

Variability in nutritional value of traditional goose meat product*

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The aim of this paper was to determine the composition of fatty acids, contents of cholesterol, vitamin E and mineral composition of a goose breast product. The study was carried out on 21 samples of Polish traditional dry cured product made from meat of White Koluda goose originating from three different regions/producers. The sensory quality and chemical composition (fatty acids, cholesterol, vitamin E and mineral composition) were determined. In the tested goose breast samples palmitic acid (C16:0), oleic acid (C18:1 cis-9) and linolenic acid n-6 C18:2 (all-cis-9-12) were the most abundant among saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA), respectively. All goose breast samples were characterised by a high ratio of n-6/n-3 acids (from 16.1 to 21.4). Statistically significant differences ($p \leq 0.05$) in fat contents were observed between the studied groups. Total cholesterol content in the tested samples of cold meats was significantly different ($p \leq 0.05$) and ranged between 53.0 mg/100g (Producer 1) and 63.0 mg/100g (Producer 2). Alpha-tocopherol was the only vitamin E homologue detected in the breast meat at amounts ranging between 3.0 and 3.4 µg/g per sample and it did not depend on the producer ($p \leq 0.05$). In terms of the mineral composition of the studied product phosphorus was the most abundant mineral (175.0-237.8 mg/100g) followed by magnesium (15-18.8 mg/100g), calcium (6.25-7.9 mg/100g), iron (2.3-2.8 mg/100g) and zinc (0.9-1.2 mg/100g). Significant differences between producers were also indicated for P and Mg levels. This study showed significant variability of fat composition, cholesterol level and sensory quality, which could be related to different regions/producers. The results also indicated that this traditional product could be a good source of vitamin E (α -tocopherol).

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The influence of food on human health is obvious. Meat and its products are essential components of our diet and contain such nutrients as fat including fatty acids and cholesterol, as well as vitamins and other substances which may have an effect on health. However, goose meat is often perceived as detrimental to health, because it may contain a high level of fat, and thus cholesterol and saturated fatty acids (SFA), which are known to raise the risk of obesity and cardiovascular diseases. This may be the cause for a shortening of life expectancy or deterioration of the quality of life [Sacks 2002, Scollan *et al.* 2006, Simopoulos 2002]. On the other hand, animal fat-soluble compounds may also have a positive effect on human health. Oleic acid has cholesterol-lowering effects as well as other health-promoting properties, including reduced risk of stroke and beneficial effects on blood pressure [Daley *et al.* 2010]. Additionally, certain polyunsaturated fatty acids (PUFA) have been studied in view of their biological effects, such as prevention of cancer, atherosclerosis, obesity, diabetes and osteoporosis [Decker and Park 2010]. Polyunsaturated n-6 fatty acids tend to decrease low-density lipoprotein (LDL) cholesterol levels, while n-3 fatty acids have limited effects on blood cholesterol, although long chain n-3 PUFAs are effective in reducing blood triacylglycerol levels [Chizzolini *et al.* 1999]. Moreover, a balanced n-6/n-3 ratio in cell membranes is associated with a reduced risk of coronary heart disease [Aldai *et al.* 2006].

Poultry meat has been considered a major source of polyunsaturated fatty acids in human diets [Howe *et al.* 2006]. Goose meat is particularly rich in fat, and thus, potentially, also in fat-soluble nutrients. The content of such nutrients in meat products depends mainly on the animals' diet and rearing conditions, as well as the adopted production technology [Castellini *et al.* 2002].

Oat fattening gives unique health-promoting and taste qualities to goose meat and fat [Żakowska-Biemans *et al.* 2016]. Grazing as well as oat grains, which constitute the main feed for oat geese, are good sources of valuable fatty acids and tocopherols, natural diterpenes with vitamin E activity, which is the primary lipid-soluble antioxidant in biological systems [Decker *et al.* 2000]. Hence, goose breast meat may be a source of important fat-soluble compounds, which is crucial for human health.

In view of the above, the aim of this paper was to determine the effect of different regions of origin and producers on the nutritional value and sensory quality of goose breast used for the Polish traditional dry cured meat product from oat geese of the White Koluda breed. We hypothesise that the quality of traditional products is characterised by high variability resulting from variability in the raw material. We need to stress a lack of results in available literature concerning the nutritional value such as fat composition, cholesterol and vitamin E as well as mineral composition of dry, cured and smoked traditional product made from meat of White Koluda geese.

Material and methods

Material and samples

The study was carried out on 21 samples of goose breasts collected from carcasses of White Koluda geese. The studied material was described in detail in a previous paper of Nowicka *et al.* [2017]. The products were obtained from three different producers and regions (Producer 1 – the Małopolska province, Producer 2 – the Mazovia province, and Producer 3 – the Warmia Masuria province), with 21 samples collected from each of the 3 producers in 2 batches. Goose breasts were obtained from White Koluda geese reared under optimal environmental conditions, with the trade mark registered in the Patent Office as "White Koluda® Geese". Such geese from each producer were fed in accordance with the principles of rearing and oat fattening following the same diet [Bielińska 2008]. During the 14-week rearing period (divided into three periods) feeding of birds was based on a concentrate mixture and fresh grass from pasture. During the first period (up to the 4th week of age) the birds were fed cereal sharps with 20% maize sharps with the addition of fodder yeast and mineral additives, and fresh grass. The nutritional value of forage was as follows: 2600-2800 kcal of metabolisable energy (ME), 19-22% crude protein, 4-5% crude fibre, 1% calcium and 0.4% assimilable phosphorus. During the second period of fattening (from the 5th to 8th week of age) cereal sharps were limited to 230-240 g/bird/day with an addition of 500-800 g of fresh grass from pasture. The nutritional value of forage was as follows: 2600-2700 kcal of ME, 16-17% crude protein, 5-7% crude fibre, 0.8% calcium and 0.35% assimilable phosphorus. In the third period (from the 9th to 14th week of age) cereal sharps were limited to 220-260 g/bird/day with an addition of 800-1000 g of fresh grass from pasture. In that feeding period the nutritional value of forage was as follows: 9-10th week – 2800 kcal of ME, 15-16% crude protein, while in the 11-14th week 2500 kcal ME, 12-13.5% crude protein, 5-7% crude fibre, 0.8% calcium and 0.35% assimilable phosphorus. During the final 3 weeks of the fattening phase (the 15-17th week of age) the geese were fed unshelled oat grains *ad libitum* (minimum 500 g daily) with mineral additives. The nutritional value of forage was as follows: 2600-2700 kcal of ME, 16-17% crude protein, 5-7% crude fibre, 0.8% calcium and 0.35% assimilable phosphorus. During the first 6 weeks of the rearing period birds were kept indoors, under controlled temperature and humidity conditions and then, up to week 17, in an open house with free access to a grass pasture. Drinking water and feeds were provided *ad libitum*, according to the feeding guidelines for meat geese. Such a requirement is set by the Commission Regulation (EEC) No. 1538/91. The birds were deprived of feed 12 h before slaughter and the distance from the farm to the slaughterhouse was about 50 km. The animals were slaughtered by electrical stunning (average current value per animal 130 mA) in accordance with the European Union Council Regulations (EC) No. 1099/2009 of 24 September 2009 for the protection of animals at the time of killing.

Goose breast fillets with skin (taken each time 24 h after slaughter by each producer) were used in the study. The samples were seasoned with a mixture of salt, nitrates and spices (400 g per kg) and kept at 4°C and relative humidity of 75-80% for 2 weeks (without packaging). Afterwards cured meat was washed with cold water to remove excess salt, then dried and formed in rolls. All the dry-cured samples obtained from the meat of White Koluda geese were subjected to a cold smoking process (16-22°C) for 2 days (4 h per day). Following the completion of the smoking process smoke cured meat was vacuum packed in order to avoid excessive dehydration of the product before evaluation.

For all the analyses the pieces of cured meat were cut in cubes of 20-30 g, packed in sealed Ziploc bags and frozen at -80°C. Cured meat material was stored for up to one month.

Tocopherols

The content of tocopherols was determined according to Sztark *et al.* [2013]. A portion of each breast was minced and a representative sample of 1 g was placed in a 50-ml polyethylene tube. Three ml of methanol, 6 ml of chloroform, 3 ml of saturated solution of sodium chloride and 0.5 ml of 200 mg/l α -tocopherol acetate solution (internal standard) were added to the samples. The tubes were capped and centrifuged at 5000 rpm for 10 min. Two ml of the aliquot of hexane containing 200 mg/l butylated hydroxytoluene (BHT) were pipetted and the sample was homogenised for a further 15 s. An aliquot of the precipitate layer was collected in a small screw teflon-lined cap tube (Phenomenex Torrance, CA, USA) and evaporated under liquid nitrogen. Samples were then reconstituted with 2 ml of 1% tetrahydrofuran (THF) in n-heptane.

Tocopherols were analysed using a high-performance liquid chromatography (HPLC) system with fluorescence detection (Schimadzu, Japan). Chromatography was performed at ambient temperature with a flow rate of 1 ml/min using a LiChrospher 100 Diol column (Merck, Germany). The mobile phase was 1% THF in n-heptane. All samples were detected using highly specific fluorescence detection at 330 nm after excitation at 295 nm. Quantification of tocopherols in the tested samples was performed by the internal standard method to compensate for losses during sample preparation for analysis as well as based on calibration curves prepared with external standards of α -, δ - and γ -tocopherol (Supelco, USA).

Fatty acids

Preparation of fatty acid methyl esters: fatty acids in the lipid extracts were converted into methyl esters including 2% sulfuric acid (v/v) in methanol. The mixture was vortexed and then kept at 50°C for 12 h. Subsequently, after being cooled to room temperature, 5 ml of 5% sodium chloride were added and then the mixture was vortexed. Fatty acid methyl esters were extracted with 2x5 ml hexane. Fatty acid methyl esters were treated with 5 ml of 2% KHCO₃ solution and then the hexane phase was evaporated under a stream of nitrogen and then dissolved in 0.5 ml

fresh hexane. Samples were placed in autosampler vials. Fatty acid methyl esters were analysed using an Agilent GC gas chromatograph with a Flame Ionization Detector (GC-FID) (Agilent, USA). A 105m long Restec-2330 (USA) capillary column with an inner diameter of 0.25 mm and film thickness of 20 microns was used. The column's temperature was kept at 120-220°C, injection temperature was 240°C and the detector temperature was set at 300°C. The helium carrier gas flow rate was 1 ml min⁻¹. The fatty acid methyl esters were identified by comparison with authentic external standard mixtures (Supelco, F.A.M.E. mix C4-C24, lot 18919, 10 mg/mL in hexane) analysed under the same conditions. The determination was performed in an accredited chemical analysis laboratory. The method was validated prior to its routine use.

Cholesterol

Total lipids from goose breast samples were extracted according to the method described by Soxhlet [PN-ISO 1444:2000]. The extraction procedure for gas chromatography (GC) analysis of cholesterol was as follows: 50-70 g fat were placed into a 100-ml tube in triplicate. One ml of the internal standard (1 mg/ml 5 α -cholestanol (Sigma Aldrich, lot 079K4101, 1 mg/ml) in hexane was evaporated to dryness under a stream of nitrogen) and then 2M KOH solution was added. The tubes were placed in a water bath at 75°C for 10 min and a thionyl chloride solution in methanol was added. The tubes were then again placed in the water bath and cooled to room temperature. Then, 2 ml of heptane and a saturated NaCl solution were added. One ml of the hexane layer containing cholesterol was placed in the vial and heptane was evaporated under a stream of nitrogen. The volume of 50 μ l of *N,O*-Bis(trimethylsilyl)trifluoroacetamide (BSTFA) + 1% chlorotrimethylsilane (TMCS) solution and 50 ml pyridine were added. The vials were capped, heated in a water bath (75-80°C/20 minutes) and cooled to room temperature. The vials were then transferred to an autosampler for analysis. An FID detector (temperature: 295°C) equipped with an HP-5MS column (0.25 μ m x 0.25 mm, 30 m) was used. The helium carrier gas flow rate was 0.6 ml min⁻¹. Cholesterol was identified by comparison with authentic external standard mixtures (Supelco 47127-U, USA) analysed under the same conditions. The determination was performed in an accredited chemical analysis laboratory. The method was validated prior to its routine use.

Mineral composition

The mineral composition of cured meats was analysed by Inductively coupled plasma atomic emission spectroscopy (ICP-AES) on digested samples. Duplicate aliquots of approximately 0.5 g (± 0.01) of the previously homogenised samples were digested in a 1200 Mega Advanced Microwave Digestion System (Milestone, Sorisole, Italy) with 7 ml of concentrated nitric acid and 1 ml of perchlorate at 220°C for 20 min. After cooling to room temperature the solution was diluted to a fixed volume (volumetric flask, 25 ml) with deionised water. The instrumental analysis was performed with a ICP-AES ThermoCAP 6500 DUO optical emission spectrometer (Thermo Fisher Scientific,

Cambridge, United Kingdom). The spectrometer was calibrated for Ca, Fe, Mg, P and Zn determinations (at 315.817/318.118/373.690/393.366 nm; 238.204/259.940 nm; 279.079/279.553/280.270/285.213 nm; 177.495/178.766/213.618/178.284 nm and 206.200/213,856 nm, respectively).

Sensory analysis

The studied products were analysed using Quantitative Descriptive Analysis (QDA) with an unstructured, linear graphical scale at 100 mm converted to numerical values (0-10 conventional units [c.u.]) and sensory assessment [ISO 13299:2016, Meilgaard *et al.* 2006]. The whole sensory profile which was established, except for fat perception, was presented and fully described in a previous paper of Nowicka *et al.* [2017].

For the purpose of this study only attributes related to fat were considered. The sensory quality of fat was characterised on the basis of 4 sensory traits: fatty odour, fatty flavour, intensity of colour of fat cover and thickness of fat cover. Samples were prepared for sensory evaluation after goose breasts were removed from packages immediately before the analysis and the cold meats were sliced into identical slices of 0.5 cm in thickness. Single slices were put into odourless, plastic, disposable containers closed with lids. The evaluation was carried out by a panel trained in the scope of the applied evaluation, with the panel members having long-term experience in conducting sensory evaluations according to the ISO 8586-2:1996 standard. The meat samples were tested at room temperature ($24\pm 2^{\circ}\text{C}$). The assessment was conducted in odourless rooms with daylight. Between subsequent evaluations the assessors received hot tea without sugar to neutralize the taste. All meat samples coming from a specific product were evaluated based on a minimum 18 individual results. The assessment and condition mode followed the method proposed by Meilgaard *et al.* [2006].

Statistical analysis

The results were elaborated with the use of STATISTICA statistics package, version 12 (StatSoft, Inc. 2014) and Microsoft Excel 2007. The normality of distribution for all analysed traits was verified using the Shapiro-Wilk test. The obtained results are presented as mean values with SD (Standard Deviation of Mean). Each parameter was calculated in triplicate. The effect of region of origin/producer on chemical composition (fatty acid profile, cholesterol, tocopherol, mineral composition) of muscle with the series (or panelists in the case of sensory traits) as a random effect was estimated using the ANOVA procedure. The least significant differences (LSD) test was applied to evaluate the significance of differences between means at the level $p\leq 0.05$. The impact of the sensory session (two sessions) was non-significant for all the evaluated attributes, which positively verifies the experience of the panel and assessment conditions. Principal Component Analysis (PCA) was applied for sensory data and the fatty acids profile.

Results and discussion

Total fatty acid compositions (% of total fatty acids) of goose breasts obtained from the 3 different producers are presented in Table 1. The most abundant saturated fatty acids (SFA) included palmitic acid (C16:0) with amounts from 22.16% to 23.97%

Table 1. Fatty acid composition (% of total fatty acids), total fat (g/100g) and cholesterol content (mg/100g) of goose breasts from 3 different producers

Fatty acids	Producer		
	1	2	3
SFA			
C12:0	0.3±0.79	-	-
C14:0	0.7±0.57	0.4±0.04	0.4±0.04
C16:0	24.0±1.90 ^a	22.7±0.67 ^{ab}	22.2±0.86 ^b
C17:0	0.1±0.02	0.1±0.03	0.1±0.02
C18:0	6.4±0.62	5.9±0.85	5.5±0.28
C20:0	0.06±0.04	0.04±0.03	0.02±0.03
C22:0	0.03±0.04	0.01±0.03	0.03±0.04
C23:0	0.06±0.04 ^a	0.01±0.02 ^b	0.04±0.04 ^{ab}
MUFA			
C14:1	0.04±0.06	-	-
C16:1	3.3±0.46 ^a	2.4±0.51 ^b	2.8±0.39 ^b
C17:1	0.1±0.04	0.1±0.04	0.1±0.03
C18:1 cis-6	0.04±0.10	0.02±0.06	0.1±0.09
C18:1 cis-9	47.6±6.55 ^a	53.1±2.16 ^b	52.2±1.81 ^{ab}
C18:1 cis-11	2.0±0.19	2.0±0.12	2.1±0.21
C21:1 cis-11	0.3±0.06	0.3±0.02	0.3±0.03
PUFA			
C18:2 (trans) iso1	0.03±0.04	-	-
C18:2 cis-9-12; n-6	10.2±5.35	8.0±3.45	11.48±2.07
C18:3 cis-6,9,12; n-6	0.01±0.03	-	-
C18:3 cis-9,12,15; n-3	0.7±0.29	0.57±0.59	0.60±0.12
C18:2 cis-9, trans-11; CLA	0.01±0.03	-	-
C20:2 cis-11,14; n-6	0.1±0.07	0.03±0.05	0.07±0.02
C20:3 cis-8,11,14; n-6	0.1±0.10 ^a	0.01±0.03 ^b	0.04±0.03 ^b
C20:4 cis-5,8,11,14; n-6	0.6±0.39 ^a	0.2±0.14 ^b	0.33±0.12 ^b
C22:6 cis-4,7,10,13,16,19; DHA; n-3	0.01±0.02	-	-
ΣSFAs (%)	31.6±2.97 ^a	29.1±1.43 ^b	28.2±1.04 ^b
ΣMUFAs (%)	53.3±6.35	58.0±1.86	57.5±1.86
ΣPUFAs (%)	11.7±6.16	8.7±4.15	12.5±2.23
PUFA:SFA ratio	0.4	0.30	0.44
Σn-3 (μg/g)	0.7±0.29	0.6±0.59	0.6±0.12
Σn-6 (μg/g)	11.0±5.89	8.2±3.62	11.9±2.17
n-6/n-3 ratio	16.1±2.95	21.4±8.38	20.1±3.51
Atherogenic SFA (mg/g)	24.0±1.90 ^a	22.7±0.67 ^{ab}	22.2±0.86 ^b
Thrombogenic SFA (mg/g)	31.1±2.49 ^a	28.9±1.40 ^b	28.1±1.00 ^b
Total fat (g/100g)	16.0±4.74 ^a	9.4±3.01 ^b	11.3±4.57 ^b
Vitamin E (μg/g)	3.4±0.56	3.1±0.36	3.0±0.27
Cholesterol (mg/100g)	52.6±12.21	62.6±13.54	53.2±21.22

SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

A^{SFA}: C12:0,+C14:0,+C16:0; T^{SFA}: C14:0+16:0+18:0.

^{ab}In rows means bearing the different superscripts differ significantly at p≤0.05.

and stearic acid (C18:0) (ranging from 5.5% to 6.4%). In the case of monounsaturated fatty acids (MUFA) the highest content was recorded for oleic acid (C18:1 cis-9) (between 47.6% and 52.2%) followed by palmitoleic acid (C16:1 cis-9) (ranging from 2.8% to 3.3%). Polyunsaturated fatty acids (PUFA) were represented by linolenic acid (n-6; C18:2 all-cis-9,12) at 8.0% to 11.5%, α -linolenic acid (n-3; C 18:3 cis-9,12,15) at 0.6% -to 0.7% and arachidonic acid (n-6; C20:4 all-cis-5,8,11,14) at 0.2% to 0.6%, respectively. These results are consistent with the studies of Biesiada-Drzazga [2006] and Okruszek [2011, 2012]. For MUFA the profile content of C16:1 was similar, while the level of oleic acid (C18:1 cis-9) is higher than that presented by Okruszek [2011, 2012] or Haraf *et al.* [2014], who studied raw goose meat and different goose breeds. The content of linolenic acid was also lower in comparison to the above mentioned studies (Tab. 1). Similar contents of α -linolenic and arachidonic acids were recorded in our study in comparison to the levels reported by Okruszek [2011, 2012] and Haraf *et al.* [2014]. To summarise, results shown in Table 1 are similar to those from the studies mentioned above for total SFA content; however, the traditional processed goose product contains more MUFA and less PUFA. On the other hand, γ -linolenic acid (C18:3 (all-cis-6,9,12)), conjugated linolenic acid (C:18:2 (cis-9, trans-11)) and docosahexaenoic acid - DHA n-3- (C22:6 (all-cis-4,7,10,13,16,19)) were present in the samples from Producer 1 in the smallest amounts. In the case of cold meats coming from the two other producers, contents of behenic acid (C 22:0), arachidic acid (C 20:0) and C18:1 (cis-6) were detected in trace amounts. It is worth mentioning that fat composition in Polish goose breeds is different than in breeds from other countries such as Turkey, China or Egypt [Coskuntuna *et al.* 2015, He *et al.* 2015, Liu *et al.* 2013, Geldenhuys *et al.* 2015]. In general, the most significant group of fatty acids in goose breast samples comprised monounsaturated fatty acids, which were present in comparable amounts in all the three groups of goose breasts. The large amount of MUFA enhances the oxidative stability of poultry meat in comparison with meat rich in PUFA. Furthermore, a high MUFA content in animal products may be beneficial for human health. A diet rich in MUFA increases resistance of plasma LDL lipoproteins to oxidative modification. This effect could lower the atherogenicity of these lipoproteins [Bonanome *et al.* 1992].

Furthermore, analysis of the fatty acid profile demonstrated significant differences in the contents of selected fatty acids in the samples coming from different producers (regions). These differences were found for palmitic acid (C 16:0), tricosanoic acid (C23:0), palmitoleic acid (C16:1 (cis-9)), oleic acid (C18:1 (cis-9)), eicosatrienoic acid (C20:3 (all-cis-8,11,14)) and n-6 arachidonic acid (C20:4 (all-cis-5,8,11,14)). This may be the result of differences in the botanical composition of meadow and pasture forages from the three different regions of Poland. Barłowska *et al.* [2012] performed botanical and weight analyses of collected grass fodder, which showed a higher share of herbs and weeds (15%) in the upland Małopolska region in comparison with the lowland regions of Mazovia and Warmia-Masuria (8, 10%). In turn, Barłowska *et al.* [2012] who studied the correlation between fatty acids in animal origin fat produced

in the lowlands and highlands of Poland and the botanical composition of the fodder showed negative correlations between grasses (*Poaceae*) and PUFA contents ($r = -0.77$), CLA ($r = -0.73$) and a positive correlation between *Asteraceae* ($r = 0.74$; $r = 0.75$, respectively) and *Apiaceae* ($r = 0.63$; $r = 0.58$, respectively). It is worth noting that in this study products from upland areas were characterised by a greater variety of PUFA in goose fat. Moreover, products from Małopolska were the only ones containing the CLA fatty acid.

The differing composition of fat in goose breasts between the producers are reflected in sensory characteristics of fat descriptors presented in Table 2. Results showed significant differences in fat taste, odour and intensity of colour (Tab. 2). The product from Producer 1 was characterised by a lower intensity of taste and odour and a greater intensity of colour (Tab. 2). Most likely this is the result of the longer smoking time used by Producer 1. All the dry-cured samples were subjected to a cold smoking process (16-22°C) for 2-7 days [Nowicka *et al.* 2017]. This time is dependent on the goose breast size and individual preferences of the producer. It must be emphasised that Polish legal provisions for the traditional Polish meat product market do not precisely specify the formulation and the production process, thus providing the grounds for preserving the unique character of production by local producers [JOURNAL OF LAWS, 2005].

Table 2. Sensory quality of goose breasts from 3 different producers in relation to fat characteristics

Attribute	Sensory descriptor	Producer		
		1	2	3
Taste	Fat taste	2.3±0.40 ^a	3.4±0.53 ^b	3.8±0.79 ^b
Odour	Fat odour	2.6±0.48 ^a	3.3±0.63 ^b	3.5±0.51 ^b
Appearance	Thickness of fat cover	3.0±1.06	3.8±1.02	4.9±1.87
Colour	Intensity of fat colour	5.1±1.75 ^a	2.9±0.66 ^b	3.4±1.60 ^b

^{ab}In rows means bearing the different superscripts differ significantly at $p \leq 0.05$.

Total fatty acid composition and its sensory quality were taken into account as criteria for the Principal Component Analysis (Fig. 1). PCA calculations were performed using STATISTICA (data analysis software system), version 12. StatSoft, Inc. (2014). PCA analysis showed that 59.4% of the total variability could be explained by two principal components (Fig. 1). The presentation shows that all groups of samples from a specific producer are described by a different set of studied attributes. For example, fat odour and fat flavour attributes as well as visible fat cover were highly and mutually correlated. The close position of Producer 3 demonstrate similarity of those samples in terms of these features (fig.1). Samples of Producer 1 differ from the other samples in fat colour. The distribution of tested samples on the axis obtained by the two first components is presented in Figure 2, which also showed a unique profile typical of each producer. This analysis also showed greater variability in fat composition and sensory quality for Producers 1 and 2, at a lesser variability for Producer 3 (Fig. 2). Similar findings in relation to discriminating dry cured hams on the basis of adipose tissue composition (fatty acid profile) according to their origin or

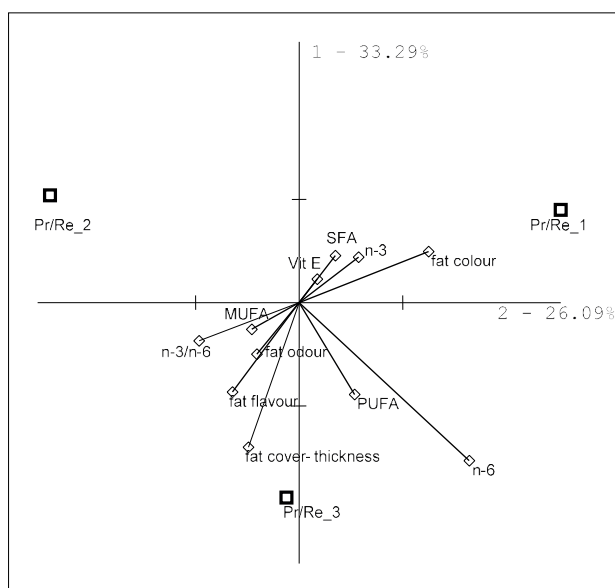


Fig.1. Results of Principal Component Analysis for fat composition and its sensory quality.

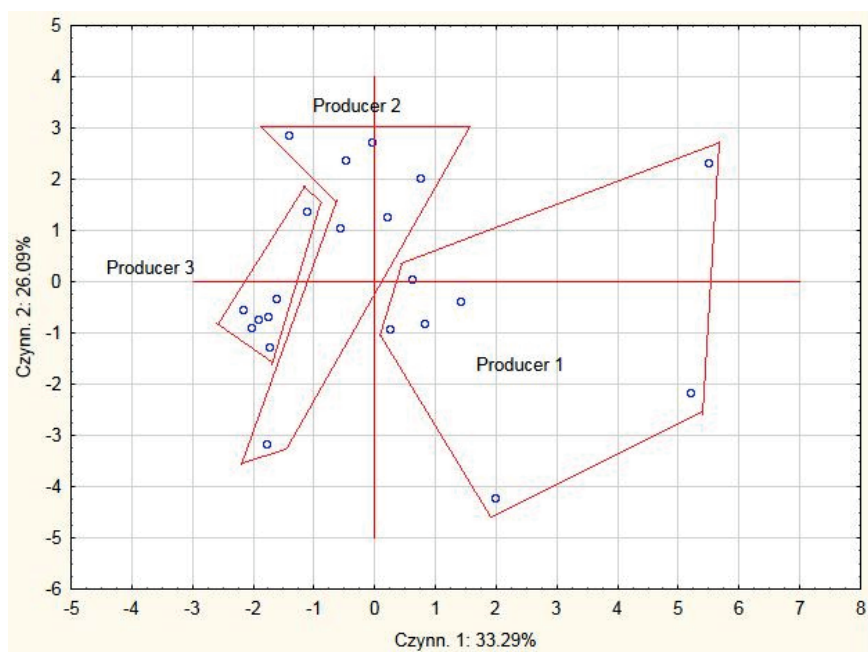


Fig. 2. The distributions of samples* from three studied producers on the axis of two principal components.

the rearing conditions of pigs were reported by Riaublanc *et al.* [1999] in France and Fernández *et al.* [2007] in Spain. On the other hand, significant differences in SFA content were demonstrated in samples from Producer 1, which were characterised by greater contents of this group of fatty acids. It must also be emphasised that n-6 fatty acids were found in much greater amounts than n-3 acids.

The ratios of n-6/n-3 acids and PUFA/SFA are widely used to evaluate the nutritional value of fat. According to the National Institute of Health, USA, the n-6/n-3 ratio should be between 1 and 2 [Simopoulos 2004]. All the goose breast samples were characterised by a high ratio of n-6/n-3 acids (from 16.1 for Producer 1 to 21.4 for Producer 2, Tab. 1). These results are related to the high content of n-6 acids in goose fat and in particular a significant percentage of linolenic acid, which most probably originated from oat grain, a component of the fed diet. This altered ratio of n-6/n-3 acids could also be related to the consumption of forage by the geese. Presented results are confirmed by studies conducted by Givens *et al.* [2011], who reported that meat from free-range birds had a consistently higher n-6/n-3 ratio than meat from intensively reared birds. Similarly, in a study conducted by Haraf *et al.* [2014], who examined the fatty acid profile of muscles and abdominal fat in geese of native Polish strains the n-6/n-3 fatty acid ratio definitely exceeded the standard. The results are not advantageous from the point of view of human nutrition. Based on dietary guidelines, intake of n-3 fatty acids should be increased relative to that of n-6 acids. A balanced n-6/n-3 ratio in the diet is critical for normal growth and development, while also decreasing the risk of cardiovascular disease and diabetes [Poławska *et al.* 2011, Simopoulos 2002]. The imbalance in the n-6 vs. n-3 acid proportion is responsible for the pathogenesis of many diseases, including cardiovascular disease, cancer, as well as inflammatory and autoimmune diseases [Simopoulos 2004].

The recommendations of the Food and Agricultural Organization and the World Health Organization (FAO/WHO) for a healthy diet also suggest that the PUFA/SFA ratio should be 0.40 or higher [FAO/WHO, 1994]. Lipids coming mainly from the subcutaneous fat of tested goose breast samples were characterised by a lower PUFA/SFA ratio than the optimum values mentioned above in the case of Producers 1 and 2 (0.37; 0.30). Only in the case of the samples coming from Producer 3 the PUFA/SFA ratio complies with the dietary guidelines and amounted to 0.44. Low PUFA/SFA ratios in the diets have been considered as major risk factors of cardiovascular diseases, which are among the most important causes of human mortality in developed countries [Ganji *et al.* 2003, Katan 2000].

Apart from the fatty acid profile, also contents of atherogenic (A^{SFA}) and thrombogenic (T^{SFA}) lipids determine the quality of fat. Their amounts come from the content of respective groups of fatty acids. Those fatty acids indicate the dietary value of lipids and their potential impact on the incidence of coronary heart disease in humans. The total concentration of atherogenic and thrombogenic lipids in the samples of goose breasts, depending on 3 different processing stages, are shown in Table 1. In all the tested samples of goose breasts the content of atherogenic and

thrombogenic lipids ranged between 22.2 mg/g and 24.0 mg/g and between 28.0 mg/g and 31.1 mg/g, respectively (Tab. 2). In the case of both these parameters, significant differences were observed (at $p \leq 0.05$) between the samples of goose breasts coming from the three different producers. Analyses demonstrated that the samples coming from Producer 1 were characterised by the greater contents of both atherogenic and thrombogenic lipids, while in the case of samples coming from the two other producers these values were lower and comparable.

Contents of fat, cholesterol and fat soluble vitamin (α -tocopherol) of goose breasts from the 3 different producers are presented in Table 3. The total fat contents demonstrated statistically significant differences ($p \leq 0.05$) between goose breast samples coming from the three different producers. The highest fat content was characteristic of samples coming from Producer 1 and amounted on average up to 16.0 g/100g of cured meat. Goose breast samples coming from the two other producers were characterised by lower and similar total fat contents (from 9.4 g/100g to 11.3 g/100g). However, this content was still high. It must be noted that nutritionists recommend limiting animal fat intake because of the higher, compared to plants, lipid content in terms of saturated fatty acids (SFA) [Simopoulos 2004]. Consumption of the meats with high lipid contents may potentially lead to the development of human cardiovascular disease, obesity, hypertension and cancer [Jimenez-Colmenero *et al.* 2001].

Table 3. The mineral composition of goose breasts from 3 different producers (mg/100g)

Mineral	Producer		
	1	2	3
Ca	6.8±0.15	6.3±0.48	7.9±1.00
Fe	2.7±0.25	2.8±0.29	2.3±0.17
Mg	17.3±0.14 ^a	18.8±0.14 ^a	15.0±0.99 ^b
P	175.0±7.07 ^a	193.3±5.58 ^a	237.8±9.19 ^b
Zn	1.1±0.12	1.2±0.92	0.9±0.09

^{ab}In rows means bearing the different superscripts differ significantly at $p \leq 0.05$.

Cholesterol is an important molecule that plays a vital role in membrane structure, while also being a precursor for the synthesis of molecules such as steroid hormones, vitamin D and bile acids [Dessi and Bstetta 2004, Michikawa 2003]. The total cholesterol content in tested samples of cold meats was significantly different ($p \leq 0.05$). Cholesterol content was higher in the products of Producer 1 (52.6 mg/100g) when compared to those of Producer 2 (62.6 mg/100g). Total cholesterol content in the tested samples of cold meats was significantly different ($p \leq 0.05$) and ranged between 52.6 mg/100g (Producer 1) and 62.6 mg/100g (Producer 2). However, cholesterol concentration significantly exceeded the normal range (40-90 mg/100 g) for poultry [Piironen *et al.* 2002]. This may be attributed to the concentrations of FAs in goose fat. It must be emphasised that coronary heart disease and atherosclerosis are both strongly related to the dietary intake of cholesterol [Ponte *et al.* 2008]. Additionally, a

strong relationship has been demonstrated between cellular cholesterol concentration and Alzheimer's disease [Michikawa 2003]; therefore, products with a high content of cholesterol should be limited.

α -Tocopherol was the only vitamin E homologue detected in goose breasts. The content of α -tocopherol in the tested samples ranged between 3.0 $\mu\text{g/g}$ and 3.4 $\mu\text{g/g}$ and did not depend on the region of origin and the applied production method ($p \leq 0.05$). The values were higher in comparison with contents of α -tocopherol in the breasts of broilers fed a basal diet, which ranged between 1.3 $\mu\text{g/g}$ [Lin *et al.* 1989] and 1.5-1.6 $\mu\text{g/g}$ [Marusich *et al.* 1975]. Slightly different results were obtained by Ponte *et al.* [2008] in their studies. They studied tocopherol and tocotrienol contents in commercial chicken breast meat from a slow-growing genotype produced under the European Union free-range system. Indeed, in their paper the content of α -tocopherol was dominant, but also hardly any traceable quantities of beta-tocopherol, γ -tocopherol and γ -tocotrienol were detected. The prevalence of α -tocopherol in meat is well known and is due to more than 10-fold preference of the tocopherol-binding protein for α -tocopherol, relative to γ -homologues, which are the most common vitamin E molecules in plant foods [Decker *et al.* 2000]. Vitamin E (tocopherol) is considered to be one of the best biological antioxidants. Tocopherol eliminates free radicals, which are responsible for damaging cellular structures and DNA, as well as lipid oxidation in the organism. Vitamin E also has impact on the quality of meat and meat products by protecting against oxidation processes [Sammet *et al.* 2006].

The Polish traditional goose breast meat product was characterised by a high Fe content. Moreover, the mineral composition of goose meat depended on the region of origin. The content of studied minerals is in agreement with values reported by Geldenhuys *et al.* [2015] in the case of P, Ca for breast meat of Egyptian geese. In relation to Mg, Fe and Zn the values presented in Table 2 were lower than those obtained by the above-mentioned authors. As stated by Geldenhuys *et al.* [2015], the mineral composition of meat may vary depending on the genetic, physiological and environmental (diet) factors. In relation to meat of other species such as chicken, mutton, pork or veal, goose meat may be a better source of Fe [Geldenhuys *et al.* 2013]. This high Fe level in breast goose muscle is related to its metabolic type and muscle fibre composition [Geldenhuys *et al.* 2013]. This muscle mainly consists of type IIa, fast oxidative fibres, with high myoglobin content for oxygen supply [Geldenhuys *et al.* 2015].

The fat composition of the goose meat product is rich in SFA and MUFA; however, a lower amount of PUFA was reported. The results indicate that goose meat is of a low nutritive value in view of fat amount and fat composition. This study showed that the Polish traditional meat product made from goose breast was characterised by a high fat content as well as variability in the fatty acid profile and its sensory properties. The high variability of fat composition may be the result of the different botanical composition of forages from the three regions of Poland, while sensory quality was most likely related to the different smoking time used by each producer. The mineral

composition of goose meat depends also on the region of origin and goose meat may be a great source of iron. Goose breast contains a relatively variable and low cholesterol level and could be a good source of vitamin E, being more abundant in comparison with contents of α -tocopherol in the breasts of broilers.

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