Early nutrition and its effect on lifelong productivity in poultry

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Summary

Early access of birds to caloric nutrients enhances growth and performance through to marketing and increases the proportion of breast meat. To understand these effects, some of the changes occurring immediately posthatch will be reviewed based mainly on the fed/held model. Fed chicks increased in BW and small intestinal weight in the initial 48 h posthatch, whereas held chicks lost BW but the small intestines still increased in weight. Posthatch poultry must adapt to utilizing external nutrient supply from sole dependence on the lipid–rich yolk during embryonic development. Pancreatic enzyme and bile secretions increased posthatch, but did not change per g feed intake. Close to hatch, fatty acids were absorbed at over 80% in contrast to glucose and methionine which were 45 to 55% absorbed. However, by day 4 ileal digestibility was over 85% for starch and fatty acids and was 78% for N. These values further increased slightly by 14 d. The small intestine showed dramatic development in the immediate posthatch days with villus volume and crypt depth and numbers increasing rapidly. The rate of intestinal growth was influenced by lack of access to feed. Posthatch muscle fibre hypertrophy occurs mainly through satellite cell fusion in poultry, and these cells are only active for several days posthatch; this process is attenuated by posthatch starvation. Thus early nutrition has important effects on further growth and development in poultry.

Keywords: poultry**,** nutrition, small intestine, muscle

Introduction

In newly hatched poultry the body weight (BW) is comprised of 15 to 25% yolk which posthatch provides a continuing source of energy (Romanoff 1960). Birds normally forage and ingest feed close to hatch, however adaptation is necessary for poultry to begin to utilize exogenous carbohydrate and protein rich feed. Under practical conditions many birds have access to feed only 36 to 48 h after hatching and during this time body weight decreases (Noy and Sklan 1998). Several authors have suggested that yolk is used for maintenance whereas exogenous energy is utilized for growth (Anthony *et al*. 1989) but studies of deutectomy, surgical removal of the yolk (Murakami *et al.* 1992), contradict this notion. This paper examines some of the effects of early nutrition and its mechanisms on growth in the hatching bird and its effects on lifelong productivity.

The effect of early access to feed

Birds are precocial and will forage for feed immediately and begin to grow, whereas holding them without feed results in body weight loss for some 24 h after birds are fed (Moran 1990; Pinchasov and Noy 1993; Noy and Sklan 1998). In practice eggs within a single tray hatch over a 24 to 36 h period, during which time the chicks which have 'pipped' their shells are without feed. Hatchery treatments and transport to the farm involve a further holding period. Thus many birds are held for 48 h or more before initial access to feed and water (Hill and Green, 1977; Misra *et al*. 1978; Noy and Sklan 1997). This paradigm of immediate feeding (fed) as compared to 48 h of lack of access to feed (held) has been used in many of our experiments to examine the effects of this holding period both on growth close to hatch and later on in development.

Providing chicks at hatching (within 1 h of clearing the shell) with either solid feed, semi–solid feed or non–nutritious bulk (sawdust) resulted in increased BW at 4 d as compared to held chicks, although the effect of sawdust was transient. This suggests that there may be some mechanical stimulation of the GIT close to hatching (Noy and Sklan 1998). Further studies addressed the effect of the form of the feed presented to the chick comparing solid feed, a liquid nutrient supplement, or water through to marketing (Noy and Sklan 1998). Provision of caloric nutrients in solid or liquid form produced a considerable increase in BW which was maximal between 4 to 8 d and then decreased. Supplying water alone also resulted in an increase in

BW, but this effect was smaller than that of feed and was no longer apparent after 8 d. At marketing all birds with early access to nutrient or nutrient solutions were 7 to 10% heavier than held or watered birds. The cumulative feed efficiency through marketing was not changed by early nutrition, whereas the percentage of breast meat was increased by 7 to 9% in all fed birds (Noy and Sklan 1998). Similar studies in poults have been carried out and the trends observed are similar to those found in chicks. An initial BW improvement of 10% was observed in response to all nutrients, and although the difference between these and held poults decreased with age at marketing, BW was 3 to 5% higher than held poults with similar feed efficiency. As in chickens the proportion of breast muscle at marketing was higher by 4 to 10% in all birds with early access to feed (Noy and Sklan 1998).

Since provision of nutrients enhanced growth, the effect of specific materials was examined by gavaging birds at hatch with glucose, starch, protein, fat or mixtures of the above close to hatch and then returning the birds to the incubation trays. Gavaging with all nutrients enhanced BW close to hatch, although glucose produced the lowest and most transient response (Moran 1990; Pinchasov and Noy 1993; Noy and Sklan 1997).

All these studies indicate that early access to nutrients produced an initial enhancement in BW which, although decreasing with age, was generally maintained through to marketing. Some of the factors involved in these processes will now be presented.

Post–hatch development and the effect of exogenous nutrients

The changes in BW, yolk, intestinal weight and their composition close to hatch as influenced by feed intake have been determined. Chicks with access to feed consumed 6.5 g in the first 48 h posthatch and BW increased by 5 g. During this period yolk size decreased by approximately 60% transferring close to 1 g fat and protein for utilization. Concomitantly the small intestines increased in weight by more than twofold. In contrast, chicks without access to feed decreased in BW by 3.5 g during the 48 h posthatch. In these chicks yolk size decreased less than in fed birds, and thus slightly less yolk fat and protein were used. Despite the lack of feed intake during this time the small intestines increased in weight by 80%. Since the held birds did not consume any exogenous protein during this period the protein required for the intestinal growth probably originated in the yolk. Examination of the changes occurring between 2 and 4 d post hatch when all birds had access to feed showed similar growth increments in both held and fed chicks although intestinal development was less in the held chicks (Noy and Sklan, 1998). This indicated that in posthatch chicks the yolk is utilized for energy supply as well as providing protein for intestinal growth.

Yolk utilization

During poultry embryonic development yolk is the sole energy source. Lipid yolk contents are transferred during this period from the yolk sac to the embryonic circulation as lipoprotein particles (Lambson 1970). Close to hatch, remaining yolk is internalized into the abdominal cavity and at hatch the intestine contains a yellow–green viscous material originating from the yolk (Romanoff 1960; Noy and Sklan 1998). Thus yolk is transported to the intestine through the yolk stalk. The morphology of the yolk stalk through the posthatch phase has been examined and an open passage was observed at hatch which became narrower with age. After 48 h the numbers of lymphoid cells began to increase in the yolk stalk and the passage was almost completely occluded by 72 h (Olah and Glick 1984; Noy *et al*. 1996).

In addition to transport of yolk to the GIT, yolk utilization via the circulation (Romanoff 1960; Lambson 1970) also remained functional during the first 48 h after hatch after which transfer began to decrease (Esteban *et al*. 1991; Noy *et al.*1996). In fact the yolk appeared to be in equilibrium with body fluids and movement was bidirectional and non–specific (Noy *et al.* 1966; Noy and Sklan 1998).

Yolk is 16 to 35% fat and 20 to 25% protein at hatch (Moran and Reinhart 1980; Reidy *et al.* 1998). Yolk lipids consists predominantly of triglycerides and phospholipids with small amounts of cholesterol esters and no free fatty acids (Noble and Ogunyemi 1989; Noy and Sklan 1998). Digestion of the yolk lipids was clarified by following the changes occurring in intestinal lipid fractions in the early post hatch period. In the poult this indicated that in the duodenum some free fatty acids are produced from acylglycerides even before hatch and this proportion increased with age while the percentage of triglycerides decreased. In the caecum, however, the composition of the lipid fractions resembles the yolk composition at hatch and only after 4 d begins to show increasing free fatty acid levels. Thus it appears that yolk reaching the distal small intestine close to hatch is probably not utilized and this may explain the green sticky viscous excretions observed (Lambson 1970).

During this period the chick must undergo significant metabolic adaptations in order to adjust to the different exogenous nutrient sources. *In vivo* and *in situ* absorption close to hatch indicated that uptakes of glucose and methionine from aqueous buffers were higher than uptake from a yolk containing medium. In contrast oleic acid was absorbed better from yolk than from buffer solutions. Thus it appears that in the intact bird while the small intestine is filled with the lipid–rich yolk, uptake of hydrophyllic compounds is hindered. In addition lack of Na also decreased the uptake of both glucose and methionine in the immediate posthatch period (Sklan 2001).

The capacity of the chick to utilize nutrients *in vivo* immediately posthatch was determined using a bolus of labelled probe and non–absorbed marker. Oleic acid was absorbed at over 80% in contrast to glucose and methionine which were only 45 to 55% absorbed (Sklan 2001).

In order for uptake to take place, hydrolysis of macromolecules is required. Measurement of net secretion of hydrolases to the duodenum has been estimated by both total collection and using non–absorbed markers. Such measurements indicated that pancreatic enzyme secretions increase with age and with feed intake. However, calculation of secretion per g feed intake indicated no major changes in quantities of trypsin, amylase and lipase activities secreted per g between 4 and 14 d post hatch (Uni *et al*. 1995). Similar measurements determining the duodenal secretion of bile acids and fatty acids to the small intestine also showed increased secretion with age but no significant increase was found in bile secretions per feed intake. However the total amount of N secreted to the intestine per g feed intake was low close to hatch and increased with age (Noy and Sklan 1995; Uni *et al*. 1995).

These factors influence intestinal digestion and absorption and thus ileal digestion of fatty acids was over 80% from hatch and increased slightly until day 14. Starch and N digestion was less then 50% at hatch and this increased to over 85% by day 14 (Noy and Sklan 1995).

In order for absorption to take place the intestinal infrastructure for uptake must be sufficiently developed and some of the changes occurring with age will now be reviewed.

GIT Development

Close to and after hatch, dramatic changes occur both in the intestinal size and morphology (Bayer *et al.* 1975; Cook and Bird 1973; Uni *et al.* 1966). In the immediate post hatch period the intestines increase in weight more rapidly than the body mass. This rapid relative growth reached a maximum at 6 to 8 d in the poult, and in the chick at 6 to 10 d (Akiba and Murakami 1995; Katanbaf *et al.* 1988; Sell *et al.* 1991). In contrast, other digestive tract organs such as gizzard and pancreas do not show parallel enhanced changes in relative size (Uni *et al.* 1998). At hatch, villi are not well developed, crypts are few and not well defined, and enterocytes are round and non–polar. Within a short time posthatch villus height and area increased rapidly but at different rates in different chick intestinal segments reaching a plateau at 6 to 8 d in the duodenum and after 10 d in the jejunum and ileum. The enterocyte changed from a round and relatively non–polar cell to an elongated polar cell and as the villus grows the number of enterocytes per villus increased. Crypts increased in number and size and branched rapidly within the immediate posthatch days. Enterocytes were almost all proliferating at hatch whereas proliferation became localized mainly in the crypt areas within the week posthatch (Geyra *et al*. 2001a).

The effect of holding on the morphological development in the different intestinal segments in the chick has been examined (Baranyiova and Holman 1976; Uni *et al.* 1998; Geyra *et al.* 2001b) as well as the effect of deutectomy (Uni *et al.* 1998). Holding birds resulted in effects which were in part region dependent. However, both growth of villi and crypts and the localization of proliferation as well as migration were delayed by holding (Geyra *et al*. 2001b; Uni *et al.* 1998). In older birds, fasting for 24 h resulted in similar effects with decreased villus height in the duodenum and jejunum and depressed mitosis (Yamauchi *et al.* 1996).

The extensive changes in the morphological development close to hatch enlarge the intestinal absorptive surface many–fold but are sensitive to pertubations in nutrient supply which lead to slower GIT development.

The effects of holding on the development of breast muscle have also been examined in both chicks and poults. Satellite cells have a transient but crucial period of activity in the hatching chick with maximal activity at 2 to 4 d and in the poult at 4 to 6 d before becoming quiescent (Halevy *et al*. 2000, 2003). Holding birds without feed alters the dynamics of the satellite cells during this period, with the maximal activity occurring later and at a lower level then in fed chicks. This is apparently mediated in part by IGF1 (Halevy *et al*. 2003).

Conclusions

Early availability of feed thus results in the following:

1. yolk is used for initial GIT growth which is supplemented by exogenous feed;
2. lack of nutrients retards GIT development;
3. oleic acid is well absorbed close to hatch. In contrast glucose and methionine are absorbed better from sodium containing aqueous solutions then in the presence of yolk;
4. exogenous feed enhances yolk utilization and is almost completely digested after 4 d;
5. in birds with early access to feed activity of muscle satellite cells are altered changing the hypertrophy of breast muscle;
6. together these changes indicate that appropriate nutrition close to hatch can accelerate GIT development and muscle growth and result in increased performance through marketing.

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