Effects of feeding whole-grain triticale and sex on carcass and meat characteristics of common pheasants

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Abstract
The aim of the present research has been to determine the effect of replacing a part of commercial compound feed with whole triticale grain on the body weight (BW), body measurements, feed conversion ratio (FCR), carcass composition and meat quality of pheasants. The study involved 80 one-day-old common pheasants. From 71 to 112 d of rearing, two diets were administered: a complete commercial diet ad libitum for control pheasants and restricted amounts of a commercial diet (50%) and whole triticale grain (50%) for experimental pheasants. Each treatment consisted of 4 replications, 10 birds each. Introducing whole triticale grain did not cause significant changes in BW, body measurements, feed intake and FCR. The carcasses of 112-d-old pheasants fed whole triticale grain diet showed a significantly lower breast muscle content (%) and a significantly higher content of skin with subcutaneous fat and carcass remainders (p < .05). Breast muscles of pheasants fed commercial compound feed and whole triticale grain exhibited significantly higher hardness, chewiness and gumminess, more palmitic acid and zinc, as well as significantly less sodium, water, linoleic acid, paullinic acid, heptadecanoic acid. There were also significant changes in water and protein, the content of fatty acids in leg muscles, except for myristic acid, pentadecanoic acid, arachidonic acid and nervonic acid. Irrespective of the type of diet, males showed a significantly higher body weight, body measurements and carcass weight, and their breast muscles demonstrated significantly higher WB shear force and the amounts of protein, linoleic acid, potassium, phosphorus, magnesium and zinc.

Introduction
Due to the most variable chemical composition of all cereals and high fluctuations in the content of antinutritive components, triticale is not a popular component of compound feeds for poultry. It is most frequently used in feeding broiler chickens and laying hens (Rachwal 2010; Djekic et al. 2011; Al-Hajo et al. 2013).

The nutritive value of triticale grain is midway between rye and wheat in terms of calorific value, and is higher than that of wheat and rye in terms of the amount of protein, and similar to parent forms in terms of the content of essential amino acids: lysine and threonine (Rachwal 2010). Non-starch polysaccharides (mostly pentosans, glucans and pectins) are the factor limiting the application of triticale, especially in young birds. They decrease bird yield, produce viscous excreta and cause deterioration in litter quality. For those reasons, it is safer to use moderate amounts of this cereal in poultry diets. Sokół and Fabijanżaska (2001) recommend using up to 30–40% triticale grain in the diet of older chickens and laying hens, and up to 20% in broilers.

In a review of research results on the use of triticale in broiler chicken nutrition from the 1980s and 1990s, Osek et al. (2010) concluded that the research generally focused on determining the effect of triticale on production parameters. The results pointed to a decrease in BW gains and deterioration in feed conversion (higher FCR). The results of experiments performed over the recent years with the use of triticale in poultry diets are not as unambiguous, and, on top of that, they mostly relate to the effect of triticale grain on the slaughter
value and poultry meat quality (Hermes and Johnson 2004; Korver et al. 2004; Osek et al. 2010; Mahbub et al. 2011; Al-Hajo et al. 2013; Osek et al. 2013).

Today, slaughter poultry (including farmed meat pheasant) nutrition is most often based on complete diets – commercial compound feeds in crumble or pellet form. As this feeding system is relatively expensive, breeders seek cheaper feeding methods. Complete compound feeds are generally twice as expensive as cereal grains, which is an incentive for poultry producers to partially replace commercial compound feeds. Also, the application of diets with whole cereal grain is considered to be more natural for birds and to favour the health of the flock. Feeding whole cereal grain decreases the cost of feed preparation, facilitates the use of cheaper farm feeds (Arroyo et al. 2014), as well as ensures better development and functioning of the alimentary canal. It can also help to reduce the incidence of leg diseases and heart attacks (Kokoszyński 2014).

Recent decades have seen a renewed interest around the world in feeding poultry with whole cereal grains, mostly wheat grain. There are relatively few papers on the application of whole triticale grain in poultry diets. Today, nutrition based on whole triticale grain in commercial poultry production is tested in broiler chickens (Ozek et al. 2012; Kliševičiūtė et al. 2014) and mule ducks (Arroyo et al. 2014, 2016).

Due to a lack of relevant studies, it is advisable to present the research results concerning the effect of diluting meat pheasant diets with whole triticale grain on carcass composition and meat quality. Reducing the costs of feeding meat pheasants offers an opportunity to lower the price of relatively expensive pheasant carcasses. Any potential improvement in carcass composition, as well as nutritional and technological value of pheasant meat will be an additional incentive to use whole triticale grain in the diets of pheasants reared for meat.

The aim of the research has been to determine the effect of diluting the diet with whole triticale grain on BW, FCR, morphometric body measurements, dressing percentage, carcass composition, texture and rheological properties, chemical composition, fatty acid profile and the content of some minerals in common pheasant meat.

Materials and methods

Birds and housing

The research involved 80 one-day-old common pheasants (Phasianus colchicus colchicus L.). The birds were randomly placed in 8 pens in a closed building, with no access to free range. 10 birds (5 males and 5 females) were kept in each 12 m² pen. The birds were divided into two diet groups, 40 pheasants each. Each diet group consisted of 4 subgroups. The research was performed with the approval of the Local Ethics Committee for Experimental Animals (UTP University of Science and Technology in Bydgoszcz, Poland/ Ministry of Science and Higher Education).

Feeding programme and experimental diets

Throughout the rearing period of 112 d, the control pheasants (C) were fed ad libitum with crumbled (1–28 d) or pelleted (29–112 d) complete diets for slaughter pheasants. The experimental group (WT) pheasants received complete diets for slaughter pheasants ad libitum up to 70 d of age, and starting from 71 d it was partially replaced by whole triticale grain. From 71 to 112 d, the amount of commercial compound feeds was limited to 50% diet. The components of compound feeds given to pheasants are listed in Table 1. The data on the chemical composition and energy value of those compound feeds are given in Table 2. The chemical composition was analysed at the Laboratory of the Division of Animal Nutrition, UTP University of Science and Technology in Bydgoszcz, Poland.

Body weight and measurements. Feed intake

On d 1, 70 and 112 of age, the pheasants were individually weighed to the nearest 1 g using an electronic hook scale (Jotafan, Kraków, Poland). Based on the body weight data from these evaluation dates, weight gains of the pheasants during the rearing period were calculated (g/d). During the second weighing, the pheasants were marked with wing tags and sex-identified based on the colour of feathers. Morphometric body measurements were made afterwards. The following parameters were tape-measured with the accuracy of 1 mm: the length of the trunk with the neck (from the first cervical vertebra to the posterior upper ischium tuberosity), the trunk length (between the tuberosity of the shoulder joint and the posterior upper ischium tuberosity), the chest circumference (behind the wings, through the anterior edge of keel and the middle thoracic vertebra), the length of keel (from the anterior to the posterior edge of the keel), the length of lower thigh (from the knee joint to the hock joint) and the length of shank (between tarsal joint and posterior area of the fourth toe at its base). The weight of feeds administered was noted down every day during rearing (for each pen separately), and at the end of rearing (112 d) the weight of feed
refusals was recorded, which facilitated the calculation of the amount of feed consumed by a single bird (g/d) and the calculation of the FCR value (kg feed/kg body weight gain).

### Carcass analysis

On d 112 of age, from each pen there were selected 2 males and 2 females with body weight approximate to the arithmetic mean for individuals of a given sex in the pen. In total, 32 birds were chosen for slaughter: 8 males and 8 females (16 birds) from each diet group. Then, before slaughter, the feed was withdrawn while water remained available. Pheasant slaughter, feather plucking and evisceration were made on the farm belonging to the Department of Poultry Breeding. During evisceration, the digestive tract and other internal organs (heart, gizzard, liver, spleen, lungs and trachea and reproductive organs) were removed from the body cavity. The birds were manually slaughtered. After stunning with a club, the birds were exsanguinated by cutting the jugular vein. Eviscerated carcasses (which contained kidneys but no lungs) were weighed with the electronic balance (Hendi, Gdańsk, Poland). Eviscerated cooled carcasses (which contained kidneys but no lungs) were weighed with the electronic balance (Medicot, Zurich, Switzerland) with the accuracy of 0.1 g. After weighing, whole carcasses were dissected following the method described by Ziolecki and Doruchowski (1989). For each carcass, the neck without skin, wings with skin, skin with subcutaneous fat (from the whole carcass, without wings), abdominal fat, breast muscles (superficial pectoral muscle plus profound pectoral muscle), leg muscles (all thigh and drumstick muscles) and carcass remainders were separated. The remainder of the carcass comprised the skeleton with some small skeletal muscles (intercostal, dorsal and others), including the kidneys. Thus separated carcass parts were weighed with the accuracy of 0.1 g using the same balance as

### Table 1. Composition of the diets for common pheasants.

| Ingredient, g/kg as fed | Starter 1–28 d | Grower 29–70 d | Finisher 71–112 d | Experimental diet* 71–112 d |
|------------------------|---------------|----------------|------------------|-----------------------------|
|  | g/kg as fed | g/kg as fed | g/kg as fed | g/kg as fed |
| Maize                  | 201.0         | 269.9          | 200.0           | 100.0                       |
| Ground wheat           | 250.0         | 250.0          | 350.0           | 175.0                       |
| Wheat meal             | 25.0          | 30.0           | 150.0           | 75.0                        |
| Barley                 | 30.0          | 50.0           | 25.0            | 25.0                        |
| Triticale grain        | --            | --             | --              | 500.0                       |
| Rice bran              | 30.0          | 20.0           | --              | --                          |
| Soybean meal, 454 g CP/kg | 337.3        | 212.4          | 22.0            | 11.0                        |
| Rape seed meal, 357 g CP/kg | 40.0        | 75.0           | 80.0            | 40.0                        |
| Sunflower seed meal, 395 g CP/kg | --        | 50.0           | 50.0            | 25.0                        |
| Corn DDGS, 280 g CP/kg | --            | 30.0           | 36.2            | 18.1                        |
| Fish meal              | 30.0          | --             | --              | --                          |
| Soybean oil            | 9.0           | 9.0            | 8.4             | 4.2                         |
| Lactic acid            | 10.0          | 9.0            | 9.0             | 4.8                         |
| Monocalcium phosphate  | 10.2          | 8.0            | 8.1             | 4.05                        |
| Sodium chloride        | 13.4          | 13.4           | 13.4            | 6.7                         |
| Sodium bicarbonate     | 2.2           | 2.4            | 2.4             | 1.2                         |
| α-α-methionine         | 1.45          | 0.35           | 0.30            | 0.15                        |
| L-lysine               | 0.55          | 0.15           | 0.10            | 0.05                        |
| Avatec                 | 7.5           | 7.5            | 7.5             | 3.75                        |
| Vitamin–mineral premix | 5.0           | 5.0            | 5.0             | 2.50                        |

*Experimental diet used only for the WT group.

### Table 2. Chemical composition of diets for common pheasants.

| Chemical analysis | Starter 1–28 d | Grower 29–70 d | Finisher 71–112 d | Experimental diet* 71–112 d |
|-------------------|---------------|----------------|------------------|-----------------------------|
|                  | g/kg as fed   | g/kg as fed   | g/kg as fed     | g/kg as fed |
| DM, %             | 91.4          | 91.3           | 91.3             | 90.0                       |
| CP, g/kg as fed   | 254.7         | 220.7          | 175.2            | 145.8                      |
| Crude fat, g/kg as fed | 39.1        | 38.6           | 23.9             | 17.0                       |
| Crude fibre, g/kg as fed | 34.9        | 41.6           | 47.0             | 37.6                       |
| Crude ash, g/kg as fed | 68.9        | 56.3           | 55.5             | 36.9                       |
| N-free extracts, g/kg as fed | 516.4       | 555.8          | 611.4            | 662.7                      |
| ME, MJ/kg         | 11.46         | 11.63          | 11.26            | 11.93                      |

*Experimental diet used only for the WT group.

bThe values are calculated from ingredient AME values.
the carcasses and their percentage in the eviscerated carcass with neck was calculated. The data on the weight of cooled eviscerated carcass with neck, and the body weight of pheasants selected for dissection were used to calculate the dressing percentage of the compared pheasant groups, taking sex into account.

**Meat quality**

The textural and rheological properties of heat-processed breast muscles were studied using an Instron 1140 testing machine (Instron Corp., Norwood, MA). The texture of meat was determined using the TPA double compression test as well as the Warner–Bratzler (WB) test; rheological properties were determined with the stress-relaxation test. A total of 20 breast muscle samples were analysed, 10 samples each from every feeding group, which were collected from 5 males and 5 females per group. Each sample was analysed 5 times (5 replications), and the average for each sample was calculated. In total, 100 determinations for 20 samples of breast muscle were made.

The pheasant breast and leg meat samples from each treatment were used to measure the chemical content, fatty acids and some minerals. The determinations were made on 32 samples of breast muscles and 32 samples of leg muscles which included 16 samples collected from 8 males and from 8 females aged 112 d from each feeding group.

The percentage of protein, fat, collagen and moisture in the breast and leg muscles was determined by near-infrared transmission (NIT) spectroscopy with calibration using artificial neural networks (ANN) and FoodScan apparatus (FoodScan Lab, FOSS, UK). AOAC International reports that the FOSS FoodScan™ method with a Marcel MEDIA EKO (Marcel, Warsaw, Poland).

**Statistical analyses**

The numerical data on the body weight and measurements, FCR, dressing percentage, carcass composition and meat quality characteristics were subjected to statistical analysis. Arithmetic means and standard error of mean (s.e.m.) were calculated. With the two-factor analysis of variance, the effect of the diet group and the sex on the meat traits in pheasants was investigated. The following linear model was applied:

\[
Y_{ijk} = \mu + D_i + S_j + (D \times S)_{ij} + e_{ijk}
\]

where \(Y_{ijk}\) is value of the analysed trait, \(\mu\) is overall mean, \(D_i\) is the effect of diet, \(S_j\) is the effect of sex, \((D \times S)_{ij}\) stands for the interaction between the diet and sex and \(e_{ijk}\) is random residual error. Statistical analyses were made with the use of SAS software, version 9.4 (SAS Institute Inc. 2014). The level of significance was at \(p < .05\). The pen was the experimental unit for daily feed intake and feed conversion ratio (FCR), and individual birds were the experimental unit for body weight, body measurements, body weight gains, all the slaughter traits and the meat quality.

**Results**

**Farm productivity**

The compared groups of common pheasants subjected to varied feeding regimes did not differ significantly \((p > .05)\) in terms of BW and body measurements on d 70 and 112, without lower thigh length on d 70. Irrespective of the diet composition, the males showed a significantly higher \((p < .05)\) body weight and body measurements at both evaluation dates, compared to females (Table 3). The compared
groups of pheasants had similar BWG, feed intake and FCR during the rearing period (Table 4).

**Carcass yield**

The carcasses from the 112-d-old pheasants fed the compound feed with whole triticale grain demonstrated a significantly lower content (%) of breast muscles, and a significantly higher content of skin with subcutaneous fat and remainders ($p < .05$). Males, as compared to females, showed higher BW and carcass weight in both groups. The diet $\times$ sex interactions for slaughter traits were non-significant (Table 5).

**Meat quality**

Introducing 50% of whole triticale grain from d 71 to d 112 of age to replace the commercial diet for slaughter pheasants (group WT) resulted in an increase in hardness, chewiness and gumminess of cooked breast muscles compared to the pheasants fed with commercial diet (group C) only. The muscles of control and WT males showed lower tenderness (higher WB shear force) than the muscles of females (Table 6).

The use of diet with whole triticale grain over the last 41 d of rearing had no significant ($p > .05$) effect on the content (%) of protein and collagen in breast and leg muscles, and on the content (%) of fat in breast muscle (superficial pectoral muscle and profound pectoral muscle) of 112-d-old pheasants. Breast muscles of WT pheasants had a significantly lower water content, and leg muscles had a lower ($p \leq .001$) content of water and fat. Significant diet $\times$ sex interactions were observed for the water, protein and fat content of leg muscles (Table 7).

**Table 3.** Effect of diet on body weight and body measurements in common pheasants during the rearing period (mean $\pm$ s.e.m.).

| Item                        | Age, d | Control (C) | Whole triticale (WT) | $p$ Value | Diet | Sex | Diet $\times$ Sex |
|-----------------------------|--------|-------------|----------------------|-----------|------|-----|-------------------|
| Number of birds             |        | 20          | 20                   |           |      |     |                   |
| BW, g                       | 70     | 826 ± 21.4  | 650 ± 24.2           | 816 ± 33.8 | 707 ± 14.6 |      | .339 < .001 .184  |
|                             | 112    | 1233 ± 28.8 | 895 ± 15.3           | 1194 ± 53.1 | 950 ± 33.5 |      | .821 < .001 .189  |
| Trunk with neck length, cm  | 70     | 28.0 ± 0.3  | 26.1 ± 0.4           | 27.5 ± 0.4 | 26.3 ± 0.2 |      | .570 < .001 .304  |
|                             | 112    | 30.6 ± 0.5  | 27.6 ± 0.2           | 30.1 ± 0.3 | 28.2 ± 0.2 |      | .768 < .001 .112  |
| Trunk length, cm            | 70     | 17.4 ± 0.4  | 15.5 ± 0.3           | 16.7 ± 0.3 | 15.2 ± 0.3 |      | .153 < .001 .535  |
|                             | 112    | 19.9 ± 0.2  | 17.2 ± 0.4           | 19.3 ± 0.4 | 17.8 ± 0.4 |      | .947 < .001 .105  |
| Chest circumference, cm     | 70     | 23.5 ± 0.5  | 21.7 ± 0.2           | 22.9 ± 0.5 | 22.0 ± 0.3 |      | .825 < .001 .187  |
|                             | 112    | 28.2 ± 0.4  | 24.9 ± 0.2           | 27.9 ± 0.5 | 25.5 ± 0.4 |      | .666 < .001 .297  |
| Breast bone length, cm      | 70     | 9.5 ± 0.1   | 8.9 ± 0.1            | 9.5 ± 0.2 | 8.8 ± 0.1 |      | .890 < .001 .782  |
|                             | 112    | 11.3 ± 0.1  | 10.2 ± 0.1           | 11.3 ± 0.2 | 10.1 ± 0.1 |      | .772 < .001 .563  |
| Lower thigh length, cm      | 70     | 12.4 ± 0.1  | 11.5 ± 0.1           | 12.9 ± 0.1 | 12.1 ± 0.1 |      | .002 < .001 .502  |
|                             | 112    | 13.6 ± 0.2  | 12.2 ± 0.1           | 13.6 ± 0.1 | 12.3 ± 0.1 |      | .426 < .001 .331  |
| Shank length, cm            | 70     | 9.0 ± 0.1   | 8.5 ± 0.1            | 9.1 ± 0.1 | 8.6 ± 0.1 |      | .211 < .001 .072  |
|                             | 112    | 9.3 ± 0.1   | 8.6 ± 0.1            | 9.2 ± 0.1 | 8.7 ± 0.1 |      | .482 < .001 .214  |

$^{a}$Control: commercial complete diet; WT: commercial complete diet (50%) plus whole triticale grain (50%) for final 41 days of rearing.

**Table 4.** Effect of diet on body weight gain (BWG), feed intake and feed conversion ratio (FCR) in common pheasants during the rearing period$^{a}$ (mean $\pm$ s.e.m.).

| Item                        | Age, d | Control (C) | Whole triticale (WT) | $p$ Value | Diet | Sex | Diet $\times$ Sex |
|-----------------------------|--------|-------------|----------------------|-----------|------|-----|-------------------|
| Number of birds             |        | 40 ± 0.1    | 40 ± 0.1             |           |      |     |                   |
| BWG, g                      | 1–70   | 10.2 ± 0.1  | 10.6 ± 0.1           |           |      |     |                   |
|                             | 71–112 | 7.8 ± 0.1   | 7.4 ± 0.1            |           |      |     |                   |
| Feed intake, g/d            | 1–70   | 33.8 ± 0.1  | 34.0 ± 0.1           |           |      |     |                   |
|                             | 71–112 | 66.6 ± 0.1  | 65.2 ± 0.1           |           |      |     |                   |
| FCR, kg/kg body weight gain  | 1–70   | 46.1 ± 0.1  | 45.7 ± 0.1           |           |      |     |                   |
|                             | 71–112 | 8.58 ± 0.1  | 8.81 ± 0.1           |           |      |     |                   |

$^{a}$Control: commercial complete diet; WT: commercial complete diet (50%) plus whole triticale grain (50%) for final 41 days of rearing.

The breast muscles of 112-d-old WT pheasants contained significantly more C16:0 and less C17:0, C20:1, C18:2n6 and C20:2 fatty acids. The male muscles had a significantly higher content of C18:2n6 fatty acid (Table 8) compared to female muscles. The ration composition also affected the fatty acid profile of lipids in leg muscles. The leg muscles in WT pheasants, as compared to C birds, contained significantly more C16:0, C14:1, C16:1, C18:1n9, MUFA, but less ($p < .05$) C12:0, C17:0, C18:0, C22:0, C20:1, C18:2n6, C20:2, C20:4n6, C22:6n3 and PUFA. The PUFAnsAFA ratio for leg muscles in 112-d-old WT pheasants was lower than in C birds (Table 9).

Restricted feeding of pheasants (whole triticale grain and commercial compound feed) significantly decreased the content of sodium in breast muscles than balanced diet (commercial compound feeds). The amount of zinc in breast muscles in WT pheasants
was, however, significantly higher than in C birds. Breast muscles in males contained significantly more ($p < .05$) potassium, phosphorus, magnesium and zinc. In terms of zinc content in breast muscles of the compared pheasant groups, significant diet × sex interaction was recorded (Table 10).

**Discussion**

**Farm productivity**

After the first commercial triticale cultivars were created, triticale cultivation was launched on a wider scale, and research efforts were initiated to determine their applicability for poultry nutrition, mostly in broiler chickens and laying hens. Initially (in the 1980s and 1990s), the research results on triticale did not encourage live bird producers to use it in poultry nutrition. Definitely more satisfactory production results (BW, FCR) were reported in research with more recent cultivars (octo- or hexaploid triticale), which points to a potential of wider application of that genus of cereals in poultry nutrition (Santos et al. 2008; Djekic et al. 2012; Osek et al. 2013). In our study, pheasants (males and females on average) fed the whole triticale grain diet and raised indoors on the floor were characterised by non-significant higher BW compared to control birds on the complete commercial diet, which contained more wheat, maize and barley. Józefiak et al. (2007) found, however, a higher body weight in 35-d-old Cobb 500 chickens, and a lower FCR value when applying diets containing triticale (with or without the enzymatic preparation

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**Table 5.** Effect of diet on body weight, dressing percentage and share (%) of carcass components in 112-d-old common pheasants (mean ± s.e.m.).

| Item                        | Control (C) | Whole triticale (WT) | $p$ Value |
|-----------------------------|-------------|----------------------|-----------|
| Number of birds             | 8           | 8                    |           |
| BW-selected for slaughter, g | 1240 ± 20.8 | 896 ± 13.7           | .271      |
| Carcass weight, g           | 898 ± 18.5  | 644 ± 9.8            | .096      |
| Dressing percentage, %      | 73.4 ± 1.0  | 71.9 ± 0.5           | .106      |
| Neck, %                     | 4.4 ± 0.2   | 3.9 ± 0.2            | .312      |
| Wings, %                    | 11.2 ± 0.3  | 11.8 ± 0.3           | .115      |
| Breast muscle, %            | 30.9 ± 1.4  | 30.7 ± 1.3           | .010      |
| Leg muscle, %               | 19.6 ± 0.8  | 17.5 ± 0.8           | .316      |
| Skin with fat, %            | 6.7 ± 0.6   | 6.2 ± 0.4            | .008      |
| Abdominal fat, %            | 0.03 ± 0.1  | 0.07 ± 0.1           | .207      |
| Remainders, %               | 27.2 ± 1.0  | 29.8 ± 1.8           | .021      |

*Control: commercial complete diet; WT: commercial complete diet (50%) plus whole triticale grain (50%) for final 41 days of rearing.*

**Table 6.** Effect of diet on texture and rheological properties of breast muscles in 112-d-old common pheasants (mean ± s.e.m.).

| Item                        | Control (C) | Whole triticale (WT) | $p$ Value |
|-----------------------------|-------------|----------------------|-----------|
| Number of birds             | 5           | 5                    |           |
| Hardness, N                 | 17.0 ± 1.3  | 19.8 ± 1.3           | .006      |
| Cohesiveness, –             | 0.22 ± 0.1  | 0.24 ± 0.1           | .062      |
| Springiness, cm             | 0.9 ± 0.1   | 0.9 ± 0.1            | .976      |
| Chewiness, N/cm             | 3.4 ± 0.5   | 4.3 ± 0.5            | .011      |
| Gumminess, N                | 3.9 ± 0.5   | 4.8 ± 0.4            | .009      |
| W–B shear force, N          | 116.4 ± 2.7 | 93.8 ± 7.3           | .522      |
| Sum of elastic moduli, kPa  | 394.7 ± 30.4| 462.2 ± 19.2         | .162      |
| Sum of viscous moduli, kPa  | 20,870 ± 2306| 23,564 ± 1729       | .476      |

*Control: commercial complete diet; WT: commercial complete diet (50%) plus whole triticale grain (50%) for final 41 days of rearing.*

**Table 7.** Effect of diet on chemical composition of breast and leg muscles in 112-d-old common pheasants (mean ± s.e.m.).

| Item                        | Control (C) | Whole triticale (WT) | $p$ Value |
|-----------------------------|-------------|----------------------|-----------|
| Number of birds             | 8           | 8                    |           |
| Water                       |             |                      |           |
| BM                          | 72.2 ± 0.1  | 72.0 ± 0.1           | .024      |
| LM                          | 71.9 ± 0.1  | 69.6 ± 0.1           | .001      |
| Protein                     |             |                      |           |
| BM                          | 27.5 ± 0.1  | 27.5 ± 0.1           | .651      |
| LM                          | 23.2 ± 0.1  | 23.1 ± 0.1           | .228      |
| Fat                         |             |                      |           |
| BM                          | 0.5 ± 0.1   | 0.5 ± 0.1            | .587      |
| LM                          | 1.2 ± 0.1   | 1.0 ± 0.1            | .974      |
| Collagen                    |             |                      |           |
| BM                          | 1.7 ± 0.1   | 1.8 ± 0.1            | .324      |
| LM                          | 1.7 ± 0.1   | 1.8 ± 0.1            | .760      |

*Control: commercial complete diet; WT: commercial complete diet (50%) plus whole triticale grain (50%) for final 41 days of rearing. BM: breast muscle; LM: leg muscle.*
Avizyme, which contained 2500 U/g endo 1,4-β-D-xylanase and 800 U/g protease) as the only cereal, as compared to the birds fed diet with rye or wheat. Similarly to earlier studies (Ricard and Petitjean 1989; Sarica et al. 1999; Kokoszyński et al. 2012; Zapletal et al. 2017), the male common pheasants had a significantly higher body weight at slaughter age (16 wk) compared to females.

Table 8. Effect of diet on the composition of fatty acids (% of total fatty acids) of the lipids of breast muscles in 112-d-old common pheasants (mean ± s.e.m.).

| Item | Control (C) | Whole triticale (WT) | p Value |
|------|-------------|----------------------|---------|
|      | ♂ | ♀ | ♂ | ♀ | Diet | Sex | Diet × Sex |
| Number of birds | 8 | 8 | 8 | 8 |    |    |          |
| C12:0 | 0.56 ± 0.28 | 0.49 ± 0.22 | 0.34 ± 0.05 | 0.43 ± 0.12 | 0.01 | 0.51 | 0.61 |
| C14:0 | 0.80 ± 0.29 | 0.66 ± 0.21 | 0.66 ± 0.01 | 0.71 ± 0.01 | 0.11 | 0.01 | 0.01 |
| C15:0 | 0.08 ± 0.01 | 0.07 ± 0.01 | 0.14 ± 0.09 | 0.18 ± 0.03 | 0.70 | 0.01 | 0.01 |
| C16:0 | 32.68 ± 0.87 | 33.76 ± 0.97 | 36.94 ± 0.56 | 43.53 ± 1.06 | 0.64 | 0.01 | 0.01 |
| C17:0 | 0.25 ± 0.01 | 0.24 ± 0.01 | 0.20 ± 0.02 | 0.18 ± 0.03 | 0.70 | 0.01 | 0.01 |
| C18:0 | 10.01 ± 1.34 | 9.62 ± 1.03 | 10.19 ± 0.29 | 9.93 ± 1.23 | 0.08 | 0.01 | 0.01 |
| C20:0 | 0.21 ± 0.09 | 0.20 ± 0.09 | 0.18 ± 0.08 | 0.16 ± 0.07 | 0.70 | 0.01 | 0.01 |
| C22:0 | 0.39 ± 0.05 | 0.43 ± 0.05 | 0.51 ± 0.02 | 0.43 ± 0.01 | 0.30 | 0.01 | 0.01 |
| C14:1 | 0.01 ± 0.01 | 0.01 ± 0.01 | 0.01 ± 0.01 | 0.01 ± 0.01 | 0.70 | 0.01 | 0.01 |
| C16:1 | 0.37 ± 0.11 | 0.29 ± 0.10 | 0.48 ± 0.06 | 0.72 ± 0.38 | 0.20 | 0.01 | 0.01 |
| C18:1n9 | 22.70 ± 0.93 | 20.71 ± 1.00 | 21.25 ± 0.59 | 21.98 ± 1.09 | 0.49 | 0.01 | 0.01 |

Table 9. Effect of diet on the composition of fatty acids of lipids (% of total fatty acids) of leg muscles in 112-d-old common pheasants (mean ± s.e.m.).

| Item | Control (C) | Whole triticale (WT) | p Value |
|------|-------------|----------------------|---------|
|      | ♂ | ♀ | ♂ | ♀ | Diet | Sex | Diet × Sex |
| Number of birds | 8 | 8 | 8 | 8 |    |    |          |
| C12:0 | 2.24 ± 0.46 | 3.29 ± 0.18 | 1.55 ± 0.18 | 1.79 ± 0.21 | 0.00 | 0.01 | 0.11 |
| C14:0 | 2.48 ± 0.45 | 3.40 ± 0.22 | 2.28 ± 0.19 | 2.53 ± 0.16 | 0.00 | 0.01 | 0.11 |
| C15:0 | 0.15 ± 0.01 | 0.17 ± 0.01 | 0.17 ± 0.01 | 0.17 ± 0.01 | 0.70 | 0.01 | 0.01 |
| C16:0 | 31.10 ± 1.61 | 31.42 ± 0.88 | 38.48 ± 1.12 | 39.92 ± 1.13 | 0.00 | 0.01 | 0.11 |
| C17:0 | 0.34 ± 0.02 | 0.32 ± 0.02 | 0.27 ± 0.02 | 0.27 ± 0.03 | 0.30 | 0.01 | 0.01 |
| C18:0 | 11.05 ± 0.78 | 5.92 ± 1.16 | 2.19 ± 0.73 | 3.28 ± 0.61 | 0.00 | 0.01 | 0.11 |
| C17:0 | 0.15 ± 0.02 | 0.10 ± 0.01 | 0.09 ± 0.01 | 0.09 ± 0.01 | 0.00 | 0.01 | 0.11 |
| C14:1 | 0.07 ± 0.01 | 0.07 ± 0.01 | 0.16 ± 0.01 | 0.15 ± 0.02 | 0.00 | 0.01 | 0.11 |
| C16:1 | 1.03 ± 0.81 | 0.99 ± 0.09 | 3.28 ± 0.37 | 3.28 ± 0.61 | 0.00 | 0.01 | 0.11 |
| C18:1n9 | 23.41 ± 1.68 | 25.94 ± 0.47 | 30.89 ± 1.18 | 30.18 ± 0.82 | 0.00 | 0.01 | 0.11 |
| C20:0 | 0.66 ± 0.16 | 0.90 ± 0.12 | 0.73 ± 0.04 | 0.83 ± 0.07 | 0.99 | 0.01 | 0.01 |
| C22:0 | 0.15 ± 0.02 | 0.10 ± 0.01 | 0.09 ± 0.01 | 0.09 ± 0.01 | 0.00 | 0.01 | 0.11 |
| C14:1 | 0.07 ± 0.01 | 0.07 ± 0.01 | 0.16 ± 0.01 | 0.15 ± 0.02 | 0.00 | 0.01 | 0.11 |
| C16:1 | 1.03 ± 0.81 | 0.99 ± 0.09 | 3.28 ± 0.37 | 3.28 ± 0.61 | 0.00 | 0.01 | 0.11 |
| C18:1n9 | 23.41 ± 1.68 | 25.94 ± 0.47 | 30.89 ± 1.18 | 30.18 ± 0.82 | 0.00 | 0.01 | 0.11 |

*Control: commercial complete diet; WT: commercial complete diet (50%) plus whole triticale grain (50%) for final 41 days of rearing.
Contrary research results were recorded by Klišević et al. (2014) in broiler chickens and by Krystianiak and Torgowski (1998) in pheasants. In the study by Klišević et al. (2014), the introduction of whole triticale grain, during rearing of Ross 308 broiler chickens, at a fixed amount of 2% (1–35 d) or a varied amount depending on age (1–7 d = 4–8%; 8–21 d = 8–16%; 22–35 d = 15–25% of diet) reduced body weight in 35-d-old chickens by 5–14% (p < .05), as compared to control birds. The FCR value increased by 1–5%, as compared to control birds (p > .05). Neither the research performed on broiler pheasants (Krystianiak and Torgowski 1998) gave favourable production results. Replacing a complete diet containing 71.5% of ground triticale with a diet containing from 10 (13 wk) to 25% (16 wk) of triticale grain decreased the body weight gains and caused deterioration in feather quality.

**Carcass yield**

The results of our experiment indicate that replacing a pelleted complete commercial diet with a diet containing 50% whole triticale grain from 71 to 112 d of age caused a significant decrease in the percentage of breast muscle, and a significant increase in the percentage of skin with subcutaneous fat in the eviscerated carcasses from 112-d-old birds. Zapletal et al. (2017) found a significantly higher content (%) of breast muscles and gizzard in females than in males aged 100 d, as well as a significantly higher content of leg percentages in 100-d-old males compared to females. Sarica et al. (1999), who investigated the effect of slaughter age on pheasant carcass traits, found a significantly higher content (%) of leg muscles in the carcasses of males aged 13–15 wk compared to females of the same age. On the other hand, female pheasants had more abdominal fat and edible inner organs compared to males. Kokoszyński et al. (2012) observed no significant effect of sex on dressing percentage and on the content of carcass components.

**Meat quality**

The present research has demonstrated significantly higher hardness, chewiness and gumminess of breast muscles in common pheasants fed the diet with whole triticale grain, as compared to the control birds (commercial diet). Because hardness is calculated based on data obtained after moving the plunger parallel to the orientation of muscle fibres, it appears that the value of this parameter is determined to a greater extent by connective tissue (thickness of perimysium and endomysium). In the case of the WB test, because cutting is perpendicular to muscle fibre orientation, the impact of muscle fibres (myofibrillar component) is stronger. This is the possible reason for the discrepancies registered.

Al-Hajo et al. (2013) study on replacing maize with triticale grain reported no significant effect of triticale on the texture of breast muscles in 42-d-old Ross TM chickens either. Moreover, the compared chicken
groups did not differ in terms of juiciness, flavour, overall acceptance, and general acceptance. Our results for the texture of breast muscles in 112-d-old pheasants are thus contrary to those reported by Al-Hajo et al. (2013). Savage et al. (1987) found, however, that using triticale in the diet of breeder turkey toms increased the tenderness of cooked breast muscles. The tenderness of breast muscles in turkey toms (evaluated instrumentally or by consumers) increased with an increase in the amount of triticale in their diet.

The fat content of leg muscles from 112-d-old pheasants fed from 71 d a diet with 50% whole triticale grain was over three times as high as in the leg muscles of pheasants fed complete feed mixture alone. Kokoszyński et al. (2010) reported significantly lower weight and percentage of testes (0.3 g and 0.02% BW) in the body of 112-d-old pheasants fed, from 29 d, with a diet which had lower protein content and contained 30% of whole wheat grain instead of the complete feed mixture compared to pheasants receiving complete feed mixture alone (1.0 g and 0.1% BW, respectively). In the present study, after introducing whole triticale grain supply also decreased, which probably suppressed the development and hormonal activity of testes. Severin et al. (2007) found significantly higher content of fat in breast and leg muscles from 32-wk-old castrated pheasants compared to uncastrated pheasants. The introduction of whole triticale grain had no significant effect on the fat content of pheasant breast muscles, which was probably related to the markedly higher deposition of fat under the skin (significantly greater amount of skin with subcutaneous fat) in experimental birds compared to control birds, rather than in breast muscles. The breast muscles of the studied pheasants contained more protein and fat compared to the breast muscles of the pheasants in a study by Hofbauer et al. (2010).

Franco and Lorenzo (2013), whose study involved pheasants in a semi-extensive system, found lower protein content, and higher water content than those observed in our study, while Litwińczuk et al. (2007) observed no significant differences in the dry matter, ash, crude protein and intermuscular fat content of breast muscle and femoral muscle from farmed and wild pheasants.

The diet with whole triticale grain reduced (with a tendency towards significance) the amount of lauric acid (C12:0) and myristic acid (C14:0). However, this corresponded with a significant increase in the amount of palmitic acid (C16:0) and a significant decrease in linoleic acid (C18:2), which must be considered unfavourable for the pheasant meat consumer. Linoleic acid is essential to the diet because it is not synthesised by the human body. However, linoleic acid deficiency is rare and most often affects individuals on a low-fat diet (infants fed on defatted milk or intravenously fed patients). There was also found a slight increase in the amount of SFAs. Contrary research results were reported by Osek et al. (2013). Feeding broiler chickens with triticale instead of wheat or maize decreased the amount of SFAs (p < .05), including the hypercholesteremic fatty acids C14:0 and C16:0, while increasing C18:2 and C18:3 fatty acids, which have anticholesterol and antiatherogenic effects. The results of our experiment are, however, consistent with the analyses of the structure of fatty acids in the experiment by Kliševićiūtė et al. (2014). As also observed in our study, the authors found an increase in C16:0 and a reduction in the amount of C18:2 (except for the diet with 2% triticale) in lipids of breast muscles after introducing whole triticale grain in chicken diets. The lipids of breast and leg muscles from the compared groups of pheasants fed different diets from 71 to 112 d of age, did not contain several unsaturated fatty acids (including C18:3n3, C20:5n3 and C22:5n3), which was reported in earlier studies (Nuernberg et al. 2011; Kotowicz et al. 2012; Quaresma et al. 2016). However, the experiments cited above evaluated the meat of wild pheasants or pheasants kept in semi-extensive conditions. The diet of wild pheasants contains not only cereal grains and legumes, which constitute the main components of the compound feeds fed to pheasants in our study, but also green plants, insects, annelids, molluscs, and others. It also varies widely according to season of the year and bird age. This has a considerable effect on the fatty acid profile.

The diet with whole triticale grain showed a definitely greater effect on the content of fatty acids in the lipids of leg muscles. A significant increase in the amount of MUFA and a reduction in the amount of PUFA in pheasant leg muscles were not confirmed in the results reported by Osek et al. (2013) for broiler chickens. In contrast to the results of our analyses, the above authors did not find any large differences in the fatty acid content of the lipid fraction of leg muscles in chicken groups fed different diets (including a diet with triticale).

Our evaluation included also the contents of selected minerals in the meat of the compared pheasant groups. The diet composition is a factor which modifies the content of minerals in meat and internal organs in birds. Tucak et al. (2004) identified a higher content of phosphorus and calcium in breast and leg muscles of wild pheasants (free range) compared to farmed birds. In a different experiment (Kokoszyński
et al. 2014), replacing a complete diet for slaughter pheasants with 30% of whole wheat grain from week 4 to 16 significantly reduced the amount of zinc and calcium in breast muscles in 16-week-old birds. A significant sodium reduction and an increase in the amount of zinc in breast muscles in pheasants on a diet with whole triticale grain in the present study must be considered positive.

Conclusions
In summing up the results of the present study, it is noted that partly replacing a complete commercial diet for pheasants with whole triticale grain from day 71 did not have a significant effect on their body weight at the age of 112 days nor on the FCR value during rearing. The carcases of pheasants fed whole triticale grain diet showed lower muscle content (including a significant reduction of breast muscle content) and a higher fat content (a significant increase in the content of skin with subcutaneous fat). Irrespective of the diet composition, males showed a significantly higher body weight and measurements than females. The incorporation of whole triticale grain led to greater hardness, chewiness and gumminess, increased the content of palmitic acid and decreased the content of linoleic acid (unfavourable changes). This was accompanied, however, by a decreased sodium content and increased amount of zinc. Restricted feeding (triticale grain) resulted in relatively large changes in the chemical composition and fatty acid profile of leg muscles, with no significant effect on the content of minerals. Irrespective of the diet composition, the males of the compared groups did not differ in terms of the content of fatty acids and minerals, as compared to females, except for the content of linoleic acid, potassium, phosphorus, magnesium and zinc in breast muscle, lauric and behenic acid in leg muscle. Therefore, the dilution of the feed with whole triticale grain had no adverse impact on farm productivity, but had a negative effect on carcass composition while the effect on meat quality varied.

Disclosure statement
The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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