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AGE-DEPENDENT CHANGES OF THE CHEMICAL AND ENERGY CARCASS COMPOSITION IN DUCKS DURING THE FIRST EIGHT POST-HATCHING WEEKS

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Abstract

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Ninety White Peking ducks were killed at weekly intervals from hatching to 56 d of age to assess age-dependent changes in their carcass mass and chemical and energy composition. During this period the carcass mass increased 50 times, water content 39 times, protein content 58 times, fat content 100 times and the gross energy (GE) content 76 times. The deposition of all the components under study was most intense in the 2nd week. The carcass hydration decreased with age more abruptly than in the domestic fowl. The protein concentration rose, after an initial decrease, to almost twice the original value by 42 d and then moderately decreased. The fat concentration rose up to 21 d, equalled the protein concentration by 35 d and then became lower again. The energy density of the tissues changed similarly to the fat energy concentration: the contribution of fat to the retention of GE did not exceed 60 %, thus being smaller than, e. g., in an average man. The performance at GE accumulation averaged 4.83 $W.kg^{-0.75}$; in the 2nd week, when it was lowest, and also in the 3rd week it was so high (11.1 $W.kg^{-0.75}$) that it exceeded the limit envisaged by Kirkwood and Webster (1984).

Duck, age-dependent changes, protein, fat, water, gross energy, carcass

Commercially important characteristics of slaughter ducks and the narrow spectrum of factors related to the profitability of duck meat production have recently been the subject of numerous studies (Pingel et al. 1969; Rudolph and Hoppe 1972; Clayton et al. 1974;

Hudský and Machálek 1978; Clayton and Powell 1979; Kočí et al. 1982; Leeson et al. 1982; Hudský and Červený 1983). Interest has also been centered upon the growth of ducks (Leclerq and de Carville 1972; Swatland 1980a; Knížetová et al. 1988), its allometric parameters (Mahelka 1964, 1973; Swatland 1980b; Baumgartner et al. 1982), some muscle groups (Swatland 1980c, 1981) and upon fat deposits (Evans 1972).

Age-dependent changes of the chemical composition of the duck carcass, on the other hand, have received relatively little attention (Baranyiová et al. 1980; Holub et al. 1988). In this respect only some organs such as the gastrointestinal tract and the liver have been described (Baranyiová et al. 1983). At present it is therefore not possible to define ducks, with reasonable reliability, as energy concentrators or protein transformers. To fill this gap in our knowledge the present study was designed.

Materials and Methods

A total of 90 White Peking ducks aged 1 to 56 d were included in the experiment. They were reared in rearing houses equipped with heaters under which the temperature was about 30 °C and the birds were free to choose the environmental temperature. They had free access to water and were fed commercial starters VKCH 1 and VKCH 2.

The measurements were carried out at weekly intervals on groups of 10 ducks each. The birds were weighed and killed by asphyxiation without bleeding. After the feathers, gastrointestinal tract and the yolk sac were removed, the carcasses were weighed and processed in a blender. After mixing, samples were taken and dried to constant mass at 90 to 95 °C for 24 h. Total nitrogen and fat content of the dry matter were determined using two samples for each analysis. Total nitrogen was measured by a micromethod (Conway 1957) and fat by 24 h petroleum-ether extraction in a Soxhlet apparatus (Montemurro and Stevenson 1960). Water content was determined from the difference between wet mass and dry matter. The same procedure was used in our previous studies to determine the chemical composition of the gastrointestinal tract, liver (Baranyiová et al. 1983) and feathers (Holub et al. 1988). Gross energy (GE) of the carcasses (including the gastrointestinal tract, liver and feathers) was calculated from their content of protein (23.9 $kJ.g^{-1}$), fat (39.4 $kJ.g^{-1}$) and occasionally saccharides (17.5 $kJ.g^{-1}$). In contrast to liver glycogen, the GE of muscle glycogen and blood glucose was not included in the computation because the evidence available did not allow us its reliable quantification. Nevertheless, the concentration of these saccharides in the muscles and blood was, no doubt, so low (Baranyiová and Holub 1969, 1971) that its contribution to total GE of the carcass did not exceed 1 % in any of the duck age categories under study and therefore could not significantly affect out results.

Relative growth of the carcass mass and its water, protein, fat and GE content were calculated according to the formula $\frac{100\ (y_2 - y_1)}{0.5\ (y_1 + y_2)}$ (Brody 1945). The increases of water, protein, fat and GE were also assessed relative to the carcass mass.

Results

The live body mass of the ducks increased 45 times, by 2 360 g, between 1 and 56 d (Table 1). The mean weekly increase was 42.9 $g.d^{-1}$, the lowest increase being recorded in the 1st week and the highest in the 5th week (it was then tenfold higher than in the 1st week) (Fig. 1).

Table 1

Changes in the live body mass and carcass mass in ducks during the first 8 post-hatching weeks

Age d	Live body mass g	Carcass mass g
1	54 ± 2	44 ± 2
7	93 ± 2	83 ± 2
14	305 ± 12	273 ± 11
21	635 ± 16	569 ± 4
28	1001 ± 47	919 ± 45
35	1451 ± 38	1282 ± 43
42	1755 ± 47	1652 ± 47
49	2135 ± 54	1968 ± 60
56	2414 ± 65	2199 ± 86

During the same period the carcass mass rose 50 times, by 2155 ± 86 g, i. e. relatively more than the live body mass (Table 1). During two 14-d periods, week 4 plus week 5 and week 5 plus week 6, i. e. each time during a quarter of the period under study, it rose by a third and by the end of the three weeks by as much as a half. Its weekly increase averaged 39.2 $g.d^{-1}$, being lowest in the 1st week and highest in the 5th week (it was then as many as 8 times higher than in the 1st week) (Fig. 1). The contribution of the carcass mass to the live body mass averaged 89.7 %. It changed with age: it was lowest after hatching, rose steeply up to 7 d and then showed only a moderate upward trend, with some fluctuations, peaking on 42 d (Fig. 2).

Water was the chemical component that contributed most to the carcass mass. Its quantity rose during the observation period more than 39 times, by 1 230 ± 39 g (Table 2). Similarly to the carcass mass, it did not increase evenly with age: it rose by a third during week 4 plus week 5 as well as during week 5 plus week 6 and by a half during these three weeks taken together. Its weekly increase averaged 22 $g.d^{-1}$, being lowest in the 1st week and highest in the 4th and 6th weeks (Fig. 3). The hydration of the carcass averaged 64.1 %. It was highest at 1 d and then declined with advancing age, falling to less than 4 fifths of the initial concentration (Fig. 4).

Table 2

Changes in the quantities of water, protein, fat and GE in ducks during the first 8 post-hatching weeks

Age d	Water g	Protein g	Fat g	GE MJ
1	32 ± 1	7	4	0.3
7	57 ± 2	12	6	0.5
14	193 ± 7	35	29	2.0
21	360 ± 10	78	91	5.8
28	571 ± 28	167	165	10.6
35	755 ± 26	242	268	16.5
42	980 ± 28	368	282	20.0
49	-	394	346	23.2
56	1262 ± 39	421	376	25.1

The actual protein quantity increased almost 58 times (Table 2). The total amount of protein deposit was 414 ±13 g; most of it was deposited in the 5th and 6th weeks (almost a half) and during the 3rd to the 6th weeks (almost three quarters). The weekly protein deposit averaged 7.5 $g.d^{-1}$;

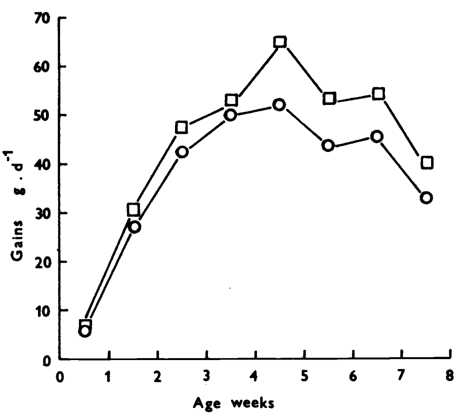

Fig. 1. Daily gains in the contribution of live (□) and carcass (○) mass in ducks during the first 8 post-hatching weeks.

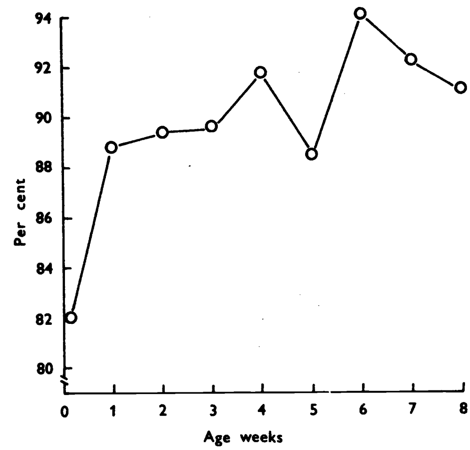

Fig. 2. Changes in the contribution of the carcass mass to the live body mass of ducks during the first 8 post-hatching weeks.

it was lowest in the 1st week and highest in the 4th and 6th weeks, i. e., it changed similarly to the water content (Fig. 3). The carcass protein concentration averaged 17.3 %. At 1 d of age it was near the mean value, declined up to 14 d, increased to almost twice as much by 42 d and then showed a moderate decline up to 56 d (Fig. 4).

The actual carcass fat mass increased more than hundredfold, thus showing a relatively higher rise than any of the remaining components under study (Table 2). The total fat deposit was 2 373 ± 14 g. After an abrupt rise during the first two post-hatching weeks the fat deposition was highest in the 3rd to 7th weeks (8 to 9 tenths of the total deposit). The weekly fat deposit averaged 6.7 $g.d^{-1}$. In the 5th week, however, it was almost fiftyfold higher than in the 1st week. Its variation with age was therefore considerable (Fig. 3). This phenomenon became apparent also in the fat concentration. This increased to more than twice the post-hatching value by 21 d and then continued at approximately the same level. By the end of the 2nd week it was lower than the protein concentration, and after equalling the latter by 35 d, became lower again (Fig. 4).

The amount of carcass GE increased 76 times, by 24.7 ± ± 0.9 MJ, during the period under study (Table 2); the

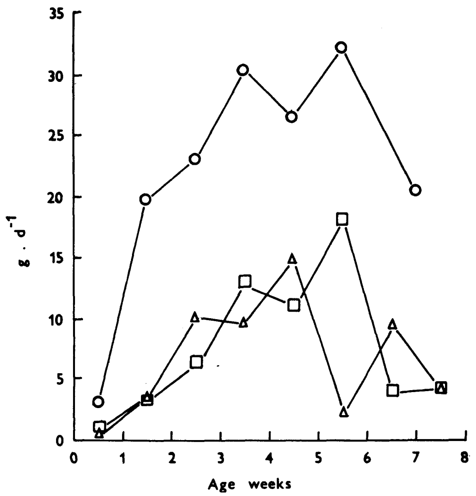

Fig. 3. Daily gains of water (O), protein (□) and fat (Δ) of uucKs during the first 8 post-hatching weeks.

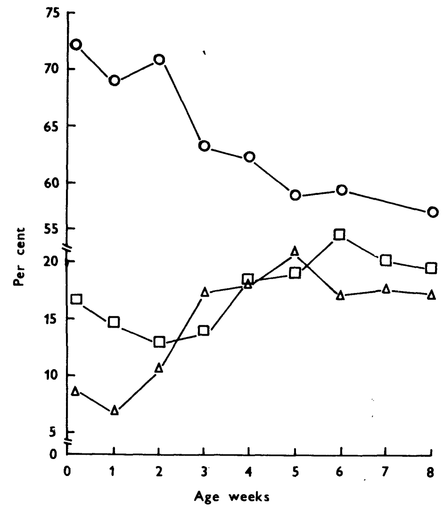

Fig. 4. Changes in proportions of water (O), protein (□) and fat (Δ) in the live body mass of ducks during the first 8 post-hatching weeks.

mean weekly increase was 0.44 MJ.d^{-1}. However, its retention varied with age: it was minimal in the 1st week, rose by almost a quarter of its total 8-week quantity in the 5th week and then declined almost equally abruptly during the following 3 weeks (Fig. 5).

There were considerable differences in the GE deposition between the individual chemical carcass components. It rose mostly in lipids, by 14.8 KJ, the mean increase there being 0.27 KJ.d^{-1}. After an abrupt rise it remained practically unchanged from the 3rd to the 7th week, exceeding the 1st-week accumulation more than 40 times. The deposit of GE in the non-fat carcass mass amounted to 9.93 MJ, the mean weekly increase being 0.18 MJ.d^{-1}. Thus the GE increase in the non-fat carcass mass was more than one third lower than in the lipids. It peaked in the 6th week, by which time it exceeded the 1st-week minimal deposition 24 times (Fig. 5).

Relative increases in the parameters under study expressed in terms of Brody's formula (1945) were 192, 190, 193, 196 and 195 for carcass mass, water, protein, respectively. and GE, resp. All of them also showed marked age changes. The values were highest in the 2nd week at which time the increases in carcass mass, water, protein

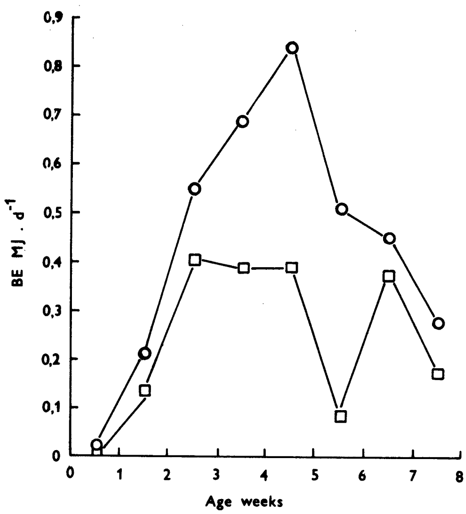

Fig. 5. Daily GE deposition in the bodies of ducks (o) and in the fat portion (□) of their carcasses during the first 8 post-hatching weeks.

fat and GE were 9.7, 4.3, 13.9, 16.3 and 14.6 higher, respectively, than the increases recorded in the 8th week (Table 3).

Expressed relative to carcass mass unit, the values for carcass mass, water, protein, fat and GE deposition yielded a different picture: the daily increases in carcass mass, water, protein and fat averaged 68, 47, 11 and 10 $g.kg^{-1}.d^{-1}$, respectively, and that in GE averaged 0.67 $MJ.kg^{-1}.d^{-1}$. Most of them peaked in the 2nd week. Afterwards the gains in carcass mass declined gradually with advancing age, falling to 10 % of the peak value. A similar development was observed in chemical carcass components. Water and protein deposition declined gradually to 9 and 11 %, respectively, of the peak values. A somewhat

Table 3

Relative growth of the carcass mass, water, protein, fat and GE in duck carcasses during the first 8 post-hatching weeks

Week	Carcass mass	Water %	Protein	Fat	GE
1	61	56	48	40	42
2	107	109	97	134	118
3	70	61	77	110	98
4	47	45	73	51	58
5	33	28	37	47	43
6	25	26	41	5	9
7	17	25	7	21	15
8	11		7	8	8
1-8	192	190	193	196	195

different situation was recorded for fat and GE: their accumulation did not peak until the 3rd week and then declined gradually to 9 % of their maximum values (Table 4).

Table 4

Contributions of the daily gains in carcass mass, water, protein, fat and GE to the relative growth of carcass mass in ducks during the first 8 post-hatching weeks

Week	Carcass mass	Water	Protein	Fat	GE
	$g.kg^{-1}.d^{-1}$		$g.kg^{-1}.d^{-1}$		$MJ.kg^{-1}.d^{-1}$
1	100	64	12.5	4.7	0.4
2	152	110	18.0	18.5	1.19
3	101	57	14.7	23.8	1.30
4	67	40	17.2	12.8	0.92
5	47	24	9.7	13.4	0.70
6	36	22	12.2	1.4	0.35
7	25		2.0	5.1	0.25
		10			
8	16		1.9	2.1	0.13

Discussion

Birds differ considerably in their post-hatching development and growth mainly in dependence on the fact whether they are precocial, nidifugous or altricial, nidicolous (R i c k l e f s 1979, 1983). N i c e (1962) has distinguished four groups of precocials, two groups of altricials and one group each of semiprecocials and semialtricials. He has classified ducks within the second group of nidifugous birds where they belong on the basis of four out of the five criteria; the remaining criterion, however, would classify them within nidicolus birds. According to behavioural changes the post-hatching period is generally divided into 6 phases (K u h l m a n n 1909; N i c e 1943, 1962). The first phase occurs during incubation and the following two within 24 h of hatching

(N i c e 1943, 1962). In our experiments ducks therefore underwent only the phases of locomotion, development of social interactions and juvenile sexual manifestations.

In our study, however, we used neither ethological nor morphological criteria because the growth of ducks can be measured reliably on the basis of changes in the parameters of mass and energy. In the first place we described therefore the accumulation of water and the retention of GE.

The growth rate of the live body mass from the 3rd to the 5th week was lower in our experiments than in those reported by C a m p b e l l et al. (1985). It was also lower than that reported by H u d s k ý and Č e r v e n ý (1983) and than that listed in the relevant Czechoslovak standard (ON 46 6541, 1979) but almost equalled the growth rate of the living body mass in ducks in a feeding experiment conducted in 1985 (K a i s l e r and H l u b o c k á 1985ab) in the same enterprise where data used for the development of the aforementioned standard were previously obtained. On the other hand, our values were higher than those reported by M a h e l k a (1964, 1973). In spite of these differences it cannot be concluded that the birds used in our experiments showed variation from the growth characteristic of the Peking breed.

The carcass water content grew in the same way as in our previous experiments; in terms of actual content it increased 40 times. The carcass hydration, on the other hand, declined with advancing age, the highest rate of the decrease being recorded in the first 3 weeks. In general, however, the carcass hydration was lower and its decrease more abrupt than in the domestic fowl (B a r a n y i o v á et al. 1973).

During the post-ha+ching period the avian carcass is characterized by relative decrease not only of water but also of protein and by a concurrent relative increase of fat. In ducks, however, the concentration of protein is generally lower and that of fat higher than, e. g., in the domestic fowl and turkey. These differences have been accounted for by the fact that ducks consume relatively more nutrients and GE than the domestic fowl and turkey (S i r e g a r and F a r r e l l 1980ab). Thus age-dependent changes in the relative carcass content of protein and fat in ducks were associated with feed consumption. More recently this statement was confirmed by the observation that restricted feed allowance resulted in a decreased proportion of fat in eviscerated duck carcasses. In ducks fed ad libitum, on the other hand, the proportion of fat was in agreement with that found in our experiments (C a m p b e l l et al. 1985).

In birds the potential of GE deposition is a function of both the living body mass (K i r k w o o d and W e b s t e r 1984) and the relative fat accumulation (R i c k l e f s 1974). Although this phenomenon is less marked in precocials than in altricials, the evidence from our experiments on ducks also showed that the increasing contribution of fat to their carcass mass resulted in increased energy density; adipose tissue contains 30 to 38 $KJ.kg^{-1}$. It is therefore almost eightfold richer in GE than non-fat tissue having only 4.7 to 5.0 $MJ.kg^{-1}$ (G a r r o w 1982; K i r k w o o d and W e b s t e r 1984).

In this connexion let us draw attention to the view that not even in growing birds the accumulation of metabolizable energy can exceed 790 $kJ.kg^{-0.75}.d^{-1}$ (K i r k w o o d and W e b s t e r 1984); their performance cannot therefore be higher than 9.4 $W.kg^{-0.75}$.

Ducks in our experiments retained, on average, 0.55 $MJ.kg^{-0.75}.d^{-1}$ during the first 8 post-hatching weeks; i. e., their performance was 6.3 W. However, their GE deposition varied with age; in the 2nd and 3rd weeks they retained 0.93 and 0.96 $MJ.kg^{-0.75}.d^{-1}$ and their performance was therefore 10.7 and 11.1 $W.kg^{-0.75}$, respectively. Since considering the objective of our study we did not think it necessary to distinguish between accumulated metabolizable energy and GE, it is obvious that the aforementioned maximum was exceeded. It was only at the end of the experimental period, i. e., in the 8th week that the retention of GE by our experimental ducks decreased ninefold, declining to 0.15 $MJ.kg^{-0.75}.d^{-1}$, i. e., to 1.7 $W.kg^{-0.75}$.

Although in our experimental ducks the amount of GE accumulated in the fat portion of the carcass was one third higher than that accumulated in the non-fat portion, the proportion of GE deposited in their lipids at 8 weeks of age was only 59.1 %, which is less than in an average man of 70 kg in body mass in whom two thirds of 559 or 660 MJ are reportedly deposited in fat (A p f e l b a u m 1978; G a r r o w 1982).

Věkové změny chemického složení a množství energie v těle kachen v postinkubačním údobí

Na 90 kachnách plemene bílého pekingského jsme od vylíhnutí do 56. dne v týdenních intervalech zjišťovali hmotnost a chemickou i energetickou skladbu těla. Zjistili jsme, že za tuto dobu se hmotnost těla zvětšila 50krát; množství vody rostlo méně, jen 39krát, bílkovin více, 58krát, tuků a BE dokonce 100 případně 76krát. Nejintenzívnější depozici všech sledovaných komponent jsme zaznamenali v týdnu druhém. Hydratace těla se s věkem snižovala prudčeji než u kurů. Koncentrace proteinů se po počátečním poklesu do 42. d zvýšila téměř na dvojnásobek; nadále se však mírně snižovala. Koncentrace lipidů do 21. d stoupala, ve 35. d se vyrovnala bílkovinám, ale u kachen vyšších věkových kategorií byla opět nižší. Energetická densita tkání těla se měnila obdobně jako koncentrace tuků. Jejich podíl na retenci BE nepřekročil 60 %. Byl tudíž menší než např. u průměrného člověka. Průměrný výkon při akumulaci energie BE byl roven 4.83 $W.kg^{-0,75}$; ve druhém týdnu, kdy byl maximální, ale i ve třetím, byl však tak velký, že dosahoval 11,1 $W.kg^{-0,75}$; přesahoval tedy limit předpokládaný Kirkwoodem a Websterem (1984).

Возрастные изменения химического состава и количества энергии в теле уток в постинкубационный период

У 90 уток белой пекингской породы со дня вылупливания до 56 суток определяли в недельных интервалах массу и химический и энергетический состав тела. Было установлено, что в течение указанного периода масса тела увеличилась в 50 раз, количество воды увеличивалось в меньшей степени, лишь в 39 раз, белков - больше - в 58 раз, жиров и BE даже в 100 или 76 раз. Самое интенсивное отложение всех исследуемых компонентов наблюдалось в течение второй недели. Гидратация тела с возрастом понижалась более стремительно чем у курицы. Концентрация протеинов после первоначального понижения до 42 суток увеличилась почти в два раза и в дальнейшем незначительно понижалась. Концентрация липидов до 21 дня увеличивалась, на 35 сутки равнялась белкам, но у уток более поздних возрастных категорий она была опять-таки более низкой. Энергетическая плотность тканей тела менялась аналогично концентрации жиров. Их дола в задержке ВЕ не превышала 60 %. Она была, следовательно, меньше доли, например, обыкновенного человека. Средняя интенсивность аккумулирования энергии ВЕ равнялась 4,83 Вт.кг$^{-0,75}$; на второй неделе она достигла максимального уровня, однако на третьей неделе она была настолько большой, что достигала 11,1 Вт.кг$^{-0,75}$, выходя, следовательно, за пределы, предполагаемые Кирквудом и Вебстером (1984).

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