Effect of age on digestibility of starch in chickens with different growth rate

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ABSTRACT: Digestibility of starch was examined in slow-growing cockerels of laying type (SG) and in fast-growing male chickens (FG) of broiler type fed *ad libitum* on a maize-type diet until Day 22 of age in one-day periods and from Day 22 to Day 100 in three-day periods. Digestibility was estimated using the chromic oxide indicator method. In SG chicks, starch digestibility rapidly increased within the first days of their lives and reached the value of 0.986 already on Day 4 of life. It was maintained on this level till the end of the experiment, which was finished at the age of 100 days. In FG chicks, which in comparison with SG birds consumed more than a double quantity of feed, high starch digestibility was observed as late as on Day 8. From Day 8 to Day 100 of age, starch digestibility slightly but highly significantly ($P < 0.01$) decreased. The average value of digestibility was lower by 0.008 in broiler type chickens than in SG chickens at this time; nevertheless, digestibility was never below 0.96. The difference was highly significant ($P < 0.001$).

Keywords: chickens; age; growth rate; starch digestibility

Starch is the main source of energy in poultry diets. Variations in starch digestibility may strongly affect the energy value of poultry diets. Starch consists predominantly of α-glucan (ca. 99% of dry matter) in the form of amylose and amylopectin. The pancreas plays a major role in starch digestion when accessible starch in the duodenum receives pancreatic α-amylase into the lumen to hydrolyse α-(1,4) bonds and thus produce glucose, oligosaccharides and dextrins. Maltose and dextrins generated from starch cannot be absorbed in the small intestine. Absorptive epithelial cells produce a number of other brush border enzymes to allow for digestion and subsequent absorption of such materials. These enzymes are not released into the lumen of the small intestine but are bound to the membrane of microvilli (Tester et al., 2003).

Chicks are very early adapted to starch digestion. They hatch with some reserves of amylase, which was accumulated during embryonic development in the pancreas (Nir et al., 1993). According to Moran (1985), α-amylase, maltase and isomaltase activities appear in the embryo on Day 18 of incubation and reach their maximum four days after hatching.

Nitsan et al. (1991) found that maximum values for amylase in the pancreas were attained on Day 8. In the intestinal chyme the activity was very low at hatching and increased markedly to peak at the end of the second week of age. In an experiment by Akiba and Murakami (1995) the activity of amylase in the pancreas at hatch and 1 day after hatch was by 10% lower than that observed on Day 21 and rose gradually to the maximum on Day 3 or Day 4 of age. The digestive enzyme activity in the intestine remained lower during the first 2 days in accordance with the low activity in pancreas and rose gradually to the maximum on Day 4 or Day 5 of age.

Nir et al. (1993) determined activities of some digestive enzymes from hatching to 14 d of age in meat- and egg-type chicks. Pancreatic digestive enzyme activities were similar in broiler and egg-type chicks, but activities in the small intestinal contents were lower in meat-type chicks. In an experiment by Uni et al. (1995) enzyme secretion to the duodenum per gram of feed intake was higher in heavy-strain Arbor Acres birds than in light-strain Lohmann chicks on Day 4 after hatching but thereafter no differences were apparent. Starch digestion ranged from 90 to 95% from Day 4 to Day 14 in Arbor Acres birds, but increased from approximately 80% on Day 4 in Lohmann chicks to 93% on Day 14.

The starch digestion rate in chickens differs in dependence on feeds. Carré et al. (2002) found that starch digestibilities observed in maize were practically always rather high (> 0.96). In contrast, the variations in starch digestibility values between samples were much higher for wheats and barleys than for maize. For wheats, the values ranging from 0.903 to 0.967 were found out. Riesenfeld et al. (1980) determined starch digestion along the chick's intestine. About 65% of ingested starch was digested up to the end of the duodenum, 85% up to the end of the jejunum and about 97% at the terminal ileum. In an experiment with 3-week-old broiler chickens fed on a maize-type diet Svihus et al. (2004) found the ileal and faecal starch digestibilities to be 0.97 and 0.98, respectively, and Maisonnier et al. (2001a) reported the faecal digestibility 0.93–0.94. In another experiment, Maisonnier et al. (2001b) found that the starch digestibility of maize-type diet was 0.96 and that of wheat-type diet 0.82–0.87. In an experiment with 21-day-old broiler chickens Svihus (2001) observed that the average starch ileal digestibilities of wheat, barley and oats diets were 0.79, 0.96 and 0.99, respectively. Pérez-Vendrell and Brufau (2003) reported starch digestibility of the wheat-based diet in 21-day-old leghorn chickens 0.979 and Skiba et al. (2003) found starch digestibility of wheat ranging from 0.911 to 0.967 in broilers between 20 and 24 days of age.

The objective of this research was to determine the influence of age on the digestibility of starch in laying and meat-type chickens. To evaluate the effect of age as exactly as possible, it was necessary to carry out estimations in very short time intervals during a longer period of life.

MATERIAL AND METHODS

Effect of age on the faecal digestibility of starch was studied using 95 Isa Brown slow-growing cockerels of laying type (SG) and 52 fast-growing Ross male chickens of meat type (FG). Birds of each group were kept in 4 pens. Data collection from the SG birds began at hatch, while data collection from the FG birds began on Day 2. Until Day 22, digestibility was investigated in one-day balance periods and from Day 22 to Day 100 in three-day subsequent periods. Excreta of groups SG and FG were collected daily and pooled from all four pens in each balance period. Chickens were fed a starter diet during the whole experimental period. The feed mixture included of 510 g of maize and 120 g of wheat and contained 225 g crude protein, 422 g starch and 12.06 MJ nitrogen-corrected metabolizable energy per kg. The feed was supplied *ad libitum* and its consumption was recorded. For details about the environment including the composition of the diet see our earlier report about fat digestibility and nitrogen retention (Zelenka et al., 2000).

The coefficients of starch digestibility were estimated using the chromic oxide indicator method. The content of chromic oxide in feed and freeze-dried excreta was estimated iodometrically (Mandel et al., 1960) and starch content enzymatically as described by Salomonsson et al. (1984). The regressions of determined values and other statistical analyses were computed according to Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Body weight, daily feed consumption and starch digestibility of FG and SG chicks till 22 days of age are presented in Table 1. Growth curves of chickens and feed consumption till the end of experiment are in Figure 1. In FG cockerels, feed intake decreased during the last balance periods and their growth rate was reduced. At the age of 100 days, the body weights of FG and SG cockerels were 6 640 g and 2 411 g, respectively. The values of starch digestibility during the whole experimental period are plotted in Figure 2.

In SG chicks, which were fed immediately after hatching, starch digestibility was 0.967 on Day 1. It is obvious that the production of amylase, including amylase that was accumulated during the embryonic development in the pancreas (Nir et al., 1993), was sufficient for the digestion of very low amounts of consumed feed (0.8 g). On Day 2 the production of amylase was not adequate and the digestibility decreased by nearly 16%. However, on Day 4 it reached the values adequate for digestion in SG chickens. Similar results were also published by Moran (1985) and Akiba and Murakami (1995).

Table 1. Consumption of feed, body weight of chicks and starch digestibility

Age in days	Dry matter intake (g)		Body weight (g)		Starch digestibility	
	FG	SG	FG	SG	FG	SG
1	0.0	0.8	44.4	36.6		0.9669
2	5.6	1.6	52.0	35.6	0.9495	0.8092
3	9.8	4.0	63.9	40.2	0.9636	0.9046
4	15.1	6.8	78.1	46.0	0.9732	0.9862
5	18.9	7.8	94.6	51.9	0.9735	0.9814
6	20.0	9.8	117.5	64.4	0.9678	0.9763
7	25.3	13.6	136.7	72.2	0.9745	0.9760
8	29.3	14.0	162.1	79.9	0.9917	0.9784
9	34.0	14.9	193.1	88.6	0.9815	0.9807
10	37.5	15.8	225.4	100.9	0.9877	0.9923
11	44.2	17.1	258.9	110.3	0.9836	0.9857
12	47.1	18.5	295.9	122.0	0.9817	0.9875
13	54.3	19.2	334.9	130.6	0.9836	0.9908
14	57.8	20.8	382.3	146.6	0.9965	0.9936
15	61.2	23.4	427.0	160.1	0.9858	0.9869
16	62.2	25.2	469.3	175.6	0.9928	0.9937
17	68.4	27.8	505.9	189.2	0.9884	0.9914
18	72.4	27.0	557.2	203.1	0.9925	0.9945
19	72.2	31.1	608.8	222.2	0.9868	0.9908
20	85.8	31.5	661.8	236.1	0.9887	0.9903
21	84.7	33.0	695.3	251.3	0.9874	0.9911
22	77.5	33.0	750.7	268.6	0.9936	0.9907

FG = fast-growing Ross 208 chicks of meat type
SG = slow-growing Isa Brown chicks of laying type

Starch digestibility reached the level of 0.986 and remained practically unchanged till Day 100 with only very slight fluctuations.

As compared with SG chicks, the feed intake in FG group was more than doubled. The production of amylase for such amounts of feed reached an adequate level as late as on Day 8 of life. This corresponds to results published by Nitsan et al. (1991), who observed that the maximum value of amylase production in the pancreas of broilers was attained on Day 8. Till this age synthesis and secretion of enzymes from the pancreas to the intestine were in a developing stage and apparently insufficient. The starch digestibility in the *ad libitum* fed chicks probably reflects the maximum synthesis capacity of amylase at this age. Higher feed intake of broiler-type chicks is reflected in a larger amount of intestinal contents and a lower amylase concentration in digesta. In Week 2, when the capacity for enzyme synthesis is fully developed, the digestibility is no longer dependent on feed intake (Mahagma et al., ex Nitsan, 1995).

From Day 8 to Day 100 the starch digestibility ranged from 0.9616 to 0.9965 and from 0.9784 to 0.9949 in FG and SG chickens, respectively. In this period, average digestibility in FG and SG birds was 0.9811 ± 0.00135 (mean ± standard error of the mean) and 0.9889 ± 0.00066, respectively. The difference of 0.0078 was highly significant ($P < 0.001$).

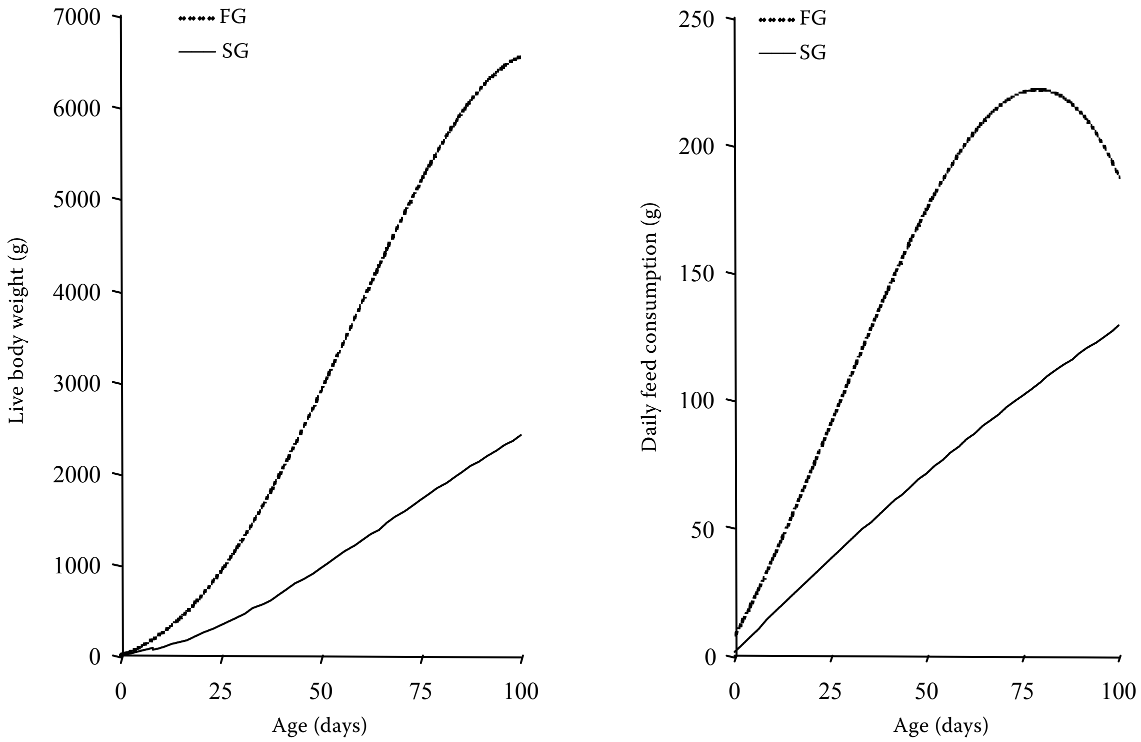

Figure 1. Body weight of chickens and daily feed consumption

Regarding the fact that starch represents the main source of energy in feed mixtures for poultry, this difference is important also from the practical aspect. In our experiment with a maize-type diet the digestibility values were higher than those reported for a maize-type diet by Maisonnier et al. (2001a) and similar to those published by Riesenfeld et al. (1980), Maisonnier et al. (2001b), Carré et al. (2002) and Svihus et al. (2004).

Dependence of starch digestibility on the age of chickens in days estimated in 41 balance experiments was expressed by linear regression equations for day 8 to 100 (r = correlation coefficient):

$Y_{FG} = 0.9905 - 0.000208\ X$; $r = 0.710$, $P < 0.01$

$Y_{SG} = 0.9895 - 0.000014\ X$; $r = 0.100$, $P > 0.05$

The deviations from linearity were not significant ($P > 0.05$). The starch digestibility in FG chickens decreased highly significantly ($P < 0.01$) linearly with increasing age.

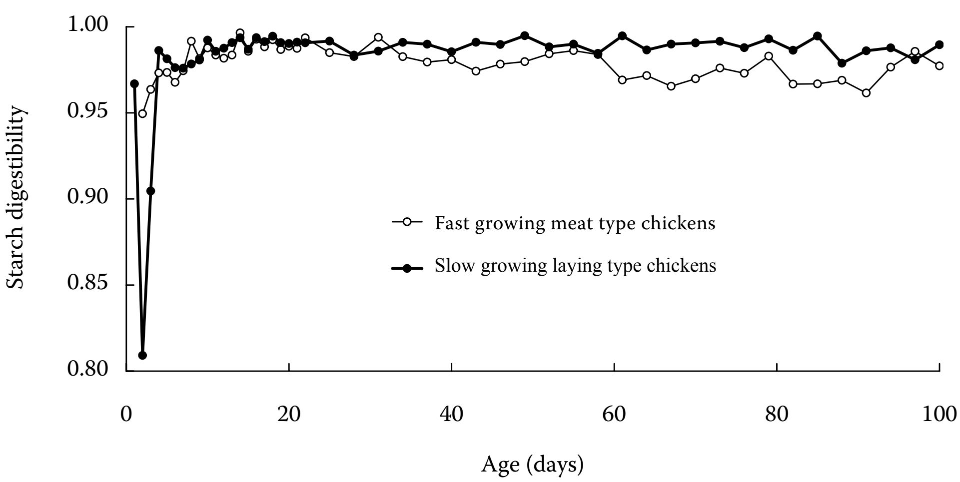

Figure 2. Digestibility of starch

REFERENCES

Akiba Y., Murakami H. (1995): Partitioning of energy and protein during early growth of broiler chicks and contribution of vitelline residue. In: Proceedings of the 10th European Symposium on Poultry Nutrition. World's Poultry Science Association, Antalya, Turkey, 44–52.

Carré B., Idi A., Maisonnier S., Melcion J.P., Oury F.X., Gomez J., Pluchard P. (2002): Relationships between digestibilities of food components and characteristics of wheats *(Triticum aestivum)* introduced as the only cereal source in a broiler chicken diet. Brit. Poult. Sci., *43*, 404–415.

Maisonnier S., Gomez J., Chagneau A.M., Carré B. (2001a): Analysis of variability in nutrient digestibilities in broiler chickens. Brit. Poult. Sci., *42*, 70–76.

Maisonnier S., Gomez J., Carré B. (2001b): Nutrient digestibility and intestinal viscosities in broiler chickens fed on wheat diets, as compared to maize diets with added guar gum. Brit. Poult. Sci., *42*, 102–110.

Mandel L., Turynek V., Trávníček J. (1960): An iodometric method of determination of chromic oxide, used as an indicator in digestibility trials. Živoč. Výr., *5*, 645–652.

Moran E.T. (1985): Digestion and absorption of carbohydrates in fowl and events through perinatal development. J. Nutr., *115*, 665–674.

Nir I., Nitsan Z., Mahagna M. (1993): Comparative growth and development of the digestive organs and of some enzymes in broiler and egg type chicks after hatching. Brit. Poult. Sci., *34*, 523–532.

Nitsan Z., Ben-Avraham G., Zoref Z., Nir I. (1991): Growth and development of the digestive organs and some enzymes in broiler chicks after hatching. Brit. Poult. Sci., *32*, 515–523.

Nitsan Z. (1995): The development of digestive tract in posthatched chicks. In: Proceedings of the 10th European Symposium on Poultry Nutrition. World's Poultry Science Association, Antalya, Turkey, 21–28.

Pérez-Vendrell A.M., Brufau J. (2003): Role of xylanase-inhibitors on nutritive value of wheat-based diets supplemented with different xylanases for poultry. In: Proceedings of the 14th European Symposium on Poultry Nutrition. World's Poultry Science Association, Lillehammer, Norway, 347–348.

Riesenfeld G., Sklan D., Bar A., Eisner U., Hurwitz S. (1980): Glucose absorption and starch digestion in the intestine of the chicken. J. Nutr., *110*, 117–121.

Salomonsson A.C., Theander O., Westerlund E. (1984): Chemical characterization of some Swedish cereal whole meal and bran fractions. Swedish J. Agric. Res., *14*, 111–117.

Skiba F., Métayer J.P., Vilarino M., Barrier-Guillot B. (2003): Relationships between crude protein content, starch content, specific weight, hardness, sprouting and the nutritive value of wheat for broiler chickens. In: Proceedings of the 14th European Symposium on Poultry Nutrition. World's Poultry Science Association, Lillehammer, Norway, 351–352.

Snedecor G.W., Cochran W.G. (1967): Statistical Methods. 6th ed. The Iowa State University Press, Ames, Iowa. 593 pp.

Svihus B. (2001): Research note: a consistent low starch digestibility observed in pelleted broiler chicken diets containing high levels of different wheat varieties. Anim. Feed Sci. Tech., *92*, 45–50.

Svihus B., Klovstad K.H., Zimonja O. (2004): The effect of using un-ground corn instead of ground corn before pelleting on performance and feed utilisation in broilers. In: World's Poultry Congress. World's Poultry Science Association, Istanbul, Turkey. CD WPC 2004, fullpaper/1053.pdf.

Tester R.F., Karkalas J., Xin Qi. (2003): Starch structure and digestibility. In: Proceedings of the 14th European Symposium on Poultry Nutrition. World's Poultry Science Association, Lillehammer, Norway, 45–54.

Uni Z., Noy Y., Sklan D. (1995): Posthatch changes in morphology and function of the small intestines in heavy-strain and light-strain chicks. Poult. Sci., *74*, 1622–1629.

Zelenka J., Fajmonová E., Blažková E. (2000): Apparent digestibility of fat and nitrogen retention in young chicks. Czech J. Anim. Sci., *45*, 457–462.

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