-t11 isomer was found in goat meat.

In the organoleptic evaluation (Table 5), no differences were found between the groups with respect to the colour of the roasted leg, smell, juiciness, and flavour (p > 0.05). All these characteristics were rated as high (more than 4 points) in both groups.

### 3.3. Chemometric classification using volatile compounds analysis

The differentiation between the Polish Heath Sheep lambs and Carpathian goat kids is presented in the scatterplot (Figure 1).

### 4. Discussion

#### 4.1. Slaughter performance parameters for kids and lambs

The meat production potential of an animal consists, on the one hand of its genetic background (breed) and on the other hand, on the influence of the environment (feeding, maintenance) which determines the fattening level and the slaughter value. The comparison of the meat production characteristics of both species focused on the dressing percentage and the mass of the valuable leg cut and its tissue composition. Dressing percentage, i.e. the ratio of the carcass weight to the live weight of the animal, is one of the most important characteristics determining the animal’s post-slaughter value. Dressing percentage is highly variable in small ruminants, ranging from 36% to about 60%, and depends on numerous factors, such as age, weight at slaughter, housing system, breed, and sex. Many Polish native sheep breeds, mostly kept in extensive systems, are characterized by not having very high dressing percentage, seldom exceeding 40% (Kawęcka and Radkowska 2018). In this experiment, the dressing percentage was also at a low level, and no significant differences were found between the species. Rodriguez et al. (2014), when analyzing the meat production of small ruminants of local breeds, grazed on tropical pastures, and comparing both species, of the same age and similar body weight at slaughter, found that the dressing percentage of kids was lower than that of lambs. A significant effect of species on dressing percentage of suckling lambs and kid was found by Santos et al. (2008), which, according to these authors, was caused by inferior conformation of the kid carcasses. Mioč et al. (2013), while analyzing selected slaughter characteristics of lambs and kid of native Croatian breeds (Dalmatian Pramenka sheep and Croatian Spotted Goat) found that species had a significant effect on all studied parameters: lamb carcasses were heavier and the dressing percentage obtained for lambs was higher than for kids (52% vs. 48%, respectively). According to these authors, lamb carcasses were better developed, with greater thorax length, hind limb length and rump width than kid carcasses; the heavier stomach and intestinal weights in Dalmatian kids compared to the lambs, while the sheep had higher carcass weights and dressing percentages than the goats.
Lambs and Carpathian goat kids. Murshed et al. (2014), by comparing the meat production parameters of indigenous sheep and goat breeds in Bangladesh, confirmed this advantage by calculating the dressing percentage of sheep at 39.8% and that of goats at 37.2%. Turner et al. (2014), while analyzing the carcass parameters of American reared Suffolk sheep, Katahdin sheep, and goat hybrids with the Boer breed found higher values of dressing percentage in the sheep breeds (49.7–51.6%) compared to the goats. Tshabalala et al. (2003) analyzed the carcass quality of native and Boer breeds of goats and Damara and Dorper breeds of sheep maintained under extensive pasture grazing system. Goats had proportionally smaller carcasses, while sheep carcasses contained more fat and meat and less bone than goat carcasses, although the lean meat content of Boer goat carcasses was comparable to sheep, but the proportion of bone was higher in the local goat breeds’ carcasses. According to Sañudo et al. (2012), Churra lambs differed from kids, especially meat breeds, due to the high proportion of bone in the studied cut (25.0% vs 21.3% to 23.7%) and more intense meat colour. Relating these observations to the results of tissue composition analyses of the leg results in this study, it was found that the meat weight was higher in young kid legs than in lamb, with a higher proportion of bone in the kid legs. Niedziółka et al. (2005) by comparing the production results of kid of White Improved breed and ram lambs of a Lowland Polish breed kept under the same conditions and fed ad libitum with pelleted feed and meadow hay, found that lambs were heavier and had higher warm carcass weights. No clear differences were found in the slaughter values and meat contents, with both species having low fat contents.

4.2. Physico-chemical properties of kid and lamb meat

One of the most important determinants of meat quality is the pH value, usually determined 24 h post mortem, as it is a measurement of the meat’s ion charge that influence meat characteristics such as colour, toughness, water binding capacity and cooking losses (Sari et al. 2019). The initial decrease in pH is due to the accumulation of lactic acid during postmortem glycogenolysis. The rate of pH decline is affected by factors such as animal species, breed, and muscle type, and the optimal pH value should be within the range of 5.4 to 6.2 (Florek et al. 2018). Results of this parameter measurements on muscles of African goats and sheep showed a decrease in pH measured 45 min after slaughter and again after 24 h from 6.5 to 5.7 in sheep and 6.57 to 5.88 in goats (Shija et al. 2013). The results of the study by Florek et al. (2018), aimed at comparing the physicochemical properties of meat of lambs and slaughter calves, confirmed a normal post-slaughter glycogenolysis process in both species: a decrease in pH from an initial level of 6.4 (lambs) and 6.6 (calves) to a final pH (48 h) of 5.4 (calves) and 5.7 (lambs) was observed. The 24 h muscle pH value of local Turkish sheep breeds ranged from 5.68 to 5.88, and that of lambs of native Polish breeds from 5.8 to 6.24 (Kawęcka and Miksza-Cybulska 2016). The meat of lambs and kids in this study did not differ significantly in pH values both 24 and 48 h after slaughter. According to Santos et al. (2008) species had no effect on muscle pH measured one hour after slaughter (6.5), whereas after 24 h, goat muscles had significantly higher pH values (5.8) than lambs (5.6). In contrast, Mioč et al. (2013) found that species significantly determined not only meat pH, but also meat colour and water absorption: lamb muscles had lower pH than kid muscles.

From the consumer’s perspective, tenderness is an extremely important meat characteristic, frequently measured by the shearing force, i.e. the maximum load needed to cut the meat perpendicularly to the fibres. Tenderness depends on many factors such as the intensity and duration of postmortem proteolysis, collagen content and solubility, sarcomere length and the amount of intramuscular fat, as well as muscle type. The shear force value is also significantly influenced by sex, rearing system, possible pre-slaughter stress, carcass cooling rate, maturation time, as well as cooking time and temperature. Destefanis et al. (2008) showed that beef with shear values above 52.68 N was perceived by most consumers as tough, and below 42.87 N as tender. According to Sañudo et al. (2003), breed was more important for affecting meat toughness.

Figure 1. Fisher’s ratio-PCA-LDA sample classification based on mass spectra (SPME-GC-MS, ZB-5 column) of volatile compounds in leg muscles of Polish Heath Sheep lambs and Carpathian goat kids.
than age or sex, and in case of 22 European sheep breeds, they found shear force values ranging from 16.7 to 40.2 N. A smaller, although statistically significant range of results (32.06 vs. 36.87) for goat and sheep meat from yearlings, respectively, was found by Alamin (2019). According to Li et al. (2014), shear force is associated with the final pH of meat, and a value lower than 5.8 makes meat more tender than that with a final pH between 5.8 and 6.2 due to higher proteolysis at the lower pH range. Similarly, Webb (2014) found that goat meat with lower pH also shows lower shear force values, therefore all the factors that affect the value and decrease in pH can affect the shear force of meat. Goat meat, although generally acceptable, is usually less tender than sheep meat (Rodríguez et al. 2014). According to Tshabalala et al. (2003), sheep having more soluble collagen than goats; an element that may explain the different shear forces noted between small ruminants. However, according to other researchers, it is the solubility rather than the amount of collagen which is an important element in increasing shear force (Hopkins et al. 2013; Santos-Silva and Vaz Portugal 2001; Starkey et al. 2017). Shija et al. (2013) found that sheep meat was more tender than goat meat by over 12% (4.24 N). The higher tenderness observed in sheep meat was also consistent with the study by Sen et al. (2004), who found sheep meat (37.4 N) to be twice as tender compared to goat yearlings (74.2 N). A similar relationship also occurred in this study, with similar shear force values (Shija et al. 2013). Sheridan et al. (2003) found no significant difference in shear force values between lambs and goat kids, although the tenderness decreased with age in both species, and the goat meat was also less juicy than the lamb. The impression of lower juiciness in goat meat is caused by cooking losses, which are usually high for this species (35%). Cooking losses have at least partly contributed to consumers’ belief that goat meat is less juicy than lamb or mutton (Tshabalala et al. 2003). This parameter did not differ between the studied groups in our case.

Meat colour is another important factor from the consumer’s perspective. Several factors such as species, breed, age, sex, and muscle pH affect this important meat quality parameter. Meat colour is largely determined by its myoglobin content and its derivatives – the more myoglobin in meat, the darker the colour. The meat of older sheep contains more muscle myoglobin and hence is darker than that of lambs. Interspecies differences in muscle colour were found by Mioč et al. (2013) when comparing native Croatian Pramenka lambs, which had lighter meat (with higher L* values) and a higher proportion of red colour (a*) than Croatian Spotted goats. Sheridan et al. (2003), when studying the meat quality of Boer goats and South African Merino lambs, found no difference between the colour of cooked goat and lamb meat, but there was a tendency for fresh lamb to have a higher a* (redness) value than goat meat. Vnučec et al. (2020) found higher values of b* for lambs than in goat kids of Croatian indigenous breeds; a similar relationship occurred in our research.

4.3. Nutritional value of meat

Kid meat is undervalued by the food industry, nutritionists, and consumers alike. It is lean, relatively rich in protein and mineral salts, low in cholesterol, and its fine-fibre structure; typically, goat meat has a higher protein content and lower fat content compared to mutton, beef, and veal (Ivanovic et al. 2014). Tshabalala et al. (2003) also observed a similar trend when comparing the chemical composition of goat and sheep carcasses, i.e. that goat muscle tissue contained more water, crude protein, and ash than sheep, while sheep had more fat. According to Marsico et al. (2005), meat from Saanen kids contained more water, was richer in protein and contained more than twice as much fat (2.0% vs. 4.8%) as meat from Gentile di Puglia lambs, regardless of the nutrition used. A different observation was made by Shija et al. (2013) – meat from goat carcasses contained significantly more water than sheep, but also fat, while protein and ash content did not differ significantly between the species. Murshed et al. (2014) compared the meat quality of Black Bengal goat and Indigenous sheep of Bangladesh from a semi-intensive management system, and found that dry matter content was significantly higher in the sheep, while protein, fat and ash contents were found to be similar between the species. After analyzing selected characteristics of meat obtained from yearling rams and goats, Alamin (2019) found that goat meat had higher water and protein contents (22.55%) compared to sheep meat (21.44%), while the fat content of the sheep meat was almost twice as high (4.89%) compared to goat meat (2.5%); there was no difference between the two types of meat in the ash content. According to Niedziółka et al. (2005), kid meat showed significantly higher content of protein (20.21%) and ash (1.13%), with lower fat content (2.28%). Similarly Vnučec et al. (2020), analyzing meat quality traits of indigenous lambs and goat kids from extensive production system showed that lamb meat contained more fat, as well as less protein and minerals than goat meat.

The type and composition of fatty acids in intramuscular fat are one of the many parameters that determine the dietary value of meat. Polyunsaturated fatty acids play a particularly important role in preventing and alleviating the course of several conditions commonly referred to as civilization diseases, such as coronary heart disease, autoimmune disorders, or neoplastic diseases. Intramuscular fat of leg muscles in both species contained more unsaturated fatty acids than saturated fatty acids. Horcada et al. (2014) found that in the intramuscular fat of Spanish goat breeds and Churra lamb sheep, the proportion of unsaturated fatty acids (PUFA + MUFA) was superior to SFA, which ranged from 45.3% to 46.2%. In this study (Horcada et al. 2014), a predominance of UFAs in young billy goat muscle fat was found; a similar relationship was observed by Marsico et al. (2005). Goat meat fat was richer in total unsaturated, mono- and polyunsaturated n-3 and n-6 fatty acids, and also showed lower atherogenicity and thrombogenicity indices, making it better from a dietary point of view. Niedziółka et al. (2005) found that kid muscles are characterized by a much lower content of palmitic acid (C16:0) and stearic acid (C18:0), and a much higher content of C18:2, C18:3, C20:4 in terms of polyunsaturated acids. In our study, the proportion of C18:3 acid was more than twice as high in the lambs group. A high proportion of n-3 fatty acids is beneficial, while the n-6/n-3 ratio should be less than 5, and a diet with such parameters is recommended to prevent
coronary heart disease; in women was associated with decreased risk for breast cancer, suppressed inflammation in patients with rheumatoid arthritis and had a beneficial effect on patients with asthma (Bhardwaj et al. 2015). According to Horcada et al. (2014), this ratio in goat kids and lambs of Spanish breeds did not differ and ranged from 7.5 to 8.9. From the human health perspective, the fatty acid profile of lamb meat in our research (Table 4) was more favourable, due to lower proportions of PUFA n-6/n-3. In contrast, the PUFA/SFA ratio should be at least 0.45 (Webb 2014). The ratio values were 0.646 for goats and 0.525 for lambs in Polish indigenous breeds. Kiani et al. (2017), by comparing the meat quality of native Iranian ruminant breeds (kids, lambs, and calves) maintained extensively under a transhumant production system, found that the n-6/n-3 ratio in meat produced under this system was significantly lower than that of concentrate-fed animals. Goat meat showed a nutritional advantage over meat from other species, and the sum of SFA in goat meat was lower than in lambs and calves (41.4% vs. 46.2% and 47.4%, respectively), explained by the authors as resulting from higher biohydrogenation in goats compared to other ruminants.

4.4. Organoleptic properties of meat

Flavour and aroma are key parameters influencing consumer acceptance of meat, and their composition depends on numerous factors such as species, breed, age, percentage of fat, type of muscle, sex, nutrition, and cooking treatment. The characteristic smell and taste of sheep and goat meat are influenced by amongst others, branched-chain fatty acids (Webb et al. 2005). The conditions and heat (cooking) treatment methods of meat are key to flavour development as thermal reactions produce numerous volatile substances that contribute to flavour. The Maillard reaction also plays an important role in the development of meat flavour, which is mediated by volatile and non-volatile precursors (Gașior et al. 2020).

According to Sen et al. (2004), similar to our studies on sensory evaluation, both species were rated almost the same in terms of overall palatability evaluation, yet numerous authors still highlight organoleptic differences between kid and lamb meat. According to Sheridan et al. (2003) each had a species-specific taste, the kid meat had a more pronounced aftertaste than the lamb meat and was less succulent than the lamb. Murshed et al. (2014), when analyzing the carcass parameters, composition, and sensory characteristics of meat of Black Bengal goat and native sheep, both reared in a semi-intensive farming system, found similar characteristics, although the sheep meat was juicier while the goat meat was more acceptable due to its characteristic taste. With respect to tenderness and juiciness, goat meat and its products have been rated lower compared to sheep meat (Tshabalala et al. 2003; Sheridan et al. 2003).

4.5. Chemometric classification using volatile compounds analysis

Most studies comparing the quality of goat and lamb meat evaluate the organoleptic properties and the physico-chemical quality of the raw material. However, lately more and more papers related to the question of differentiating of food products using volatiles analysis by GC/MS methods have been published (Gașior and Wojtycza 2016). Chromatographic fingerprinting technique was described by Zhan et al. (2017) for quality control of mutton, and Calik et al. (2017) for classification of cooked meat from capons and cockerels. The chemometrics based on volatile compounds analysis can also be used to visualize differences between animal-derived products due to the impact of nutrition (Rivas-Cañedo et al. 2013), age (Gașior et al. 2018), and breed and age (Gașior et al. 2020). The multivariate statistical analysis applied for distinguishing of omega-3 enriched lamb meat supplemented with natural antioxidants (Rivas-Cañedo et al. 2013) showed that the first two principal components accounted for 58% of the total variance. In the studies on volatile compounds distinguishing the meat of Polish Carpathian goats aged 12 and 9 months (Gașior et al. 2018), and the meat of Polish native sheep breeds at the age of 9 and 7 months (Gașior et al. 2020), the first two principal components accounted for 88.8%, and 78.6% of the total variance, respectively. The classification accuracy given in the latter two studies was 100%.

In this study the proportion of the total variance explained by the first two principal components was 86.8%, and perfect sample distribution with a 100% of classification performance was also achieved [Fig. 1]. Our experiment confirmed the usefulness of the Fisher’s ratio-PCA-LDA method based on mass spectra of HS-SPME-GC/MS analysis of volatile compounds, for the leg meat samples classification belonging to the two species.

5. Conclusions

Species had no effect on slaughter parameters of kids and lambs of native Polish breeds but had a significant effect on the tissue composition of the leg. Cuts obtained from kid carcasses contained more meat and bone. There were differences found between the species with respect to meat quality. The kids meat contained less moisture and more protein; it was characterized by better water absorption, yet was less tender than lamb meat. From the human health perspective, the fatty acid profile of lamb meat was more favourable, due to the lower proportions of PUFA n-6/n-3; the PUFA/SFA ratio was beneficial to both groups. The presented studies showed differences in most of the analyzed parameters of lamb and kid meat quality, and the analysis of volatile compounds confirmed the difference of the product from these two species. In the organoleptic assessment, no differences were found between roasted meat from lambs and goats, and both products were rated highly.

Despite the differences in the assessment of the physico-chemical and nutritional parameters of lamb and goat meat, both types of meat can be considered are a valuable component of the diet, while high values of the organoleptic assessment indicate a good reception of both products by consumers.

Disclosure statement

No potential conflict of interest was reported by the author(s).
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