The Effect of Early Feeding on Growth and Small Intestinal Development in the Posthatch Poul
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ABSTRACT

Poults with early access to feed in the hatchery or turkey house grew more than those reared under standard commercial practice. During 48 h posthatch, fed poults utilized yolk and exogenous feed to increase BW by 11 g. The small intestine increased from 3.8% of BW at hatch to 8.9% after 48 h. In contrast, BW in feed-deprived poults decreased by 10 g, whereas the small intestine increased slightly in weight and composed 4.5% of BW after 48 h. The number of cells per villus and the villus surface area increased dramatically posthatch in the duodenum but more slowly in the jejunum and ileum. Enterocyte width changed little, but length increased more than twofold in the duodenum and by approximately 50% in the jejunum and ileum by 6 d posthatch. Lack of access to feed depressed the rate of growth of villi and enterocyte length in all intestinal segments until 6 d posthatch.

(Key words: poul, early feeding, enterocyte, development)

INTRODUCTION

Toward the end of incubation, residual yolk is internalized into the abdominal cavity and is the sole nutrient source until exogenous food replaces it after hatch. Residual yolk at hatch comprises 20 to 25% of the chick BW and 10 to 12% of the poult BW (Noy and Sklan, 1998a). Because turkey and chicken embryos vary extensively in the timing of pipping, commercial hatcheries are not emptied until the maximum number of eggs hatch; thus, at exit from the hatchery, birds average 1 to 2 d of age (Moran and Reinhart, 1980).

The timing and form of nutrients supplied posthatch is critical for development (Noy and Sklan, 1998b). In previous reports of chicks and poults, early access to feed resulted in enhanced initial growth that is maintained through market age. Feed efficiency is not influenced, yet the carcass composition is altered (Noy and Sklan, 1999a; Sklan et al., 2000). In chickens, early access to feed enhanced BW, the size of the pectoralis, and small intestinal development (Noy and Sklan, 1998b, 1999a; Uni et al., 1998a).

Yolk provides major metabolites for the embryo during incubation, directly through circulation, whereas close to hatch and thereafter yolk also reaches the gastrointestinal tract (Noy and Sklan, 1998a). Examination of changes occurring close to hatch in the chick indicated that yolk during the initial 48 h posthatch contributes to maintenance and small intestinal development (Noy and Sklan, 1999b). However, in poults the changes accompanying development and early feeding have not been extensively examined. This paper will report on the effect of early access to feed in poults and examine yolk utilization and intestinal morphological changes and monitor plasma composition posthatch.

MATERIALS AND METHODS

Poults

Four hundred eighty British United Turkeys (BUT; Big 6) turkey eggs were purchased directly from a

Abbreviation Key: BUT = British United Turkeys, NEFA = nonesterified fatty acids, PCNA = proliferating cell nuclear antigen, PL = phospholipids, T3 = triiodothyronine, TG = triglycerides.
breeder flock (48 wk of age). Eggs were preweighed and selected for an average weight of 90 g (range 85 to 95 g). At 10 d of incubation, all eggs were candled and infertile eggs were removed. The incubation procedure was according to the BUT manual. After 600 h of incubation, eggs were transferred to hatching trays (n = 40), and humidity and ventilation were changed accordingly. Hatching trays were examined every 3 h, and any birds that had cleared the shell (defined as time of hatch) were weighed and wing-banded, and hatching time was recorded. Hatching trays were divided with a partition down the middle, and two different experiments were carried out. One treatment involved placing starter feed\textsuperscript{2} [crumbles, meeting or exceeding NRC (1994) recommendations] in troughs on alternate sides of six of the trays. These poults were weighed after 668 h of incubation and transferred to floor pens in a temperature-controlled turkey house with free access to starter feed and water.

In the second treatment, poults from one-half of six additional hatching trays were transferred every 3 h to floor pens in a temperature-controlled facility with free access to starter feed and water. Poults from the remaining half of all the hatching trays remained in the incubator until 668 h of incubation and served as controls. In addition, two poults per tray were sampled on clearing the shell at peak of hatch, and two more were sampled at 2 and 4 d later for proximate carcass analysis from both treatments. Male poults were sampled for blood and intestines, removed for histology, at 0, 2, 3, 6 (7), and 9 d in Treatment 1.

**Morphological Examination**

The small intestines of poults were removed, and segments of approximately 2 cm were taken from the midpoint of the duodenum (duodenum), from the midpoint between the point of bile duct entry and Meckel’s diverticulum (jejunum), and midway between Meckel’s diverticulum and the ileo-ceacal junction (ileum). Segments were gently flushed twice with phosphate-buffered saline to remove the intestinal contents and then fixed in a 4% neutral-buffered formalin solution and embedded in paraffin. All histological studies were performed on 5-µm sections. Samples were stained for detection of proliferating cell nuclear antigen (PCNA)\textsuperscript{3} as antibody (Uni et al., 1998b). After being dried, sections were analyzed under a light microscope (Olympus BX-40),\textsuperscript{4} and morphometric indices were determined with computer-assisted image analysis (Uni et al., 1995).

\textsuperscript{2}Matmor Inc., M.P. Evtach, 79258 Israel.
\textsuperscript{3}Zymed PCNA staining kit, Zymed Laboratories, San Francisco, CA 94080.
\textsuperscript{4}Olympus, Melville, NY 11747.
\textsuperscript{5}Sigma Chemical Co., St. Louis, MO 63718.
\textsuperscript{6}Kit no. TKC 35, Pharmade-Veterinary, Kefr Saba, 44425, Israel.
Examination of the changes in BW, yolk, and intestinal weight and their compositions close to hatch as influenced by feed intake are shown in Figure 2. BW and protein changes between hatch and 48 h and between 48 and 96 h are shown for poults in Treatment 2. Between 0 and 48 h posthatch, poults with access to feed increased BW by approximately 11 g. During this period, yolk size decreased by 3 g, transferring 0.9 g of protein and 0.5 g of fat (data not shown) for use by the poult. The weight of the total small intestine grew by 3.5 g in this period.

Poults without access to feed decreased in BW by 10 g in the 2 d posthatch, and their yolk decreased by 2.8 g. During this period, the small intestine increased by 0.2 g, and dry matter changed little. These birds did not receive any exogenous protein during this period; thus, the protein necessary for this slight intestinal growth must have originated in the yolk. The small intestines composed 3.8% of BW at hatch, and in fed poults this weight increased to 8.6% after 48 h. In contrast, small intestines of feed-deprived birds increased to 4.8% of BW at 48 h posthatch, indicating that small intestinal growth occurs before BW gain. During the 2 to 4 d posthatch, when all birds had access to feed, fed birds had greater growth increments; however, in feed-deprived poults, small intestine growth was more rapid during this period.

Histological examination of small intestinal segments indicated more rapid growth in the duodenum, jejunum, and ileum of poults that were fed while in the turkey house as compared to feed-deprived birds. Duodenal...
surface area and cell size were greater than jejunal area and size, which, in turn, were greater than ileal area (Figures 3 and 4). Poults that were feed-deprived had less villus surface area and smaller cell size until 6 d posthatch. Because the duodenal and jejunal villi were larger than the ileal villi, parallel trends were observed in villus cell numbers (Figure 5).

Proliferative cells were identified with PCNA, and the proportion of proliferating cells in crypts decreased after hatching to approximately 40 to 50% within 48 h in feed-deprived and fed birds. In fed poults, a plateau of 50 to 60% proliferating crypt cells was observed after 48 h posthatch in all segments (Figure 6). However, in feed-deprived poults a smaller proportion of cells were proliferating prior to feed intake. After ingestion of feed, there was a rapid increase in percentage of proliferating cells, to 60 to 70%, in all segments, followed by a decrease to the levels of fed birds after 150 h. In all poults, all cells

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**FIGURE 3.** Changes in the villus surface area of the duodenum, jejunum, and ileum in fed (▲) and feed-deprived (○) poults. Results are means, and bars are SD and are shown when they do not fall within the symbols. Significant differences were found in the duodenum and jejunum of fed and feed-deprived poults at 48 and 72 h.

**FIGURE 4.** Changes in enterocyte length of the duodenum, jejunum, and ileum in fed (▲) and feed-deprived (○) poults. Results are means, and bars are SD and are shown when they do not fall within the symbols. Significant differences were found in the duodenum of fed and feed-deprived poults at 48 and 72 h and in the jejunum at 48 h.
FIGURE 5. Changes in the number of cells per villus in the duodenum, jejunum, and ileum of fed (▲) and feed-deprived (○) poults. Results are means, and bars are SD and are shown when they do not fall within the symbols. Significant differences were found in the duodenum and jejunum of fed and feed-deprived poults at 48 and 72 h and in the ileum at 48 h.

along the villus were proliferating at hatch, and this proportion decreased rapidly to approximately 6 to 8% after 72 h. The proportion of proliferating cells along the villus was similar for fed and feed-deprived birds in all intestinal segments (Figure 6).

Examination of plasma composition, close to hatch, in poults immediately transferred to the turkey house indicated that glucose, Na, PL, and TG concentrations were similar for fed and feed-deprived poults during the early posthatch period (Table 1). Plasma T3 concentrations were depressed in feed-deprived poults until 7 d of age, whereas NEFA levels were increased in feed-deprived poults as compared to those fed throughout.

DISCUSSION

Early access to feed for chicks and poults has repeatedly been shown to enhance growth (Noy and Sklan, 1998a). Under commercial conditions, the pipping process involves a 24-to-48-h window of hatching, during which time poults that hatch first are without feed and water. In the absence of feed within the incubator, a linear reduction in poult BW occurs at 0.17 g/h (Sklan et al., 2000). Delay of placement exacerbates this condition with further decreases in weight. The initial BW loss following hatch is mainly due to metabolism and possibly some dehydration occurring during holding time in the incubator and postincubator (Noy and Sklan, 1997). In previous reports of chicks (Noy and Sklan, 1999a) and in the current study of poults, BW begins to increase 24 to 48 h after access to feed. Previous poult early nutrition trials (Noy and Sklan, 1999a) indicate that access to feed in different forms, whether liquid or solid, results in faster weight gains compared to poults with late access to feed; this advantage is maintained through marketing. The present report extended these findings and indicated that pouls with access to feed in incubator trays or on farm showed BW improvement compared to poults held in the hatchery.

Examination of the changes in body composition posthatch indicated that poults with access to feed at hatch used the exogenous nutrient source as well as 3 g of endogenous yolk in the 48 h posthatch. These poults increased in BW by 10 g, which included 1.3 g protein. Small intestines comprised 3.8% of BW at hatch, and this proportion increased to 8.9% after 48 h. In contrast, in feed-deprived poults, BW decreased initially, and most of this weight loss was accounted for by the decrease in yolk weight, with little detectable change in water content. Intestinal weight, as a percentage of BW increased, but to only 4.5% during this period. During the 48 h posthatch, approximately 1.0 g of yolk fat and 0.7 to 0.8 g of yolk protein were transported in these feed-deprived poults; and 0.1 g of protein and almost 0.9 g fat were lost from the BW.

The yolk fat was probably used for maintenance energy, which would be approximately 4 kcal/d per poult. This level of maintenance in hatching poults is of a similar order of magnitude to that previously reported for chicks (Kuenzel and Kuenzel, 1976; Noy and Sklan, 1999b). The small intestines of the feed-deprived poults increased slightly in weight during this period, indicating that small intestine growth takes precedence over body growth in utilizing yolk protein.

In this study, we examined some of the changes in the morphology of the small intestine as influenced by feeding. Small intestine growth preceded other body organs in the immediate posthatch period (Uni et al.,
Feed deprivation, in this study, partially arrested this preferential development. Examination of the intestinal morphology indicated that this arrested preferential development was reflected in decreased enterocyte length and villus surface area until after feeding. After access to feed, these poults exhibited accelerated intestinal growth and reached a similar stage of development to the fed birds in some of the parameters examined after 4 d posthatch, whereas in others a gap in growth was still apparent after 7 d.

In contrast to adult mammals, proliferation of enterocytes in the chick small intestine is not confined to the crypts but also occurs along the villus (Uni et al., 1998b). In the newly hatched poult, all cells along the villus and crypt were proliferating, as has been previously reported by Applegate et al. (1999). This proliferation rate changed rapidly with a decrease in the proportion of proliferating villus cells to less than 10% in all intestinal segments within 48 h. This rate of decrease in the number of proliferating enterocytes in the different intestinal seg-
ments may well indicate a rapid rate of maturation of enterocytes. In other mammals, villus enterocytes are proliferating at birth (Quaroni, 1985), and in the rat, enterocyte proliferation becomes restricted to the crypt in the third postnatal week (Hermos et al; 1971). In poult crypts, all cells were proliferative at hatch, and approximately 50% of these cells were still proliferating after 48 h in all intestinal segments. Feed intake did not affect the proportion of proliferating cells along the villus; however, in the crypts of feed-deprived poult, the proportion of proliferating cells was depressed prior to feed intake. Ingestion of solid nutrients caused proliferation to rebound to over 60% by 72 h before plateauing at the same level as feed poult, which indicates that lack of feed decreases crypt proliferation and may then limit the number of enterocytes available for villus growth. This reduction in crypt proliferation would then contribute to the decreased observed in the villus absorptive surface area.

In addition to examining intestinal ontology, we followed changes in plasma concentrations of some metabolites with age. We found that plasma Na concentrations in fed and held poult were strictly regulated posthatch. Plasma glucose concentration was maintained at relatively constant levels in fed and held birds, despite the lack of exogenous carbohydrate intake in held birds. In a recent report, Turner et al. (1999) indicated that poult were able to regulate plasma glucose concentrations close to hatch, unless high carbohydrate diets were fed. Posthatch changes in plasma lipid concentrations were to be expected because yolk supplies lipids directly for circulation; however, concentrations of PL and TG changed only slightly with age, regardless of treatment. In contrast, plasma NEFA concentrations were increased in feed-deprived poult over the 7-d period examined, which suggests that these poult were using higher amounts of NEFA for their energy needs than feed poult that were also using exogenous nutrients. It is possible that yolk lipids are transported to peripheral tissues where they are hydrolyzed to NEFA for energy utilization or from lipid mobilized from liver.

Plasma concentrations of T3 were decreased in unfed poult but increased after feeding. It has been previously reported that a significant linear correlation exists between plasma T3 concentrations and feed intake (Klandorf and Harvey, 1985; Yahav et al., 1995, 1998; Yahav and Hurwitz, 1996). The main effect of T3 in homeotherms is to stimulate oxidative metabolism (Oppenheimer et al., 1991). In addition, T3 has been found to increase crypt cell proliferation and mucosal thickness in rats (Hodin et al., 1992). It is unclear whether T3 secretion in this trial was initiating these changes or was responding to some other signal.

Thus, withholding feed from posthatch poult depresses BW and intestinal growth, including that of villi and enterocyte proliferation, and these changes are possibly mediated via decreased plasma T3 concentrations. The decreased intestinal absorptive area in feed-deprived poult may limit the nutrient uptake capacity and contribute to decreased growth.

**REFERENCES**


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**TABLE 1. Plasma concentrations of some metabolites with age in fed and feed-deprived poults**

<table>
<thead>
<tr>
<th>Age (d)</th>
<th>Treatment</th>
<th>Glucose (mg/dL)</th>
<th>T3 (ng/mL)</th>
<th>Na (mm)</th>
<th>PL (mg/ml)</th>
<th>NEFA (mg/ml)</th>
<th>TG (mg/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Fed</td>
<td>310 ± 30</td>
<td>2.23 ± 0.42</td>
<td>160 ± 5</td>
<td>4.40 ± 0.51</td>
<td>1.17 ± 0.13</td>
<td>0.28 ± 0.07</td>
</tr>
<tr>
<td>2</td>
<td>Feed-deprived</td>
<td>288 ± 39</td>
<td>2.21 ± 0.31*</td>
<td>153 ± 4</td>
<td>3.76 ± 0.17</td>
<td>0.91 ± 0.21*</td>
<td>0.54 ± 0.20</td>
</tr>
<tr>
<td>4</td>
<td>Fed</td>
<td>302 ± 24</td>
<td>1.48 ± 0.35</td>
<td>156 ± 6</td>
<td>3.85 ± 0.35</td>
<td>1.35 ± 0.16</td>
<td>0.38 ± 0.16</td>
</tr>
<tr>
<td>7</td>
<td>Feed-deprived</td>
<td>264 ± 17</td>
<td>3.15 ± 0.25*</td>
<td>150 ± 7</td>
<td>2.81 ± 0.48</td>
<td>0.93 ± 0.14*</td>
<td>0.32 ± 0.05</td>
</tr>
<tr>
<td></td>
<td>Fed</td>
<td>231 ± 35</td>
<td>2.48 ± 0.31</td>
<td>142 ± 8</td>
<td>2.27 ± 0.27</td>
<td>1.59 ± 0.28</td>
<td>0.22 ± 0.15</td>
</tr>
<tr>
<td></td>
<td>Feed-deprived</td>
<td>283 ± 17</td>
<td>3.43 ± 0.48</td>
<td>145 ± 4</td>
<td>2.75 ± 0.30</td>
<td>0.60 ± 0.19*</td>
<td>0.32 ± 0.16</td>
</tr>
<tr>
<td></td>
<td>Feed-deprived</td>
<td>284 ± 34</td>
<td>3.69 ± 0.35</td>
<td>139 ± 5</td>
<td>2.35 ± 0.44</td>
<td>0.96 ± 0.07</td>
<td>0.28 ± 0.14</td>
</tr>
</tbody>
</table>

*T3 = triiodothyronine; PL = phospholipids; NEFA = nonesterified fatty acid; TG = triglycerides.

*Differs significantly from feed-deprived poults (P < 0.05).*