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Ontogeny of Intestinal Glucose Transport in Heavy and Light Body Weight Turkey Poults[1]

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Abstract: Development of intestinal tissue was measured in newly hatched poults. Both anatomical and physiological measurements were made on poults produced by two half sibling sires with hens that were their full or half siblings. The poults from one sire (HBW) weighed more at hatching than those from the other sire (LBW). Survival of the heavier poults was poor indicating metabolic insufficiencies. A significant positive correlation was noted between hatchling body weights and blood glucose concentration (Christensen *et al*., 2000a), and this was accompanied by depressed gluconeogenesis in HBW poults. The hypothesis was proposed that the HBW poults with elevated plasma glucose concentrations might have greater glucose absorption from intestinal tissue than did the LBW poults. The data confirmed heavier weights in HBW poults than LBW, and HBW jejunum weight relative to body weight was less than that of LBW. The poults did not differ in intestinal length, glucose transport, maltase activities or plasma triiodothyronine and thyroxine or glucose concentrations. The HBW poults also utilized less yolk during development than did the LBW indicating that the HBW embryos rely more on gluconeogenesis for survival during development than do the LBW. It was concluded that the increased body weight of HBW poults compared to LBW may be due to increased absorption of all nutrients because of a greater intestinal mass relative to body weight rather than to differences in glucose digestion and uptake rates.

Key words: Poult embryos, glucose transport, poult weight

Introduction

The avian intestine experiences major functional demands upon hatching. Prior to hatching the avian embryo depends primarily upon lipid stores from the yolk. Immediately upon hatching, the young bird makes a transition to an adult-based diet of variable composition. In addition, the hatchling uses the remaining yolk lipids as a source of energy for a few days after hatching (Uni *et al*., 1998). The gastrointestinal tract must adapt anatomically and physiologically to digest and absorb the carbohydrates and proteins available in the feed.

Intestinal glucose transport has been well characterized in mammals, and studies have been performed in chickens (Bogner and Haines, 1964; Holdsworth and Wilson, 1967; Obst and Diamond, 1992; and Uni *et al*., 1998). Compared to chicks, glucose transport in the turkey is poorly understood. Mortality of neonatal poults is also much greater than that of chicks and accounts for much of the management related problems for commercial turkey growers. Thus, it is important to understand mechanisms of intestinal glucose transport in developing turkeys whereby dietary manipulations could influence intestinal function and prevent susceptibility of the poult to stress and disease states.

The hypothesis was proposed that ontogeny of the small intestine and the glucose transporter might differ in poults of a similar genetic background but of different body weights. The first objective of the experiment reported here was to compare intestinal weights and glucose absorption associated with glucose transport in the intestines of the heavy and light body weight embryos and poults. The second objective was to study age-related changes associated with the same variables during perinatal and hatching phases of development of turkey poults.

Materials and Methods

In a related study, 50 sires that were full or half siblings were identified using DNA markers (Grimes *et al*., 1996). In these sires, a highly significant correlation was observed between hatchling body weight and plasma glucose concentration at hatching (Christensen *et al*., 2000a). Poults sired by the selected individuals not only showed the significant correlation, but heavier hatchlings continued to be heavier at 4, 8, 12 and 16 weeks (Grimes *et al*., 1996). For the current study, two sires were selected from the 50 whose poults were at the extremes of the weight distribution (Christensen *et al*., 2000a). Genetically similar sires and their progeny

[1]The mention of trade names in this publication does not imply endorsement of the products mentioned nor criticism of similar products not mentioned.

can assist in understanding the physiological factors responsible for the correlation of increased body weights and blood glucose concentrations at hatching. Each sire was mated to five randomly selected hens that were either half or full siblings of the sires. The hens have been described in detail in a previous study (Christensen *et al.*, 2000b). Five poults from the heavy sire (HBW) and five poults from the light sire (LBW) were sampled at days 25, 26, 27 of incubation as well as at hatching. On day 17 posthatching 9 poults were sampled from the LBW group, but due to mortality only one poult was sampled in the HBW group. All poults were treated in accordance with the guidelines of the Institutional Animal Care and Use Committee of North Carolina State University. Following hatching, poults were housed in an electrical battery brooder and offered standard turkey starter feed and water *ad libitum*.

Sampling procedures: Fertilized eggs from the two groups were incubated in a commercial incubator at the recommended temperature (37.5°C) and relative humidity (54%). Beginning at the completion of 25 days of development, embryos were carefully removed from the eggshells and bodies were weighed with and without the yolk. Embryos were then euthanized by decapitation. A blood sample was collected into heparinized tubes, mixed gently then centrifuged at 2000xg for 15 minutes under refrigeration (4°C). The resulting plasma was decanted and stored at –20°C prior to glucose analysis.

Intestinal tissue collection: The abdominal cavity was exposed and two cuts, one at the end of the duodenal loop and the other at the yolk stalk attachment (Meckel's diverticulum) were made to excise the jejunum. The jejunum was flushed with physiological saline, blotted dry and the length measured then weighed. The jejunum was then divided into four equal quarters. The second quarter was used to measure glucose uptake and was placed in ice cold glucose transport buffer (Black, 1988). The third quarter was placed in a capped vial containing 2 ml of saline and stored at –20°C for maltase and protein assays. The remaining quarters were used for related studies.

Glucose uptake assay: Active glucose uptake by jejunal rings was measured according to Fan *et al.* (1996). The technique was a modification of that described by Black (1988) using 3H-O-methyl-D glucose to measure active glucose uptake. Jejunal rings, 1 mm wide, were cut from the second quarter of each jejunum sample with a special device designed for this purpose (Bird *et al.*, 1994). After cutting, jejunal rings from each poult were placed in a beaker of glucose transport buffer. Glucose transport buffer (GTB) contained 140 mM NaCl, 4.8 mM KCl, 2.0 mM $CaCl_2$, 1.2 mM KH_2PO_4, 1.2 mM $MgSO_4$, 25 mM HEPES, 0.5 mM b-hydroxybutyrate and 2.5 mM L-glutamine (pH 7.4). A beaker with three jejunal rings in the 2 ml GTB and a duplicate set of beakers containing 1 mCi ^{3}H-O-methyl-D glucose (79 Ci/mmol; New England Nuclear) in addition to 2 ml GTB were incubated in a Dubnoff Shaking Incubator (Precision Dubnoff metabolic Shaking Incubator, Baxter Scientific, McGraw Park, IL). Three adjacent 1mm jejunal rings were placed in another beaker and incubated with GTB and 1 mmol/L phlorizin (Sigma Chemical, St. Louis, MO), an inhibitor of Na^+-dependent active glucose uptake. The beakers were incubated for 10 min at 37°C with a shaking speed of 60 cycles/min. An additional incubation of two 1 mm rings at 4°C for 15 min with phlorizin was used to determine the nonspecific absorption of ^{3}H-O-methyl-D glucose. Transferring the rings individually into the isotope-containing beakers at timed intervals started the assay. Since glucose uptake is linear with time for at least 15 min (Bird *et al.*, 1994), the jejunal rings were incubated for 5 min at 37°C with a shaking speed of 100 cycles/min. The assay was terminated by rinsing the rings with 3 ml of ice-cold 300 mM mannitol. Jejunal rings were then immersed in 2 ml of TCA (25 g TCA/L) and incubated for 60 min at room temperature to extract the isotope. The extracted jejunal rings were removed, blotted and dried. The TCA extract was centrifuged for 5 min at 2000 x g, and 1 ml of supernatant was counted to 10 ml of Scinti Verse Bio-HP (Fisher Scientific Co.) in a Packard Tri-carb 300 liquid scintillation counter. The difference in ^{3}H-O-methyl-D glucose uptake by the jejunal rings incubated with and without phlorizin was used to calculate Na^+ dependent jejunal active glucose transport. The difference in ^{3}H-O-methyl-D glucose uptake by the jejunal rings in GTB without phlorizin and rings incubated at 4°C was used to calculate total glucose uptake. The difference between total and active uptake was used to estimate the passive glucose uptake.

Plasma glucose analysis: Plasma glucose was measured using a YSI model 27 industrial analyzer fitted with a YSI #2365 glucose membrane (Yellow Springs Instrument Co., OH 45387) that utilized a glucose oxidase reaction and an amperometric electrode detector.

Plasma thyroid hormone analysis: Plasma triiodothyronine (T_3) and thyroxine (T_4) were assayed using Coat-a-Count kits (Diagnostic Products Corporation, Los Angeles, CA 90045). All samples were measured in a single assay so there was no interassay variation, but intra assay variation was less than 1% for both T_3 and T_4.

Maltase assay: Before analysis jejunal samples were thawed and homogenized in 2 ml of saline. Homogenates were kept on ice and samples were used immediately to assay for maltase activity (Dahlqvist,

Table 1: Body and yolk weights of light (LBW) and heavy (HBW) body weight poults during development

	Stage of development				
Sire	e 25	e 26	e 27	Hatch	Mean
Total Body weight (g)					
LBW	70.98	68.80	68.24	65.80	68.45[b]
HBW	74.90	73.10	75.50	74.78	74.57[a]
Mean	72.94[a]	70.95[a]	71.87[a]	70.29[a]	
√ ± SEM	71.51±0.93				
Probabilities					
Sire	0.0001				
Stage	NS				
Sire x Stage	NS				
Body weight without yolk (g)					
LBW	53.67	53.00	55.75	58.10	55.13[b]
HBW	54.06	56.00	60.48	63.38	58.48[a]
Mean	53.87[c]	54.50[c]	58.12[b]	61.04[a]	
√ ± SEM	56.78±0.99				
Probabilities					
Sire	0.02				
Stage	0.0001				
Sire x Stage	NS				
Yolk weight (g)					
LBW	17.32	15.80	11.87	7.69	13.17[b]
HBW	20.84	17.10	15.02	11.40	16.09[a]
Mean	19.07[a]	16.45[b]	13.45[b]	9.55[c]	
√ ± SEM	14.63±0.51				
Probabilities					
Sire	0.0003				
Stage	0.0001				
Sire x Stage	NS				

1964). The original assay was scaled down to a micro titer plate assay. Diluted homogenate (20ul for each well) was incubated with 20 ul of 28 mM maltose, dissolved in 50 mM maleate buffer, (pH=5.8) at 37°C for 30 min. The glucose released by the action of maltase in the homogenate was oxidized by tris-glucose oxidase (250 ul) and measured spectrophotometrically at 415 nm. Units of maltase specific activity were defined as micro moles of substrate hydrolyzed per µg of protein in jejunal tissue per hour. Total protein was analyzed to determine specific maltase activity. Tissue protein values were determined by using the micro titer plate procedure for the BCA protein assay kit (Pierce Biochemicals, Rockford, IL).

Statistical analysis: Data were arranged in a 2 x 2 factorial design and analyzed statistically by using two-way (age x sire treatment) general linear model procedure of SAS with a significance level of P = 0.05. Least square means procedure was used to separate means determined to differ significantly. No comparisons were made for the 17 day data.

Results

Total body weights with the yolk as well as body weight without the yolk of the HBW and LBW poults are given for each day between 25 days of development and hatching in Table 1. Embryo weights without the yolk were heavier for the HBW than the LBW poults from 25 to 28 days of development. The HBW poults at hatching were significantly heavier than were the LBW and were in agreement with previous observations (Christensen *et al.*, 2000b). Yolk weights were also significantly heavier from the HBW poults at hatching than the LBW poults. When the data were examined as total body weight including residual yolk, significantly heavier weights were seen only for 26 days of development and at hatching. Body weights increased as the embryos approached hatching and yolk weights declined.

The weight of the jejunum for the LBW embryos and poults was greater than HBW when compared relative to BW (Table 2), but absolute jejunum weights and lengths did not differ between HBW and LBW. Jejunum weight increased from 190 mg to 450 mg as the HBW and LBW embryos neared hatching and the length of the jejunum increased from 9.94 cm to 12.5 cm.

Active, passive and total glucose uptake rates did not differ between HBW and LBW poults (Table 3). The uptake rates were compared on a specific as well as on a total basis for all of the measures. Active glucose

Table 2: Jejunum weights and lengths of light (LBW) and heavy (HBW) body weight poults during development

	Stage of development				
Sire	e 25	e 26	e 27	Hatch	Mean
Absolute jejunal weight (mg)					
LBW	200	220	280	470	290
HBW	180	190	290	420	270
Mean	190	200	270	450	
√ ± SEM	280 ± 0.01				
Probabilities					
Sire	NS				
Stage	NS				
Sire x Stage	NS				
Relative jejunal weight (%)					
LBW	0.28	0.32	0.41	0.72	0.43[a]
HBW	0.25	0.26	0.38	0.56	0.36[b]
Mean	0.27[c]	0.29[c]	0.40[b]	0.64[a]	
√ ± SEM	0.40 ± 0.02				
Probabilities					
Sire	0.01				
Stage	0.0001				
Sire x Stage	NS				
Jejunal length (cm)					
LBW	9.56	9.58	10.20	12.10	10.61
HBW	10.32	9.80	11.14	13.10	10.79
Mean	9.94[c]	9.69[c]	10.67[b]	12.50[a]	
√ ± SEM	10.70 ± 0.32				
Probabilities					
Sire	NS				
Stage	0.0001				
Sire x Stage	NS				

transport rates remained constant between day 25 of development and hatching, but passive transport increased steadily. The net result of these two changes was that total glucose transport increased nearly 3-fold between 25 days of development and hatching.

Additionally, neither maltase nor alkaline phosphatase activities differed between the body weight groups (Table 4). However, maltase specific activity in both treatments increased nearly 5-fold from 25 days of development to hatching, and total maltase activity increased from 30.9 to 513.7 µmol substrate/h/jejunum.

Plasma concentrations of T_3 and T_4 did not differ between the weight groups at any of the stages of development examined (Table 5). The plasma ratios of T_3 to T_4 did not differ between HBW and LBW poults, but increased significantly as the embryos aged. Both plasma concentrations of T_3 and T_4 increased dramatically at 27 days of development then declined to prepipping levels at hatching. No significant differences were noted in plasma glucose concentrations of HBW and LBW poults, but it should be noted that the values at hatching approached significance ($P < 0.07$).

Discussion

Developmental Changes Due to Age. HBW and LBW poults from both sires displayed differences in body weight and blood glucose concentrations at hatching in the current study similar to those shown previously (Christensen *et al.*, 2000a). The heavier progeny at hatching also suffered a 30 percent increase in mortality during the initial days of life free from the shell compared to the progeny of the sire whose poults weighed less (Christensen *et al.* Unpublished data).

Based on data from the current study the turkey intestine of progeny from HBW and LBW sires was undoubtedly capable of glucose absorption prior to hatching. Although no differences were seen among the embryonic stages tested in the current study, a dramatic increase was seen when the rate was measured at 17 days posthatching. Intestinal glucose transporters are functional prior to birth in a number of mammals including humans and sheep (Buddington and Diamond, 1989; Shirazi-Beechey *et al.*, 1991).

The process of hatching leaves the poult with little carbohydrate reserves. Tissue glycogen stores at hatching are minimal, and glucose for metabolism is created by gluconeogenesis (Freeman, 1965). Early poult mortality is a common problem facing commercial turkey farms that may be related to stress and low glycogen reserves. Poults are able to alter their metabolism, i.e. decrease gluconeogenesis and increase hepatic glycogen within one hour of oral

Table 3: Jejunum function measured by glucose transport in light (LBW) and heavy (HBW) body weight poults during development

	Stage of development				
Sire	e 25	e 26	e 27	Hatch	Mean
Active transport (pmol/min/mg of tissue)					
LBW	71.5	62.9	74.6	51.3	65.1
HBW	69.0	65.4	73.3	81.3	72.2
Mean	70.2	64.2	73.9	66.3	
± SEM	68.6 ± 9.80				
Probabilities					
Sire	NS				
Stage	NS				
Sire x Stage	NS				
Passive diffusion (pmol/min/mg tissue)					
LBW	22.7	25.4	30.7	42.9	30.2
HBW	17.1	22.7	23.4	47.6	27.7
Mean	19.9^{c}	23.6^{bc}	27.1^{b}	45.3^{a}	
√ ± SEM	29.0 ± 2.90				
Probabilities					
Sire	NS				
Stage	0.0001				
Sire x Stage	NS				
Total transport (pmol/min/mg tissue)					
LBW	94.2	87.4	105.3	94.2	95.3
HBW	86.0	88.1	96.7	121.1	98.0
Mean	89.5	88.4	101.5	111.4	
√ ± SEM	96.6 ± 9.5				
Probabilities					
Sire	NS				
Stage	NS				
Sire x Stage	NS				
Integrated total transport (nmol/min/jejunum)					
LBW	18.6	19.4	29.3	44.9	28.1
HBW	15.2	16.8	30.0	57.8	30.0
Mean	16.9^{c}	18.1^{c}	29.7^{b}	51.4^{a}	
√ ± SEM	29.1 ± 4.4				
Probabilities					
Sire	NS				
Stage	0.0001				
Sire x Stage	NS				

administration of carbohydrates (Donaldson and Christensen, 1991 and 1994). Thus, it seems to be critical that the intestine responds mechanistically at the levels of digestion and absorption to replenish the carbohydrate reserves for the poult survival and growth. The current study is the first in turkeys to describe the ontogeny of the glucose transport system for the newly hatched turkey poult. Studies in chicken, lambs and rats have found higher transport rates after birth (Obst and Diamond, 1992; Shirazi-Beechey *et al.* 1991; Toloza and Diamond, 1992).

Developmental Changes Due to Body Weight: Body weight results from the current study confirmed those of a prior study (Christensen *et al.*, 2000a). Even though egg weights of dams assigned to each of the sires did not differ (Christensen *et al.*, 2000b), poults sired by one brother (HBW) weighed significantly more at hatching than those sired by the second brother (LBW). Yolk weights were also heavier in the HBW embryos and poults than in the LBW progeny. Previous research indicated that lines of chickens selected for greater adult body weights also displayed greater residual yolk weights in the progeny of the high body weight line than the progeny of the low body weight line (Anthony *et al.*, 1989; Nitsan *et al.*, 1991), but those results were indicative of egg size. Greater residual yolk weights have been noted in poults sired by a light than a heavy body weight line when the sires were mated to the same hens (Christensen *et al.*, 2004). Differences in yolk utilization may be attributed to one of at least two possibilities. First, a difference in partitioning of the yolk

Table 4: Jejunum function measured by maltase activity in light (LBW) and heavy (HBW) body weight poults during development

	Stage of development				
Sire	e 25	e 26	e 27	Hatch	Mean
Maltase specific activity (µmol of glucose/mg tissue/h)					
LBW	171	174	696	1,174	554
HBW	120	372	586	1,166	561
Mean	145[c]	273[c]	641[b]	1.170[a]	
± SEM	558 ± 55				
Probabilities					
Sire	NS				
Stage	0.0001				
Sire x Stage	NS				
Maltase specific activity (µmol of glucose/µg protein/h)					
LBW	5.7	5.1	11.6	23.1	11.4
HBW	2.2	7.6	10.8	19.6	10.3
Mean	4.0[c]	6.3[bc]	11.2[b]	21.4[a]	
√ ± SEM	10.8 ± 1.1				
Probabilities					
Sire	NS				
Stage	0.0001				
Sire x Stage	NS				
Integrated maltase activity (µmol of glucose/jejunum/h)					
LBW	33.7	38.2	205.0	546.4	164.6
HBW	28.1	59.7	177.1	481.1	186.5
Mean	30.9[c]	48.9[b]	191.0[b]	513.7[a]	
√ ± SEM	175.6 ± 20.1				
Probabilities					
Sire	NS				
Stage	0.0001				
Sire x Stage	NS				

by the embryos may exist, or second, heavier body weights may place fewer demands on nutrients from the yolk because of increased gluconeogenesis (Donaldson and Christensen, 1994).

Two mechanisms control yolk utilization (Noy and Sklan, 1998). Yolk material is transferred directly from the yolk into the blood, and antiperistaltic movement of yolk occurs from the distal end toward the proximal small intestine where it is absorbed. It has been suggested that the yolk contents are used in the development of the intestine during the embryonic period to prepare for posthatch food digestion (Nitsan *et al.*, 1991). The yolk sac, in addition to the intestine, transports sugar actively into the chick prior to hatching (Holdsworth and Wilson, 1967). Thus, it is possible that the larger yolk mass seen in HBW embryos allows for the increased growth earlier in development.

During the initial period after hatching, the weight of intestinal segments increases to a greater extent than body weight (Lilja, 1981; 1983; Sell *et al.*, 1991; Obst and Diamond, 1992). The assertion is that, in birds, energy supply available for growth is partly limited by the size of the digestive tract and that early investment of growth resources in development of this supply organ favors a subsequent high growth rate capacity (Mitchell and Smith, 1991). Increases in the weight and length of the small intestine are common mechanistic adaptations. The rapid increase in intestinal mass ensures that the animal is ready to meet the increased demand of nutrients to maintain tissue and promote growth as well as accommodate some reserve capacity (Ferrais and Diamond, 1997). Obst and Diamond (1992) studied intestinal nutrient transport in chickens and suggested a lag in intestinal response to sudden changes in nutrients and that modification to the intestinal epithelium may be at the expense of body growth.

The results of the current study show clearly that jejunum weight relative to body weight was significantly greater in the LBW than HBW poults. Jejuna from the LBW grew from 0.28% to 0.72% of the BW from 25 to 28 days of development whereas jejuna from the HBW embryos grew from 0.25% to 0.56% of the BW from 25 to 28 days of development. Increased relative size of the intestine suggests that at hatching the LBW intestine is capable of greater amounts of digestion and absorption than HBW of not only carbohydrates but also lipids and proteins in the LBW poults (Ferrais and Diamond, 1997). Increased intestinal size may indicate greater absorptive

Table 5: Plasma thyroid hormone (ng/ml) and glucose (mg/dl) concentrations of light (LBW) and heavy (HBW) body weight poults during development

	Stage of development				
Sire	e 25	e 26	e 27	Hatch	Mean
Plasma triiodothyronine concentration					
LBW	2.1	3.3	10.1	7.0	5.6
HBW	3.3	2.1	9.5	7.3	5.5
Mean	2.7[c]	2.7[c]	9.8[a]	7.2[b]	
√ ± SEM	5.6 ± 0.6				
Probabilities					
Sire	NS				
Stage	0.0001				
Sire x Stage	NS				
Plasma thyroxine concentration					
LBW	9.2	14.2	21.6	8.3	13.3
HBW	11.6	9.7	36.7	10.0	17.0
Mean	10.4[b]	12.0[b]	29.2[a]	9.1[b]	
√ ± SEM	15.2 ± 3.2				
Probabilities					
Sire	NS				
Stage	0.01				
Sire x Stage	NS				
Plasma glucose concentration					
LBW	134	169	193	190	171
HBW	131	160	193	198	170
Mean	133[c]	164[b]	193[a]	194[a]	
√ ± SEM	170 ± 5				
Probabilities					
Sire	NS				
Stage	0.0001				
Sire x Stage	NS				

area to provide for greater nutrient demand at a critical period of growth. We speculate the larger absorptive surface area of LBW poults may improve the availability of energy sources such as glucose at hatching. A greater absorptive area is suggested as a possible reason for the greater survival rate of LBW compared to HBW poults (Christensen *et al.*, unpublished data).

Neonatal poults are utilizing glucose from gluconeogenic amino acids as the preferred substrate immediately posthatching (Donaldson and Christensen, 1994), and previous studies indicated LBW poults inherently had a greater rate of gluconeogenesis (glucose-6-phosphatase activity) than did HBW (Christensen *et al.*, 2000a). The results from the current study indicated no differences between HBW and LBW embryos in glucose transport rates in agreement with previous poshatching studies with a growth-selected line of turkeys (Fan *et al.*, 1997 and 1998). Additionally, in the current study no differences were noted between HBW and LBW embryos for maltase activity or plasma T_3 and T_4 concentrations. Thus, it is suggested that the difference in body growth may be due to increased absorption of all nutrients due to greater intestinal mass rather than to specific changes in glucose uptake.

Glucose uptake measurements in the current study demonstrate that the turkey embryo intestine is capable of glucose absorption prior to hatching. This appears redundant because glucose was not the preferred substrate of hatchlings (Donaldson and Christensen, 1994). Although glucose transport rates did not increase during development prior to hatching, there was a dramatic increase in transport capability at 17 days posthatching. Intestinal transporters have also been found to be functional prior to birth in a number of mammals (Buddington and Diamond, 1989; Shirazi-Beechey *et al.*, 1991). These findings indicate that glucose transporters in the turkey embryo are functional prior to hatching in anticipation of function after hatching. However, the results of the current study indicated no differences between HBW and LBW embryos for glucose transport rates, maltase or plasma T_3 and T_4 concentrations prior to hatching. Previous studies also found selection for growth did not change glucose transport rates despite heavier jejuna (Fan *et al.*, 1997 and 1998). Thus, differences in body weights of turkey poults may be due to increased absorption of all nutrients because of greater intestinal mass rather than due to differences in glucose uptake rates. It is also suggested that differences in the survival rates of poults from the two sires may be due to the relatively larger

intestine in LBW poults compared to HBW. This may lead to an increased amino acid uptake that was not tested in the current study.

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