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THE EFFECT OF CORN OR BEET PULP SILAGE SUPPLEMENTED DIET ON PRODUCTION PARAMETERS, OXIDATIVE STABILITY OF MUSCLES AND FATTY ACID COMPOSITION OF ABDOMINAL FAT IN GEESE*

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Abstract

The aim of this study was to assess the production parameters of White Koluda® geese fed with a corn or beet pulp silage supplemented diet. The oxidative stability of breast and thigh muscles during frozen storage and the fatty acid composition of abdominal fat were also investigated. Measurements were carried out on a total of 42 geese of the White Koluda® W31 strain that were divided into three experimental groups: group I (control) – basal diet, group II – basal diet with corn silage addition, group III – basal diet with pressed beet pulp silage addition. Diets containing *ad libitum* maize silage or sugar beet pulp silage supplemented with a limited amount of commercial diets, significantly reduced BW (about 9%) and ADG (about 27%) of birds compared to the control group in the 14th week of rearing. Feeding corn or sugar beet pulp silage to geese did not affect pH values, heme iron content, colour parameters but decreased lipid oxidation values in muscles 3 days after slaughter. The abdominal fat of geese fed with the pressed beet pulp silage supplemented diet was characterized by a significantly higher content of myristic and linoleic acid and a lower content of oleic acid. In conclusion, feeding geese with limited amount of commercial mixtures supplemented with maize or sugar beet pulp silages may be recommended primarily for increasing financial efficiency in White Koluda® geese farms but also for improving the quality of goose carcasses, due to their low fat and high quality of meat.

Key words: geese, breast muscle, thigh muscle, abdominal fat, lipid oxidation

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Poland is one of the leading producers and exporters of geese in Europe. The most desirable product is the White Koluda® strain fattened with oats and exported mainly to Germany (Rosiński, 2002; Biesiada-Drzazga, 2006 b; Krawczyk and Bielińska, 2007). Its carcass is called "oat goose" and is famous for its high protein content (ca. 23%) and relatively low levels of fat (3–5%) and cholesterol (51–83 mg 100 g^{-1} tissue). Furthermore, "oat goose" fat contains high proportion of PUFAs and is rich in vitamins and essential minerals, and therefore may be treated as a "functional food". Increased consumption of unsaturated *n*-3 fatty acids (e.g. α-linolenic) reduces the risk of angina pectoris in humans (Wężyk et al., 2003). Goose fat is rich in oleic acid, which can lower blood cholesterol levels (Wood et al., 2003). However, unsaturated fatty acids are highly oxidizable substrates and may act as pro-oxidants.

The diet of animals can significantly affect the susceptibility of meat components to oxidative deterioration, by modifying the pro-oxidant components of the muscle (unsaturated fatty acids, heme iron). Feeding silage to geese can be a great alternative when there is a lack of access to pasture or forage deficiency, due to adverse weather conditions and relatively short growing season of these plants (Arslan, 2003; Arslan and Saatci, 2003; Puchajda-Skowrońska et al., 2006; Wang et al., 2008). Arslan (2005) has already observed positive results on growth performance by feeding silage to geese. Additionally, it is demonstrated that lactic acid bacteria (LAB), which is the dominant microbial population in forage crops and silage, are related with several health and nutritional benefits (Gaggìa et al., 2010). There are a few papers highlighting the impact of silage on the physicochemical parameters of muscle and adipose tissue (Biesiada-Drzazga, 2006 a; Okruszek et al., 2008; Batkowska et al., 2011). Previously published data (Kokoszyński et al., 2014) indicated that the partial replacement of the commercial feed mixture with corn silage did not have any significant effect on body weight of 17-week-old geese. Ensiling pressed beet pulp for animal feed is a relatively new practice in breeding and animal husbandry. Ensiled sugar-beet pulp has a high feeding value and shows a positive dietetic effect on ruminant fermentation (Formigoni et al., 1993).

However, to our knowledge the scientific literature contains relatively little information regarding the oxidative stability of goose muscles during freeze storage. Freezing is an excellent process for preserving the quality of meat for long periods but deterioration of quality caused by chemical or physical factors can occur (Leygonie et al., 2012).

Therefore, the objective of this study was to assess the production parameters of White Koluda® geese fed with a corn or beet pulp silage supplemented diet. The oxidative stability of breast and thigh muscles during frozen storage and the fatty acid composition of abdominal fat in geese were also investigated.

Material and methods

Measurements were carried out on a total of 42 geese of the White Koluda® W31 strain that were purchased from the National Research Institute of Animal Production in Kołuda Wielka. The study was performed at the Animal Experimental Station belonging to the University of Technology and Life Sciences in Bydgoszcz (Poland) with the approval of the Local Ethics Committee for Animal Experimentation. One-day-old goslings marked with padlock tags were randomly divided into three dietary treatments of 14 birds each (8 male and 6 female). The geese were kept in pens of 12 m^2 each (14 birds per pen) in controlled environmental conditions of light (24-h program up to 3 days, 14-h program up to 3 weeks) and temperature (an additional heat source up to 3 weeks). Free access to water and diets was ensured. From hatching to 3 weeks of age all geese were fed *ad libitum* with the same complete commercial diet (M-1). During the next periods of rearing, the control group (group I) was fed *ad libitum* only mixtures (M-2 from 4 to 8 weeks; M-3 from 9 to 14 weeks). The experimental birds had *ad libitum* access to silages either from whole crop maize (group II) or pressed sugar beet pulp silage (group III) while the amount of commercial mixtures was limited (M-2 to 260 g day^{-1} from 4 to 8 weeks; M-3 to 220 g day^{-1} from 9 to 14 weeks). From 15 to 17 weeks of age, according to the standard procedure in Poland, all geese were fattened *ad libitum* with whole oat grain. All birds received mineral supplement (Ca, P, Na, Zn, Mn, Cu, Fe, Se, Co), coarse grit and had free access to water. The commercial diets (M-1, M-2 and M-3) were balanced according to the recommendations of poultry nutrition standards (Smulikowska and Rutkowski, 2005). Chemical composition of the feeds was determined following the methods of the AOAC (2002) and energy value calculated according to the formulas given by Barteczko (2009) (Table 1). During the study, geese were weekly weighed and feed intake was daily monitored to determine body weight (BW), average daily gain (ADG) and feed conversion ratio (FRC).

At 17 weeks of age, five males and five females (with a body weight similar to the mean weight for a given sex in the pen) of each group were randomly selected and slaughtered at the National Research Institute of Animal Production in Kołuda Wielka. The birds were slaughtered by stunning and severing the carotid artery and jugular vein. After plucking and eviscerating carcasses were chilled for about 18 h at +4°C and then the right half-carcasses were dissected and evaluated following the method of Ziołecki and Doruchowski (1989). The left half-carcasses were transported in portable refrigerator at 8–10°C to the Department of Meat Technology and Food Quality, University of Life Sciences in Lublin. The breast, thigh muscles and abdominal fat were separated. The muscles were divided into three parts. One of them and abdominal fat were used for direct measurements (3 days after slaughter). The others were packed individually into HDPE bags and frozen at –24°C for 60 and 180 days. Before analysis, samples were wrapped in an aluminum sheet to avoid exposure to light and thawed at 20 ± 2°C in a thermostatic bath. Thawing was terminated when deep muscle temperature reached 10°C. The pH, colour, heme iron content and TBARS of muscles were determined at 3, 60 and 180 days of storage. Fatty acid composition of abdominal fat was determined only once during storage. Three days after slaughter, abdominal fat separated from the carcasses has been frozen at –24°C and was kept under these conditions until analysis (9 days).

Table 1. Analysis (g kg^{-1} DM) and nutritive value (MJ kg^{-1} DM) of the diets (means ± SD)

Item	Commercial mixtures			Oat grain (15–17 wk.)	Maize silage	Sugar beet pulp silage
	0–3 wk. M-1	4–8 wk. M-2	9–14 wk. M-3			
DM	890.2±0.6	907.6±0.2	906.3±0.8	906.3±0.8	375.1±8.7	186.8±12.0
CA	59.8±4.0	52.8±1.8	61.4±1.8	25.6±2.0	37.2±2.6	57.6±7.8
CP	219.0±3.0	188.4±3.9	161.3±4.3	151.7±3.5	84.3±5.1	135.8±8.2
CFa	26.1±0.2	24.2±0.3	29.2±0.8	54.0±0.4	33.4±3.5	9.5±2.6
CF	53.4±5.9	66.2±3.4	74.0±2.0	120.8±4.7	175.5±7.4	182.1±10.6
EM	13.3±0.3	12.7±0.2	11.7±0.1	12.4±0.2	9.0±0.4	2.6±0.3

DM – dry matter; CA – crude ash; CP – crude protein; CFa – crude fat; CF – crude fiber; EM – metabolizable energy.

Mixtures components (%): M-1 – barley (9.2), corn (17.0), wheat (20.0), malt sprouts (8.0), dried distillers grains with solubles (DDGS) (2.0), maize bran (12.2), soybean (19.0) and rapeseed (8.0) meal, soybean oil (2.5); M2 – barley (25.0), maize (11.7), oat (5.0), triticale (6.0), malt sprouts (15.0), DDGS (3.0), maize bran (14.0), soybean (7.0) and rapeseed (8.0) meal, soybean oil (2.0); M-3 – barley (12.0), maize (6.2), oat (15.0), triticale (24.0), malt sprouts (15.0), wheat bran (5.0), corn bran (9.0), soybean (1.4) and rapeseed (7.7) meal, soybean oil (1.5). All concentrates were supplemented with monocalcium phosphate, sodium bicarbonate, calcium carbonate, sodium chloride, antioxidant, and M-1 and M-2 mixtures also with mineral-vitamin premix with lysine and methionine.

pH measurement

For measurement of pH, 10 g of minced meat was homogenized with 100 ml of distilled water for 1 min using a homogenizer (IKA ULTRA-TURRAX T25 Basic, Germany). The pH of the homogenate was measured with a digital pH-meter CPC-501 (Elmetron, Poland) equipped with a pH electrode (ERH-111, Hydromet, Poland).

Measurements of thiobarbituric acid reactive substances (TBARS)

Lipid oxidation was determined by the thiobarbituric acid reactive substances (TBARS) method according to Pikul et al. (1989). The rose-pink colour obtained from the reaction between malondialdehyde (MDA) and 2-thiobarbituric acid was measured at 532 nm (Nicole Evolution 300, Thermo Electron Corporation). The results were expressed as mg of MDA per kg of the sample (TBARS units).

Heme iron determination

Heme iron was determined following the analytical methods described by Clark et al. (1997) and Hornsey (1956). Samples of minced meat cuts (in triplicate) were weighed in the dark, placed in a capped centrifuge tube and homogenized with 20 ml of acid–acetone mixture (40 ml of acetone, 9 ml of water and 1 ml of concentrated hydrochloric acid) for 30 s using a homogenizer (IKA ULTRA-TURRAX T25 Basic, Germany). Then, an additional 20 ml of acid-acetone mixture was added and the sample was homogenized for another 30 s. The tube was then capped and kept in the dark for 1 h. The extract was centrifuged at 2200 g for 10 min using a MPW-350R centrifuge (MPW Med-Instruments, Poland). The supernatant was filtered through glass microfiber filters (Whatman GF/A). The filtered supernatant's absorbance was measured at 640 nm against a blank containing acidified acetone in a UV-VIS spectrophotometer (Nicolet Evolution 300, Thermo Electron Corporation). The total pigments were calculated as haematin using the following formula (Lee et al., 1999): total pigment (mg kg^{-1}) = A640×680. The heme iron content was calculated as described by Clark et al. (1997): heme iron (mg kg^{-1} of meat) = total pigment (mg kg^{-1}) × 8.82/100.

Colour measurements

Colour parameters (L*,a*,b*) were assessed on a freshly cut surface of the muscles using an X-Rite Color® Premiere 8200 colorimeter (X-Rite Incorporated, Michigan, USA) with a D_{65} illuminant and a 10° standard observer following the recommendations of AMSA (1991). Samples for colour measurements were 5 cm thick and excised at a depth of 20 mm. Before colour determination, the meat samples were wrapped in an oxygen permeable polyethylene film. Each time before use the colorimeter was standardized against a white ceramic calibration tile wrapped in the same polyethylene film used for the meat samples.

Fatty acid analysis

The method of Folch et al. (1957) was used for the extraction of lipids from samples. Fatty acid profile of meat samples was determined by gas chromatography after conversion of the fats to fatty acids methyl esters (AOCS, 1997). The fatty acids methyl esters (FAME) were quantified by gas chromatograph method using a fused silica capillary column (Select TM Biodiesel for FAME, Varian, USA) (30 m× ×0.32 mm×0.25 µm film thickness) and flame-ionization detector Varian 450-GC (Varian, USA) at injection volume of 1 mL/min and split ratio 1/50, respectively. Helium was used as the carrier gas. The detector and injector temperatures were chosen as 300°C and 250°C, respectively. The initial column temperature of 150ºC was held for 1 min, increased to 200ºC at 3ºC/min and held for 10 min. Then, it was increased to 240ºC at the rate of 3ºC/min and maintained for 4 min. Quantification of lipid FAMEs was carried out using nonadecanoic acid (C19:0) as an internal standard.

Statistical analysis

Data were analysed by using SAS/STAT package (2003). Compatibility of characteristics distribution with normal distribution was examined with Shapiro-Wilk's test. Arithmetical means ($\bar{x}$) and standard deviations (±SD) were calculated. Studying the effect of diet on growth parameters and carcass composition used a one-way analysis of variance according to the model:

$$Y_{ij} = \mu + A_i + e_{ij}$$

where:

Y_{ij} – value of the studied feature;
μ – population average;
A_i – effect of treatments (Group I, Group II, Group III);
e_{ij} – random error.

Differences between the mean values were determined with Duncan's test, at P≤0.05. A two-way analysis of variance (variables included diet and storage time of meat) was conducted in accordance with the model:

$$y_{ijl} = m + a_i + b_j + ab_{ij} + e_{ijl}$$

where:

y_{ij} – value of the studied feature,
m – population average,
a_{i-i} – effect of treatments (Group I, Group II, Group III),
b_{j-j} – effect of storage time,
ab_{ij} – effect of interaction between i and j,
e_{ijl} – random error.

Differences between the mean values were determined with Tukey's test, at P≤0.05.

Results

Table 2 shows that 3-week-old geese had similar BW and ADG. The diets containing *ad libitum* maize silage or sugar beet pulp silage with a limited amount of mixtures, in the 14th week of rearing, significantly reduced BW (about 9%) and ADG (about 27%) of birds, compared to the control group. Sugar beet pulp silage had a greater negative effect on BW compared to maize silage. After three weeks of oat fattening (17th week of age) differences in BW ($P \leq 0.05$) were found only in group III fed a diet supplemented with sugar beet pulp silage (6839.3 g) compared to the other two groups. However, the ADG of experimental birds during this period were significantly higher in supplemented silage than control birds (about 37% as it was fed the diet supplemented with corn silage and about 94% as it was fed the diet with supplemented silage fodder beets). ADG analysis for the whole testing period showed a significant difference ($P \leq 0.05$) only between the control birds (62.4 g) and the birds fed a diet with sugar beet pulp silage (55.6 g). From hatching to 3rd week of life all geese fed *ad libitum* only basal diet and feed consumption per kg body weight gain (FCR) was 1.7–1.8 kg. During the next growth period (4–14 weeks) FCR value for mixture in the control group (*ad libitum* feeding with a basal diet) was 6.3. In the experimental groups FCR value for mixtures ranged from 4.1 when the diet with maize silage was fed (group II) to 5.6 as it was fed the diet supplemented with sugar beet pulp silage (group III). Comparing FCR of roughage, it was found that maize silage was slightly better utilized (4.9 $kg \times kg^{-1}$ BWG) than the sugar beet pulp silage (6.8 $kg \times kg^{-1}$ BWG). Geese of group I consumed 10.9 kg oat per kg BWG. It was more compared to geese of groups II and III (by 29% and 72%, respectively). Total protein and metabolizable energy intake per kg BWG in the experimental birds was lower than in control group (140.0 g and 6.3 MJ in maize silage supplemented group and 71 g and 8.9 MJ in sugar beet pulp silage supplemented group, respectively). The differences in carcasses weight of 17-week-old birds were found only in the group fed a diet with sugar beet pulp silage (lower by 10.5%) compared with the control group. There was no significant effect of feeding on percentage of breast and thigh muscles in carcasses. Supplementing diets with pressed sugar beet pulp silage decreased ($P \leq 0.01$) the percentage of abdominal fat in carcasses compared with the control group (by 29%) and the other experimental group (by 21%).

No significant differences were observed in pH values of breast muscles after 3, 60 and 180 days of storage across the dietary treatments (Table 3). As far as the results of the measurements for thigh muscles are concerned, the results of pH measurements at 180 days of frozen storage indicated statistically significant differences among groups, since thigh muscles pH of geese from group II was significantly lower compared to pH from geese of groups I and III (Table 4). Breast and thigh muscles at 60 and 180 days of frozen storage had significantly lower pH values compared to muscles at 3 days of chilled storage.

The extent of lipid oxidation in goose breast and thigh muscles varied with storage time and dietary treatment (Tables 3 and 4). Incorporation of corn and beet pulp silage in geese diets had an effect ($P<0.05$) on the TBARS values of breast and thigh muscles measured at 3 days of chilling storage. The results showed that muscles of geese fed with the corn or beet pulp silage supplemented diets had lower TBARS values compared to geese of control group. An evaluation of the TBARS values after 60 and 180 days of storage at –24 ºC indicated no significant differences among groups. Breast and thigh muscles at 60 and 180 days of frozen storage had significantly higher TBARS values compared to muscles at 3 days of chilled storage.

Table 2. Effect of corn or pressed beet pulp silage on growth performance (n=14) and some carcass components (n=10) (means ± SD)

	Group I	Group II	Group III
BW – body weight (g)			
at 1 day	108.6±9.4	105.5±10.7	112.8±9.9
at 3 weeks	1634.3±155.6	1575.0±175.0	1585.7±208.2
at 14 weeks	6625.0 C±630.4	6050.0 B±601.2	4850.0 A±507.1
at 17 weeks	7657.1 b±771.6	7467.9 b±862.0	6839.3 a±666.3
ADG – average daily gain (g)			
1 day to 3 weeks	72.7±7.4	70.0±8.2	70.1±9.8
4–14 weeks	64.8 C±7.9	57.9 B±6.7	42.4 A±5.0
15–17 weeks	49.2 A±9.6	67.5 B±7.8	95.5 C±11.6
1 day to 17 weeks	62.4 bc±6.4	60.7 ac±7.0	55.6 a±5.5
FCR – feed conversion ratio (kg·1 kg^{-1} body weight gain, BWG)			
1 day to 3 weeks			
mixture	1.7	1.8	1.8
4–14 weeks			
mixture	6.3	4.1	5.6
silage		4.9	6.8
15–17 weeks			
oat	10.9	8.4	6.3
Total protein (g) and metabolizable energy (MJ) intake per kg^{-1} BWG			
1 day to 17 weeks			
total protein	917.3	777.0	846.3
metabolizable energy	66.1	59.8	57.2
Carcass components			
Carcass weight (g)	4902.1 b±771.3	4717.7 ab±550.4	4388.2 a±491.7
Carcass yield (%)	64.8±1.4	65.0±1.3	63.8±1.7
Breast muscles (%)	16.5±1.7	17.1±0.7	17.4±1.1
Leg muscles (%)	13.0±1.4	13.7±1.0	13.8±0.7
Abdominal fat (%)	8.5 B±1.4	7.6 B±0.8	6.0 A±0.9

Group I: geese fed *ad libitum* only mixtures; Group II: geese fed diet supplemented with silages from whole crop maize; Group III: geese fed diet supplemented with pressed sugar beet pulp silage

a, b, c – values in rows with different letters differ significantly (P≤0.05); A, B, C – as above for P≤0.01.

Tables 3 and 4 also show that the heme iron content of breast and thigh muscles did not differ significantly among the groups and with storage time. It was also noted that freezing for 60 and 180 days at –24°C does not affect the heme iron content of goose muscles.

Table 3. Effect of corn or pressed beet pulp silage on pH, TBARS and heme iron content of breast muscles in goose during storage (n=10) (means ± SD)

Parameter	Storage time (days)	Group I	Group II	Group III
pH	3	5.81 aC±0.11	5.72 aC±0.04	5.78 aC±0.05
	60	5.23 aA±0.01	5.23 aA±0.02	5.21 aA±0.02
	180	5.45 aB±0.04	5.49 aB±0.03	5.48 aB±0.05
TBARS ($mg\ kg^{-1}$)	3	1.22 cA±0.14	0.72 bA±0.09	0.48 aA±0.10
	60	1.50 aB±0.04	1.96 aB±0.65	1.64 aB±0.20
	180	1.74 aB±0.25	1.67 aB±0.08	1.68 aB±0.15
Heme iron ($mg\ kg^{-1}$)	3	22.19 aA±3.3	22.17 aA±1.8	21.05 aA±1.7
	60	21.84 aA±1.3	21.34 aA±3.2	21.27 aA±4.9
	180	20.36 aA±2.4	20.64 aA±1.9	21.04 aA±2.0

Group I: geese fed *ad libitum* only mixtures; Group II: geese fed diet supplemented with silages from whole crop maize; Group III: geese fed diet supplemented with pressed sugar beet pulp silage.

a, b, c – means followed by the same letters between the samples at the same storage time are significantly different (P≤0.05).

A, B – means followed by the same letters between the same sample at different storage times are significantly different (P≤0.05).

Table 4. Effect of corn or pressed beet pulp silage on pH, TBARS and heme iron content of thigh muscles in goose during storage (n=10) (means ± SD)

Parameter	Storage time (days)	Group I	Group II	Group III
pH	3	6.67 aC±0.16	6.79 aB±0.27	6.60 aC±0.28
	60	5.91 AaA±0.06	6.02 aA±0.11	5.90 aA±0.05
	180	6.29 bB±0.15	6.06 aA±0.05	6.38 bB±0.07
TBARS ($mg\ kg^{-1}$)	3	1.15 bA±0.13	0.60 aA±0.11	0.56 aA±0.13
	60	1.64 aB±0.15	1.77 aB±0.49	1.47 aB±0.28
	180	1.31 aB±0.26	1.30 aB±0.12	1.23 aB±0.07
Heme iron ($mg\ kg^{-1}$)	3	14.50 aA±1.6	14.23 aA±0.7	12.63 aA±0.2
	60	14.46 aA±1.5	14.16 aA±1.7	12.80 aA±1.2
	180	13.14 aA±2.1	13.52 aA±1.9	12.44 aA±2.3

Group I: geese fed *ad libitum* only mixtures; Group II: geese fed diet supplemented with silages from whole crop maize; Group III: geese fed diet supplemented with pressed sugar beet pulp silage.

a, b – means followed by the same letters between the samples at the same storage time are significantly different (P≤0.05).

A, B, C – means followed by the same letters between the same sample at different storage times are significantly different (P≤0.05).

Table 5 shows the results for breast muscle colour parameters (L*a*b*) measured after 3 days of chilling storage and after 60 and 180 days of freezing. An evaluation of the L*a*b* values indicated that feeding diets with beet pulp or corn silage did not influence the colour parameters of the breast muscles. Statistical analysis also indicated no effect of storage time on the L*a*b* values of breast muscles of geese. As far as the results of measurements of thigh muscles are concerned, significant differences occurred between the treatment groups after 3 days of chilling storage

(Table 6). Results of L* parameter measurements carried out at 3 days after slaughter revealed that the thigh muscles of geese fed with a corn silage supplemented diet had significantly lower lightness than the muscles of geese fed with a beet pulp silage supplemented diet. Thigh muscle colour parameters of all samples were not changed during storage, which is similar to the results obtained for breast muscles.

Table 5. Effect of corn or pressed beet pulp silage on colour parameters of breast muscles in goose (n=10) (means ± SD)

Parameter	Storage time (days)	Group I	Group II	Group III
L*	3	41.0 aA±2.5	40.0 aA±1.7	40.9 aA±2.2
	60	39.0 aA±2.8	38.9 aA±1.6	41.7 aA±1.9
	180	40.9 aA±3.9	41.9 aA±4.6	40.3 aA±3.1
a*	3	9.9 aA±0.9	10.7 aA±0.6	10.1 aA±0.7
	60	10.3 aA±1.8	11.6 aA±1.9	10.3 aA±0.7
	180	10.1 aA±2.5	9.9 aA±1.9	11.1 aA±1.9
b*	3	7.1 aA±1.8	7.9 aA±1.7	7.5 aA±1.5
	60	8.1 aA±1.6	9.4 aA±1.7	9.3 aA±0.9
	180	10.0 aA±1.3	8.6 aA±1.1	9.5 aA±1.2

Group I: geese fed *ad libitum* only mixtures; Group II: geese fed diet supplemented with silages from whole crop maize; Group III: geese fed diet supplemented with pressed sugar beet pulp silage.

a, b, c – means followed by the same letters between the samples at the same storage time are significantly different (P≤0.05).

A, B – means followed by the same letters between the same sample at different storage times are significantly different (P≤0.05).

Table 6. Effect of corn or pressed beet pulp silage on colour parameters of thigh muscles in goose (n=10) (means ± SD)

Parameter	Storage time (days)	Group I	Group II	Group III
L*	3	44.9 abA±4.0	41.4 aA±3.2	48.1 bA±1.9
	60	43.3 aA±2.6	41.9 aA±1.3	43.1 aA±3.1
	180	45.2 aA±3.4	50.3 aB±4.3	45.7 aA±4.2
a*	3	6.5 aA±1.8	7.8 aA±1.8	6.6 aA±1.1
	60	7.5 aA±2.1	8.8 aA±1.9	6.9 aA±1.7
	180	9.3 aA±3.3	7.4 aA±1.8	7.8 aA±2.3
b*	3	6.1 aA±1.7	6.9 aA±0.8	6.3 aA±0.9
	60	8.2 aA±1.9	8.1 aA±1.5	7.8 aA±1.5
	180	9.8 aA±2.9	8.8 aA±1.9	8.3 aA±1.9

Group I: geese fed *ad libitum* only mixtures; Group II: geese fed diet supplemented with silages from whole crop maize; Group III: geese fed diet supplemented with pressed sugar beet pulp silage.

a, b, c – means followed by the same letters between the samples at the same storage time are significantly different (P≤0.05).

A, B – means followed by the same letters between the same sample at different storage times are significantly different (P≤0.05).

The fatty acids of abdominal fat in White Koluda® goose samples are shown in Table 7. The predominant saturated fatty acid (SFA) in all samples was palmitic acid (C16:0), followed by stearic acid (C18:0). As far as the unsaturated fatty acids were concerned, in all of the analysed samples the highest value was observed for oleic acid (18:1), followed by linoleic acid (18:2 *n-6*) and palmitoleic acid (16:1). Feeding corn silage did not affect the amount of both saturated and unsaturated fatty acids of abdominal fat in geese, as is shown in Table 7. In comparison to group I, the abdominal fat of geese fed with pressed beet pulp silage supplemented diet were characterized by a significantly higher content of myristic (C14:0) and linoleic acids and a lower content of oleic acid.

Table 7. Fatty acid composition of abdominal fat of goose (%) (n=10) (means ± SD)

	Group I	Group II	Group III
Saturated:			
14:0	0.38 a±0.02	0.34 a±0.06	0.44 b±0.03
16:0	21.58 a±0.78	20.80 a±0.54	23.95 a±3.27
18:0	5.81 a±0.62	5.88 a±0.23	6.20 a±0.20
total	27.87±1.30	27.23±0.95	30.73±3.13
Monounsaturated:			
16:1	3.39 a±0.29	2.96 a±0.21	3.30 a±0.43
18:1	55.10 b±0.59	55.27 b±1.15	52.54 a±1.16
20:1	0.31 a±0.07	0.37 a±0.03	0.39 a±0.04
total	59.21±0.78	58.61±1.29	56.28±1.48
Polyunsaturated:			
18:2 *n-6*	12.03 a±0.63	13.01 ab±0.52	13.06 b±0.17
18:3 *n-3*	0.75 a±0.08	0.77 a±0.07	0.67 a±0.06
20:4 *n-6*	0.07 a±0.02	0.07 a±0.01	0.09 a±0.02
total	12.86±0.61	13.86±0.48	13.82±0.18

Group I: geese fed *ad libitum* only mixtures; Group II: geese fed diet supplemented with silages from whole crop maize; Group III: geese fed diet supplemented with pressed sugar beet pulp silage.

a, b – means followed by the same letters between the samples are significantly different (P≤0.05).

Discussion

In our study, limiting the quantity of basal diet and feeding *ad libitum* silages from 4 to 14 weeks decreased significantly BW and ADG of 14-week-old birds in comparison with a group fed only with the commercial mixture. The greatest decrease in BW and ADG (about 27% and 35%, respectively) was observed for geese fed with a sugar beet pulp silage supplemented diet. Arslan (2003) reported that sugar beet pulp contains high levels of pectins, which increase the viscosity of the intestinal content and delay the absorption of nutrients in the intestinal tract of birds. Wang et al. (2008) showed that proper addition of corn straw silage to the diet for geese (24–49%) was beneficial to digestion and absorption of protein and proliferation of beneficial intestinal bacteria. Our results indicated that during the oat fattening period (15–17 weeks of age), compensation of growth in experimental birds was observed. At 17 weeks of age, significant differences in final body weight were found only between the control group and the group fed with the sugar beet pulp silage supplemented diet (7657.1 and 6839.3 g, respectively). Compared with the control group, geese fed with the silage supplemented diet and then with oat needed less protein and metabolizable energy to produce 1 kg BWG. This fact may be of economic importance in rearing geese. Birds fed with the sugar beet pulp silage supplemented diet were characterized by lower BW, ADG, carcass weight and content of abdominal fat in carcasses, compared with geese fed only commercial mixtures. The slaughter performance and musculature of carcasses were similar in all groups. It should be noted that in our study, regardless of the type of diet, the performance and dissection results were comparable or better than in a study conducted on White Kołuda geese by other authors (Wężyk et al., 2003; Kapkowska et al., 2011; Haraf, 2014). These authors reported that body weight and tissue composition of goose carcasses are influenced by genotype, conditions of living, nutrition and the length of rearing. A study conducted on young White Koluda geese (Bochno et al., 2007) showed that feed restriction in rearing period allows the reduction of carcass fat content and the improvement of feed conversion efficiency compared to *ad libitum* feeding. The best results (comparable weight, better muscled carcasses and feed conversion) were achieved when geese were fed *ad libitum* for the first six weeks, and then were offered a restricted ration from the 7th week until the completion of the experiment. Murawska et al. (2010) showed that restriction of mixtures (by 20%) during rearing from 7 to 12 weeks of age, in comparison to *ad libitum* access significantly increased the body weight of birds but with less muscles and more fatness in carcass. Arslan (2003) stated that replacement of concentrate diet by alfalfa, grass and dried sugar beet pulp meal leads to more economical feeding of native Turkish geese (without negative affect on growth parameters, feed conversion) and production of goose carcasses with low fat. The best results were obtained when the level of replacement by these fiber feedstuffs was 5% in starter and 10% in grower period. However, another study (Arslan, 2005) stated that diets supplementation by grass and sugar beet pulp at 10% in starter or 20% in grower period did not affect body weight, daily gain, carcass yield but slightly decreased feed conversion of geese. Similar relationships were shown in the fattening of young native Turkish geese by feeding system based on basal diets with access to pasture (Arslan and Tufan, 2011).

Some publications demonstrate the impact of the application of silage to animal feed on production parameters; however, scarce data exist concerning the quality of meat. He et al. (2015) detected no difference in pH and muscle colour of geese when different fiber source (among others corn straw silage) was offered to geese in the growing period. Similarly, Bartoň et al. (2010) showed that the replacement of legume-cereal/lucerne silage by maize silage did not affect muscle quality parameters.

The results of our study did not indicate any effect of feeding corn or sugar beet pulp silage to geese on pH values of muscles with the exception of the results obtained for the thigh muscle at 180 days of frozen storage. The thigh muscles of geese fed corn silage supplemented diet had significantly lower pH compared to geese from other groups. During storage, the pH value of thigh and breast muscle decreased at 60 days of storage and then began to increase. These data are in agreement with results from studies on chicken patty (Ozer and Sariçoban, 2010). According to Ozer and Sariçoban (2010), such an increase in the pH of frozen chicken patties is due to the accumulation of metabolites by bacterial action in meat and deamination of proteins (ammonia). Probably bacterial action in thigh muscle of geese fed corn silage supplemented diet was the most intense as this sample reached the lowest pH.

Some studies have shown that oxidation processes are one of the main causes of quality losses in frozen stored meat (Gokalp et al., 1983; Jeong et al., 2011). Controlling these oxidative reactions is crucial in order to produce high-quality products since oxidation of unsaturated fatty acids has been shown to be responsible for both colour and flavour deterioration as well as loss of nutritional value and structural changes (Morrissey et al., 1998). The results of our study showed that incorporation of corn or beet pulp silage in geese led to a decrease in lipid oxidation of muscles at 3 days of storage. Corn is an essential source of various phytochemicals, such as carotenoids, phenolic compounds and phytosterols (Ramos-Escudero et al., 2012). The results obtained by Aarabi et al. (2015) also showed that sugar beet pulp is a good source of phenolic compounds. Łozicki et al. (2015) indicated that the ensiling did not lower the silage antioxidant potential. Therefore, the bioactive compounds in silages could affect antioxidant potential of meat and prevent lipid peroxidation. It was also noted that at 60 days of freeze storage the TBARS values of goose muscles increased and then decreased at 180 days of storage. The decrease in TBARS values of goose muscles at 180 days of frozen storage is probably the result of malondialdehyde reaction with proteins. The end products of such reactions may be complexes involving lipid-protein cross-links. The overall effect of these reactions is damage to amino acid residues, the most sensitive of which are histidine, cysteine/cystine, methionine, lysine, tyrosine, and tryptophan (Esterbauer et al., 1991).

An evaluation of the colour parameters values at 3 days of chilling storage indicated that feeding diets with beet pulp and corn silage did not influence the L*a*b* of the breast muscles. The results of colour parameters obtained in our study were comparable with the results of Okruszek et al. (2008). Pietrzak et al. (2013) showed that a properly balanced own production feed mixture can be used in geese feeding without a negative effect on the colour parameters of meat. During freezing, the L*a*b* values of breast and thigh muscles of geese did not change. The results have shown that the diets applied to the feeding of geese positively influenced the colour stability of meat during freezing. It was also indicated that freezing does not affect the heme iron content of goose muscles. According to Leygonie et al. (2012), the subsequent release of iron from the porphyrine ring of myoglobin has been reported to occur as a consequence of damage to cell membranes by ice crystals during freezing and thawing. In our study such relationship was not observed.

The fatty acid composition of abdominal fat is important for two main reasons: it determines the nutritional value and it affects many aspects of fat quality, including shelf life and oxidative stability (Wood et al., 2003). Feeding corn silage did not affect the total amount of both saturated and unsaturated fatty acids of abdominal fat in geese. Compared to a previous study that analysed the abdominal fat of 10-week-old White Kołuda geese, lower total MUFA and higher total PUFA levels were observed (Biesiada-Drzazga, 2006 b). Biesiada-Drzazga (2006 b) reported that abdominal fat in geese fed with mixtures containing soybean and rapeseed extracted meals was characterized by lower saturated and higher unsaturated fatty acids content in comparison with birds fed with mixtures containing only soybean extracted meal.

Summary

Feeding geese limited amount of commercial basal diet and *ad libitum* maize or pressed sugar beet pulp silages significantly reduced growth parameters at 14 weeks of age in comparison with the control group (*ad libitum* feeding of commercial basal diets). However, these differences were compensated during the oat fattening period (15-17 weeks). The evaluation of birds' growth parameters (BW, ADG, FCR) has shown that whole crop maize silage was more effective than pressed sugar beet pulp silage in rearing period of geese (4–14 weeks).

Feeding geese, as described in the current article, with diets based on a limited amount of commercial mixtures supplemented *ad libitum* with maize or sugar beet pulp silages, is recommended for increasing economic efficiency in White Koluda geese and for producing goose carcasses with low fat.

Feeding corn or sugar beet pulp silage to geese did not affect the pH values, heme iron content, colour parameters of muscles and decrease lipid oxidation in muscle at 3 days after slaughter. Additionally, feeding corn silage did not affect the total amount of both saturated and unsaturated fatty acids of abdominal fat in geese. The quality of both meat and fat is of interest because these are the main products of fattening geese. Further research is needed to determine the effect of using corn and pressed beet pulp silage on meat taste, tenderness and other quality measurements.

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