The effect of age on the growth rate of tissues and organs and the percentage content of edible and inedible components in Koluda White geese

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ABSTRACT The parts of carcasses of slaughtered animals that are not intended for human consumption are referred to as inedible components. The total percentage of edible to inedible components in the carcasses of different poultry species is an important economic consideration. The objective of this study was to determine the effect of age on the growth rate of tissues and organs and the percentage change in edible to inedible components in geese. A flock of 240 Polish Koluda White geese was raised to 12 wk of age. The percentage content of edible components increased \((P < 0.001)\) and the percentage content of inedible parts decreased \((P < 0.001)\) as the birds grew older. Among edible components, the most considerable changes were noted in the growth rates of muscle tissue \((10.5\% \text{ increase}; P < 0.001)\) and giblets \((5.1\% \text{ decrease}; P < 0.001)\). The percentage share of muscle tissue increased to 10 wk of age. Lean meat weight increased from 175 g in wk 2 to 1,482 g in wk 12. The increase in lean meat weight varied considerably between body parts. The proportion of breast muscles in total meat weight increased substantially \((by 26\%)\), whereas the proportion of leg muscles decreased \((by 34\%)\). An increase in the weight of skin with subcutaneous fat was observed until the end of the rearing period, but the percentage content of this component remained at a similar level throughout the experiment \((19.1 \text{ to } 19.6\%)\). The decrease in the percentage content of inedible components was mostly due to a decrease in the share of slaughter offal \((by approximately 6.5\%)\) because the proportion of bones remained at a stable level \((approximately 11.9 \text{ to } 11.5\%)\). The weight of abdominal fat, which can be classified as edible or inedible, increased significantly with age, from 15.1 g in wk 2 to 205.1 g in wk 12, accounting for 1.6\% and 4.0\% total BW, respectively.

Key words: geese, edible component, inedible component, growth, age

INTRODUCTION A major portion of a poultry carcass, referred to as the inedible portion \((i.e., \text{offal})\), is not intended for human consumption \((Romans et al., 1994; Ristic et al., 2006)\). This is an important economic consideration, particularly in view of the fact that global poultry meat production continues to increase \((Meeker and Hamilton, 2006; Korniłłowicz-Kowalska and Bohacz, 2011; Plumber and Kiepper, 2011)\). Body growth rate varies over time, and so does the growth rate of internal organs and tissues \((Gille et al., 1999)\), leading to changes in the proportions between edible and inedible components. From a biometric perspective, growth is defined as change in length, area, volume, or weight over time \((Specht, 1968)\). Age, species, and environmental conditions are the key factors affecting body growth rate.

Progress in poultry breeding and production has contributed to a faster growth rate of birds. Modern poultry lines are characterized by a high carcass yield and high feed conversion efficiency \((Havenstein et al., 2003, 2007; Case et al., 2010)\). Gallineceous birds differ considerably from waterfowl in many ways. For instance, the growth rate of Pekin ducks and geese is relatively fast at the early stages of life, and it slows down at the age of 7 wk in ducks and 10 wk in geese. Broiler chickens and turkeys grow more slowly than ducks and geese in the first few weeks of their life, and faster in the subsequent weeks. Waterfowl are characterized by a lower carcass yield, lower carcass lean content, and relatively high carcass fat levels \((Bochno et al., 2006)\). The share of poultry meat in total meat consumption is growing worldwide, but goose meat production remains at a low level of 2.7\% \((Pingel 2011)\). Total annual goose meat consumption is 0.4 kg per capita in Europe, and 1.7 kg per capita in some regions of China where 94.1\% of goose meat consumed annually worldwide is produced \((The Poultry Site, 2010)\). In waterfowl, abdominal fat

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can be classified either as an edible or as an inedible component, depending on the approach adopted. Abdominal fat is sometimes treated as slaughter offal at the abattoir because contemporary consumers show a distinct preference for low-fat meat products (Ristic, 2010). On the other hand, in many parts of the world it is used as raw material for manufacturing regional food specialties. The abdominal fat content of goose carcasses is higher than in other domestic poultry species (Janiszewska, 1993; Liu et al., 2011). Duck and goose fat is considered to be healthier than pork fat, due to higher concentrations of essential unsaturated fatty acids (Chartrin et al., 2006). However, some researchers emphasize the lower stability of unsaturated fats (Betti et al., 2009). Continuous efforts are being made to increase the lean meat content of the carcass and reduce fatness in waterfowl species (Łukaszewicz et al., 2008). The weight of fat and skin increases, at a different rate, throughout the growth period of waterfowl. The weight of muscle tissue increases rapidly to 9 wk of age in Pekin ducks and to 8 wk in geese, whereas bone growth is complete at 7 and 8 wk, respectively (Bochno et al., 2005, 2006). In poultry, edible components also include the heart, liver, and gizzard. Research results show that the share of inedible components decreases as birds grow older (Plavnik and Hurwitz, 1982; Pingel et al., 1987), which affects the ratio between edible and inedible weights.

The carcasses of 4 domestic poultry species, mostly chickens and turkeys, followed by geese and ducks, are used as raw materials for large-scale meat production. The total percentage content of edible versus inedible components in the carcasses of different poultry species is an important economic consideration because the waste load from meat processing plants has to be effectively managed or disposed of. Experiments performed on broiler chickens (Murawska et al., 2011), Pekin ducks (Murawska, 2012), and turkeys (Murawska, 2013) revealed considerable age-related changes in the percentage content of edible and inedible components, which proceeded at a different rate. In view of the above, the objective of this study was to determine the effect of age on the growth rate of tissues and organs and the percentage content of edible and inedible components in geese.

MATERIALS AND METHODS

The experiment used 240 Koluda White geese (120 males and 120 females). One-day-old sexed birds were weighed, marked with wing tags, and randomly placed in 16 pens, each with an area of 3.6 m²: 8 pens of males and 8 pens of females, 15 birds per pen. The birds were kept indoors on litter of finely chopped rye straw. The lighting program was as follows: 5 W/m² day and night on the first 3 d, 15 h of light per day (3 W/m²) from d 3 to wk 3, 12 h of light per day (2 W/m²) from wk 4 until the end of the experiment. For the first 4 wk, the birds were kept warm with infrared heaters, and temperature in pens was consistent with the relevant guidelines. The birds were fed ad libitum starter (until wk 5) and grower/finisher diets (from wk 6) containing 20.16 and 19.14% total protein and 12.34 and 12.10 MJ of ME, respectively. Geese were raised to 12 wk of age.

Birds were weighed on d 1 and then at 2-wk intervals until 12 wk. From the second week of rearing, every 14 d, 10 males and 10 females were selected randomly for slaughter. Geese were fasted for 10 h before slaughter (electrical stunning followed by cutting the jugular vein). Carcasses were bled hanging, for 5 min. The feathers were removed manually. Carcasses were scalded in water (for approximately 1 min, at approximately 63°C), plucked, and eviscerated. Live BW, carcass weight, and the weight of heart, liver, gizzard, and abdominal fat were determined. Carcasses were chilled for 18 h, and were divided into parts (neck, wings, breast, legs, back), which were weighed and dissected to separate lean meat, skin, fat, and bones (Ziołecki and Doruchowski, 1989).

Abdominal fat was classified as an edible (variant I) or inedible component (variant II). Slaughter offal weight was calculated as the difference between live BW and carcass weight including giblets, and abdominal fat in classification variant I. Carcass weight was determined after the removal of trachea, lungs, kidneys, and reproductive organs.

The edible portion consisted of lean meat (muscle tissue inclusive of intermuscular fat), skin with subcutaneous fat and giblets: gizzard, liver, and heart, and abdominal fat in variant I. The inedible portion consisted of bones and slaughter offal (blood, feathers, head, feet, gastrointestinal tract with the digesta and peri-intestinal fat) and other offal such as the trachea, lungs, kidneys, reproductive organs, and abdominal fat in variant II.

The statistical analysis included the characteristics of the analyzed traits: arithmetic means and SD and the determination of the significance of differences in mean values between age and sex groups. The results were verified by 2-way crossed ANOVA (A × B, 6 × 2). The significance of differences in age groups was estimated by Duncan’s D test. Differences were considered significant at $P < 0.05$. Computations were performed using Statistica 8.0. (StatSoft Inc., version 8, 2008).

RESULTS

The BW and carcass weight of geese increased steadily over the growth period. In wk 2, the BW of birds was 970 g, and it increased to 5,185 g in wk 12 ($P < 0.001$), whereas carcass weight increased from 511 g in wk 2 to 3,136 g in wk 12 ($P < 0.001$). Age-related changes were also observed in the weight of edible and inedible components, and the growth rate of the edible components was faster. When abdominal fat was classified as edible (variant I), the weights of edible and inedible compo-
components reached 482 g and 470 g, respectively, in wk 2, and 3,004 and 2,147 g in wk 12 ($P < 0.001$ and $P < 0.001$). When abdominal fat was classified as inedible (variant II), the respective values were as follows: in wk 2, 467 g and 485 g, in wk 12, 2,798 and 2,353 g ($P < 0.001$ and $P < 0.001$). The weight of body, carcass, edible, and inedible components was affected by sex. Mean values of the above traits were significantly higher in males than in females (Table 1; weight of body, $P < 0.001$; carcass, $P < 0.001$; edible components variant I, $P = 0.008$; inedible components variant I, $P < 0.001$; edible components variant II $P = 0.003$; inedible components variant II, $P < 0.001$).

The weight of individual edible parts in geese showed a rising tendency for different periods of time. The weight of lean meat, the most valuable component, increased until wk 10 ($P < 0.001$); in wk 2, it was determined at 175.4 g, and it increased 8.5-fold by wk 12 (to 1,482.0 g, Figure 1a). Muscle growth rate in different body parts of birds varied widely. Breast muscle weight increased 42.1-fold, whereas leg muscle weight increased only 4-fold (breast muscle weight and leg muscle weight in wk 2 and 12 were 11.3 and 473.5 g, respectively; Figure 1a).

The weight of skin and subcutaneous fat was increasing steadily during the entire growth period. Between wk 2 and 12, it increased 5.4-fold (from 186.3 to 1,017.3 g), and the highest growth rate (181.4%) was observed from 2 to 4 wk of age (Figure 1b). The weights of giblet components were increasing for different periods of time. Liver weight was increasing to wk 4 (from 34.6 g to 80.1 g), gizzard weight to 6 wk (from 64.8 to 190.5 g), and heart weight to 8 wk (from 5.9 to 28.3 g; Figure 1c, d, and e). Total muscle weight, gizzard weight, and heart weight were higher in males than in females (Figure 1a, f, and e). Abdominal fat weight increased 13.6-fold throughout the experiment, from 15.1 g in wk 2 to 205.9 g in wk 12 (Figure 1c). Sex had no effect on abdominal fat weight.

The weight of inedible components, including slaughter offal and bones, increased with age. Between wk 2 and 12, it increased 5.4-fold (from 186.3 to 1,017.3 g), and the highest growth rate (181.4%) was observed from 2 to 4 wk of age (Figure 1b). The values of the above traits were higher in males than in females (Figure 1a, c, d, and e). Total muscle weight, gizzard weight, and heart weight were higher in males than in females (Figure 1a, f, and e). Abdominal fat weight increased 13.6-fold throughout the experiment, from 15.1 g in wk 2 to 205.9 g in wk 12 (Figure 1c). Sex had no effect on abdominal fat weight.

The weight of edible components in the BW of geese increased with age, as follows: from 49.7% in wk 2 to 57.9% in wk 12.

### Table 1. Arithmetic means and SD for BW, carcass weight, and edible and inedible weights in 240 Koluda White geese

<table>
<thead>
<tr>
<th>Age (wk)</th>
<th>Sex</th>
<th>Weight (g)</th>
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<tr>
<td></td>
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<td>2</td>
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<tr>
<td></td>
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</table>

*Values followed by different letters (age) or * (sex) differ significantly: $P < 0.05$.  
1. Edible components with abdominal fat and inedible components without abdominal fat.  
2. Edible components without abdominal fat and inedible components with abdominal fat.
when abdominal fat was classified as edible: variant I (Figure 3a), and from 48.2% in wk 2 to 54.0% in wk 12 when abdominal fat was classified as inedible: variant II (Figure 3b). The percentage content of inedible parts decreased as geese grew older, in contrast to edible parts. In variant I, it reached 48.8% in wk 2 and 41.6% in wk 12 (Figure 3a), and in variant II, the respective values were 50.2 and 45.4% (Figure 4b).

The share of the most valuable edible component, lean meat, increased with age from 18.1% in wk 2 to 28.6% in wk 12 (Figure 4). In wk 2, breast muscles and leg muscles accounted for only 6.59% and almost 66.0% of total BW, respectively. At 12 wk of age, the proportion of breast muscles increased to 32.1%, whereas the proportion of leg muscles decreased to 31.9% (Figure 4). The percentage of skin and subcutaneous fat in total BW remained at a similar level of around 19.1 to 19.6% between wk 2 and 12 (Figure 4).

The percentage content of giblets in total BW decreased with age (in contrast to the remaining edible portions), from 10.1% in wk 2 to 5.8% in wk 12. Over that period, the share of gizzard and liver decreased by 3.1% (from 6.7 to 3.6%) and 2.0% (from 3.6 to 1.6%), respectively, whereas the share of heart remained stable at around 0.6% (Figure 4).

Inedible parts consist of slaughter offal and bones. The share of bones in the total BW of geese varied insignificantly throughout the experiment, and it was determined at 11.5%. Total slaughter offal content (without abdominal fat) decreased by 6.5%. In wk 2 and 12,
slaughter offal accounted for 35.1 and 28.6% of total BW, respectively. When abdominal fat was classified as inedible, the above values changed because abdominal fat content increased with age, from 1.6% in wk 2 to 4.0% in wk 12 (Figure 4).

DISCUSSION

Meat-type poultry production is aimed at obtaining high-quality raw material within a relatively short period of time. Poultry producers aim at increasing the...
growth rate of muscle tissue because lean meat is regarded to be the most valuable part of the carcass.

Very young goslings and ducklings have well-developed leg muscles and poorly developed breast muscles (Lilja, 1981). Bochno et al. (2006) reported that the weight of leg muscles decreases in geese from 2 wk of age, whereas the weight of breast muscles increases rapidly (until 10 wk). As a result, the percentage of meat located in the breast increases substantially, whereas leg muscle content decreases (Figure 4).

In poultry, an increase in the weight of muscle tissue and fat with skin is accompanied by a decrease in giblet content (Plavnik and Hurwitz, 1982; Murawska et al., 2011; Murawska, 2012). As demonstrated by Pingel et al. (1987), the development of the heart, liver, and gizzard in poultry ends at the early stages of life, which is why their share of the total BW decreases with age. A similar trend was observed in our study of Koluda White geese. The content of the gizzard, liver, and leg muscles stabilized in geese at 8 wk of age (Figure 4).

The share of giblets decreased in growing birds, and the highest decrease was noted in gizzard weight and liver weight. Heart weight (Figure 4) remained at a stable level of around 0.6%. Between wk 2 and 12, the BW of geese increased 5.3-fold (Table 1). Over that period, gizzard weight and liver weight increased 2.9- and 2.4-fold, respectively (Figure 1d, Figure 1f). As a result, the share of the above organs in total BW changed as well. The increase in heart weight (5.4-fold, Figure 1e) was similar to that determined for BW, and the percentage share of heart in total BW remained at a stable level over the entire growth period. Plavnik and Hurwitz (1982) also observed only minor changes in heart weight in growing broiler chickens. The weight of individual digestive organs in the body is significantly affected by the nutritional regimen. Geese are usually raised under extensive conditions and they are fed farm-made feed and green forage, so a well-developed gizzard is a priority in this species (Ristic et al., 1995). Numerous research efforts have been made to

Figure 4. Percentage content of particular components in the BW of Koluda White geese fasted for 12 h (%). *loss = BW loss during post-slaughter processing and dissection, **slaughter offal = blood, feathers, head, feet, and gastrointestinal tract.
intensiﬁy goose production and improve the efﬁciency of feed utilization in geese (Biesiada-Drzazga et al., 2010; Łukaszewicz et al., 2011).

The growth rate of osseous tissue decreases signiﬁcantly with age, in comparison with the growth rate of other tissues. Because neither bones nor slaughter offal are intended for human consumption, the decrease in their proportion is highly desirable. Environmentally safe disposal and management of poultry by-products is an important issue for both economic and sanitary reasons (Dalev, 1994; Plumber and Kiepper, 2011). In broiler chickens aged 1 to 6 wk, the proportion of bones and slaughter offal diminishes by approximately 2.5 and 12.5%, respectively (Murawska et al., 2011). In Pekin ducks aged 1 to 8 wk, slaughter offal content decreases, whereas bone content remains relatively stable (Murawska, 2012). A similar trend can be observed in Koluda White geese. The growth pattern of BW and bone weight was similar until 12 wk of age (5.3- and 5.2-fold increase, respectively). Bone weight increased until wk 8 (Figure 2d), and the proportion of bones in total BW remained at a similar level throughout the growth period (Figure 4). Between wk 2 and 12, the growth pattern of slaughter offal was as follows: slaughter offal weight increased rapidly (2.9-fold) from wk 2 to 4, then stabilized and remained relatively unchanged until wk 10, to increase again from wk 10 to 12 (Figure 2a and b). The main reason for the increase in slaughter offal weight in geese aged 10 to 12 wk could be enhanced peri-intestinal fat deposition (Wilkiewicz-Wawro, 1997). Despite the increase in slaughter offal weight, its proportion in total BW decreased by around 6.5% from wk 2 to 12 (Figure 4).

The proportion between edible and inedible parts is less desirable in geese than in gallinaceous birds. Significant differences between the 4 poultry species with regard to the above trait have also been noted by Michalik (1994), who found that geese had the lowest proportion of edible components in the carcass (geese, 57%; ducks and chickens, 60%; turkeys, 64%). The results of the present study corroborate the ﬁndings of Michalik (1994; Figure 3a and b). However, it should be stressed that a comparison of the current results with the ﬁndings of other authors could be difﬁcult due to certain methodological differences regarding carcass preparation (carcass with or without the neck and wing tips) and the classiﬁcation of abdominal fat as an edible or inedible component. The increase in edible weight observed in Koluda White geese from wk 2 to 12 resulted primarily from an 8.5-fold increase in muscle weight and a 5.4-fold increase in the weight of skin with subcutaneous fat. Breast muscle weight increased as much as 42.1-fold. Total giblets weight increased 2.9-fold. The growth of inedible components was less rapid. Bone weight increased 5.2-fold (Figure 2d), and slaughter offal increased 4.2-fold (Figure 2a) or 4.6-fold, depending on the classiﬁcation of abdominal fat (Figure 2b). The growth rates of individual tissue components were reﬂected in the percentage content of edible and inedible parts in the BW of birds. The percentage content of edible components increased and the percentage content of inedible components decreased. Greater changes in the ratio between edible and inedible weights can be observed in broiler chickens and turkeys (Murawska et al., 2011; Murawska, 2013). In Pekin ducks aged 1 to 8 wk, the proportion of edible weight in total BW increases by 17% (Murawska, 2012).

It may be concluded that the proportions of edible and inedible portions in growing Koluda White geese undergo desirable changes. The percentage content of edible components increases and the percentage content of inedible parts decreases. Among edible components, the most considerable changes were noted in the growth rates of muscle tissue (10.5% increase) and giblets (5.1% decrease). The proportion of breast muscles in total meat weight increased substantially (by 26%), whereas the proportion of leg muscles decreased (by 34%). The percentage content of skin with subcutaneous fat remained at a similar level throughout the experiment (19.1 to 19.6%).

The decrease in the percentage content of inedible components noted in Koluda White geese was mostly due to a decrease in the share of slaughter offal (by 6.5%) because the proportion of bones remained at a stable level (approximately 11.9 to 11.5%).

The edible and inedible weights may vary, depending on whether abdominal fat is classiﬁed as edible or inedible, because the weight of abdominal fat increases considerably with age (from 15.1 g in wk 2 to 205.1 g in wk 12).

REFERENCES