The effect of age on the growth rate of tissues and organs and the percentage content of edible and nonedible carcass components in Pekin ducks

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ABSTRACT Age has a significant effect on carcass tissue composition, which is an important consideration in slaughter animals because age-related changes are observed in both edible and nonedible carcass components. In this study, the above changes were analyzed in Pekin ducks. The weight of individual edible and nonedible components in ducks increased for different periods of time, and the growth rate of tissue components varied considerably. The percentage content of edible components in the total BW of Pekin ducks increased from 42.8% in wk 1 to 59.9% in wk 8, mostly due to a significant (13.3%) increase in the share of muscle tissue. The percentage content of skin and subcutaneous fat remained at a stable level from wk 4, whereas the share of giblets decreased from 6 wk of age. The percentage content of nonedible components in the total BW of Pekin ducks decreased from 48.6% in wk 1 to 34.6% in wk 8, mainly due to a decrease in slaughter offal content (from 39.7% in wk 1 to 27.2% in wk 8). Minor changes were noted in the proportion of bones (11.7% in wk 1 and 10.9% in wk 8).

Key words: ducks, edible components, nonedible components, growth, age

INTRODUCTION

Age has a significant effect on body growth rate and carcass tissue composition. From a biometric perspective (Specht, 1968), growth is defined as change in length, area, volume, or weight over time. Carcass tissue composition is an important consideration in farm animals, including poultry. The rise in carcass dressing percentage, observed recently, results primarily from an increase in the content of edible portions in the total BW of birds but also from a decrease in the content of nonedible components (Shahin, 2000). As birds grow older, the percentage content of lean meat and fat with skin in the carcasses increases, and the percentage content of bones decreases (Bochno et al., 2003; Bochno et al., 2006). The rate of the above changes is particularly fast in broiler chickens and turkeys (McKay et al., 2000). Continuous efforts are being made to increase the lean meat content of the carcass and reduce fatness in waterfowl species, in which subcutaneous fat may account for up to 76% total fat content (Pingel, 2006). The weight of fat and skin increases at a different rate throughout the growth period of birds. The weight of muscle tissue increases quickly to 8 wk of age in geese and to 7 wk of age in Pekin ducks (Bochno et al., 2005), whereas bone growth is complete at 7 and 8 wk, respectively. In poultry, edible components include meat, skin with subcutaneous fat, and giblets (gizzard, liver, heart), and sometimes also abdominal fat in waterfowl. Fast-growing birds need concentrated feeds in an adequate amount and appropriate form. Changes in the nutritional regimen affect the function of gastrointestinal tract segments and the weight of internal organs (Plavnik and Hurwitz, 1982; Havenstein et al., 1994; Fan et al., 2008; Vegani and Korver, 2008). The percentage content of offal not intended for human consumption, such as feathers, blood, head, and other, also increases with age (Ristic et al., 2006). Experiments performed on broiler chickens revealed considerable age-related changes in the percentage content of edible and nonedible components, which proceeded at a different pace (Murawska et al. 2011). Therefore, it seemed interesting to examine such relationships in other domestic fowl species, in particular ducks, because the share of duck meat in total poultry meat production has been declining in recent years. In view of the above, the objective of this study was to determine the effect of age on carcass tissue composition, the percentage content of selected organs intended for consumption, and nonedible components in Pekin ducks.

MATERIALS AND METHODS

The experimental materials comprised 220 Pekin ducks (sex ratio of 1:1) raised to 8 wk of age and fed ad
libitum standard diets: 1 to 14 d, starter (20.0% protein, 2,700 kcal/kg of ME); 15 to 28 d, grower (18.3% protein, 2,749 kcal/kg of ME); from d 29 until the end of the experiment, grower (17.0% protein, 2,798 kcal/kg of ME). Throughout the experiment, all birds were weighed individually at 7-d intervals, and total feed intake was recorded.

Starting from the first week of rearing, every 7 d, 10 males and 10 females were selected randomly for slaughter and postslaughter analysis. Ducks were fasted for approximately 12 h and were slaughtered by cervical dislocation. Carcasses were bled hanging, for around 5 min. To facilitate plucking, carcasses were scalded in water (63°C) for 1 min. The feathers were removed manually. Following the removal of the head (between the occipital condyle and the atlas) and feet (at the carpal joint), carcasses were eviscerated, removing the gastrointestinal tract, including the liver, heart, trachea, perirectal fat and abdominal fat. Live body weight, carcass weight after bleeding and plucking, and the weight of head, feet, hot carcass, heart, liver, gizzard, gastrointestinal tract (including the digesta and perirectal fat), excluding the gizzard), trachea, and abdominal fat were determined. Carcasses were chilled for approximately 18 h and were divided into parts (neck, wings, breast, legs, back) that were weighed and dissected to separate lean meat with intermuscular fat, skin with subcutaneous fat, and bones (Ziołecki and Doruchowski, 1989).

Edible components comprised lean meat (muscle tissue inclusive of intermuscular fat), skin with subcutaneous fat, and giblets (gizzard, liver, and heart). Nonedible components comprised bones, slaughter offal (blood, feathers, head, feet, gastrointestinal tract with the digesta, and perirectal fat) and other offals, (trachea, lungs, kidneys, and reproductive organs), and abdominal fat.

Because modern consumers tend to avoid eating fat, and the aim of numerous selection and breeding programs is to reduce poultry carcass fatness, abdominal fat was classified as nonedible offal.

The statistical analysis included the characteristics of the analyzed traits (arithmetic means and standard deviations or SEM) 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, 2×8). The significance of difference in age groups was estimated by Duncan’s D test. Computations were performed using STATISTICA 8.0 software (Statistica, 2008).

RESULTS

The BW and carcass weight of ducks increased steadily over the growth period. In wk 1, the BW of birds was 210 g, and it increased to 3,452 g in wk 8, whereas carcass weight increased from 99 g in wk 1 to 2,303 g in wk 8. The patterns of changes in BW and carcass weight in age groups were comparable (Table 1).

Age-related changes were also observed in the weight of edible and nonedible components, which in wk 1 amounted to 90.2 g and 108.4 g, respectively. Both edible and nonedible weights increased with age, but the weight of edible portions increased much faster. At 8 wk of age, the weight of edible and nonedible components reached 2,070.7 g and 1,312.7 g, respectively (Table 1).

The weight of body, carcass, edible, and nonedible components was significantly affected by sex. Mean values of the above traits were significantly higher in males than in females (Table 1). An interaction between age and sex was noted with respect to BW and the weight of nonedible parts. Body weight and the weight of nonedible components were similar in males and females at 4 and 7 wk of age. A significant increase in the BW of females was observed until wk 7 (Figure 1).

The weight of individual edible parts in Pekin ducks showed a rising tendency for different periods of time. The weight of lean meat, the most valuable component, was increasing until the end of rearing, from 35.8 g in 1-wk-old birds to 1,047.1 g at 8 wk (a 29.3-fold increase; Figure 2a). Muscle growth rate in different

Table 1. Arithmetic means and SD for BW, carcass weight, and edible and nonedible weights in Pekin ducks

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1Values followed by different letters (age) or * (sex) differ significantly; for capital letters or **, α = 0.01, and for small letters or *, α = 0.05.
body parts of birds varied widely. Breast muscle weight increased 188-fold, whereas leg muscle weight increased only 13.6-fold over 8 wk (breast muscle weight and leg muscle weight in wk 1 and 8 was 1.9 g and 349.6 g vs. 20.9 g and 283.9 g, respectively; Figure 3a). In 1-wk-old ducklings, breast muscles and leg muscles accounted for 5.2% and as much as 58.2% total muscle weight, respectively. At 8 wk of age, the proportion of breast muscles increased to 33.4%, while the proportion of leg muscles decreased to 27.1% (Figure 3b).

A significant increase in the weight of skin and subcutaneous fat was observed until wk 7. Between 1 and 7 wk of age, the weight of skin and subcutaneous fat increased 25.7-fold (from 32.9 g to 847.8 g; Figure 2b). Heart weight was increasing until 7 wk of age (from 1.1 g to 21.7 g), liver weight until 5 wk (from 9.1 g to 61.2 g), and gizzard weight until the end of the rearing period, that is, to 8 wk (from 10.2 g to 97.4 g; Figure 2c,d,e). Total muscle weight, breast muscle weight, leg muscle weight, and gizzard weight were higher in males than in females (Figures 2a,e).

The weight of nonedible components increased nearly 12.1-fold (from 108.4 g in wk 1 to 1,312.7 g in wk 8; Table 1), including an 11.2-fold increase in slaughter offal weight (from 83.7 g to 937.8 g) and a 15.2-fold increase in bone weight (from 24.7 g to 374.9 g). Among slaughter offal, the most profound changes were noted in the weight of feather and abdominal fat. Between 1 and 8 wk of age, feather weight increased approximately 65-fold (from 2.5 g to 158.9 g; Figure 4b). The carcasses of 1-wk-old birds contained only 0.37 g abdominal fat, and abdominal fat weight increased around 200-fold by wk 8 (to 63.8 g; Figure 4f). The growth rate of the remaining nonedible components was slower. Between 1 and 8 wk of age, blood weight increased from 18.4 g to 204.2 g (Figure 4a), head weight from 21.6 g to 166.3 g (Figure 4c), shank weight from 12.3 g to 88.0 g (Figure 4d), and gastrointestinal tract weight from 28.6 g to 260.5 g (Figure 4e). The weights of head, shanks, and bones were found to be affected by sex. The values of the above traits were higher in males than in females (Figures 4c,d,g).

To better illustrate the discussed age-related changes in growing Pekin ducks, edible and nonedible weights were expressed as a percentage of total BW. The values of the above traits were influenced by age, but not by sex. Thus, data are given for both males and females (Figures 3b, 5, 6). The percentage content of edible components in the BW of ducks increased with age (Figure 5). In birds aged 1 wk and 8 wk, edible components accounted for 42.8% and 59.9% total BW, respectively. The percentage content of nonedible parts decreased as the ducks grew older, from 48.6% in wk 1 to 34.6% in wk 8 (Figure 5).

The share of the most valuable edible component, muscle tissue, increased with age, from 17.1% total BW in wk 1 to 30.4% in wk 8 (Figure 6). In wk 1, breast muscles and leg muscles accounted for 0.9% and 9.9% total BW, respectively. At 8 wk of age, the proportion of breast muscles increased to 10.2%, while the proportion of leg muscles decreased to 8.2%. The percentage of skin and subcutaneous fat in total BW increased from 15.6% in wk 1 to 24.3% in wk 8, but the increase was significant only during the first 3 wk (7.5% between 1 and 3 wk of age, and 1.2% between 3 and 8 wk; Figure 6).

The percentage content of giblets decreased with age (in contrast to the remaining edible portions), from 10.1% total BW in wk 1 to 5.3% in wk 8. Over that period, the share of the liver, gizzard and heart decreased by 2.5% (from 4.3% to 1.9%), 2.0% (from 4.8% to 2.8%), and 0.4% (from 1% to 0.65%), respectively (Figure 6).

Nonedible parts comprise slaughter offal and bones. The share of bones in the total BW of ducks varied insignificantly throughout the experiment, and it was determined to be 11.7% in wk 1 and 10.9% in wk 8. Over that period, the share of the liver, gizzard and heart decreased by 2.5% (from 4.3% to 1.9%), 2.0% (from 4.8% to 2.8%), and 0.4% (from 1% to 0.65%), respectively (Figure 6).

The estimated world’s duck meat production ranges from around 4.3% (Bernacki et al., 2008) to 7% (Pingen, 2006) of the total poultry meat production. Duck meat is popular among gourmets, but its consumption remains low. China and Southeast Asian countries are global leaders in duck meat production (Ali et al., 2007). In most European countries, excluding France, annual duck meat consumption oscillates around 0.5 kg per capita (Bernacki et al., 2008). In comparison with chickens and turkeys, Pekin ducks and geese (Bochno et al., 2005) are characterized by a lower muscle con-

**DISCUSSION**

The estimated world’s duck meat production ranges from around 4.3% (Bernacki et al., 2008) to 7% (Pingen, 2006) of the total poultry meat production. Duck meat is popular among gourmets, but its consumption remains low. China and Southeast Asian countries are global leaders in duck meat production (Ali et al., 2007). In most European countries, excluding France, annual duck meat consumption oscillates around 0.5 kg per capita (Bernacki et al., 2008). In comparison with chickens and turkeys, Pekin ducks and geese (Bochno et al., 2005) are characterized by a lower muscle con-
tent and a higher fat content. Research results show that despite long-term selection aimed at eliminating atavistic features, fat deposition as a reserve of energy is still observed in modern commercial duck and goose lines (Fan et al., 2008; Tsuji et al., 2008). The proportions between edible and nonedible parts are also less desirable in ducks and geese, compared with turkeys and chickens. Pour (1991) demonstrated that the content of edible components in total BW in 4 poultry species ranged from 47% to 60% (turkeys, 60.0%; chickens, 50.0%; ducks and geese, 47%, at slaughter age). Michalik (1994) also studied the above 4 poultry species and found that at slaughter age turkeys had the highest proportion of edible components in the carcass (over 64%), followed by ducks, chickens (around 60%), and geese (around 57%). A comparison of the present results with the findings of other authors would 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 a nonedible component.

Body growth rate varies over time and so does the growth rate of internal organs and tissue components (Reeds et al., 1993; Gille et al., 1999). Internal organs

Figure 2. Arithmetic means and ± SEM for the edible portion (grams). a) Lean meat, b) skin and subcutaneous fat, c) heart, d) liver, e) gizzard. Values followed by different letters (age) or * (sex) differ significantly; for capital letters or **, α = 0.01, and for small letters, α = 0.05.
develop at a different rate, depending on the functions they perform. Nervous tissue develops first, followed by osseous tissue, muscle tissue, and adipose tissue (Pals-son, 1955; Reeds et. al., 1993). This affects the proportions between edible and nonedible weights. From wk 1 to 8, the BW of ducks increases over 16-fold, the total weight of edible parts in ducks increases approximately 23-fold, while the total weight of nonedible parts increases approximately 12-fold (Table 1). The proportions between tissue components change as well over that period. In 1-wk-old ducks, edible components consist of approximately 40% muscle tissue, 37% skin and fat, and 24% giblets. At 8 wk of age, meat accounts for 50% total edible weight—skin and fat for 41%, and giblets for only 9%. Greater changes are observed in chickens over the same period: the weight of edible and nonedible components increases 37-fold and 18-fold, respectively (Murawska et al., 2003). In Pekin ducks, lean weight increases quickly until about 9 wk of age, whereas bone weight increases to only 6 wk. In both ducks and geese, the share of leg muscles decreases and the share of breast muscles increase with age (Bochno et al., 2005). Such a trend was also noted in the present study. Pekin ducks are characterized by a higher fat content and a lower lean content than Muscovy ducks (Omojola, 2007). In poultry, an increase in the weight of muscle tissue and fat with skin is accompanied by a decrease in giblets content (Plavnik and Hurwitz, 1982). 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. Plavnik and Hurwitz (1982) reported that changes in the content of the above internal organs occur at a different rate and that heart weight undergoes minor age-related changes. A similar trend was observed in our study. The share of giblets decreased from 10.1% in wk 1 to 5.35% in wk 8, and the highest decrease was noted in liver weight, followed by gizzard weight and heart weight. The content of the liver and gizzard stabilized at 6 wk of age, and heart content stabilized already at 3 wk (Figure 6). Nitsan et al. (1991) and Nir et al. (1993) demonstrated that in fast-growing broilers, the percentage share of digestive organs decreases starting from 9 d of age, and the changes occur at a faster rate than in slow-growing birds. The share of digestive organs in total BW is also influenced by nutritional regimen (Amerach et al. 2007; Obum, 2008). According to Shahin (2000), the weights of the heart, liver, and gizzard are highly correlated with BW in Pekin ducks, yet body growth rate and the growth rate of internal organs may differ widely. For instance, between wk 1 and 8, the BW of male and female ducks increased 16.4-fold (Table 1), while the weights of heart, liver, and gizzard increased over this period approximately 10.3-fold, 7-fold, and 9.5-fold, respectively (Figure 2c,d,e).

Figure 3. Arithmetic means and ± SEM for a) weight of breast muscles and leg muscles (grams), b) percentage share of breast muscles and leg muscles in total weight, subject to the age of birds. Values followed by different letters (age) differ significantly; for capital letters, $\alpha = 0.01$, and for small letters, $\alpha = 0.05$.  

Broiler chickens grow more slowly than ducks and geese in the first few weeks of their life and faster in the subsequent week. This is due to differences in the growth rates of different tissues in the above species. The fat content of the total BW increases over time; therefore, birds raised for meat are slaughtered at a specified age. Age-related changes in carcass tissue composition are accompanied by changes in the distribution of lean meat, skin with fat, and bones in carcass parts. In 2-wk-old broiler chickens, approximately 36% lean meat is deposited in the breast and 35% in the legs. The percentage content of meat in the breast increases to 44% at 12 wk of age, and the percentage content of meat in the legs decreases to 32% (Bochno et al., 2003). Very young goslings have well-developed leg muscles and poorly developed breast muscles. However, from 2 wk of age, the weight of leg muscles decreases, and the weight of breast muscles increases rapidly (until approximately 10 wk). As a result, the percentage of meat located in the breast increases substantially (Bochno et al., 2006). In Pekin ducks, lean weight increases quickly until about 9 wk of age, whereas bone weight increases to only 6 wk. In both ducks and geese, the share of leg muscles decreases and the share of breast muscles increase with age (Bochno et al., 2005). Such a trend was also noted in the present study. Pekin ducks are characterized by a higher fat content and a lower lean content than Muscovy ducks (Omojola, 2007). In poultry, an increase in the weight of muscle tissue and fat with skin is accompanied by a decrease in giblets content (Plavnik and Hurwitz, 1982). 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. Plavnik and Hurwitz (1982) reported that changes in the content of the above internal organs occur at a different rate and that heart weight undergoes minor age-related changes. A similar trend was observed in our study. The share of giblets decreased from 10.1% in wk 1 to 5.35% in wk 8, and the highest decrease was noted in liver weight, followed by gizzard weight and heart weight. The content of the liver and gizzard stabilized at 6 wk of age, and heart content stabilized already at 3 wk (Figure 6). Nitsan et al. (1991) and Nir et al. (1993) demonstrated that in fast-growing broilers, the percentage share of digestive organs decreases starting from 9 d of age, and the changes occur at a faster rate than in slow-growing birds. The share of digestive organs in total BW is also influenced by nutritional regimen (Amerach et al. 2007; Obum, 2008). According to Shahin (2000), the weights of the heart, liver, and gizzard are highly correlated with BW in Pekin ducks, yet body growth rate and the growth rate of internal organs may differ widely. For instance, between wk 1 and 8, the BW of male and female ducks increased 16.4-fold (Table 1), while the weights of heart, liver, and gizzard increased over this period approximately 10.3-fold, 7-fold, and 9.5-fold, respectively (Figure 2c,d,e).
As a result, the share of the above organs in total BW changed as well. Similar relationships were observed in broiler chickens by Kamińska (1986).

Slaughter offal and bones are classified as nonedible parts. The share of nonedible components decreases substantially as birds grow older. The intensity of age-

Figure 4. Arithmetic means and ± SEM for the nonedible portion (grams). a) Blood, b) feather, c) head, d) shanks, e) gastrointestinal tract, f) abdominal fat, g) bones. Values followed by different letters (age) or * (sex) differ significantly; for capital letters or **, $\alpha = 0.01$, and for small letters and *, $\alpha = 0.05$. 
related changes in the proportions of nonedible parts varies among poultry species. The growth rate of osseous tissue decreases significantly with age, in comparison with the growth rate of other tissues (Bochno et al., 2003; Murawska et al., 2005). In 1-wk-old chickens, nonedible components account for 47% total BW (bones, around 12%; slaughter offal, 35.0%). By 8 wk of age, bone and offal content decreases by 3% and over 14%, respectively (Murawska et al., 2011). In Pekin ducks aged 1 wk, the percentage content of nonedible parts is higher than the percentage content of edible components (48.6% and 42.8%, respectively; Figure 5). The percentage content of nonedible components diminishes until 8 wk of age, mostly due to a decrease in slaughter offal content, because bone content remains relatively stable. According to Pingel et al. (1987), the development of the gastrointestinal tract, head, and blood is completed at the early stages of life, and therefore their share decreases most with age. Kamińska (1986) studied the growth dynamics of chickens and found that the proportion of head in their BW decreased already during the first 7 d of their life, while the proportion of feet decreased at a much slower rate. A similar trend was noted in the present study.

In contrast to the remaining slaughter offals, the proportions of feathers and abdominal fat considerably increased in growing ducks (Figure 6). Plumage development is particularly important in ducks and geese because carcass quality deteriorates during the feathering process, which affects the processing suitability of raw material. In our study, the percentage content of feathers in the BW of Pekin ducks increased from 1.2% to 4.6% over the experimental period (Figure 6). In birds at slaughter age, feathers make up 4.2, 4.5, and 5.4% live BW in turkeys, chickens, and ducks, and geese, respectively. The rate of feathering is species-specific, affected by nutrition, and determined genetically (Leeson and Walsh, 2004).
In poultry, fat deposition in the lower parts of the body is part of adaptation to the environmental conditions. The carcasses of 1-wk-old birds contain only around 0.2% abdominal fat, and abdominal fat weight increases approximately 200-fold by wk 8 to 1.9%. Similar values have been reported for broiler chickens (Murawska et al., 2011) and they are not high for ducks (Fan et al., 2008). In broiler chickens of modern strains, at 6 wk of age, abdominal fat content oscillates around 2%, and it is approximately 5-fold higher than in layers (Murawska et al., 2005). Duck and goose fat is considered to be healthier than pork fat, due to higher concentrations of essential unsaturated fatty acids (Ch artırı̈n et al., 2006; Pingel, 2006). However, some researchers emphasize the lower durability of the former (Leskanich et al., 1997; Huang et al., 2006; Betti et al., 2009). Abdominal fat is treated as slaughter offal because contemporary consumers show a distinct preference for low-fat meat (Kostecka, 2008; Ristic, 2010).

In ducks, abdominal fat weight increases over the entire growth period, thus increasing both the weight of undesirable offal and overall production costs.

In Pekin ducks, changes in the growth rates of internal organs and tissues lead to changes in the percentage content of edible and nonedible components in total BW. The content of the most valuable tissue components, muscles and skin with subcutaneous fat, increases over longer periods of time, compared with nonedible portions. The percentage content of edible components in total BW increases mostly due to a significant increase in the share of muscle tissue. The weight of skin and subcutaneous fat increases over the entire rearing period, and their content remains at a stable level from 4 wk of age. The content of nonedible components reduces with age, mostly due to a decrease in slaughter offal, as bone content changes insignificantly.

REFERENCES