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Age-related Changes in the Percentage Content of Edible and Non-edible Components in Broiler Chickens

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ABSTRACT : The objective of this study was to determine age-related changes in the percentage content of edible and non-edible components in broiler chickens. The experimental materials comprised 240 Ross 308 chicks (sex ratio 1:1) raised to 10 weeks of age and fed standard diets *ad libitum*. Starting from the first week of rearing, every 7 days 10 males and 10 females were selected randomly for slaughter and post-slaughter analysis. The data obtained were verified statistically. The percentage content of edible components increased and the percentage content of non-edible parts decreased as the chicks grew older. In broilers aged 1 week and 10 weeks, edible components accounted for 47.0% and 66.4% total body weight, respectively. The share of muscle tissue increased considerably over this period, from 30.9% total body weight in week 1 to 52.4% in week 10. An increase in the percentage of skin and subcutaneous fat was observed for the first three weeks only, while the percentage content of giblets (in contrast to the remaining edible parts) decreased with age. For non-edible parts, the share of bones diminished by 2.5% and the proportion of slaughter offal reduced by 13.8%. A rising tendency was noted with respect to feathers and abdominal fat, while the content of the remaining offal decreased. (**Key Words :** Chickens, Edible Parts, Non-edible Components, Age)

INTRODUCTION

The proportions between body parts and carcass tissue components change with age (Murawska and Bochno, 2007; Murawska and Bochno, 2008). The growth rate of tissue components in carcass parts also varies during the growth period (Bochno et al., 2003; Murawska et al., 2005; Bochno et al., 2006). Internal organs develop at a different rate, depending on the functions they perform (Reeds et al., 1993).

Selection progress in broiler chickens has contributed to an increase in their body weight and to a shorter production period, mostly due to a faster growth rate (Flock and Seemann, 1993; Havenstein et al., 1994b; McKay et al., 2000; Taylor, 2007). The lean meat content of the carcass, in particular of breast, has increased greatly as well (McKay et al., 2000; Pym, 2000). The rise in carcass dressing percentage, observed recently, results primarily from an increase in the content of edible portions in the total body weight of broilers, but also from a decrease in the content of non-edible components. Commercial mixed diets with high nutrient concentrations fed to chickens affect the function and weight of gastrointestinal tract segments (Plawnik and Hurwitz, 1982; Shires et al., 1987; Nir et al., 1993; Obun, 2008). Thus, full expression of the genetic potential of broilers is largely dependent on their nutrition (Lilburn, 1985; Havenstein et al., 1994b).

From the standpoint of both producers and consumers, the proportion of edible components in broiler carcasses should be as high as possible. The ratio between edible and non-edible parts is affected by the growth rate of tissues, which varies over time. In view of the above and due to a limited amount of available literature on the topic, the objective of the present study was to determine age-related changes in the proportions of edible and non-edible components in broiler chickens.

MATERIALS AND METHODS

The experimental materials comprised 240 sexed Ross 308 chicks (sex ratio 1:1) raised to 10 weeks of age and fed

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ad libitum standard diets, starter (0-2 weeks), grower (2-7 weeks) and finisher (from 7 weeks until the end of the experiment). The diets contained 12.3, 12.6 and 12.6 MJ energy and 20.5, 19.0 and 18.5% protein, respectively. One-day-old chicks were marked with wing tags and were randomly placed in pens (males and females separately). Birds were kept indoor, on straw litter, in accordance with standard production technology.

Starting from the first week of rearing, every 7 days, 10 males and 10 females were selected randomly for slaughter and post-slaughter analysis. Chickens were fasted for approximately 12 h, and were slaughtered by cervical dislocation. Carcasses were bled (by cutting the jugular vein) hanging, for around 5 minutes. To facilitate plucking, carcasses were scalded in water (63°C) for 1 minute. The live body weight of birds as well as carcass weight after bleeding and plucking were determined. 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 pancreas, spleen, liver, heart, periintestinal fat and abdominal fat. The weight of head, feet, hot carcass, heart, liver, gizzard, gastrointestinal tract (including the digesta, periintestinal fat, pancreas and spleen, excluding the gizzard) and abdominal fat was determined. Carcasses were chilled at 4°C for approximately 18 hours, and were divided into parts (breast, legs, wings, back, neck) which were weighed and dissected.

Edible cuts comprised lean meat (muscle tissue inclusive of intermuscular fat), skin with subcutaneous fat and giblets-gizzard, liver and heart. Non-edible cuts comprised bones and slaughter offal, including blood, feathers, head, feet, gastrointestinal tract with the digesta and periintestinal fat, abdominal fat and other offals, trachea, lungs and reproductive organs, pancreas, spleen and kidneys.

The statistical analysis included the characteristics of the analyzed traits-arithmetic means ($\overline{X}$) and standard deviations (SD) and the determination of the significance of differences in mean values between age and sex groups, by Duncan's D test. The results were verified by two-way crossed ANOVA. Computations were performed using STATISTICA 8.0 software.

RESULTS

The body weight and carcass weight of birds increased steadily over the growth period. In week 1, the body weight of birds was 162 g, and it increased to 4,853 g in week 10, whereas carcass weight increased from 90.7 g in week 1 to 3,687 g in week 10. The patterns of changes in body weight and carcass weight in age groups were comparable (Table 1).

An increase in edible and non-edible weights was observed until the end of the rearing period, but statistically significant differences were noted only until 9 weeks. One-week-old chicks were characterized by similar weight of edible and non-edible portions 76.5 g and 73.5 g respectively, while at 9 weeks the weight of edible cuts reached 3,107 g and the weight of non-edible components 1,463 g (Table 1).

The weight of body, carcass, edible and non-edible components was significantly affected by gender. 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 body weight, carcass weight and edible and non-edible weights. Until week 4, the weight of body, carcass, edible and non-edible components was similar in males and females, whereas in subsequent weeks it was higher in males than in females. The age x sex interaction resulted from sexual dimorphism which manifested itself at 4 weeks

Table 1. Arithmetic means ($\overline{X}$) and standard deviations (SD) for 12 h fasted body weight, carcass, edible and non-edible weights in broiler chickens

Specification	Statistical measures	Age of birds (weeks)										Sex		Interaction
		1	2	3	4	5	6	7	8	9	10	♂	♀	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Weight of (g):														
Body	$\overline{X}$	162.40^{A}	441.00^{B}	921.00^{C}	1,388.00^{D}	2,239.00^{E}	2,907.00^{F}	3,674.00^{G}	4,289.00^{H}	4,628.00^{I}	4,853.00^{J}	2,809.90**	2,279.98	**
	SD	9.75	30.35	59.15	88.29	143.56	238.42	334.77	524.84	704.52	725.55	1,923.20	1,474.84	
Carcass	$\overline{X}$	90.75^{A}	291.58^{B}	643.79^{C}	992.88^{D}	1,618.90^{E}	2,133.52^{F}	2,753.20^{G}	3,194.06^{H}	3,524.04^{Ia}	3,687.41^{Ib}	2,086.02**	1,692.13	**
	SD	6.15	20.80	43.16	77.62	115.12	167.51	246.85	398.97	546.15	574.26	1,473.89	1,135.40	
Edible components	$\overline{X}$	76.49^{Aa}	241.55^{Ab}	541.71^{B}	839.16^{C}	1,387.00^{D}	1,32.21^{E}	2,386.57^{F}	2,801.52^{G}	3,107.86^{H}	3,219.87^{H}	1,799.07**	1,481.36	**
	SD	5.50	16.51	41.95	62.92	92.41	120.30	191.65	333.46	456.81	484.96	1,287.62	1,012.67	
Non-edible components	$\overline{X}$	73.49^{Aa}	177.28^{Ab}	343.35^{B}	501.12^{C}	785.19^{D}	1,002.99^{E}	1,182.57^{F}	1,321.04^{G}	1,463.06^{H}	1,468.92^{H}	916.07**	744.29	**
	SD	4.17	20.09	25.37	31.93	64.93	117.97	149.50	192.90	282.03	251.56	577.26	458.73	

Values followed by different letters (age) or* (sex) differ significantly: Capital letters or ** -α = 0.01, Small letters or * -α = 0.05.

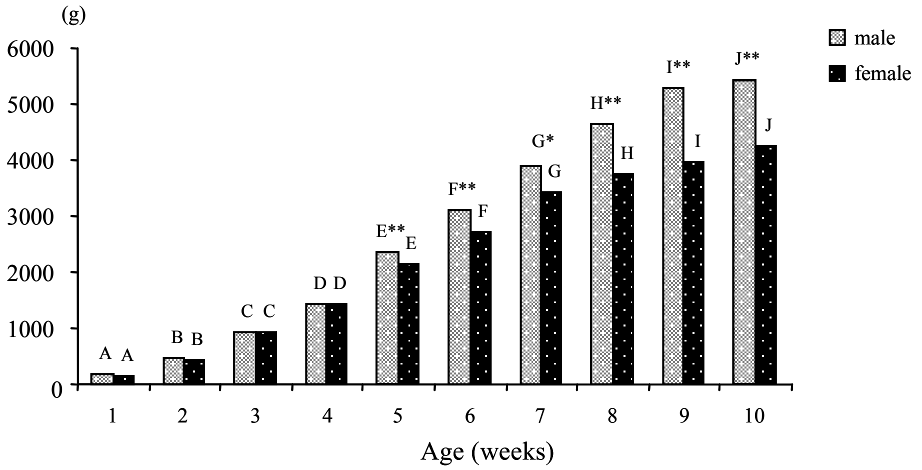

Figure 1. Arithmetic means ($\overline{X}$) for the body weight of males and females (g). Values followed by different letters (age) or * (sex) differ significantly: Capital letters or ** -α = 0.01 Small letters or * -α = 0.05.

of age (Figure 1).

The weight of individual edible parts in broiler chickens showed a rising tendency for different periods of time. Lean meat weight was increasing over the first nine weeks, from 50.1 g in one-week-old birds to 2,431 g in those aged 9 weeks (Figure 2a, b). The weight of skin and subcutaneous fat was increasing steadily during the entire growth period, from 13 g in week 1 to 608 g in week 10. The growth of

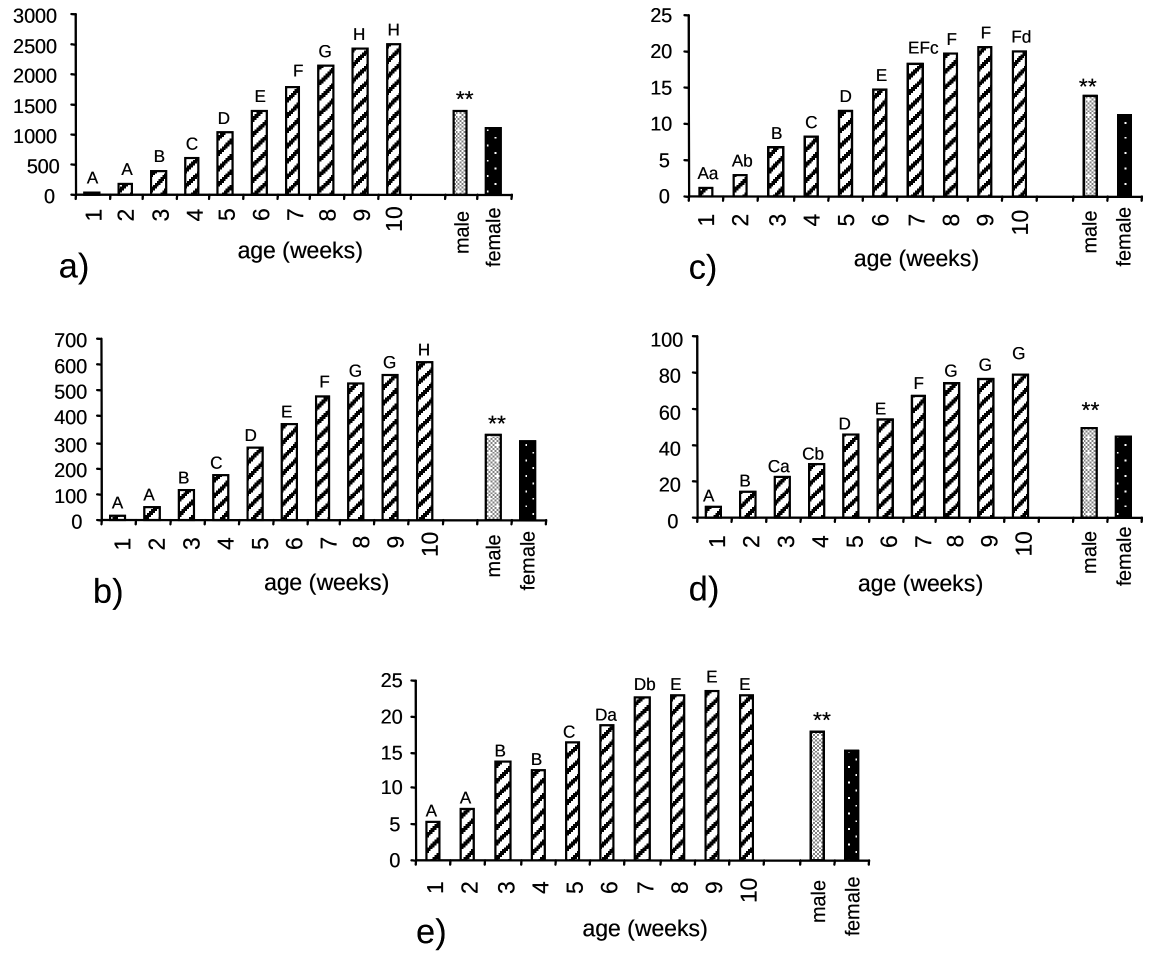

Figure 2. Arithmetic means ($\overline{X}$) for the edible portion (g). a) lean meat, b) skin and subcutaneous fat, c) heart, d) liver, e) gizzard. Values followed by different letters (age) or * (sex) differ significantly: Capital letters or ** -α = 0.01, Small letters or * -α = 0.05.

giblets ended earlier than the growth of the remaining edible components. Heart weight was increasing until 7 weeks of age and liver and gizzard weights until 8 weeks (Figure 2c, d, e).

Among non-edible cuts (Figure 3), the most profound changes were noted in the weight of feathers and abdominal fat. Between 1 and 10 weeks of age, feathers weight increased approximately 83-fold (Figure 3b). The carcasses of one-week-old birds contained no abdominal fat. In chickens aged 2 weeks abdominal fat weight was 3.66 g, and it increased 41.2-fold by week 10 (Figure 3f) The growth rate of the remaining non-edible components was slower (Figure 3). Between 1 and 10 weeks, blood weight increased, 13.7-fold (Figure 3c), head weight 10.1-fold (Figure 3d), shank weight 18.6-fold (Figure 3a), and gastrointestinal tract weight 11.3-fold (Figure 3e) Apart from slaughter offal, the non-edible portion of the carcass includes also bones whose weight increased 23.6-fold over the growth period (Figure 3g).

The values of traits presented in Figure 2 and 3 were

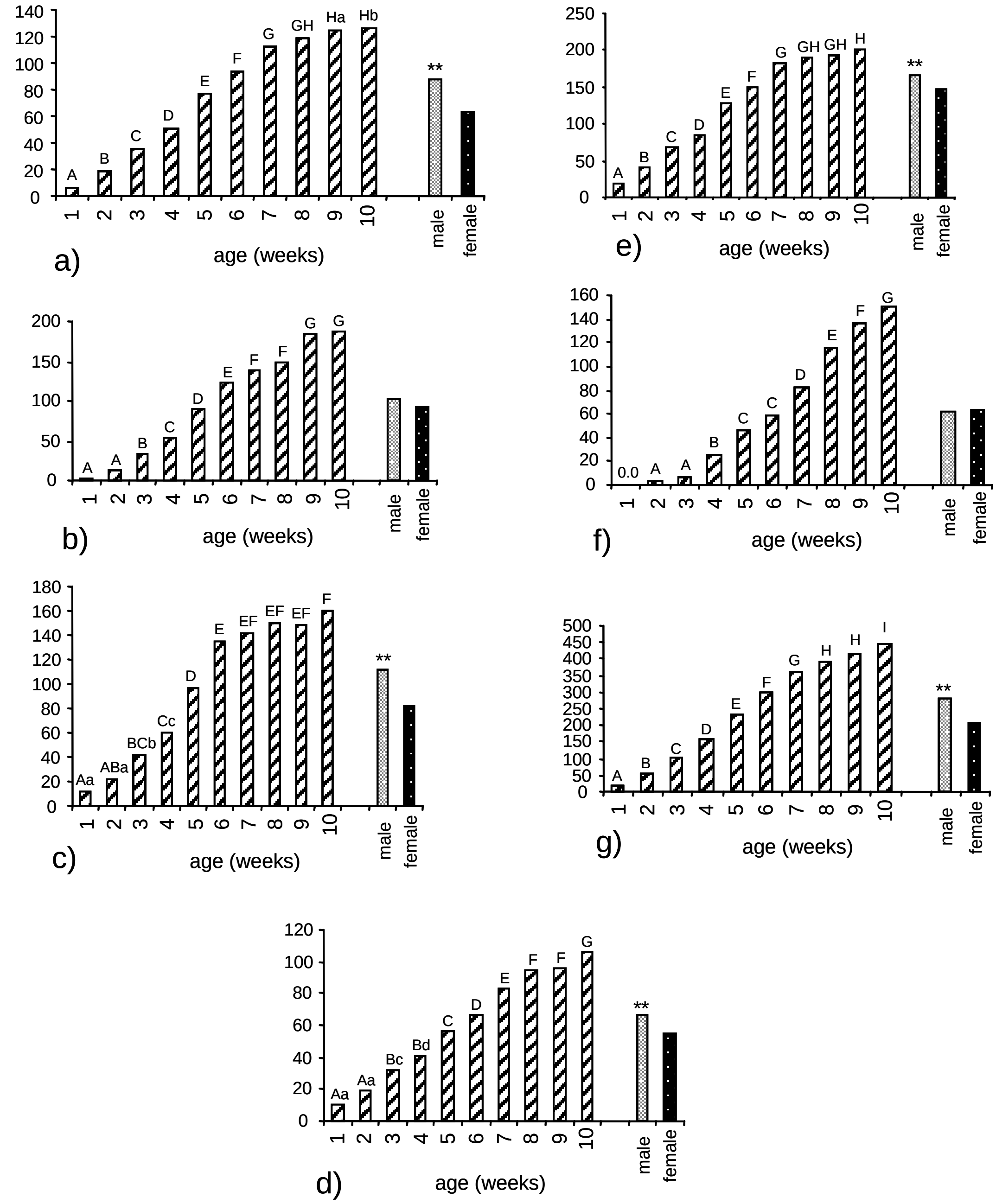

Figure 3. Arithmetic means ($\overline{X}$) for the non-edible portion (g). a) shanks, b) feathers, c) blood, d) head, e) gastrointestinal tract f) abdominal fat, g) bones. Values followed by different letters (age) or * (sex) differ significantly: Capital letters or ** -α = 0.01, Small letters or * -α = 0.05.

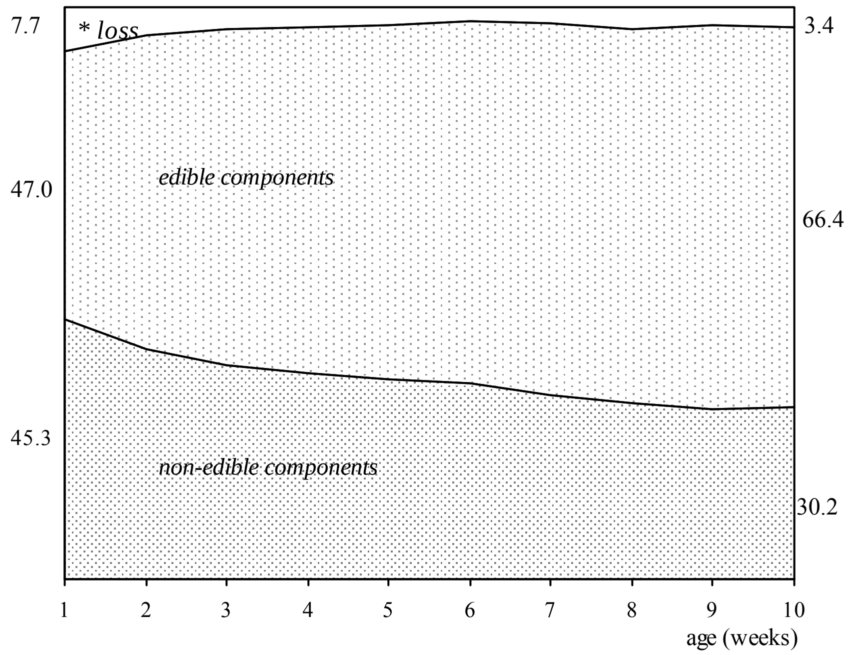

Figure 4. Percentage content of edible and non-edible components in the body weight of chickens fasted for 12 hours (%). * loss = body weight loss during post-slaughter processing and dissection (drip loss, evaporation, drying+fragments of the trachea, lungs and kidneys).

found to be significantly higher in males than in females, except for the weight of feathers and abdominal fat which was comparable in both groups. An interaction between age and sex was observed in the majority of traits. Among edible cuts, the age x sex interaction was observed with respect to lean meat weight, heart weight and gizzard weight. Among non-edible components, this interaction was noted in the weight of blood, head, shanks, gastrointestinal tract and bones. Similarly as in the traits given in Table 1, the above interaction was due to sexual dimorphism that became visible since 4 weeks of age. Until 4 weeks the values of the analyzed traits in males and females showed no statistically significant differences. The traits shown in Figure 2 and 3 were affected by the same type of interaction as those in Table 1, therefore no additional table presenting data separately for males and females was compiled.

To better illustrate the discussed age-related changes in growing broiler chickens, edible and non-edible weights were expressed as a percentage of total body weight. The values of the above traits were influenced by age, but not by gender. Thus, data are given for both males and females.

The percentage content of edible components in the body weight of chickens increased with age (Figure 4). 1 In broilers aged 1 week and 10 weeks, edible components accounted for 47.0% and 66.4% total body weight, respectively. The growth rate of edible components was very fast for the first six weeks, and slower during the next three weeks, until 9 weeks of age.

The percentage content of non-edible parts decreased as the chicks grew older (Figure 4), from 45.3% in week 1 to 34.4% and 30.2% at 6 and 10 weeks respectively.

The share of the most valuable edible component, muscle tissue, increased considerably with age, from 30.9% total body weight in week 1 to 52.4% in week 10. It should be stressed that until 6 weeks lean meat content increased by 16.5%, and between 6 and 9 weeks by only 3.8% (Figure 5). An increase in the percentage of skin and subcutaneous fat was observed for the first three weeks only (from 7.85% in week 1 to 12.63% in week 3). In subsequent weeks, until the end of the experiment, their content remained at a stable level of 12.5% (Figure 5).

The percentage content of giblets (in contrast to the remaining edible cuts) decreased with age, from around 8.2% in week 1 to 3.0% in week 6 and 2.4% in week 10 (Figure 5). The highest decrease was reported for gizzard content.

Non-edible parts comprise slaughter offal and bones. The total content of offal and bones in broiler carcasses decreased with age. The share of bones diminished from 11.6% in week 1 to 9.1% in week 8, and it remained at this level until the end of the experiment. Greater changes were reported for slaughter offal whose content reduced by 13.8% (from 33.0% to 19.2%) between week 1 and 7. A rising tendency was noted with respect to feathers and abdominal fat, while the content of the remaining offals decreased. The proportion of feathers was increasing until 4 weeks of age (from 1.8% to 4.0%), and abdominal fat content until 8 weeks (from 0.9% to 2.8%). Head content

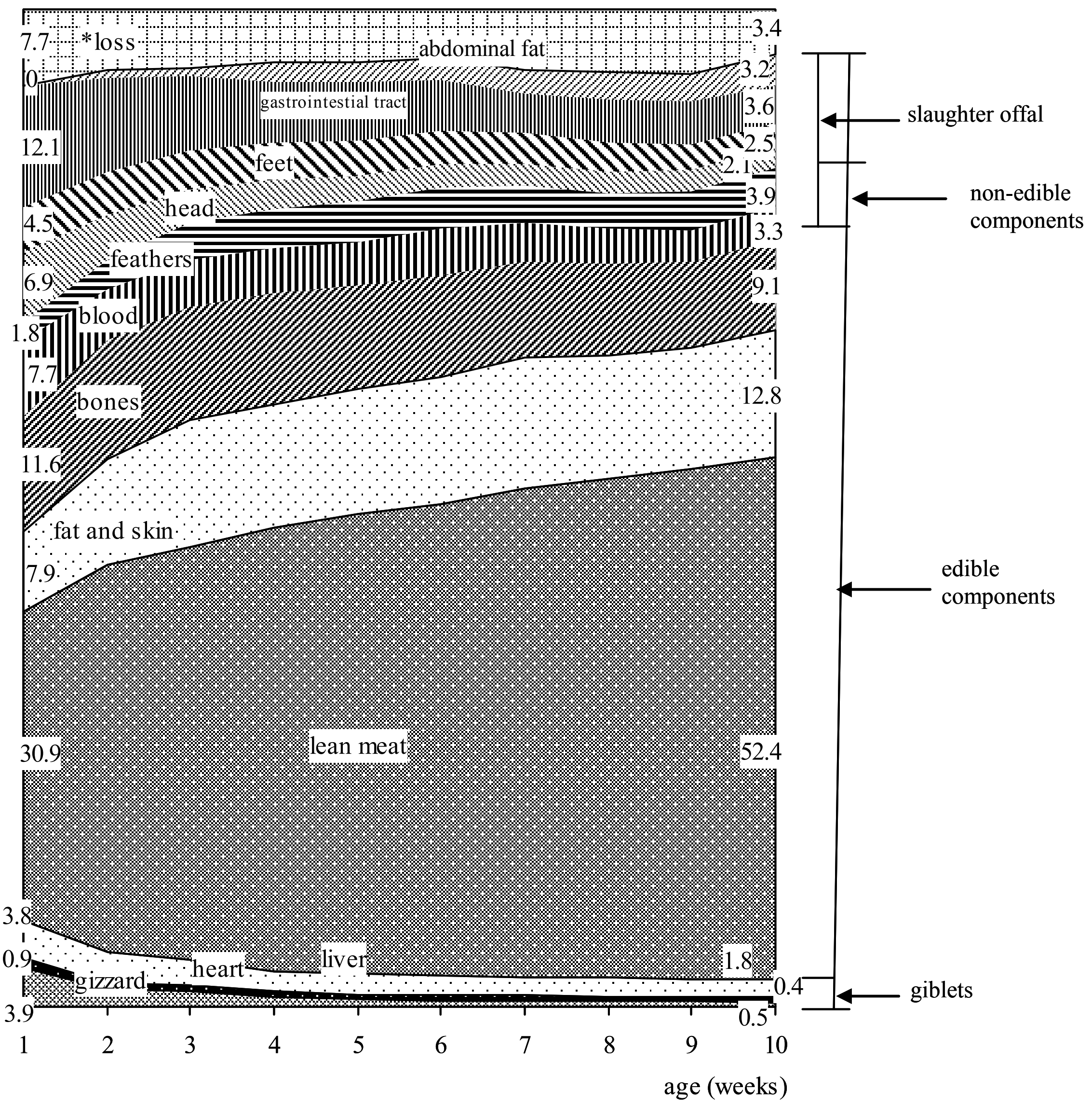

Figure 5. Percentage content of particular components in the body weight of chickens fasted for 12 h (%).* loss = body weight loss during post-slaughter processing and dissection (drip loss, evaporation, drying+fragments of the trachea, lungs and kidneys).

was decreasing for the first six weeks (from 6.9 to 2.3%), and the proportions of blood (from 7.7% to 3.9%), feet (from 4.5% to 3.0%) and gastrointestinal tract (from 12.1% to 4.0%) for seven weeks.

DISCUSSION

Among domestic poultry, chickens and turkeys have a very high lean meat content and a relatively low fat content (Lewczuk et al., 1994; Bochno et al., 2003). Among waterfowl, Pekin ducks (Bochno et al., 2005) and geese (Janiszewska, 1993) are characterized by a lower meat content and higher fat content. Michalik (1994) studied four 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%). Pour (1991) demonstrated that the content of edible components was substantially higher in gamefowl (Galliformes) than in waterfowl, although the values reported by this author (turkeys 60.0%, chickens 50.0%, ducks and geese 47%, at slaughter age) were much lower than those obtained by Michalik (1994). 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 neck and wing tips) and the classification of abdominal fat as an edible or a non-edible component.

Body growth rate varies over time, as so does the growth rate of internal organs and tissue components. This affects the proportions between edible and non-edible weights. From week 1 to 10, the total weight of edible parts in chickens increases approximately 42-fold, while the total weight of non-edible parts approximately 20-fold (Table 1). In one-day-old broilers edible portion content is around 47%, compared with 43% in layers, and they are characterized by poor growth of muscle and adipose tissue (Janiszewska et al., 1998). As birds grow older, the share of these tissues increases while bone tissue content decreases, which improves carcass quality. In chickens the above changes are most pronounced until 6 weeks of age (Bochno et al., 2003). In ducks lean weight increases fast until about 9 weeks of age, while bone weight to only 6 weeks (Bochno et al., 2004). It should be noted than in chickens an increase in the weight of muscle tissue and fat with skin is accompanied by a decrease in giblets content (Plavnik and Hurwitz, 1982; Janiszewska et al., 1998). The cited authors found that changes in the content of internal organs occur at a different rate, and that gizzard weight undergoes the greatest age-related changes. A similar trend was observed in the present study. In modern broilers the gizzard “works” less intensively due to considerable modifications in the composition and structure of feed, and so this organ gradually diminishes in size (Nir et al., 1978; Shires et al., 1987). Nitsan et al. (1991) demonstrated that in fast-growing broilers the percentage share of digestive organs decreases starting from 9 days of age, and the changes occur at a faster rate than in slow-growing birds. The proportions between individual organs in total body weight are also affected by nutritional regime (Obum, 2008). Body growth rate and the growth rate of internal organs may differ widely (Kamińska, 1986). For instance, between week 1 and 10 the body weight of chickens increased 30-fold, while the weight of heart, liver and gizzard increased over this period approximately 15-fold, 14-fold and only 4.2-fold respectively (Table 1 and Figure 3c, d, e).

The overall value of non-edible components is determined by the carcass content of slaughter offal and bones. The share of non-edible components decreases substantially as birds grow older, which is advantageous for both producers and consumers. The intensity of age-related changes in the proportions of non-edible parts varies. The growth rate of bone tissue significantly decreases with age, in comparison with the growth rate of other tissues (Lewczuk et al., 1994; Bochno et al., 2003; Murawska et al., 2005). Bones made up around 11.6% of the body weight of one-week-old chickens, and their share decreased to 9% at 8 weeks (Figure 5). Slaughter offal content reduced by over 14% during this period (Figure 5). At the beginning of chickens’ life, gastrointestinal tract weight accounted for over 12% of their body weight, and after the period of intensive growth (at 7 weeks of age) it diminished to approximately 4% (Figure 5). The significant decrease in the proportion of gastrointestinal tract in the total body weight of growing chickens is a natural consequence of their adjustment to feeding conditions (Lilburn, 1985; Havenstein et al., 1994). Lower activity of digestive enzymes in broilers, despite higher feed intake, was reported by Nir et al. (1993), and Shires et al. (1987) pointed to a relatively low capacity of the crop and intestines in broilers, as compared with layers.

Kamińska (1986) studied the growth dynamics of chickens and found that the proportion of head in their body weight decreased already during the first seven days of their life, from 13% to around 9%. At 12 weeks head content decreased to 2.5% total body weight. The proportion of feet decreased at a much slower rate, from 6% in 2-day-old chicks to around 4% in birds aged 12 weeks. 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 broilers (Figure 5). Feathering is naturally related to birds’ age. The rate of feathering is species-specific, affected by nutrition and determined genetically (Lesson et al., 2004; Nahashon et al., 2004; Da Silva et al., 2007). According to Grabowski (1993), in birds at slaughter age feathers make up 4.2%, 4.5% and 5.4% live body weight in turkeys, chickens and ducks, and geese respectively.

Selection programs designed to increase body weight and lean carcass yield in broilers have also caused an increase in carcass fat (in particular abdominal fat) content (Leenstra, 1986; McKay et al., 2000; Pym, 2000; Taylor et al., 2007). At the age of 6 weeks, abdominal fat content is approximately five-fold higher in broilers than in layers (Murawska et al., 2005). The carcasses of one-week-old chickens contain a very slight amount of abdominal fat. In six-week-old birds abdominal fat makes up over 2% of their total body weight, and its content continues to increase. At 10 weeks of age the proportion of abdominal fat is almost equal to that of gastrointestinal tract. Abdominal fat weight increases during the entire growth period, thus increasing both the weight of undesirable slaughter offal and overall production costs.

CONCLUSIONS

The proportion of edible parts increases and the proportion of non-edible parts decreases as broiler chickens grow older. As regards edible cuts, the greatest age-related changes are observed with respect to muscle tissue (increase) and giblets (decrease). The percentage of skin and subcutaneous fat remains stable from 4 weeks of age. As regards non-edible cuts, the proportion of bones and slaughter offal reduces with age. The percentage of feathers and abdominal fat shows a rising tendency, while the content of the remaining offals, in particular gastrointestinal tract, decreases.

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