The Effects of Delayed Access to Feed and Water on the Physical and Functional Development of the Digestive System of Young Turkeys[1]

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ABSTRACT Three experiments were conducted with turkeys to determine the influence of delayed access to feed and water on the development of the digestive system. In all experiments, poults were randomly assigned to three placement times, 6, 30, and 54 h posthatch. Experiments 1, 2, and 3 were terminated when poults were 10, 28, and 14 d old, respectively. In Experiment 1, six poults per treatment were sampled on Days 1, 2, 3, 4, 5, 6, 8, and 10. In Experiment 2, 12 poults per treatment were sampled on Days 1, 2, 3, 4, 5, 10, 15, and 28. The objective of Experiment 3 was to determine the effect of delayed placement on dietary ME_n. Delaying access to feed and water for 54 h adversely affected BW through 10, 28, and 14 d of age in Experiments 1, 2, and 3, respectively ($P \leq 0.01$). Delayed access to feed and water for 54 h decreased the absolute weights of the small intestine and pancreas and reduced lengths of the small intestine through 5 d posthatch ($P \leq 0.05$). The relative weights of the small intestine and proventriculus were reduced by delayed access to nourishment through 4 d posthatch. Poults placed on feed at 54 h posthatch had decreased pancreatic amylase activity ($P \leq 0.05$) at 3 and 4 d, and trypsin activities were depressed at 3 d posthatch ($P \leq 0.05$). In Experiment 3, dietary ME_n value determined at 4 d of age with poults placed 54 h posthatch was less ($P \leq 0.07$) than the ME_n value obtained with poults placed at 6 h posthatch. A 54-h delay in access to feed and water generally delayed development of the digestive system, impaired nutrient utilization, and reduced BW.

(*Key words*: poult, delayed feed access, gastrointestinal tract development, digestive enzymes)

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INTRODUCTION

Before and immediately after hatch, turkey poults are dependent on the lipids and proteins of the egg yolk as main sources of nutrients. The yolk is usually depleted within 5 to 6 d posthatch (Sell *et al.*, 1991). Thus, progress in the physical and functional development of the gastrointestinal tract (GIT) is necessary to enable newly hatched poults to efficiently utilize nutrients supplied by the diet. Because of distances of shipment or delays in shipment, poults are often subjected to delayed access to feed and water, which may retard the development of the GIT, limiting nutrient utilization and performance of the turkey. Early access to feed and water after hatch has been shown to be an important factor for subsequent performance (Moran, 1990). Poults deprived of feed and water for 48 h lost 10.7% of their initial posthatch weight (Pinchasov and Noy, 1993). Moran (1978) reported that depriving poults of feed and water for 24 h posthatch led to reduced BW through 14 wk of age.

Uni *et al.* (1998) reported that withholding feed from chicks for 36 h posthatch resulted initially in retarded growth of all segments of the small intestine. Murakami *et al.* (1992) found that delaying access to feed and water slowed the growth of the small intestine and proventriculus in broiler chicks. Donaldson and Christensen (1991) reported that poults deprived of feed 24 h posthatch had significantly lighter liver weights than fed poults. Noy and Sklan (1997) concluded that one effect of delayed placement on both chicks and poults was that the organs of the GIT (crop, small intestine, and large intestine) grew less by 48 h posthatch than did organs of poults or chicks placed immediately on feed and water. Depriving poults of feed for 48 h posthatch led to reduced uptake of residual yolk and greater yolk weights than was observed with poults given immediate access to feed and water (Moran and Reinhart, 1980; Moran, 1989; Pinchasov and Noy, 1993). Murakami *et al.* (1992) reported yolk weight decreases of 48 and 41%/d for fed and feed-deprived broiler chicks, respectively.

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Abbreviation Key: GIT = gastrointestinal tract.

Research has shown that the digestibility of nutrients in young poultry increases with age. Experimentally determined ME_n values of diets fed to poults were lowest between 4 and 7 d of age (Sell, 1996). Weights of the GIT increase more rapidly than BW in young turkeys until 6 d of age. Total activities of pancreatic enzymes increase substantially after hatching, mainly because of increased pancreas weight (Sell *et al.*, 1991). Absorption of nutrients from the GIT is dependent on digestion, mainly by pancreatic enzyme activity. Lack of pancreatic enzymic hydrolysis in the intestinal lumen decreases the apparent digestibility of dietary components (Corring and Bourdon, 1977). Siddons (1972) reported that by 16 d of age, chickens deprived of feed for 72 h posthatch had lower total activities of all disaccharidases (maltase, sucrase, isomaltase, and palatinase) in the small intestine than chickens deprived of feed for 24 h posthatch. The ability of young poultry to utilize certain dietary fats is especially limited for the first few days after hatch, possibly due to limited pancreatic lipase activity (Krogdahl and Sell, 1989). The production and secretion of digestive enzymes in the posthatch chick could be limiting factors in digestion and subsequently in feed intake and growth (Nitsan *et al.*, 1991).

The results described above reflect the importance of the supply organs (e.g., intestine, pancreas, and liver) immediately after hatch, demonstrating that the development of the GIT and associated digestive enzyme production may be the limiting factors in posthatch growth. Moreover, limited research has been done to determine the effects of delaying access to feed and water on the development of the GIT of poults. On the basis of previous research, it was hypothesized that delayed access to feed and water would retard development of the GIT, impairing nutrient utilization and resulting in reduced growth. The three experiments reported herein were conducted to assess the effects of delaying access to feed and water for 6, 30, or 54 h posthatch. Two experiments examined the changes in the GIT, digestive enzymes, and BW, and the third experiment evaluated the changes in utilization of dietary energy.

MATERIALS AND METHODS

Experimental Design

Three experiments were conducted with turkey poults obtained from a commercial hatchery. Poults arrived at the experimental farm approximately 6 h after removal from the hatcher. Poults within each experiment were randomly assigned to three placement times. These placement times were 6, 30, and 54 h after removal of poults from the hatcher (referred to hereafter as posthatch), and these times were when the poults were allowed access to feed and water. Poults of the delayed placement groups (30 and 54 h) were held in shipping boxes until given access to feed and water. At the appropriate times, poults were placed in floor pens (1.2 m^2) equipped for brooding (Experiments 1 and 2) or in electrically heated brooder batteries[4] (Experiment 3). After placement, poults were provided feed and water for *ad libitum* consumption. All poults were fed a corn-soybean meal diet formulated to meet or exceed nutrient concentrations recommended by the NRC (1994) (Table 1). The diet fed in Experiments 2 and 3 contained Celite[5] (acid insoluble ash) as an indigestible marker.

Experiment 1. One hundred and ninety-two male turkey poults were divided into three groups of 64 poults, such that group weights were similar. Room temperatures ranged between 25 to 27 C and poults had access to 35 C under brooder heat lamps for the first 7 d and 32 C for the remaining 3 d of the experiment. Weight gain and feed consumption were determined when poults were 1, 2, 3, 4, 5, 6, 8, and 10 d of age.

Experiment 2. Female turkey poults were obtained from a commercial hatchery and 22 poults were placed in each of 18 floor pens (six pens per treatment). Room temperatures ranged between 25 and 29 C, and poults had

[4]Petersime, Gettysburg, OH 45328.
[5]Sigma Chemical, St. Louis, MO 63178-9916.

TABLE 1. Composition and calculated analysis of the corn-soybean meal diet

Ingredients	Experiment 1	Experiments 2 and 3
	(%)	
Soybean meal	53.15	53.15
Corn	37.67	36.97
Meat and bone meal	3.00	3.00
Animal-vegetable fat	2.68	2.68
Dicalcium phosphate	1.64	1.64
Limestone	0.97	0.97
Celite™[1]		0.70
Vitamin premix[2]	0.30	0.30
Mineral premix[3]	0.30	0.30
Methionine	0.20	0.20
Sodium chloride (iodized)	0.06	0.06
BMD[4]	0.03	0.03
Calculated analysis		
DM	90.59	90.59
ME_n kcal/kg	2,850.00	2,850.00
Crude protein	28.50	28.50
Total sulfur amino acids	1.05	1.05
Methionine	0.61	0.61
Lysine	1.67	1.67
Calcium	1.20	1.20
Nonphytate phosphorus	0.60	0.60

[1]Sigma Chemical Co., St. Louis, MO 63178-9916.

[2]Supplied per kilogram of diet: vitamin A (retinyl acetate), 8,065 IU; cholecalciferol, 1,580 IU; vitamin E (dl-α-tocopheryl acetate), 15 IU; vitamin B_{12}, 16 μg; vitamin K (menadione sodium bisulfite), 1.98 mg; riboflavin, 7.8 mg; pantothenic acid, 12.8 mg; niacin, 75 mg; choline, 509 mg; folic acid, 1.62 mg; biotin, 270 μg.

[3]Supplied per kilogram of diet: manganese, 70 mg; zinc, 40 mg; ferrous sulfate, 37 mg; copper, 6 mg; selenium, 0.15 mg; sodium chloride, 2.6 g.

[4]Bacitracin dimethylene salicylate, A. L. Pharma, Inc. Ft. Lee, NJ 07024.

access to 35, 32, and 29 C under brooder heat lamps for the 1st, 2nd, and 3rd wk, respectively. Weight gain and feed consumption were determined when poults were 7, 14, 21, and 28 d of age. Feed efficiency was calculated as the feed intake to BW gain ratio.

Experiment 3. Seventy-two female turkey poults were obtained from a commercial hatchery and randomly assigned to 12 pens (4 pens per treatment, 6 poults per pen). Room temperatures ranged between 25 and 29 C, and the brooder temperatures were kept at 35 and 32 C for the 1st and 2nd wk, respectively. Weight gain and feed consumption were determined when poults were 7 and 14 d of age. Feed efficiency was calculated as the feed intake to BW gain ratio.

Sampling

In Experiments 1 and 2 five poults were sampled at 6 h posthatch for baseline measurements. In Experiment 1, six poults per placement time were selected randomly for sampling when poults were 1, 2, 3, 4, 5, 6, 8, and 10 d of age. Each poult was treated as an experimental unit. In Experiment 2, 2 poults per pen (12 per treatment) were selected randomly for sampling when poults were 1, 2, 3, 4, 5, 10, 15, and 28 d of age. The average of two poults per pen was treated as an experimental unit. In Experiments 1 and 2, poults were weighed, killed by inhalation of Halothane®,[6] and the abdominal cavity opened. The residual yolk (with yolk sac) was removed from the GIT and weighed. The proventriculus, gizzard, and small intestine were separated, and weights of the proventriculus and gizzard were recorded after ingesta were removed. In Experiment 1, the spleen, heart, and liver were excised and weighed. In Experiment 2, the bursa of Fabricius was excised and weighed. The small intestine with the pancreas was suspended vertically with a weight of 3.5 or 10 g (varying with age) attached to the lower end to apply uniform tension for length measurements. For length and weight measurements, the small intestine was divided into three segments: duodenum (from gizzard to entry of the bile and pancreatic ducts), jejunum (from entry of the ducts to yolk stalk), and ileum (from yolk stalk to ileocecal junction). The pancreas was removed from the duodenal loop, placed in preweighed vials, and immediately frozen in liquid nitrogen. The duodenum and ileum were flushed with 10 to 20 mL of deionized water, and the empty weight recorded. Because maltase activity of the jejunum was to be determined, this segment was flushed with 10 to 20 mL of saline solution, and the empty weight recorded. Approximately 10 cm of the middle portion of the jejunum was placed in preweighed vials and immediately frozen in liquid nitrogen. Jejunal and pancreatic samples were stored at –20 C until prepared for further analysis.

Determination of Enzyme Activities

After their weights were determined, jejunal and pancreas samples were thawed and homogenized with a Polytron homogenizer[7] at a speed setting of 4 (low to moderate) for 45 s with sufficient cold deionized water to result in a concentration of 50 mg tissue/mL of homogenate. Aliquots of the homogenates were taken for determination of protein concentration (Lowry *et al.*, 1951) and enzyme assays. Jejuna were assayed for maltase (EC 3.3.1.20) activity by using maltose as a substrate (Dahlquist, 1964). Pancreas homogenates were analyzed for amylase (EC 3.2.1.1) by using the Phadebas blue starch procedure (Ceska *et al.*, 1969). Trypsin activity in the pancreas was determined by the method of Erlanger *et al.* (1966). Amylase, maltase, and trypsin specific activities were expressed as micromoles of substrate hydrolyzed hourly per milligram of tissue protein. Pancreatic lipase activity was determined by the procedure of Nitsan *et al.* (1974) as modified by Palo (1994), and specific activities are expressed as milligrams of naphthol released in 60 min at 37 C/g of protein.

Determination of Nitrogen-Correcrted Metabolizable Energy

In Experiment 3, ME_n was determined when poults were 4, 7, and 14 d of age. Excreta collection per pen was done over a 24-h period with the exception that the collection period was 36 h at 4 d of age. After preliminary drying, feed and excreta samples were ground to pass through a 0.5-mm mesh sieve. Dry matter of the feed and excreta was determined by drying the samples in a forced-draft oven at 72 C for 48 h (AOAC, 1980:Section 7.003). The gross energy of feed and excreta were determined using an adiabatic bomb calorimeter.[8] Feed and excreta were analyzed for nitrogen concentration by the macroKjeldahl method; AOAC, 1980:Section 2.057). Nitrogen concentration was multiplied by 6.25 to calculate the protein percentage (AOAC, 1980:Section 14.068). The concentration of acid insoluble ash in the feed and excreta was determined by the method described by Vogtmann *et al.* (1975). The ME_n of the diets was calculated using the equation described by Hill and Anderson (1958).

Statistical Analysis

Data from Experiments 1, 2, and 3 were analyzed using the General Linear Models procedure of SAS® (SAS Institute, 1985) to determine the effects of delayed access to feed and water. Significant differences among treatment means were separated by Duncan's multiple range test (Duncan, 1955) with a 5% level of probability.

RESULTS AND DISCUSSION

Body Weight and Feed Consumption

Body weights of poults in Experiment 1 were affected adversely ($P \leq 0.01$) by delayed access to feed and water,

[6]Halocarbon Laboratories Incorporated, North Augusta, SC 29841.
[7]Kinematica PT 10-35, Brinkman Instruments, Westbury, NY 11590.
[8]Parr Instruments Co., Moline, IL 61265.

TABLE 2. Effect of placement time on the body weight of poults, Experiments 2 and 3

Experiment	Placement time	Days of age			
		7	14	21	28
	(h)	(g/poult)			
2	6	128.4[a,1]	260.2[a]	491.4[a]	824.1[a]
	30	118.3[b]	241.1[b]	468.6[b]	796.4[a]
	54	96.2[c]	206.5[c]	403.5[c]	703.6[b]
	SEM	1.8	5.9	6.5	12.1
	P	0.01	0.01	0.01	0.01
3	6	126.2[a,2]	277.8[a]	[3]	
	30	115.8[b]	263.5[a]		
	54	87.5[c]	214.9[b]		
	SEM	3.0	5.1		
	P	0.01	0.01		

[a–c]Means in columns and within experiment with no common superscript differ significantly ($P \leq 0.05$).

[1]Means represent six pens per treatment, 22 female poults per pen at the start of the experiment.

[2]Means represent four pens per treatment, six female poults per pen.

[3]Experiment 3 was terminated at 14 d of age.

whereby average 10-d BW of poults placed at 30 and 54 h posthatch were 175 and 161 g, respectively, compared with 208 g for poults placed at 6 h posthatch. Similar effects of delayed placement occurred in Experiments 2 and 3 (Table 2). Poults not allowed access to feed and water until 30 or 54 h posthatch weighed less ($P \leq 0.01$) than those placed at 6 h posthatch at 7, 14, and 21 d of age in Experiment 2 and at 7 d of age in Experiment 3. The adverse effect on BW for poults placed at 54 h posthatch was still evident when Experiments 2 and 3 were terminated at 28 and 14 d, respectively. Adverse effects on BW due to a 24-h delay in access to feed and water of turkeys also was reported by Chilson and Patrick (1946) and Moran (1978). In the latter instance, the adverse effect was evident through 14 wk of age.

Feed consumption in Experiment 1 was less for poults placed at 30 or 54 h posthatch, than that of poults placed at 6 h (data not shown). However, because of lack of pen replication, statistical evaluation of these data could not be done. In Experiments 2 and 3, delayed access to feed and water for 30 or 54 h posthatch generally decreased feed intake (Table 3). This effect was most evident in the instance of cumulative 28-d feed consumption in Experiment 2. Noy and Pinchasov (1993) reported that broiler chicks denied access to feed and water for 24 h posthatch consumed less feed through 40 d of age. This result corresponds to those reported here with turkeys, in that a delay in access to feed and water decreased feed consumption. There were no significant effects ($P > 0.05$) of delayed access to feed and water on cumulative feed efficiency, which agrees with findings of Noy and Pinchasov (1993). In contrast, Moran (1978) previously reported improved feed to gain ratios between 2 and 6 wk of age when poults were denied feed for 24 h posthatch. Moran (1978) reported 50% greater mortality when poults were deprived of feed for 24 h after hatch compared with fed poults. Chilson and Patrick (1946) also reported greater mortality rates of poults as the delay in access to nourishment increased. In the current study, mortality of poults placed on feed and water at 30 or 54 h posthatch did not differ from that of poults placed on feed and water at 6 h posthatch.

Digestive Organs

Weights of the small intestine, pancreas, proventriculus, and gizzard, and the length of the small intestine increased markedly during the 1st wk after hatch (Tables 4 and 5). Growth of the GIT has been shown to exceed that of total BW for the first 6 d of a poult's life (Sell *et al.*, 1991). Katanbaf *et al.* (1988) and Nitsan *et al.* (1991) emphasized

TABLE 3. Effect of placement time on the feed consumption of poults, Experiments 2 and 3

Experiment	Placement time	Days of age				Cumulative feed consumption
		7	14	21	28	
	(h)	(g/poult)				
2	6	86.7[a,1]	193.3[a]	380.4[a]	512.9[a]	1,173[a,2]
	30	82.0[a]	159.6[b]	360.6[b]	498.6[a]	1,101[b]
	54	59.6[b]	149.2[b]	304.5[c]	447.4[b]	961[c]
	SEM	1.9	9.2	5.1	8.6	20.4
	Probabilities	0.01	0.01	0.01	0.01	0.01
3	6	87.7[a,3]	196.1[a,4]			283.8[a,5]
	30	77.2[b]	188.3[a]			265.5[a]
	54	53.2[c]	161.9[b]			215.1[b]
	SEM	2.3	4.4			6.1
	Probabilities	0.01	0.01			0.01

[a–c]Means in columns and within experiment with no common superscript differ significantly ($P \leq 0.05$).

[1]Means represent feed consumption for a 1-wk period and represent six pens per treatment, 22 female poults per pen at the start of the experiment.

[2]Cumulative means represent feed consumption through 28 d of age.

[3]Means represent feed consumption for a 1-wk period and represent four pens per treatment, six female poults per pen.

[4]Experiment 3 was terminated at 14 d of age.

[5]Cumulative means represent feed consumption through 14 d of age.

TABLE 4. Effect of placement time on the physical characteristics of the small intestinal segments of poults, Experiment 1

Age	Placement time	Weight			Length			Weight/length		
		Duodenum	Jejunum	Ileum	Duodenum	Jejunum	Ileum	Duodenum	Jejunum	Ileum
(d)	(h)	(g/poult)			(cm/poult)			(g/cm)		
1	6	0.61[a,2]	0.72[a]	0.68[a]	9.5	16.7	12.7	0.064[a]	0.041	0.053[a]
	30	0.42[b]	0.56[b]	0.51[b]	9.0	15.8	13.5	0.047[b]	0.036	0.039[b]
	54	0.42[b]	0.56[b]	0.51[b]	9.0	15.8	13.5	0.047[b]	0.036	0.039[b]
	SEM	0.06	0.05	0.05	0.3	0.5	1.0	0.017	0.003	0.003
	P	0.04	0.04	0.02	0.35	0.26	0.55	0.05	0.20	0.01
2	6	0.78[a]	1.19[a]	1.05[a]	10.3[a]	19.8[a]	16.3	0.076[a]	0.061[a]	0.068
	30	0.66[b]	0.97[b]	0.86[b]	10.0[a]	18.1[b]	14.2	0.066[a]	0.054[a]	0.064
	54	0.46[c]	0.54[b]	0.70[c]	9.0[b]	15.6[c]	12.6	0.051[b]	0.035[b]	0.055
	SEM	0.04	0.05	0.05	0.3	0.5	1.2	0.004	0.003	0.006
	P	0.01	0.01	0.01	0.01	0.01	0.14	0.01	0.01	0.39
3	6	0.96	1.38[a]	1.07[b]	11.2	19.7	16.6[a]	0.086	0.073	0.065[b]
	30	1.15	1.52[a]	1.24[a]	11.5	20.7	15.0[a]	0.101	0.073	0.083[a]
	54	1.08	1.08[b]	0.86[c]	10.6	16.4	11.6[b]	0.104	0.066	0.075[ab]
	SEM	0.07	0.08	0.05	0.4	1.2	0.9	0.006	0.005	0.004
	P	0.15	0.01	0.01	0.33	0.06	0.01	0.13	0.55	0.02
4	6	2.00[a]	2.12[a]	1.91[a]	12.7	26.0[a]	19.8	0.158[a]	0.082[a]	0.095
	30	1.96[a]	1.96[a]	1.74[a]	12.3	25.4[a]	19.4	0.159[a]	0.077[a]	0.098
	54	1.40[b]	1.45[b]	1.37[b]	11.5	22.3[b]	17.2	0.121[b]	0.065[b]	0.080
	SEM	0.11	0.07	0.10	0.4	0.7	0.8	0.007	0.003	0.007
	P	0.01	0.01	0.01	0.12	0.01	0.09	0.01	0.01	0.31
5	6	2.58[a]	2.46[a]	1.95	14.3[a]	27.9	22.4	0.179[a]	0.088[a]	0.088
	30	2.20[b]	2.17[b]	1.77	13.0[b]	27.5	21.9	0.169[a]	0.079[b]	0.080
	54	1.97[b]	2.16[b]	1.68	13.0[b]	25.9	20.8	0.151[b]	0.084[ab]	0.081
	SEM	0.11	0.08	0.11	0.4	0.8	0.9	0.006	0.002	0.004
	P	0.01	0.04	0.22	0.05	0.21	0.45	0.01	0.05	0.31

[a–c]Means in columns and within age with no common superscript differ significantly ($P \leq 0.05$).
[1]One day of age corresponds to 30 h after arrival at the research farm.
[2]Means represent six male poults per treatment.

the close relationship between digestive organ development and growth of newly hatched birds. It is believed that most of the nutrients available are devoted to the rapid development of the GIT to facilitate nutrient utilization so that rapid increases in BW can occur.

In agreement with reports from Murakami *et al.* (1992) and Uni *et al.* (1998), withholding feed and water initially resulted in retarded growth of all segments of the small intestine (Tables 4 and 5). In Experiments 1 and 2, absolute weights of the small intestine were less for the first 2 d after hatch when poults were placed 30 h posthatch. A 54-h placement resulted in decreased intestinal weights through 5 d of age. Uni *et al.* (1998) concluded that depressed intestinal weights may indicate reduced morphological development.

Weights of the intestinal segments increased markedly in poults within each placement time group in response to consumption of feed and water. For example, weights of the duodenum and jejunum of poults deprived of nourishment for 30 h posthatch in Experiment 1 increased 57 and 73%, respectively, within 24 h after feed and water consumption. Weights of these intestinal segments of poults deprived of feed and water for 54 h posthatch increased 135 and 100%, respectively, within 24 h of feed and water intake. Similar responses were observed for increased weight per length of intestinal segment in Experiments 1 and 2. These data support the observations of Uni *et al.* (1998) that feed consumption stimulated intestinal development in poults as compared with delayed access to feed.

When expressing the weight of the small intestine segments on a relative basis (grams per 100 g BW), differences were observed due to delayed access to feed and water (Table 6). A 30-h delay in access to feed and water affected each segment of the small intestine differently. In Experiment 1, a 30-h delay only resulted in reduced jejunal weights at 2 d of age, whereas in Experiment 2, reduced weights were observed for the duodenum at 4 d of age and the ileum at 3 and 4 d of age with no effect on the weight of the jejunum compared with poults placed at 6 h posthatch. Delaying access to feed and water for 54-h posthatch had a more severe and constant effect on relative weights of the small intestine, in which reduced weights were observed on Days 3 and 4 in all segments of the small intestine in Experiments 1 and 2. In the current study, delaying access to feed and water prolonged the duration of small intestine growth relative to BW. The small intestine weight of poults placed at 6 and 30 h posthatch increased faster than BW until 5 d of age, but when poults were placed 54 h posthatch, the small intestine increased in weight faster than BW until approximately 15 d of age.

As mentioned above, weights of intestinal segments increased markedly within 24 h after the poults denied feed and water for 30 and 54 h posthatch had access to feed and water. These rapid increases in intestinal weights together with lighter concurrent BW resulted in seemingly compensatory development of the intestines. For example, the relative weights of the jejunum of the 6, 30, and 54 h placement groups were 0.98, 1.26, and 1.42 g/100 g, respectively, at 24 h after access to feed and water. Although these increases in relative intestinal weights are suggestive of a compensatory response to nutrient intake by previously deprived groups, they did not alleviate the carryover effects of delayed access to feed and water on subsequent growth of the poults in the current study.

Lengths of the small intestinal segments were shorter due to delayed placement on feed and water (Tables 4 and 5). In Experiment 1, a 30-h delay in access to feed and water after hatch resulted in reduced lengths of the duodenum at 5 d of age and the jejunum at 2 d of age. In Experiment 2, a 30-h delay reduced the length of the duodenal and ileal at 3 d of age and reduced jejunal lengths between 1 and 3 d of age. Poults placed at 54 h posthatch had shorter small intestines between 2 and 5 d of age and at 10 d of age. Comparing the weight to length ratio (density, grams per centimeter) of the small intestines allows for indirect observation of increases in mucosal mass in the intestine. Lower intestinal density may represent decreased villus height and diameter, which would reduce the digestive and absorptive abilities of the intestines (Uni *et al.*, 1998). The effects of delayed placement on the intestinal density of poults varied in each segment of the small intestine. Duodenal density was lower at 1 d of age for both delayed placement groups, continuing through 5 d of age for the 54-h placement group. In the jejunum, placement at 30 h posthatch decreased the density at 5 d and 4 d of age in Experiment 1 and 2, respectively, whereas a 54-h delay resulted in lower densities at 2 and 4 d of age in Experiment 1 and 4 and 5 d of age in Experiment 2. Ileal density was lower at 1 d of age due to a 30- and 54-h delay in Experiment 1. In Experiment 2, a reduction in ileal density due to a 30-h delay was observed at 2 d of age, whereas a 54-h delay reduced ileal density between 2 and 4 d of age compared with poults placed at 6 h posthatch. These results suggest that the presence of feed will stimulate the morphological development of the intestines, in agreement with reports of Uni *et al.* (1998).

In agreement with reports from Phelps *et al.* (1987b), the yolk of poults in the current research was essentially depleted by 5 or 6 d of age (Tables 7 and 8). Several researchers have shown that denying poults feed and water for 48 h after hatch reduced the uptake of residual yolk (Moran and Reinhart, 1980; Moran, 1989; Pinchasov and Noy, 1993). Heavier absolute yolk weights were observed at 5 and 4 d of age in Experiments 1 and 2, respectively, due to delayed placement. In Experiment 2, relative yolk weight (grams yolk per 100 g BW) was greater between 2 and 4 d of age in poults deprived of feed

TABLE 5. Effect of placement time on the physical characteristics of the small intestinal segments of poults, Experiment 2

Age	Placement time	Weight			Length			Weight/length		
		Duodenum	Jejunum	Ileum	Duodenum	Jejunum	Ileum	Duodenum	Jejunum	Ileum
(d)	(h)	(g/poult)			(cm/poult)			(g/cm)		
1	6	0.54[a,2]	0.74[a]	0.58	9.3	19.2[a]	8.2	0.059[a]	0.038	0.075
	30	0.40[b]	0.58[b]	0.49	9.0	15.3[b]	8.9	0.044[b]	0.038	0.059
	54	0.40[b]	0.58[b]	0.49	9.0	15.3[b]	8.9	0.044[b]	0.038	0.059
	SEM	0.03	0.05	0.04	0.4	0.9	0.9	0.004	0.002	0.008
	P	0.01	0.04	0.12	0.62	0.01	0.57	0.02	0.86	0.16
2	6	0.84[a]	1.21	0.79[a]	10.6	19.1[a]	11.7	0.079	0.063	0.067[a]
	30	0.66[b]	0.95	0.66[b]	9.7	16.5[b]	11.0	0.068	0.057	0.061[b]
	54	0.47[c]	0.68	0.44[c]	8.6	14.6[c]	9.6	0.055	0.046	0.046[c]
	SEM	0.03	0.09	0.02	0.3	0.4	0.4	0.004	0.005	0.002
	P	0.01	0.26	0.01	0.17	0.02	0.15	0.06	0.67	0.01
3	6	1.04[a]	1.54[a]	1.17[a]	12.1[a]	20.6[a]	14.0[a]	0.086[a]	0.075	0.084[a]
	30	0.93[a]	1.23[b]	0.88[a]	11.1[b]	18.0[b]	12.1[b]	0.081[a]	0.068	0.073[ab]
	54	0.67[b]	0.88[c]	0.66[b]	9.8[c]	15.8[c]	10.6[c]	0.064[b]	0.056	0.063[b]
	SEM	0.05	0.09	0.07	0.3	0.4	0.5	0.005	0.010	0.004
	P	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.06	0.01
4	6	1.61[a]	2.03[a]	1.49[a]	12.7[a]	22.0[a]	15.7[a]	0.128[a]	0.092[a]	0.096[a]
	30	1.19[b]	1.72[b]	1.22[b]	12.2[a]	21.1[a]	14.3[a]	0.098[b]	0.082[b]	0.086[ab]
	54	1.01[b]	1.22[c]	0.89[c]	11.0[b]	17.5[b]	12.1[b]	0.092[b]	0.070[c]	0.074[b]
	SEM	0.08	0.06	0.04	0.3	0.4	0.5	0.006	0.002	0.005
	P	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
5	6	1.71[a]	2.26[a]	1.68[a]	13.0[a]	23.9[a]	18.3[a]	0.132[a]	0.095[a]	0.093
	30	1.60[a]	2.13[a]	1.50[a]	12.9[a]	23.4[a]	16.7[ab]	0.121[a]	0.091[a]	0.090
	54	1.17[b]	1.53[b]	1.17[b]	11.8[b]	20.7[b]	15.1[b]	0.099[b]	0.074[b]	0.078
	SEM	0.07	0.11	0.07	0.3	0.6	0.6	0.005	0.005	0.004
	P	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.06

[a–c]Means in columns and within age with no common superscript differ significantly ($P \leq 0.05$).

[1]One day of age corresponds to 30 h after arrival at the research farm.

[2]Means represent two female poults per pen, six pens per treatment.

TABLE 6. Effect of placement time on the relative weight of all segments of the small intestine in poults

		Relative weight					
		Experiment 1[1]			Experiment 2[2]		
Age	Placement time	Duodenum	Jejunum	Ileum	Duodenum	Jejunum	Ileum
(d)	(h)	(%)					
1[3]	6	0.86	0.98	0.96	0.88	1.21	0.95
	30	0.68	0.90	0.82	0.79	1.14	0.96
	54	0.68	0.90	0.82	0.79	1.14	0.96
	SEM	0.07	0.07	0.05	0.05	0.07	0.06
	P	0.09	0.47	0.07	0.20	0.50	0.96
2	6	0.99	1.52[a]	1.33	1.23	1.78	1.15
	30	0.86	1.26[b]	1.13	1.05	1.52	1.06
	54	0.82	0.96[c]	1.24	1.03	1.52	0.98
	SEM	0.06	0.07	0.08	0.06	0.15	0.05
	P	0.13	0.01	0.23	0.07	0.38	0.06
3	6	1.15	1.63	1.27[ab]	1.37[a]	2.03[a]	1.54[a]
	30	1.32	1.74	1.42[a]	1.38[a]	1.83[a]	1.32[b]
	54	1.46	1.42	1.14[b]	1.12[b]	1.47[b]	1.10[c]
	SEM	0.08	0.10	0.05	0.06	0.08	0.07
	P	0.06	0.09	0.01	0.01	0.01	0.01
4	6	2.04[a]	2.19[a]	1.94[a]	1.80[a]	2.27[a]	1.66[a]
	30	2.00[a]	1.99[a]	1.77[ab]	1.50[b]	2.14[a]	1.52[b]
	54	1.66[b]	1.70[b]	1.63[b]	1.48[b]	1.79[b]	1.31[c]
	SEM	0.09	0.07	0.06	0.07	0.05	0.04
	P	0.02	0.01	0.01	0.01	0.01	0.01
5	6	2.24	2.13	1.69	1.80	2.38[a]	1.77
	30	2.02	1.99	1.62	1.74	2.37[a]	1.67
	54	1.96	2.15	1.66	1.59	2.09[b]	1.6
	SEM	0.10	0.08	0.09	0.06	0.07	0.05
	P	0.13	0.29	0.84	0.09	0.02	0.12

[a–c]Means in columns and within age with no common superscript differ significantly ($P \leq 0.05$).

[1]Means represent six male poults per treatment.

[2]Means represent two female poults per pen, six pens per treatment.

[3]One day of age corresponds to 30 h after arrival at the research farm.

and water 54 h posthatch than in poults placed on feed and water at 6 h posthatch (Table 8). These observations suggest that poults may have the ability for selective rate of nutrient withdrawal from the yolk when fasted or, as Noy and Sklan (1997) concluded, the effect of feed intake on yolk utilization may be attributed to enhanced transport of yolk to the GIT due to increased intestinal motility and activity after feed and water are ingested.

Phelps *et al.* (1987a) noted that the pancreas is the fastest growing organ in poults during the first 10 d after hatch. Delaying access to feed and water adversely affected the absolute pancreas weight in Experiments 1 and 2 (Tables 7 and 8), whereby a 30-h placement time resulted in reduced absolute and relative weights of the pancreas at 2 d of age. A 54-h placement time depressed pancreas weight between 2 and 4 d of age. In contrast, Pinchasov and Noy (1993) found no difference in relative pancreas weight due to a 24- or 48-h delay in placement time. Because digestive enzyme activity in the pancreas is highly correlated to pancreas weight, changes in pancreas weight might represent changes in digestive capability.

Delaying access to feed and water resulted in decreased weights of the proventriculus and gizzard in Experiments 1 and 2 (Tables 7 and 8). Poults denied feed and water for 30 h posthatch had depressed absolute weights of these organs through 4 d of age, whereas a delay of 54 h posthatch reduced absolute weights through 10 d of age. The relative gizzard and proventriculus weights also were depressed at 2 d of age for poults deprived of feed and water for 30 h posthatch. Placement at 54 h posthatch decreased relative weights of the gizzard and proventriculus between 2 and 4 d of age. These findings contradict those reported by Pinchasov and Noy (1993), which indicated that delayed placement increased the relative weight of the gizzard. In the current study, delaying access to feed and water resulted in decreased relative weight of the gizzard and proventriculus.

Researchers have reported increased liver weights due to delayed access to feed and water (Moran, 1989, 1990; Pinchasov and Noy, 1993), but this effect on liver weights was not observed in the current study. In Experiment 1, the effect of a 30-h delay on liver weights was not observed until 10 d of age. At this time, liver weight was depressed. A 54-h posthatch placement time decreased the absolute liver weight at 2, 3, 6, and 10 d of age. When expressing the liver weight on a relative basis (grams per 100 g BW) a delay of 54 h posthatch still had an adverse effect on the liver weight at 2 d of age.

Weight of the bursa of Fabricius was adversely affected by delaying placement 30 h posthatch at 1 d of age, whereas a 54-h posthatch placement decreased bursa weight at 1, 4, 5, and 10 d of age in Experiment 2. On a relative basis, only a delay of 54 h posthatch had an adverse effect on the bursa, and this occurred at 4 d of age. Phelps *et al.* (1987a) reported that the bursa does not mature until 5 or 6 wk of age, so early reductions in weight may have no real impact on the function of the bursa. No consistent effects on the weights of the heart or spleen were observed in Experiment 1 due to delayed access to feed and water (data not shown).

Selected Digestive Enzymes

Greatest specific activities of jejunal maltase were observed when poults were 1 d old (30 h after arrival from hatchery) in Experiment 1 and when poults were 2 d old in Experiment 2 (Tables 9 and 10). Maltase activity decreased thereafter, most rapidly in poults given access to feed and water at 6 h posthatch. Sell *et al.* (1991) also reported greatest specific activity of maltase in 1-d-old poults, followed by a decrease in activity until 6 to 7 d of age. Specific activity of maltase has been used as an indicator of enterocyte maturity (Ortega *et al.*, 1995). Thus, the decline in specific activity of the jejunal maltase shortly after access to feed and water may be related to the rapid growth of the intestine that would result in a greater proportion of immature enterocytes containing less active maltase. Poults in the current research that were given access to feed and water 54 h posthatch tended to have greater specific activity of maltase in the jejunum (just before they were provided with feed and water) than poults placed at 6 or 30 h posthatch. When comparing the maltase activity on a relative basis (micromoles of maltase hydrolyzed hourly per 100 g of BW), poults placed within 6 h posthatch had the greatest maltase activity at 2 d of age. In Experiment 1, the relative maltase activity decreased after 1 through 10 d of age. The decrease did not occur until 2 d of age in Experiment 2, continuing until 15 d of age, then increasing through 28 d of age (Tables 9 and 11). The high level of maltase activity at 1 d of age suggests that turkey poults have the maltase required to digest maltose immediately after hatch.

At 2 d of age in both experiments, poults allowed access to feed and water 54 h posthatch had the highest specific amylase activity in the pancreas, but by 3 d of age these poults had the lowest activity compared with poults placed at 6 h posthatch (Tables 10 and 11). As observed by Sell *et al.* (1991) and Krogdahl and Sell (1989), amylase activity generally increased with age. In the current study, at 1 d of age (30 h posthatch), all poults denied feed and water had greater relative amylase activity than poults placed within 6 h posthatch. By 2 d of age, poults denied feed until 54 h posthatch had the highest level of relative amylase activity. However, by Days 3, 4, and 5, poults

TABLE 7. Effect of placement time on the absolute and relative weight of various organs in poults, Experiment 1

Age	Placement time	Absolute weight			Relative weight		
		Pancreas	Gizzard	Yolk	Pancreas	Gizzard	Yolk
(d)	(h)	(g/poult)			(%)		
1[1]	6	0.16[2]	2.92[a]	5.16	0.23	4.15	7.61
	30	0.16	2.39[b]	5.07	0.26	3.86	8.15
	54	0.16	2.39[b]	5.07	0.26	3.86	8.15
	SEM	0.01	0.16	0.71	0.02	0.15	1.25
	P	0.85	0.04	0.93	0.27	0.22	0.77
2	6	0.29[a]	3.70[a]	2.16	0.37[a]	4.71[a]	2.72
	30	0.20[b]	3.24[b]	2.85	0.27[b]	4.22[b]	3.60
	54	0.16[b]	2.28[c]	2.96	0.28[b]	4.06[c]	5.24
	SEM	0.02	0.08	0.57	0.02	0.10	0.75
	P	0.01	0.01	0.58	0.02	0.01	0.09
3	6	0.31[ab]	3.99[a]	2.02	0.37	4.74	2.42
	30	0.36[a]	4.03[a]	1.46	0.41	4.62	1.67
	54	0.24[b]	3.22[b]	1.86	0.31	4.25	2.44
	SEM	0.03	0.14	0.31	0.03	0.14	0.38
	P	0.01	0.01	0.44	0.13	0.07	0.29
4	6	0.42[a]	4.70[a]	0.79	0.42	4.82	0.82
	30	0.41[a]	4.58[a]	0.68	0.42	4.67	0.69
	54	0.31[b]	3.75[b]	1.10	0.37	4.41	1.34
	SEM	0.03	0.21	0.17	0.02	0.15	0.21
	P	0.03	0.01	0.25	0.25	0.18	0.10
5	6	0.55	5.46	0.74[ab]	0.48	4.73	0.62[ab]
	30	0.47	5.03	0.27[b]	0.43	4.60	0.24[b]
	54	0.47	4.73	0.91[a]	0.47	4.69	0.88[a]
	SEM	0.03	0.24	0.20	0.02	0.19	0.17
	P	0.06	0.13	0.09	0.28	0.89	0.05

[a–c]Means in columns and within age with no common superscript differ significantly ($P \leq 0.05$).

[1]One day of age corresponds to 30 h after arrival at the research farm.

[2]Means represent six male poults per treatment.

TABLE 8. Effect of placement time on the absolute and relative weight of various organs in poults, Experiment 2

Age	Placement time	Absolute weight			Relative weight		
		Pancreas	Gizzard	Yolk	Pancreas	Gizzard	Yolk
(d)	(h)	(g/poult)			(%)		
1[1]	6	0.11[2]	2.51[a]	3.65	0.19	4.14	6.08
	30	0.11	1.95[b]	3.50	0.21	3.84	6.82
	54	0.11	1.95[b]	3.50	0.21	3.84	6.82
	SEM	0.01	0.12	0.37	0.02	0.13	0.64
	P	0.65	0.01	0.78	0.18	0.12	0.42
2	6	0.21[a]	3.17[a]	2.19	0.31	4.66[a]	3.26[b]
	30	0.16[b]	2.54[b]	2.37	0.26	4.07[b]	3.81[b]
	54	0.13[c]	1.79[c]	2.63	0.28	3.92[b]	5.67[a]
	SEM	0.01	0.10	0.41	0.02	0.11	0.58
	P	0.01	0.01	0.89	0.32	0.01	0.02
3	6	0.28[a]	3.67[a]	1.39	0.37[a]	4.86[a]	1.85[b]
	30	0.23[b]	3.25[b]	1.66	0.34[a]	4.89[a]	2.49[ab]
	54	0.17[c]	2.38[c]	2.04	0.28[b]	3.97[b]	3.40[a]
	SEM	0.01	0.10	0.23	0.01	0.11	0.33
	P	0.01	0.01	0.17	0.01	0.01	0.02
4	6	0.36[a]	4.48[a]	0.78[b]	0.41[a]	5.01[a]	0.88[b]
	30	0.33[a]	3.89[b]	1.66[a]	0.41[a]	4.83[a]	2.08[a]
	54	0.24[b]	3.05[c]	1.45[a]	0.34[b]	4.47[b]	2.10[a]
	SEM	0.02	0.14	0.19	0.02	0.09	0.24
	P	0.01	0.01	0.01	0.01	0.01	0.01
5	6	0.39	4.74[a]	0.46	0.41	4.98	0.48
	30	0.38	4.42[a]	0.51	0.42	4.95	0.54
	54	0.31	3.39[b]	0.91	0.43	4.64	1.24
	SEM	0.03	0.14	0.25	0.03	0.11	0.30
	P	0.14	0.01	0.41	0.84	0.07	0.17

[a–c]Means in columns and within age with no common superscript differ significantly ($P \leq 0.05$).

[1]One day of age corresponds to 30 h after arrival at the research farm.

[2]Means represent two female poults per pen, six pens per treatment.

deprived of feed for 54 h posthatch had the lowest levels of amylase activity per 100 g BW compared with poults placed within 6 h posthatch. In Experiments 1 and 2, relative amylase activity increased more than 5-fold by 2 d of age, whereas the specific activity increased only 1.5-fold by 2 d of age (Tables 9 and 11). These results agree with those of Moran (1982), who reported that chicks have the ability to release sufficient amylase for digestion of carbohydrates, especially right after hatch. However, results of the current research indicate that a 54-h delay in placement may decrease amylase activity enough to affect nutrient utilization between 3 and 4 d of age.

In Experiment 2, specific lipase activity in the pancreas was greatest at 1 d of age, but specific lipase activity decreased rapidly by 3 d of age and then fluctuated without any great change, which agrees with reports from Sell *et al.* (1991). At 2 d of age, poults denied access to feed and water for 54 h posthatch had the greatest specific and relative lipase activities, but by 3 d of age they had the lowest relative activity compared with poults placed within 6 h posthatch (Tables 10 and 11). Krogdahl and Sell (1989) and Escribano *et al.* (1988) reported that the total lipase activity per pancreas increased slowly between 4 and 10 d of age even though the weight of the pancreas increased rapidly. In relation to BW, lipase activity increased until 10 d of age, then decreased through 28 d of age in Experiment 2. Krogdahl and Sell (1989) reported that lipase activity approaches maximum levels between 42 and 56 d of age. The low lipase activity at hatch without significant improvements during the first 2 wk could partly explain the relatively poor utilization of certain dietary fats by poults during early growth (Krogdahl and Sell, 1989).

At 2 d of age, specific and relative trypsin activities in the pancreas were highest for poults deprived of feed for 54 h posthatch in Experiment 2 (Table 10 and 11). By 3 d of age (1 d after access to feed and water), poults denied feed for 54 h posthatch had the lowest specific and relative trypsin activities. Trypsin activities, both specific and relative, increased slowly with age, which may help explain the improved utilization of dietary protein with age as reported by Sell *et al.* (1991).

Poults denied access to feed and water for 54-h posthatch had the highest relative and specific activities of pancreatic amylase, lipase, and trypsin at 2 d of age. These high levels agree with the observations of Hulan and Bird (1972) and Krogdahl and Sell (1989) that the act of eating serves as a stimulus to the pancreas to secrete pancreatic juice. At 2 d of age, the 54-h treatment group had not yet had access to the stimulus of feed and water, which may have resulted in increased concentrations of digestive enzymes in the pancreas. Krogdahl and Sell (1989) postulated that feeding also would stimulate pancreatic enzyme synthesis. This hypothesis could explain why poults placed on feed and water within 6 h

TABLE 9. Effect of placement time on the specific and relative activity of digestive enzymes of poults, Experiment 1

Age	Placement time	Specific activity of enzymes: Jejunal maltase	Specific activity of enzymes: Pancreatic amylase	Relative activity of enzymes: Jejunal maltase	Relative activity of enzymes: Pancreatic amylase
(d)	(h)	(μmol substrate hydrolyzed/mg protein/h)		(μmol of substrate hydrolyzed hourly/100 g BW)	
1[1]	6	46.5[2]	410	6,247	7,516[b]
	30	49.5	270	5,878	12,309[a]
	54	49.5	270	5,878	12,309[a]
	SEM	1.9	46	490	962
	P	0.3	0.07	0.59	0.01
2	6	29.0[b]	601[b]	6,707[a]	40,514[b]
	30	27.9[b]	446[b]	5,601[b]	20,562[b]
	54	33.5[a]	1,040[a]	5,116[b]	73,325[a]
	SEM	1.3	111	363	9,056
	P	0.02	0.01	0.02	0.01
3	6	10.1[b]	889[a]	2,291	57,746[a]
	30	23.5[a]	1,005[a]	5,916	75,954[a]
	54	23.7[a]	547[b]	4,477	30,921[b]
	SEM	3.6	97	1,004.	6,608
	P	0.03	0.01	0.06	0.01
4	6	21.8	1,831	2,161	145,250[a]
	30	17.2	1,601	2,022	140,998[a]
	54	14.4	1,399	1,937	86,673[b]
	SEM	4.2	144	447	12,172
	P	0.47	0.14	0.94	0.01
5	6	6.4	1,619	851	137,067
	30	11.4	1,575	1,343	124,164
	54	12.4	1,697	1,725	145,486
	SEM	1.9	349	438	28,573
	P	0.08	0.97	0.08	0.87

[a–c]Means in columns and within age with no common superscript differ significantly ($P \leq 0.05$).

[1]One day of age corresponds to 30 h after arrival at the research farm.

[2]Means represent six poults per treatment.

TABLE 10. Effect of placement time on the specific activity of digestive enzymes of poults, Experiment 2

Age	Placement time	Specific activity of enzymes: Jejunal maltase	Pancreatic amylase	Pancreatic trypsin	Pancreatic lipase
(d)	(h)	(μmol substrate hydrolyzed/mg protein/h)			(mg naphthol/mg protein/h)
1[1]	6	23.4[2]	575	3.79	444.2
	30	23.1	599	3.40	535.2
	54	23.1	599	3.40	535.2
	SEM	1.6	186	0.25	150.0
	P	0.82	0.08	0.28	0.68
2	6	26.0[b]	918[b]	4.27[ab]	119.2[c]
	30	26.2[b]	658[b]	3.58[b]	199.9[b]
	54	33.7[a]	1,243[a]	5.04[a]	513.0[a]
	SEM	2.3	95	0.28	26.0
	P	0.05	0.01	0.01	0.01
3	6	18.2	1,203[a]	4.63[a]	125.3
	30	21.0	948[b]	3.31[b]	125.7
	54	22.3	729[b]	3.38[b]	61.3
	SEM	1.7	74	0.30	27.0
	P	0.25	0.01	0.01	0.18
4	6	15.1	1,701[a]	5.91	102.7
	30	13.6	1,598[ab]	5.99	90.2
	54	16.9	1,320[b]	7.10	105.9
	SEM	1.7	92	0.38	20.0
	P	0.41	0.03	0.66	0.84
5	6	14.3	1,545	4.72	124.9
	30	14.9	1,600	5.66	185.2
	54	17.3	1,842	6.11	245.9
	SEM	2.1	169	0.45	52.0
	P	0.59	0.44	0.12	0.30

[a–c]Means in columns and within age with no common superscript differ significantly ($P \leq 0.05$).

[1]One day of age corresponds to 30 h after arrival at the research farm.

[2]Means represent two poults per pen, six pens per treatment.

TABLE 11. Effect of placement time on the relative activity of digestive enzymes of poults, Experiment 2

Age	Placement time	Relative activity of enzymes			
		Jejunal maltase	Pancreatic amylase	Pancreatic trypsin	Pancreatic lipase
(d)	(h)	(μmol substrate hydrolyzed h/100 g BW)			(mg naphthol released h/100 g BW)
1[1]	6	3,753	16,344[b]	131.6	9,326
	30	3,371	33,820[a]	108.0	15,580
	54	3,371	33,820[a]	108.0	15,580
	SEM	316	4,518	12.6	3,880
	P	0.41	0.02	0.22	0.28
2	6	5,691	253,137[ab]	199.8[b]	3,522[b]
	30	5,055	174,836[b]	141.9[b]	5,349[b]
	54	5,994	340,001[a]	300.3[a]	22,816[a]
	SEM	812	42,710	24.2	1,580
	P	0.71	0.05	0.01	0.01
3	6	4,262	70,034[a]	267.2[a]	5,059[a]
	30	4,400	51,949[a]	181.2[b]	4,210[ab]
	54	4,074	30,149[b]	104.1[b]	1,665[b]
	SEM	407	6,120	22.8	870
	P	0.85	0.01	0.01	0.03
4	6	3,819	115,149[a]	357.4	5,143
	30	2,983	115,965[a]	338.9	4,531
	54	3,023	72,217[b]	268.4	3,795
	SEM	405	9,808	29.3	880
	P	0.29	0.01	0.11	0.57
5	6	3,796	115,529	353.8	6,457
	30	3,853	113,271	398.7	9,500
	54	3,835	149,260	480.4	13,298
	SEM	469	60,853	42.1	2,720
	P	0.99	0.36	0.13	0.25

[a–c]Means in columns and within age with no common superscript differ significantly ($P \leq 0.05$).

[1]One day of age corresponds to 30 h after arrival at the research farm.

[2]Means represent two poults per pen, six pens per treatment.

posthatch had the highest levels of pancreatic enzyme activity at 3 d of age.

Birds denied access to feed and water for 54 h posthatch had a slightly lower ($P \leq 0.07$) ME_n value at 4 d of age (Table 12) than poults placed within 6 h after hatch. This effect on ME_n occurred during the time when greatest physical and functional changes in the intestinal tract were observed. The ME_n values determined at 4, 7, and 14 d of age, irrespective of placement times, were well below values calculated on the basis of ingredient data presented by the NRC (1994). At 4 d of age the determined ME_n value of the diet for poults placed at 54 h posthatch was 10% less than the value determined for poults placed at 6 h posthatch and 23% less than calculated values. Soto-Salanova *et al.* (1991) and Sell (1996) reported the lowest ME_n values for diets fed to poults at 4 and 7 d of age. The unusually low values obtained when poults were 14 d old in the current study are believed to be due, in part, to a coronavirus infection, which was first noted when poults were 12 d old. The infection was confirmed diagnostically at the Iowa State University Veterinary Medical Research Institute. This infection occurred after most of the effects of different placement times on intestinal development were observed and was assumed to not have had much impact on the effects of delayed placement.

TABLE 12. Effect of placement time on the nitrogen-corrected metabolizable energy values of diets fed to poults, Experiment 3

Placement time	Days of age		
	4	7	14
(h)	(kcal/kg of DM)		
6	2,641[1,2]	2,857	2,648
30	2,556	2,802	2,617
54	2,377	2,732	2,550
SEM	72	45	72
Probabilities	0.07	0.20	0.63

[1]Means represent four pens per treatment, six female poults per pen.

[2]Calculated ME_n value of the diet was 3,107 kcal/kg of DM.

The weight of digestive system organs, particularly the small intestine, were inversely proportional to the duration of placement delay. The inhibition of the development of these supply organs was transitory. By 4 wk of age, no significant physiological or functional differences were observed among supply organs of poults from different placement times. However, BW was still less at 28 d of age for poults denied feed for 54 h posthatch, showing that retardation of supply organ development had a carry-over effect on performance. Effects on GIT organs were more severe and longer lasting for poults denied feed for 54 h than for those denied feed for 30 h posthatch. Results of the current study show that substantial delays in access to feed and water will retard development of the digestive system and limit capabilities of poults to utilize dietary nutrients, resulting in reduced BW.

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REFERENCES

Association of Official Analytical Chemists, 1980. Official Methods of Analysis of the Association of Analytical Chemists. 13th ed. Association of Official Analytical Chemists, Washington, DC.

Ceska, M., K. Birath, and B. Brown, 1969. A new and rapid method for the clinical determination of alpha-amylase activities in human serum and urine. Optimal conditions. Clin. Chim. Acta 26:437–444.

Chilson, W. T., and H. Patrick, 1946. Effect of withholding feed and water on early poult mortality and growth. Poultry Sci. 25:86–87.

Corring, T., and D. Bourdon, 1977. Exclusion of pancreatic exocrine secretion from intestine in the pig: Existence of a digestive compensation. J. Nutr. 107:1216–1221.

Dahlquist, A., 1964. Method for assay of intestinal disaccharidases. Anal. Biochem. 7:18–25.

Donaldson, W. E., and V. L. Christensen, 1991. Dietary carbohydrate level and glucose metabolism in turkey poults. Comp. Biochem. Physiol. 98A:347–350.

Duncan, D. B., 1955. Multiple range and multiple F tests. Biometrics 11:1–42.

Erlanger, B. F., N. Kokowsky, and W. Cohen, 1966. Preparation and properties of two new chromogenic substrates of trypsin. Arch. Biochem. Biophys. 95:271–278.

Escribano, F., B. E. Rahn, and J. L. Sell, 1988. Development of lipase activity in yolk membrane and pancreas of young turkeys. Poultry Sci. 67:1089–1097.

Hill, F. W., and D. L. Anderson. 1958. Comparison of the metabolizable energy and productive energy determination with growing chicks. J. Nutr. 64:587–603.

Hulan, H. W., and F. H. Bird, 1972. Effect of fat level in isonitrogenous diets on the composition of avian pancreatic juice. J. Nutr. 102:459–468.

Katanbaf, M. N., E. A. Dunnington, and P. B. Siegel, 1988. Allomorphic relationships from hatching to 56 days in parental lines and F_1 crosses of chickens selected 27 generations for high or low BW. Growth Dev. Aging 52: 11–22.

Krogdahl, A., and J. L. Sell, 1989. Influence of age on lipase, amylase, and protease activities in pancreatic tissue and intestinal contents of young turkeys. Poultry Sci. 68: 1561–1568.

Lowry, O. H., N. J. Rosebrough, A. L. Farr, and R. J. Randall, 1951. Protein measurement with the folin phenol reagent. J. Biol. Chem. 193:265–275.

Moran, E. T., Jr., 1978. Performance and carcass quality of broiler tom turkeys subjected to a post-hatch fast and offered starting rations of different nutrient concentration. Can. J. Anim. Sci. 58:233–243.

Moran, E. T., Jr., 1982. Starch digestion in fowl. Poultry Sci. 61: 1257–1267.

Moran, E. T., Jr., 1989. Effects of posthatch glucose on poults fed and fasted during yolk sac depletion. Poultry Sci. 68: 1141–1147.

Moran, E. T., Jr., 1990. Effects of egg weight, glucose administration at hatch, and delayed access to feed and water on the poult at 2 weeks of age. Poultry Sci. 69: 1718–1723.

Moran, E. T., Jr., and B. S. Reinhart, 1980. Poult yolk sac amount and composition upon placement: Effect of breeder age, egg weight, sex and subsequent change with feeding or fasting. Poultry Sci. 59:1521–1528.

Murakami, H., Y. Akiba, and M. Horiguchi, 1992. Growth and utilization of nutrients in newly-hatched chicks with or without removal of residual yolk. Growth Dev. Aging 56: 75–84.

National Research Council, 1994. Nutrients Requirements of Poultry. 9th rev. ed. National Academy Press, Washington, DC.

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

Nitsan, Z., Y. Dror, I. Nir, and N. Shapiro, 1974. The effects of force-feeding on enzymes of the liver, kidney, pancreas and digestive tract of chicks. Br. J. Nutr. 32:241–247.

Noy, Y., and Y. Pinchasov, 1993. Effect of a single posthatch intubation of nutrients on subsequent early performance broiler chicks and turkey poults. Poultry Sci. 72:1861–1866.

Noy, Y., and D. Sklan, 1997. Posthatch development in poultry. J. Appl. Poult. Res. 6:344–354.

Ortega, M. A., A. Gil, and A. Sancherz-Pazo, 1995. Maturation status of small intestinal epithelium in rats deprived of dietary nucleotides. Life Sci. 56:1623–1630.

Palo, P. E., 1994. Effect of Early Nutrient Restriction on Performance and Development of Selected Characteristics of Gastrointestinal Tract of Broiler Chickens. Ph.D. thesis. Iowa State University, Ames, IA.

Phelps, P. V., F. W. Edens, and V. L. Christensen, 1987a. The posthatch physiology of the turkey poult—I. Growth and development. Comp. Biochem. Physiol. 86A:739–743.

Phelps, P. V., F. W. Edens, and R. P. Gildersleeve, 1987b. The posthatch physiology of the turkey poult—III. Yolk depletion and serum metabolites. Comp. Biochem. Physiol. 87A:409–415.

Pinchasov, Y., and Y. Noy, 1993. Comparison of post-hatch holding time and subsequent early performance of broiler chicks and turkey poults. Br. Poult. Sci. 34:111–120.

SAS Institute, 1985. SAS® User's Guide: Statistics. Version 5 Edition. SAS Institute, Inc., Cary, NC.

Sell, J. L., 1996. Physiological limitations and potential for improvement in gastrointestinal tract function of poultry. J. Appl. Poult. Res. 5:96–101.

Sell, J. L., C. R. Angel, F. J. Piquer, E. G. Mallarino, and H. A. Al-Batshan, 1991. Developmental patterns of selected characteristics of the gastrointestinal tract of young turkeys. Poultry Sci. 70:1200–1205.

Siddons, R. C., 1972. Effect of diet on disaccharidase activity in the chick. Br. J. Nutr. 27:343–352.

Soto-Salanova, M., D. Barker, A. G. Halstead, P. J. Gorden, P. M. Ermer, and J. L. Sell, 1991. Age-related changes in utilization of diets containing animal-vegetable fat, tallow, or coconut oil by young turkeys. Poultry Sci. 70(Suppl. 1): 115. (Abstr.)

Uni, Z., S. Ganot, and D. Sklan, 1998. Posthatch development of mucosal function in the broiler small intestine. Poultry Sci. 77:75–82.

Vogtmann, H., P. Frirter, and A. L. Prabuck, 1975. A new method of determining metabolizability of energy and digestibility of fatty acids in broiler diets. Br. Poult. Sci. 16: 531–534.