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CHANGES IN THE MASS AND CHEMICAL COMPOSITION OF THE GASTROINTESTINAL TRACT AND LIVER OF DUCKS IN THE FIRST TWO MONTHS AFTER HATCHING

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Abstract

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Quantitative changes and chemical composition of the individual digestive organs and liver were investigated in 90 White Pekin ducks from hatching to 56 days of age.

The greatest live body mass increase was found in the fourth and fifth weeks whereas the actual mass of the whole gastrointestinal tract (GIT) grew most rapidly in the third week and that of the liver in the second week. The greatest contribution to the GIT growth rate was that of the intestines followed by the gizzard. The contributions of the esophagus, crop and proventriculus were small.

Despite of its great increase in mass the GIT showed a fairly constant relative water and protein content but its fat content, especially in the intestine and liver, was sharply decreased by the end of the first posthatching week.

The actual gross energy content of the investigated organs increased to different degrees; an almost 40fold increase was observed in the GIT but only a 20fold in the liver. The small increase in gross energy content of the liver was accounted for by low increase in its fat but also glycogen amounts. Consequently, the importance of the liver as a readily available energy reserve for ducklings declines with their advancing age.

Protein, fat, ash, gross energy.

Posthatching development of the gastrointestinal tract (GIT) in various avian species has received relatively little attention (Latimer 1924; Kaufman 1927). More recently, it has been studied especially in connection with growth rates and performance of domesticated avian species and with their food utilization (Doskočil 1966, 1967). It was found, for instance, that the GIT of chickens grew rapidly in the first posthatching week with the small intestine increasing its mass by more than six times in this period (Baranyiová 1972ab), and that the chemical composition of their gastrointestinal tract may be affected by feeding schedules (Doskočil 1966, 1967).

Similar observations have been reported for the duck (Mahelka 1968). However, the chemical composition of their digestive organs has not been studied as yet. This fact prompted us to investigate the changes in composition of the individual digestive organs in this economically important avian species during the two posthatching months.

Material and Methods

Ninety White Pekin ducks aged 1 to 56 days were used in the experiment. They were reared in rearing houses and fed the Czechoslovak standard commercial feed mixtures for ducks (VKCH 1 and 2).

The analyses were carried out at weekly intervals, using invariably 10 birds. They were weighed and killed by asphyxiation. The bodies were cut open, and the digestive organs were removed. The esophagus plus crop, proventriculus, gizzard and the intestines of each duckling were cut lengthwise, cleaned of the contents and weighed. The tissue samples were then dried to constant mass at 90 – 95 °C for 24 hours. The individual chemical components were determined in dry matter using always 2 parallel samples: total nitrogen by a micromethod (Conway 1957), fat by 24 h petroleum-ether extraction (Montemurro and Stevenson 1960). For ash determination, the samples were combusted in an electric oven at 500 °C for 24 h, then sprinkled with 0.3 ml 30 % H_2O_2 and combusted for another 24 h. The water content of the samples was calculated from the difference between wet mass and dry matter mass. Gross energy content of the GIT and liver was calculated from the amounts of protein (23.9 kJ in 1 g), fat (39.4 kJ in 1 g), and glycogen (17.5 kJ in 1 g). Clycogen energy content of the duck liver was calculated using our earlier data (Baranyiová and Holub 1971).

The results were evaluated by Student's t-test.

Results

The live body mass of ducklings increased 45 times in 56 days from 54 ± 2 to 2414 ± 205 g. Its greatest actual increase was observed in the fifth week after hatching (64.3 g . d^{-1}).

During the same period, their GIT mass increased almost 56 times, from 2.7 ± 0.1 to 150.2 ± 5.8 g, and their liver mass increased more than 50 times, from 1.4 ± 0.1 to 70.6 ± 5.6 g. Thus the liver and especially the GIT mass grew more rapidly than the live body mass. The GIT mass grew most rapidly in the third week, that of the liver in the second week, i. e. earlier than both the GIT and live body mass (Table 1).

On day 1 after hatching the contribution of the GIT to the live body mass

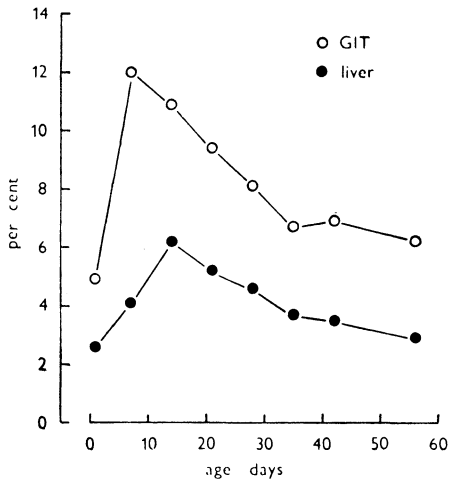

Fig. 1. Contribution of the GIT and liver to the live body mass of ducks aged 1 to 56 days.

Table 1

Live body mass, GIT mass and liver mass of ducks aged 1 to 56 days

Age d	Live body mass g	GIT mass g	Liver mass g
1	54 ± 2***	2.7 ± 0.1***	1.4 ± 0.1***
7	93 ± 2***	11.2 ± 0.4***	3.8 ± 0.2***
14	305 ± 12***	33.2 ± 1.2***	18.8 ± 1.4***
21	635 ± 16***	59.5 ± 1.5***	32.9 ± 1.0***
28	1001 ± 147***	80.6 ± 3.1**	46.0 ± 2.8
35	1451 ± 121***	97.2 ± 3.2***	53.6 ± 2.3*
42	1755 ± 147**	122.8 ± 3.7***	61.1 ± 2.0
56	2415 ± 205	150.2 ± 5.8	70.6 ± 5.6

Values are means ± S.E.M.

*** $P < 0.001$

** $P < 0.01$

* $P < 0.05$ (significantly different from the value obtained at the subsequent collection)

of ducklings was lowest (5.0 ± 0.2 %). During the first week it rapidly increased so that on day 7 it reached a maximum (12.0 ± 0.2 %). Similarly, the contribution of the liver was smallest on day 1 (2.6 ± 0.1 %), increased thereafter reaching a peak on day 14 (6.2 ± 0.3 %) (Fig. 1).

The actual water amount of the GIT increased 48 times by day 56 (from 2.2. ± 0.1 to 103.0 ± 33.5 g). The protein amount increased even more, namely 59 times (from 0.4 ± 0.1 to 22.0 ± 1.2 g), the fat amount only 19 times (from 0.2 ± 0.0 to 3.9 ± 0.6 g), the ash content showed a 30fold increase (from 0.03 ± ± 0.00 to 0.85 ± 0.20 g).

Esophagus and crop

The actual mass of the esophagus plus crop increased 12 times in the first two posthatching weeks from 0.2 ± 0.0 to 2.4 ± 0.1 g. Then it increased at a slower rate until day 42. The contribution of these organs to the GIT mass was greatest on day 1 and decreased progressively thereafter (Table 2).

Table 2

Mass and chemical composition of the esophagus and crop of ducks aged 1 to 56 days

Age d	Actual mass g	Water g	Protein g	Fat g	Ash g
1	0.2 ± 0.0***	0.19 ± 0.00***	0.04 ± 0.00	0.12 ± 0.00	0.01 ± 0.00
7	0.8 ± 0.0***	0.63 ± 0.10***	0.13 ± 0.00	0.02 ± 0.00	0.01 ± 0.00
14	2.4 ± 0.1***	1.91 ± 0.10***	0.36 ± 0.00	0.05 ± 0.00	0.02 ± 0.00
21	4.2 ± 0.2**	3.24 ± 0.10***	0.75 ± 0.00	0.07 ± 0.00	0.04 ± 0.00
28	5.5 ± 0.3***	4.25 ± 0.20***	0.82 ± 0.15**	0.14 ± 0.02	0.04 ± 0.01
35	7.3 ± 0.3***	5.78 ± 0.20***	1.05 ± 0.04	0.13 ± 0.01*	0.07 ± 0.01
42	9.3 ± 0.4	7.53 ± 0.30	1.10 ± 0.04**	0.24 ± 0.05	0.08 ± 0.01
49	9.7 ± 0.5	7.80 ± 0.50	1.30 ± 0.06**	0.22 ± 0.03	0.08 ± 0.01
56	11.1 ± 0.6	8.90 ± 0.50	1.66 ± 0.09	0.31 ± 0.04	0.07 ± 0.01

See footnotes to Table 1

The actual water content of the esophagus plus crop increased almost linearly from 0.2 ± 0.01 g on day 1 to 8.9 ± 0.5 g on day 56. The relative hydration increased sharply between days 1 and 14 (from 75.6 ± 1.0 g to 79.5 ± 0.3 g) and showed little change thereafter oscillating between 78.6 ± 2.1 and 81.0 ± ± 0.6 %. The actual protein mass increased 41 times within the first two months of life, rising particularly from day 28 onwards. The relative protein content had a slightly downward trend. The actual fat mass increased 3 times to day 56, the relative fat content slightly increased between days 7 and 14. The actual ash mass of the esophagus plus crop increased 22 times in 56 days of posthatching life. The relative ash content was highest on day 1 (1.4 ± 0.0 %) and decreased thereafter.

Proventriculus

On days 1 and 7 the proventriculus was analyzed together with the gizzard (Table 3). Their actual mass increased considerably during this period and their contribution to the GIT mass was highest on day 1. The actual mass of the proventriculus itself increased significantly from day 14 to day 42.

Table 3

Mass and chemical composition of the proventriculus and gizzard of ducks aged 1 to 56 days

Age d	Organ mass g		Water g		Protein g		Fat g		Ash g	
	proven-triculus	gizzard	proven-triculus	gizzard	proven-triculus	gizzard	proven-triculus	gizzard	proven-triculus	gizzard
1	1.7 ± 0.1***		1.36 ± 0.05***		0.23 ± 0.01***		0.04 ± 0.00		0.02 ± 0.00	
7	6.2 ± 0.2***		4.89 ± 0.20***		0.98 ± 0.05		0.11 ± 0.00		0.07 ± 0.00	
14	1.8 ± 0.1***	14.5 ± 0.6***	1.39 ± 0.06***	12.33 ± 0.54***	0.27 ± 0.00	1.67 ± 0.11***	0.58 ± 0.03	0.15 ± 0.02***	0.03 ± 0.00	0.10 ± 0.01
21	2.9 ± 0.1***	29.3 ± 1.2***	2.21 ± 0.07***	22.56 ± 1.05***	0.48 ± 0.00	5.27 ± 0.26***	0.11 ± 0.00	0.51 ± 0.05	0.04 ± 0.00	0.07 ± 0.01***
28	3.6 ± 0.1**	44.7 ± 1.7**	2.77 ± 0.11**	34.59 ± 1.31**	0.62 ± 0.00	8.64 ± 0.37*	0.19 ± 0.00	0.57 ± 0.04**	0.04 ± 0.00	0.43 ± 0.02**
35	4.2 ± 0.1**	56.0 ± 2.7**	3.26 ± 0.09**	42.22 ± 2.02**	0.64 ± 0.02	10.43 ± 0.61*	0.15 ± 0.01	0.80 ± 0.06	0.05 ± 0.01	0.54 ± 0.02**
42	5.1 ± 0.2**	69.0 ± 2.8***	3.96 ± 0.20	53.51 ± 2.20***	0.71 ± 0.00	12.57 ± 0.51***	0.15 ± 0.15	0.79 ± 0.06***	0.05 ± 0.00	0.68 ± 0.04***
56	5.5 ± 0.2	82.0 ± 3.5	4.17 ± 0.20	61.82 ± 2.75	0.86 ± 0.03	16.13 ± 0.98	0.27 ± 0.05	1.52 ± 0.21	0.14 ± 0.06	0.80 ± 0.07

See footnotes to Table 1

The actual mass of all chemical components showed an increase. The relative hydration of proventriculus, however, decreased form 81.0 ± 0.4 % to 76.0 ± ± 1.3 %, most of this decrease occurring during the first 14 days. The relative protein content oscillated between 13.6 ± ± 0.4 and 16.7 ± 1.0 %, the proportion of fat increased from 2.6 ± 0.0 to 4.9 ± ± 0.9 %. The relative ash content oscillated between 1.0 ± 0.1 and 1.2 ± 0.0 %.

Gizzard

The actual mass of this part of the GIT rose throughout the experimental period (Table 3) whereas its contribution to the GIT mass did not change appreciably after an initial drop in the first week.

The increase in the actual mass was especially sharp with water and protein; however, the relative hydration decreased from day 14 from 85.1 ± 0.6 to 75.2 ± ± 0.6 % on day 56. The relative protein content rose sharply between days 14 and 21 (from 11.5 ± 0.5 to 18.0 ± ± 0.8 %). The relative fat content of the gizzard was more than one-half that found in the proventriculus. The actual fat content gradually increased from 0.04 ± 0.0 (day 1) to 1.52 ± 0.21 g (day 56) (Table 3). After a slight increase between days 14 and 21 the relative ash content oscillated around 1 %.

Intestine

The actual mass of the intestine rose until day 42. Most of this increase, however, occurred in the first week when the initial mass increased 5.5 times (Table 4). Consequently, its contribution to the overall GIT mass increased from 28.5 % on day 1 to 44.0 % on day 14.

The actual water content of the intestinal wall increased markedly, especially in the first three weeks of life. The relative hydration of the intestine oscillated only within very narrow limits, i.e. between 78.0 ± 0.7 and 80.4 ± 0.3 %. The actual protein mass increased considerably in the third, and somewhat less

Table 4

Mass and chemical composition of the intestine of ducks aged 1 to 56 days

Age d	Organ mass g	Water g	Protein g	Fat g	Ash g
1	0.76 ± 0.05***	0.60 ± 0.03***	0.10 ± 0.00	0.04 ± 0.00	0.01 ± 0.00
7	4.16 ± 0.22***	3.32 ± 0.18***	0.58 ± 0.00	0.14 ± 0.00	0.51 ± 0.00
14	14.6 ± 0.52***	13.01 ± 0.49***	0.93 ± 0.04***	0.31 ± 0.01***	0.09 ± 0.00
21	23.2 ± 0.76***	18.37 ± 0.60**	3.18 ± 0.14*	0.93 ± 0.04*	0.19 ± 0.01
28	27.9 ± 1.49*	21.99 ± 1,18	3.64 ± 0.14**	1.22 ± 0.11	0.22 ± 0.01
35	29.8 ± 0.85*	23.32 ± 0.70***	4.29 ± 0.17***	1.18 ± 0.10	0.21 ± 0.01**
42	39.3 ± 1.10	31.60 ± 0.94	5.44 ± 0.15	1.15 ± 0.08*	0.30 ± 0.02
49	40.7 ± 1.67	31.77 ± 1.30	5.12 ± 0.22	1.47 ± 0.14*	0.28 ± 0.02
56	44.6 ± 1.88	35.02 ± 1.37	5.53 ± 0.57	2.30 ± 0.41	0.30 ± 0.01

See footnotes to Table 1

in the fourth, fifth and sixth weeks. On the other hand, the relative protein content oscillated between 12.5 ± 1.4 and 14.6 ± 0.2 %. The actual fat content increased considerably in the third week, less in the fourth, seventh and eight weeks. The relative fat content was highest after hatching (5.9 ± 0.0 %), later it oscillated between 2.1 ± 0.1 and 4.4 ± 0.6 %. The actual ash content of the intestine increased significantly only in the sixth week (Table 4); the relative ash content was highest on days 1 and 7 (1.2 ± 0.0 %), thereafter it slightly decreased and oscillated about 0.7 % until the end of the experiment.

Liver

The actual liver mass doubled in the first week and the actual water content increased as many as 3.5 times (Table 1). The relative hydration of the liver increased from 60.5 ± 0.7 to 75.0 ± 0.4 % and remained at this level until day 56. The actual protein content rose from 0.2 ± 0.0 g (day 1) to 11.2 ± 1.2 g (day 56). The relative protein content increased slightly from 12.0 ± 2.0 % on day 1 to 17.0 ± 0.5 % on day 21, and it oscillated about this value until day 56. The actual fat content of the liver decreased in the first week, and rose between days 14 and 35 again. During the first posthatching week its relative content decreased from 21.6 ± 0.1 on day 1 to 5.1 ± 0.01 % (i.e. 6 times), and continued to decline until day 56, reaching 2.2 ± 0.1 %. The actual ash content rose 48.5 times whereas the relative one showed almost no changes during the experimental period (Table 5).

Table 5

Chemical composition of the liver of ducks aged 1 to 56 days

Age d	Water g	Protein g	Fat g	Ash g
1	0.85 ± 0.04***	0.17 ± 0.03	0.30 ± 0.00***	0.02 ± 0.00
7	2.80 ± 0.15***	0.58 ± 0.03	0.19 ± 0.00	0.51 ± 0.00
14	14.09 ± 1.02***	2.88 ± 0.18***	0.80 ± 0.13	0.26 ± 0.04**
21	24.77 ± 0.86***	5.58 ± 0.16**	1.17 ± 0.15**	0.38 ± 0.01**
28	34.61 ± 2.15	7.25 ± 0.51*	1.77 ± 0.13	0.54 ± 0.06
35	39.11 ± 1.49**	9.23 ± 0.55	1.43 ± 0.12	0.65 ± 0.03
42	49.38 ± 1.66	10.36 ± 0.30	1.48 ± 0.08	0.72 ± 0.02
49	48.39 ± 1.88	11.40 ± 0.51	1.55 ± 0.03	0.77 ± 0.03
56	53.05 ± 4.18	11.22 ± 1.15	1.58 ± 0.05	0.97 ± 0.04

See footnotes to Table 1

Gross energy of the GIT and liver

The actual amount of gross energy in the GIT organs rose from 17.3 kJ on day 1 to 678.6 kJ on day 56, i.e. 39.2 times. The energy of proteins accounted for 8.9 kJ in newly hatched ducklings, and rose to 524.0 kJ at the end of the experiment, i.e. it increased 58.9 times. The fat energy rose from 8.4 kJ to 154.6 kJ during the same period, i.e. it increased only 18.4 times (Table 6). Thus the proportions of protein energy and fat energy were almost equal in newly hatched birds but then changed entirely so that by day 56 the fat energy contribution dropped to 22.8 %, i.e. by more than one-half the original value (Fig. 2).

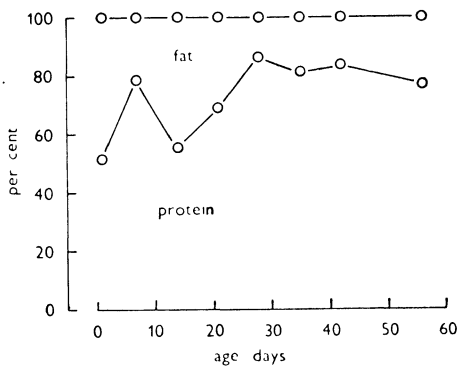

Fig. 2. Gross energy content in the GIT of ducks aged 1 to 56 days.

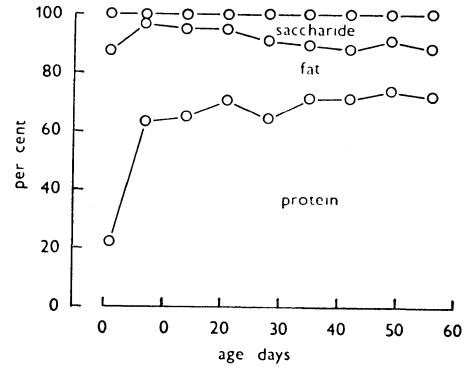

Fig. 3. Gross energy content in the liver of ducks aged 1 to 56 days.

Table 6

Gross energy in the GIT and liver of ducks aged 1 to 56 days

Age d	GIT			Liver			
	Fat kJ	Protein kJ	Total kJ	Fat kJ	Protein kJ	Glycogen kJ	Total kJ
1	8.4	8.9	17.3	11.9	4.1	2.3	18.3
7	9.5	35.0	44.5	7.6	13.8	0.7	22.1
14	37.8	46.8	84.6	31.8	68.7	5.5	106.0
21	42.4	95.7	138.2	46.5	133.1	9.8	189.4
28	51.7	327.8	379.5	70.4	173.0	24.6	268.0
35	89.8	391.4	481.2	56.8	220.2	32.2	309.2
42	92.5	474.6	567.1	58.8	247.2	41.0	347.0
56	154.6	524.0	678.6	62.8	267.7	42.5	373.0

The actual gross energy content of the liver rose from 18.3 kJ on day 1 to 373.0 kJ on day 56, i.e. it increased 20.4 times (Table 6). The protein energy accounted for 4.1 kJ on day 1 and 267.7 kJ on day 56 presenting a 65.3fold increase. The fat energy was 11.9 kJ on day 1; by the end of the first week it was considerably lower. Later it rose again but at a rate much slower than the protein energy content so that on day 56 it accounted for only 62.8 kJ (i.e. a 5.3fold increase). From the data reported previously (Baranyiová and Holub 1971) we also calculated the energy content of liver carbohydrates in ducks; these provided 2.3 kJ on day 1 and 42.4 kJ on day 56, presenting an 18.6 fold increase (Fig. 3).

Discussion

The growth rates of the GIT and liver in the duck change considerably during the first 8 posthatching weeks as demonstrated by the present data. This fact is documented by their changing contributions to the live body mass (Mahelka 1968; Baranyiová et al. 1980) but also by comparison with the mallard *(Anas platyrhynchos)* in which the live body mass as well as that of the GIT and liver increase at a slower rate (Mahelka 1973).

In birds, there are well-known great interspecies differences in posthatching GIT growth rate. They result, no doubt, from nutritional differences in hatchlings. Thus, e.g. in intensively fed pigeons a 38-fold increase in GIT mass was observed from hatching until 4 weeks of age (Kaufman 1927). Direct experimental evidence concerning the effect of nutrition upon the GIT immediately after hatching has been presented in chickens (Baranyiová 1972 ab).

In ducklings as in chickens (Baranyiová 1972 ab) or goslings (Knutsson et al. 1980; Knutsson and Sperber 1981), the GIT and liver growth rates surpass that of the live body mass: the GIT by about 20 %, and the liver by 22 %. The smallest contribution to this rapid growth rate was by the esophagus plus crop, a somewhat greater contribution was by the proventriculus followed by the gizzard, and the greatest was that of the intestine which increased its mass by 27 % more than the esophagus plus crop.

Even with considerable increases in mass and thus in actual content of the individual chemical components the relative water and protein content of the GIT remained relatively constant; any changes that occurred were observed in the first and second posthatching weeks. When compared with chickens (Doskočil 1966, 1967) the esophagus and crop of newly hatched ducklings contain relatively less water and protein but more fat whose relative content is higher also in the intestinal wall.

These facts may also be affected by factors involved in water status of newly hatched birds (Tullett and Burton 1982), and in redistribution of their body fat in the course of hatching (Holman 1969; Baranyiová and Holman 1972).

In ducks the chemical composition of the liver is changing in a way similar to that found in chickens (Doskočil 1966, 1967) except that their liver hydration is lower than in chickens. On the other hand, the fat content in ducks is twice that found in chickens. During the first posthatching week, as evidenced also by Evans (1972), it declines to about one third of the original value. A similar trend has been described also in chickens (Doskočil 1966, 1967; Baranyiová and Holman 1972). During the same period, the liver glycogen stores decline to almost one third (Baranyiová and Holub 1971).

The chemical composition of the GIT of ducks in the first two months after hatching is characterized by a relatively high water content of the esophagus and crop, a high protein content of the gizzard and in the first week, a sharp decline of fat content in the intestine and liver.

Of interest are the changes in gross energy of the GIT and liver mass. The contribution of the GIT to the energy content increased from less than one-half on day 1 to almost two thirds on day 56. The contribution of the liver changed reciprocally. This change is accounted for by a small increase in the fat content of the liver. Neither the glycogen content of the liver rose in parallel to its mass; the glycogen increment was by more than three fifths smaller.

These data on gross energy in the liver indicate that in spite of relative increase

of energy metabolism in the duck during the first posthatching week and its continued actual growth (Romijn and Lokhorst 1964; Romijn and Vreugdenhil 1969; Kotrbáček 1972) this organ becomes less important as a readily available energy reserve with advancing age.

Změny hmotnosti a chemického složení gastrointestinálního traktu a jater kachen v prvých dvou měsících života

Na 90 kachňatech plemene bílého pekingského jsme sledovali změny hmotnosti a chemického složení jednotlivých částí GIT a jater od vylíhnutí do stáří 56 dní.

Absolutní hmotnost GIT roste nejrychleji v týdnu třetím, jater v druhém, což vede ke zvyšování jejich podílů na živé hmotnosti. Na tomto růstu se u GIT nejvíce podílí střevo, potom žaludky, nejméně jícen a vole.

Při velkém zvyšování hmotnosti GIT zůstává jeho relativní obsah vody a bílkovin dosti stálý, obsah tuku, a to zvlášť ve střevě a v játrech se během prvého týdne prudce snižuje.

Bruttoenergie (BE) v hmotě sledovaných orgánů absolutně, a to značně rozdílně, stoupá; v GIT téměř 40krát, v játrech však jen 20krát. U jater se na tomto malém nárůstu BE rozhodujícím způsobem podílí především malý vzestup absolutního množství tuku, ale i glykogenu. V důsledku toho s přibývajícím věkem kachňat ztrácejí játra jako pohotová energetická rezerva na významu.

Изменение массы и химического состава желудочно-кишечного тракта и печени уток в первые два месяца жизни

На 90 утятах белой пекинской породы проводились исследования изменений массы и химического состава отдельных частей желудочно-кишечного тракта и печени после вылупливания до возраста 56 суток.

Абсолютная масса желудочно-кишечного тракта быстрее всего увеличивается в течение третей недели, у печени — в течение второй недели, что выливается в увеличении их доли в живой массе. В данном росте желудочно-кишечного тракта самая большая доля приходится на кишечник, желудок, меньше всего на пищевод и зоб.

При больчшом увеличении массы желудочно-кишечного тракта его относительное содержание воды и белков отличается сравнительным постоянством, содержание жиров, в особенности в кишечнике и печени, в течение первой недели резко понижается.

Суммарная энергия (BE) в массе исследуемых органов абсолютно, но с существенной разностью, повышается; в желудочно-кишечном тракте почти в 40 раз, однако в печени лишь 20 раз. Решающая дола в приведенном небольшом увеличении BE у печени приходится прежде всего на небольшое увеличение абсолютного количества жиров и гликогена. В результате этого с увеличивающимся возрастом утят печень в качестве активного энергетического резерва теряет свое значение.

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