

The effect of various protein sources in goose diets on meat quality, fatty acid composition, and cholesterol and collagen content in breast muscles

Jakub Biesek,^{*,1} Joanna Kuźniacka,^{*} Mirosław Banaszak,^{*} Giuseppe Maiorano,[†] Małgorzata Grabowicz,[‡] and Marek Adamski^{*}

^{*}Department of Animal Breeding, Faculty of Animal Breeding and Biology, University of Science and Technology in Bydgoszcz, 85-084 Bydgoszcz, Poland; [†]Department of Agricultural, Environmental and Food Sciences, University of Molise, 86100 Campobasso, Italy; and [‡]Department of Animal Physiology, Physiotherapy and Nutrition Faculty of Animal Breeding and Biology, University of Science and Technology in Bydgoszcz, 85-084 Bydgoszcz, Poland

ABSTRACT Goose meat is characterized by good quality and a good fatty acid composition. Geese do not need many compounds in their feed to ensure suitable growth. The main source of protein in most feed is soybean meal (SBM). New cultivars of yellow lupin with fewer antinutrients could be a substitute for soybean. The study's aim was to compare the quality of the carcass and meat, as well as the fatty acid composition and the collagen and cholesterol content in the breast muscles from geese fed a diet based on yellow lupin as an replacement for soybean meal. In the study, geese were divided into 2 study groups. The first was a control group (Group 1), fed a feed based on SBM; the second one was an experimental group (Group 2), fed a feed based on yellow lupin "Mister", potato protein, and brewer's yeast. The rearing period was divided into 3 stages, and the last stage was oat fattening. Each group (105 birds in each group) was divided into 5 replications with 21 birds. After 16 wk of rearing, 10 geese from each group were slaughtered. The carcasses were analyzed for physicochemical

traits (dissection, color, water-holding capacity, and chemical composition of the breast and leg muscles, as well as pH level, drip loss, and fatty acid profile of the breast muscles). The drip loss from the breast muscles was higher ($P < 0.05$) and the water-holding capacity of the leg muscles lower ($P < 0.05$) in Group 1 than in Group 2. Group 1 also displayed a higher content of protein and water in breast and leg muscles ($P < 0.05$) but lower fat content than that of Group 2 ($P < 0.05$). The linoleic acid content of the breast muscles was higher in Group 2 ($P < 0.05$), whereas the other fatty acid levels were comparable between the groups. The total content of polyunsaturated fatty acid (PUFA) (n-6 and n-3) and the PUFA/saturated fatty acid ratio was higher in Group 2 ($P < 0.05$). Moreover, the thrombogenic index was lower ($P < 0.05$) in the geese fed a lupin-diet. Overall, the yellow lupin-based feed had beneficial effects on the goose meat's traits, and it can be used as a high-protein compound in diets for geese. It is also possible to produce traditional geese fattened by oats.

Key words: goose, yellow lupin, meat quality, muscle, fatty acids

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INTRODUCTION

The quality of goose meat is important for producers and potential consumers. Meat quality is determined by many factors, including diet, genotype, and the age and sex of the birds (Adamski et al., 2016). Product

quality also depends on how the birds are handled between rearing and slaughter (Petracci et al., 2010). Quality traits determine the suitability of raw meat for further processing. Quality can be expressed by the meat's color, water-holding capacity, and chemical composition (an indicator of the nutritional value of meat). The quality of the carcass is analyzed in terms of the proportion of muscle mass, the weights of various carcass elements, the fat content, and its general appearance. Goose meat has many features which are beneficial to human health. It is less calorific than red meat, and it is an important source of protein (Oz and Celik, 2015). Goose fat is one of the healthiest animal fats. Goose

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¹Corresponding author: jakub.biesek@utp.edu.pl

meat is a valued produce on the European market. White Kołuda Geese are reared in Poland, and 90% of the production volume is exported. This breed is a meat-type hybrid originating from the maternal line W11 and the paternal line W33; it is designated by the symbol W31 (Polish oat goose). Goose meat has a high nutritional value and a characteristic flavor, because of the traditional method of fattening birds on oat grain, so the goose meat develops a fat with a higher content of valuable polyunsaturated fatty acid (PUFA) (Okruszek et al., 2013; Haraf, 2014; Oz and Celik, 2015; Adamski et al., 2016; Lewko et al., 2017; Orkusz, 2018; Uhlřřová et al., 2018).

The high content of PUFA can lead to a reduction of cholesterol levels. Poultry meat is a good source of PUFAs, especially n-3 PUFAs, including linolenic acid C18:3n-3, eicosapentaenoic acid C20:5n-3, and docosahexaenoic acid C22:6n-3, which produce beneficial effects in the brain and cardiovascular system (Stahl et al., 2008; Laudadio and Tufarelli, 2011; Wang et al., 2017). Uhlřřová et al. (2019) reported that goose fat is relatively safe for consumers because of the high levels of oleic, linoleic, and arachidonic acids. As other researchers have reported, the amounts of saturated fatty acid (SFA) and unsaturated fatty acid (UFA) depend on dietary intake, which may be manipulated (Połowska et al., 2013; Łukaszewicz et al., 2016; Uhlřřová et al., 2019). Yellow lupin (*Lupinus luteus* L.) could be an alternative source of protein in poultry diets for soybean meal (SBM). Lupin seeds have a similar content of protein as soybean and the levels of utilization are also comparable (Kaczmarek et al., 2016). The authors cited above also reported that fat content positively correlates with the digestibility and metabolizable energy of amino acids, which indicates the nutritional value. Rybiński et al. (2018) described that yellow lupin seeds contain approximately 5.1% oil. The quality of the oil depends on the fatty acid profile. The most important ones are UFA—especially PUFAs, which are essential fatty acids; the n-6/n-3 ratio should also be taken into consideration in animal feeding. Generally, lupin oil is balanced. The fatty acid profile should amount 10% SFA and 90% UFA. In a study where broilers were fed a diet based on yellow lupin meal, the author concluded that the use of an alternative protein source in the diet had a beneficial effect on the fatty acid composition of fat fraction with prohealth for the broilers (Olkowski, 2018).

Collagen is an important substance in meat, which is associated with the texture of meat, determining the meat's toughness (El-Sensousey et al., 2013). As Buzafa et al. (2014) reported, goose meat not only has a lot of high-quality protein, but there is also a low collagen content (0.39–0.91%). The low fat content in goose meat has a large amount of UFA and a low cholesterol content: 52 to 76%. The cholesterol content in the breast muscle of various geese has been analyzed in many studies. There were differences depending on genotype, as well as the maintenance system and period of assessment. However, no relationship between fat and

cholesterol content in the breast muscle of geese has been conducted.

Soybean meal is mainly used in poultry and other monogastric animal nutrition. There is a decent amount of protein. However, the majority of SBM is genetically modified, as Banaszak et al. (2020) reported. Not every small-scale farm is able to use this kind of feed, so there is a search for alternative protein sources. Legume seeds, including yellow lupin, could be serve as an alternative, because of its high protein content and similar level of utility like SBM. The new cultivars contain much less of antinutritional factors, which were a big problem in the past (Kaczmarek et al., 2014; Rutkowski et al., 2017). This is important because small-scale farms mainly produce feed with plants from their own crops.

The hypothesis tested in this study is that yellow lupin seeds, with the addition of potato protein and brewer's yeast, used as a high-protein component to substitute for SBM in complete feed impact the fatty acid profile, collagen, and cholesterol content in the breast muscle of geese.

The aim of the study was to assess the fatty acid composition and the collagen and cholesterol content in the breast muscles of geese fed mixtures containing yellow lupin, potato protein, and brewer's yeast as an alternative to SBM.

MATERIAL AND METHODS

According to the law and EU directive no. 2010/63/EU, the experiment did not require approval from the local ethical committee as it was done by local farmers on a small scale (in the production conditions). The main part of the experiment started after the slaughter when the raw material was provided.

Animals and Diets

The study was conducted on 210 White Kołuda geese, divided into 2 groups, with 105 birds per group. The control group (Group 1) was fed a mixture containing SBM, whereas the treatment group (2) was fed a diet containing ground seeds of yellow lupin "Mister". The potato protein and brewer's yeast were added to equalize the protein concentration in the diet. These components do not influence the quality of the meat in such small quantities. Both groups were divided into 5 subgroups with 21 birds each. The birds were not divided according to sex, as differences in sexual dimorphism is not noticeable during the rearing of geese for slaughter, particularly because these geese were commercial crossbreed. There were 3 feeding phases (Table 1). The composition of concentrates is presented in Table 2. The feed composition with nutrition compounds was established based on the recommendations of Smulikowska and Rutkowski (2018), wherein protein content in feed was at 15.0 to 22.0% and the metabolic energy (ME) was at 11.7–12.0 MJ. In our feed (both groups), the crude protein content was 19.50%, whereas the ME was 11.90 MJ/kg of feed.

Table 1. Proportion in feed for geese during the 3 stages of rearing.

Stages	Concentrate	Wheat
Week 1 to 6 of rearing		
Control group (1)	50%	50%
Experimental Group (2)	50%	30%
Week 7 to 13 of rearing		
Control group (1)	40%	60%
Experimental group (2)	40%	60%
Week 14 to 16 of rearing	Fattening on oats (<i>ad libitum</i>)	

The geese were reared for 13 wk and then fattened on oats *ad libitum* for another 3 wk. The oat seeds contained 8.90% crude protein, whereas the ME was 10.20 MJ/kg. Up to the age of 6 wk, the geese were kept indoors; they were then moved to free-range pens. The pens were specially adapted for the study groups inside and outside the building. The light program until week 6 was consistent with the recommendations for goose production. After 6 wk, the geese were outside, exposed to natural light (from July to September). The outside pens were built by the farmers; they were fenced in, partially covered, and provided full access to feed and fresh water. The ground was covered with soil and part of the pens was grassy.

Meat Quality Analysis

The slaughter procedure was supervised by the farmers with the cooperation of the local slaughterhouse. From each group, 10 birds were chosen for slaughter. The birds were taken according to the average live body weight, so all the geese were weighed before the end of the experiment. During this procedure, the geese were assigned by padlock stamps with an individual number and were taken as an individual samples for further analysis. The geese were slaughtered by cutting the carotid arteries (cutting off the head), which resulted in immediate bleeding and a quick death. The heads and feet were removed before assessment.

Table 2. Composition of concentrates for geese, in percent.

Ingredient	Group ¹	
	1	2
Soybean meal 44%	65.00	-
Yellow lupin	-	68.98
Potato protein	-	3.00
Brewer's yeast	-	3.00
Triticale in concentrate	23.040	12.00
Soybean oil	5.20	5.40
Premix 1%	2.00	2.00
Fodder chalk	2.00	2.00
Monocalcium phosphate	1.52	1.74
NaHCO ₃	0.84	0.80
Fodder salt	0.18	0.12
L-lysine	-	0.32
DL-methionine	0.20	0.40
L-threonine	0.02	0.24
Metabolic energy (MJ/kg of feed)	11.90	11.90
Crude protein (%)	19.50	19.50

¹Group 1 = feed based on soybean meal; Group 2 = feed based on yellow lupin.

The plucked and gutted carcasses were stored in a refrigerator for 24 h, in a temperature of 4°C, and analyzed for qualitative parameters. The parts of the carcasses that were separated included the breast and leg muscles, the skin with subcutaneous fat, the abdominal fat, the offal (liver, stomach, and heart), the wings with skin, the neck with skin (cut off between last cervical vertebra and the first thoracic vertebra of the spine), and the carcass remains (trunk and leg bones). The pH value of the breast muscles was measured 15 min post-mortem (pH₁₅). The carcasses were chilled at 2°C for 24 h, and the pH was measured again (pH₂₄), using a CX-701 pH meter with a knife electrode (Elmetron). The carcasses were then weighed on RADWAG scales with an accuracy to the nearest 0.01 g. Next, the carcasses were dissected (Ziotecki and Doruchowski, 1989), and the following parts were separated: breast muscles, leg muscles, skin with subcutaneous fat, abdominal fat, offal (liver, heart, stomach), wings with skin, neck with skin, and carcass remains. Each carcass element was weighed. The color of the breast and leg muscles was assessed with a colorimeter (CR400, Konica Minolta, Tokyo, Japan), calibrated using the white calibration plate no. 21033065 and the D₆₅Y_{86.1}X_{0.3188}Y_{0.3362} scale. The color was graded according to the CIE system for L* (lightness), a* (redness), and b* (yellowness) (CIE, 1986). The drip loss from the breast muscles was also measured. The breast muscles were, accordingly, weighed postmortem (M1) and after 24 h of storage at 2°C (M2) (Honikiel, 1987). Subsequently, the water-holding capacity of the breast and leg muscles was analyzed (Grau and Hamm, 1952): pooled samples of homogenized muscles (0.300 g ± 5%) were wrapped in Whatman grade 1 filter paper and kept under 2 kg of pressure for 5 min. The water-holding capacity of the meat was calculated based on the difference in weight before and after the test. Pooled samples of homogenized breast and leg muscles (90 g) from each group were also analyzed for the amounts of protein, fat, and water according to the standard PN-A-82109: 2010 (2010) and with the use of a FoodScan apparatus (FOSS), by way of applying Near InfraRed Transmission spectrometry calibrated for an artificial neural network. Furthermore, 100 g of each left breast muscle was frozen and lyophilized to determine the collagen content. Ten right breast muscles were also frozen after dissection, and color analysis was carried out to analyze the content of cholesterol and the fatty acid composition.

Collagen and Cholesterol Analyses

The methods used in our experiment followed the procedure reported by Maiorano et al. (2011).

Collagen

Samples of muscles were thawed at room temperature, trimmed of fat and epimysium, lyophilized for 48 h, and hydrolyzed in Duran glass tubes (Schott AG, Mainz, Germany) in 5 mL 6N HCl at 110°C for 18 to 20 h for

the determination of hydroxyproline and network forming. The analyses were carried out in 2 replicates. The concentration of intramuscular collagen was calculated assuming that the weight of collagen is 7.25-times higher than the measured mass of hydroxyproline and is expressed in micrograms of hydroxyproline per milligram of lyophilized tissue.

Cholesterol

The cholesterol was extracted (Maraschiello et al., 1996) and then quantified using HPLC and a Kontron HPLC system (model 535, Kontron Instruments, Milan, Italy) with a Kinetex C18 reversed-phase column (150 × 4.6 mm × 5 μm; Phenomenex, Torrance, CA). The operating parameters of the HPLC system were as follows: mobile phase acetonitrile:2-propanol ratio—55:45, v/v; flow rate—1.0 mL/min; and detection wavelength—210 nm. The quantitative determination of the cholesterol content was based on an external standard method, using a pure cholesterol reference standard (Sigma, St. Louis, MO).

Fatty Acid Analyses

The lipids were extracted from the breast muscles (Folch et al., 1957). The fatty acids were quantified as methyl esters (FAME) using a GC Trace 2000 gas chromatograph (ThermoQuest EC Instruments) with a flame ionization detector (260°C) and a fused-silica capillary column (ZebronZB-88, Phenomenex). The foil thickness was 100 m × 0.25 mm × 0.20 μm. Helium was used as the carrier gas. The temperature was set at 100°C for 5 min, then it was increased at a rate of 4°C/min to 240°C, and was maintained at 240°C for 30 min. Individual fatty acid peaks were identified by comparing the retention times with those for authentic FAME standards run under the same operating conditions. The results are expressed as the percentage of the total identified fatty acids. To assess the nutritional implications, the n-6:n-3 fatty acid ratio and the PUFA-to-SFA ratio (**P/S**) were calculated. The atherogenic index (**AI**) and thrombogenic index (**TI**) were derived (Ulbricht and Southgate, 1991). The method of fatty acid analysis was done according to Stanek et al. (2018).

Statistical Analysis

Numerical data were analyzed using statistical software STATISTICA 10.0 PL (2011). Mean values of the examined parameters and the SEM were calculated via one-way analysis of variance. The significance of differences was verified by the post-hoc Scheffe test, with a significance level of $P < 0.05$. P -values less than 0.05 indicated statistically significant differences between groups. The effect of different diets on the growth performance and quality and chemical composition of goose meat was evaluated (each group: 10 birds = 2 birds (1 male and 1 female)/pen).

RESULTS

Meat Quality

The preslaughter body weight and the weight of the carcass and dressing percentage of geese from the 2 groups did not differ significantly ($P > 0.05$). However, geese from Group 1 were 91.25 g heavier than those in Group 2, and the carcass weight in Group 2 was 44.83 g higher than in Group 1, which was associated with a 1.35% higher dressing percentage in Group 2 (68.41%) compared with Group 1. There were no significant differences ($P > 0.05$) in the weight of individual carcass elements and their proportion in the carcass weight (Table 3). The muscle content was comparable in the 2 groups, but the weights of leg muscles and total muscles were higher in Group 1 (by 36.98 g and 35.61 g, respectively). In contrast, the content of fat in the carcass was 66.51 g higher in Group 2 than in Group 1 (Table 4). The pH of meat 15 min and 24 h postmortem was comparable between the groups. The breast muscles from geese fed yellow lupin (Group 2), however, displayed a higher water-holding capacity. While drip loss from meat was significantly lower in Group 2 (0.34%) compared with Group 1 (0.67%) ($P < 0.05$), the water-holding capacity of leg muscles from Group 2 (32.68%) was significantly higher ($P < 0.05$) than in Group 1 (30.10%). This implies that the use of yellow lupin was associated with a higher loss of water from the meat. The color of breast and leg muscles in the 2 groups was comparable (Table 4).

Chemical Composition of Muscles

The analysis found a significantly higher ($P < 0.05$) protein and water content in Group 1, and a significantly higher fat content in the breast and leg muscles from Group 2. The cholesterol and collagen content in the breast muscles did not differ significantly between the groups ($P > 0.05$) (Table 5). Though the total content of intramuscular fat per 100 g of breast muscle was 0.24 g higher in Group 2, this difference was not

Table 3. Traits of goose meat.

Indicator	Group ¹		SEM	<i>P</i> -value
	1	2		
Preslaughter body weight (g)	6,482.50	6,391.25	25.31	0.070
Weight of carcass (g)	4,328.16	4,372.99	37.26	0.752
Dressing (%)	67.06	68.41	0.47	0.160
Weight and proportion in carcass				
Neck with skin (g)	394.60	353.53	16.36	0.221
Neck with skin (%)	9.11	8.09	0.40	0.212
Wings (g)	576.58	535.83	13.29	0.129
Wings (%)	13.30	12.27	0.38	0.180
Offal (g)	357.53	342.59	7.84	0.359
Carcass remains (g)	1,019.75	964.80	37.98	0.344

¹10 geese were used in the quality analysis; each value represents the mean of 5 samples (2 geese/pen) from each group; no significant differences (P -value > 0.05).

¹Group 1 = soybean meal; Group 2 = feed based on yellow lupin.

Table 4. Content of muscles and fat in goose carcass.

Item	Group ¹		SEM	P-value
	1	2		
Weight and proportion in carcass				
Breast muscles (g)	625.15	626.53	17.39	0.970
Breast muscles (%)	14.38	14.33	0.38	0.957
Leg muscles (g)	500.96	463.98	11.80	0.120
Leg muscles (%)	11.52	10.61	0.26	0.083
Total muscles (g)	1,126.11	1,090.50	23.83	0.474
Total muscles (%)	25.90	24.95	0.52	0.375
Skin with subcutaneous fat (g)	1,139.68	1,184.41	25.99	0.408
Skin with subcutaneous fat (%)	26.18	27.09	0.52	0.403
Abdominal fat (g)	203.58	225.35	12.66	0.409
Abdominal fat (%)	4.66	5.16	0.28	0.401
Total fat (g)	1,343.25	1,409.76	35.39	0.365
Total fat (%)	20.71	22.07	0.55	0.228

10 geese were used in the quality analysis; each value represents the mean of 5 samples (2 geese/pen) from each group; no significant differences (P -value > 0.05).

¹Group 1 = soybean meal; Group 2 = feed based on yellow lupin.

statistically significant ($P = 0.518$). The fatty acid composition was similar between the groups. However, the content of linoleic acid (C18:2 n-6) was significantly higher ($P < 0.05$) by 2.43% in the breast muscles from geese fed yellow lupin than in the control group. The total content of PUFA, as well as PUFA n-6 and n-3, were also higher ($P < 0.05$) by approximately 3% in Group 2. Furthermore, the P/S was significantly higher ($P < 0.05$) in Group 2. In contrast, the TI was significantly lower ($P < 0.05$) in Group 2 (0.90) than in Group 1 (1.04) (Table 6).

Table 5. Physicochemical parameters of breast and leg muscles from geese.

Item ¹	Group ²		SEM	P-value
	1	2		
Breast muscles				
pH ₁₅	6.32	6.26	0.04	0.522
pH ₂₄	6.27	6.38	0.09	0.558
Colour				
L*	41.25	40.89	0.83	0.835
a*	13.98	13.61	0.29	0.554
b*	5.03	3.97	0.46	0.261
Water holding capacity (%)	25.53	30.35	1.27	0.055
Drip loss (%)	0.67 ^a	0.34 ^b	0.06	0.005
Protein (%)	22.11 ^a	21.77 ^b	0.05	0.000
Fat (%)	3.08 ^b	3.91 ^a	0.11	0.000
Water (%)	73.69 ^a	72.47 ^b	0.16	0.000
Cholesterol (%)	67.01	63.63	1.51	0.274
Collagen (%)	33.20	29.06	1.80	0.124
Leg muscles				
Color				
L*	39.42	39.49	0.76	0.965
a*	12.18	10.99	0.67	0.397
b*	3.01	1.83	0.45	0.205
Water holding capacity (%)	30.10 ^b	32.68 ^a	0.65	0.042
Protein (%)	19.06 ^a	18.89 ^b	0.02	0.000
Fat (%)	8.21 ^b	8.93 ^a	0.09	0.000
Water (%)	71.14 ^a	70.13 ^b	0.13	0.000

^{a,b}The means in columns marked with different letters differ significantly between groups (P -value < 0.05).

10 geese were used in the quality analysis; each value represents the mean of 5 samples (2 geese/pen) from each group.

¹pH₁₅ – 15 min postmortem, pH₂₄ – 24 h postmortem L* - lightness, a* - redness, b* - yellowness.

²1 = soybean meal, 2 = feed based on yellow lupin.

DISCUSSION

Adamski et al. (2016) investigated the effect of selected factors on the dressing percentage and quality of goose meat and reported a body weight of 17-wk-old White Kołuda geese comparable to that found in our study (6,706.00 g and 6,482.50 g, respectively). The dressing percentage of geese in our study was 2% higher than that reported by the authors cited. According to Adamski et al. (2016), the dressing percentage and quality of carcass is largely determined by the genotype and age of the birds and their management system and diet. Their study also revealed an age-related increase in the proportion of fat. The content of abdominal fat was 5.00% in 17-wk-old birds and 5.3% in 24-wk-old birds. In the present study, the content of abdominal fat was 4.66% in birds fed SBM and 5.16% in birds fed yellow lupin. Differences were also found in the content of intramuscular fat. Our study revealed a significantly higher content of intramuscular fat in geese fed yellow lupin. This is not a negative trait, because other researchers (Damaziak et al., 2019; Giller et al., 2019) reported that fat is a carrier of flavors in meat. The water binding of meat is expressed as water-holding capacity and amount of drip loss (the values indicate how much water was lost). The lower the loss of water, the better the suitability of meat for further processing (Damaziak et al., 2016). Our study revealed that the breast muscles of geese fed a diet based on yellow lupin were more suitable for processing (0.34% loss of water after drip loss), whereas the water-holding capacity was higher in geese fed SBM. The quality of goose meat was also analyzed by Biesiada-Drzazga et al. (2006). In their experiment, SBM was replaced with rapeseed meal (10%) and yellow lupin (25–50%) in Group 2 and with sunflower meal (10%) and yellow lupin (25–50%) in Group 3. The geese were reared for 10 wk. As in our study, the researchers found no effect of alternative feed components on the body weight of geese or their carcasses and muscles. In both cases, the dietary inclusion of lupins had no effect on the body weight of geese and their carcasses.

Table 6. Total lipid content (g/100 g) and fatty acid composition (% of total fatty acids) of breast muscles from geese.

Indicator	Group ¹		SEM	P-value
	1	2		
Total lipids (g/100g)	2.95	3.19	0.17	0.518
C14:0	0.42	0.34	0.03	0.181
C16:0	25.47	23.25	0.58	0.054
C16:1n-7	2.84	2.66	0.13	0.500
C18:0	10.50	9.88	0.23	0.184
C18:1n-9	39.42	38.79	0.54	0.581
C18:2 n-6	14.66 ^b	17.09 ^a	0.35	0.000
C18:3 n-3	0.80	1.14	0.10	0.091
C20:1n-9	0.15	0.21	0.02	0.115
C20:4 n-6	4.95	5.15	0.44	0.831
C20:5 n-3	0.07	0.10	0.03	0.593
C22:4 n-6	0.21	0.21	0.02	0.886
C22:5 n-3	0.22	0.23	0.02	0.711
C22:6 n-3	0.27	0.25	0.02	0.616
ΣSFA	36.39	33.47	0.67	0.025
ΣMUFA	42.42	41.67	0.53	0.495
ΣPUFA	21.20 ^b	24.19 ^a	0.65	0.016
PUFA n-6	19.82 ^b	22.46 ^a	0.63	0.034
PUFA n-3	1.37 ^b	1.73 ^a	0.08	0.025
n-6/n-3	14.92	13.81	0.89	0.549
P/S	0.59 ^b	0.73 ^a	0.03	0.010
AI	0.43	0.37	0.01	0.058
TI	1.04 ^a	0.90 ^b	0.03	0.013

^{a,b}Means in columns marked with different letters differ significantly between groups, *P*-value <0.05.

10 geese were used in the quality analysis; each value represents the mean of 5 samples (2 geese/pen) from each group.

Abbreviations: AI, atherogenic index; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; P/S, PUFA/SFA ratio; SFA, saturated fatty acids; TI, thrombogenic index.

¹1 = soybean meal, 2 = feed based on yellow lupin.

Bieliński et al. (1982) also found no negative effect of a diet with 12 to 15% inclusion of lupins and SBM on the quality of meat from 10-wk-old geese. No negative effect of 10 to 15% inclusion of lupins on the quality of meat from 88-day-old geese was also reported by Pietrzak et al. (2013). The chemical composition, including the fatty acid, collagen, and cholesterol content, in the breast muscle of geese was evaluated by other researchers. Biesiada-Drzazga (2008) found significantly lower levels of UFA in the meat from 10-wk-old geese fed a diet containing 3.8 to 10 to 12% lupin and sunflower meal as partial substitutes for SBM. Our study revealed a positive effect of yellow lupin on the content of linoleic acid (C18:2 n-6). Nowicka et al. (2018) analyzed the composition of fatty acids in meat from White Kołuda geese fed a diet with 20% SBM, fodder yeast, and fresh grass. The geese were sourced from 3 producers. The total content of PUFA reported by Nowicka et al. (2018) was lower than in our study (8.7–12.5% and 21.20–24.19%, respectively). They also found lower PUFA/SFA ratios (0.30–0.44) than in our study (0.59–0.73). However, the n-6:n-3 ratio was higher by 2.29 to 6.48 than in our work. Uhlřová et al. (2019) investigated the content of fatty acids in the Czech goose and Novohradská goose. The birds were fed on wheat, corn, and SBM. The study reported TI values in the range of 0.72 to 0.78 (Czech goose) and 0.76 to 0.78 (Novohradská goose). In the present study, the TI was in the range of 0.90 to 1.04 and was lower in geese fed yellow lupin. The AI was also lower in the geese fed yellow lupin

compared with birds fed SBM (0.37 vs. 0.43). Lower values of the TI indicates a more beneficial effect of the meat on human health (Ulbricht and Southgate, 1991). The study subjected with lupin seeds and fatty acids profile in meat was also evaluated on other species of poultry. Tufarelli et al. (2015) replaced SBM with micronized, dehulled white lupin in guinea fowls. The results indicated that the use of a lupin diet improved the fatty acid profile in the meat. The concentration of PUFA increased, whereas the SFA and MUFA content decreased. In another study, where lupin seeds were used in chicken diets, a lower content of SFA, a lower n6:n3 ratio, and lower AI and TI values were found, whereas the PUFA and MUFA contents in muscles were higher (Laudadio and Tufarelli, 2011). The same authors (Laudadio and Tufarelli, 2010) checked the fatty acid profile and AI and TI values in broiler chicken meat, where micronized, dehulled pea seeds were used. In the first diet (lupin), these indices were lower than in the other study (pea diet). This finding may indicate that lupins are more functional in feeding. In our research, the AI and TI values were lower in the meat from geese fed lupins but were still higher than in chicken meat. This may be because of the genotype and species of birds. Also, Krawczyk et al. (2015) reported that the use of yellow lupin in a turkey diet improved the AI and TI values and the PUFA content but not the n6:n3 ratio. A similar conclusion was drawn where the use of lupin meal in broiler chickens' diet was studied (Strakova et al., 2010). According to the other cited authors, there is decrease of SFA and increase of MUFA, especially oleic acid. In our study, the oleic acid content was lower in the experimental group, but it may be affected by the use of another cultivar of lupin or a different species of bird. However, in both studies, the concentrations of PUFA n3 was higher. Mieczkowska and Smulikowska (2005) reported that lupins in the diet of broiler chickens could be an important source of linolenic acid (C18:3 n3) and may have a beneficial effect on the fatty acid profile in poultry meat. In own research, the level of C18:3 n3 was higher in the muscles of geese fed a diet based on yellow lupin seeds, but this difference was not statistically significant (*P* > 0.05). Most experiments where the effect of a lupin-rich diet on the fatty acid profile of poultry meat was analyzed reported a similar conclusion. Almost every study found that lupin seeds had an impact on decreasing SFA and increasing PUFA or MUFA and improving AI and TI. These conclusions are compatible with our results, where the PUFA content in the breast muscles of geese fed a yellow lupin diet was higher (*P* < 0.05), and the SFA content was lower (*P* < 0.05). Small differences between results from various studies may be affected by using various species of birds with a different genotype, sex, or maintenance conditions (Łukaszewicz et al., 2008; Buzafa et al., 2014). Also, the lupins came from different crops and various cultivars were used. The geese in our study were kept for 16 wk, including the fattening with oats, so these seeds may have affected the results. As Bielińska et al. (2018) reported, the naked oat seeds

had an effect on the fatty acid profile changes and increased cholesterol.

Soybean meal and legume meals play a role in reducing cholesterol levels. In legume seeds, soluble non-starch polyoligosaccharides act as a cholesterol-reducing agent (Viveros et al., 2007). In our study, the cholesterol content of the breast muscles of geese fed with lupins was over 3% lower than in the breast muscles from geese fed SBM, but it was not statistically significant. Viveros et al. (2007) concluded that the use of white lupin contributed to lowering the cholesterol content in chicken meat. Tufarelli et al. (2015) also noticed lower total lipids and cholesterol content in meat from guinea fowls fed with lupins ($P < 0.05$). However, our results showed a similar content of cholesterol in Polish oat geese fed either with lupins or SBM to results obtained by Boz et al. (2019). There may be small differences among genotype, sex, or conditions, or even age at slaughter (Haraf et al., 2014). It is important that in our research, the geese were raised to the 16th wk of age. As mentioned above, in the last 3 wk the geese were fattened by oats; this may have had an effect on the chemical composition of the meat.

Collagen is a main protein included in the intramuscular connective tissue of muscles. Its characteristics depend on the material and the extraction conditions (Schmidt et al., 2016). The importance of collagen is that it plays role in the texture of meat, its tenderness and toughness to be precise (Purslow, 2018). In our study, the content of collagen was found to be over 4 $\mu\text{g}/\text{mg}$ lower, but this difference was not statistically significant ($P > 0.05$). There is a correlation between higher shear force and higher collagen concentration in goose muscles (Geldenhuis et al., 2015). Biesek et al. (2020) reported that the collagen content of the breast muscle of geese fed yellow lupin was lower than that of breast muscles of geese fed SBM ($P < 0.05$). It is important to mention that method of analysis was different in the 2 studies, which may suggest that various methods have different sensitivity and may yield different results. On the other hand, Kuźniacka et al. (2020) did not find an impact of a lupin-rich diet on the collagen content of ducks' breast muscles. Even in the meat of fattening pigs fed a yellow lupin-based diet, no effect on the collagen content was noticed (Sońta et al., 2017). Starkey et al. (2017) reported that collagen content is an indicator of the degree of myofibrillar degradation, as well as of the meat's tenderness and the sarcomere length in the muscles. This finding may indicate that geese fed yellow lupin or soybean could be characterized by similar structure and texture of the breast muscles. As the results indicate, the use of yellow lupin or other legume seeds has a similar effect on the fatty acid profile and the cholesterol and collagen content in poultry meat—and even pigs. It may be surmised that there is the same mechanism of dietary inclusion of legumes.

The present study demonstrated that the inclusion of yellow lupin (*L. luteus* L.) as a dietary substitute for SBM had a positive effect on the quality of meat from geese reared in a semi-intensive management system.

There was no deterioration in the traits of the meat or the content of muscle and fat. The analysis revealed a lower drip loss from breast muscles, beneficial levels of linoleic acid and PUFAs, a beneficial P/S ratio, and lower (favorable) values of TI, when compared with geese fed with SBM. Geese rearing with yellow lupin in the diet allow to produce traditional geese fattened by oats.

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