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Relationships among Post-Hatch Physiological Parameters in Broiler Chicks Hatched from Young Breeder Hens and Subjected to Delayed Brooding Placement[1, 2]

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Abstract: Increased mortality during the first wk of brooding is typical in broiler offspring from young breeder hens. Therefore, the purpose of this study was to evaluate the age-dependent changes in various physiological parameters of broiler chicks from young breeder parents (29 wk of age) through the early stages of brooding (72 h), and to identify those parameters which might be most predictive of future performance. In an effort to simulate procedures in the poultry industry, chicks were subjected to a 12-h delay in brooding placement after hatch in a broiler hatchery. In association with growth through 72 h post-hatch, chick relative liver weight (RLW) and liver glycogen content (LGLY) peaked at 72 and 48 h, respectively, and chick rectal temperature (RT) was greater between 24 and 72 h compared to that at both 0 and 6 h. Furthermore, plasma refractive index (RI) was greatest at 24 h and RI at 48 h was greater than that at 6 h. At hatch (0 h), RI was negatively correlated with BW but was positively correlated with RT, and RLW at hatch was positively correlated with hematocrit (HCT) at 6 h. Also, plasma glucose (GLU) at hatch and RT at 6 h were positively correlated. Between 24 and 72 h, BW was positively correlated with RLW and RT, and was negatively correlated with HCT and RI. There was a negative correlation between HCT and RI, but HCT was positively correlated with body fat loss score (BFLS) and RI. Also, between 24 and 72 h, chick RT was negatively correlated with BFLS and RI, and LGLY and GLU were positively correlated. These data demonstrate a close association between metabolic rate and growth in these post-hatch chicks, and while they experienced increases in BW and RT through 72 h, dehydration, as indicated by increased RI at 24 h, may have retarded growth. Plasma refractive index was the only blood parameter that changed significantly over time, fluctuated oppositely to that of BW between 24 and 72 h, and increased significantly between 6 and 24 h when chicks failed to gain BW. These associated changes with time and the maintenance of consistent negative correlations between RI and BW at hatch and between 24 and 72 h post-hatch indicate that RI may be a sensitive, practical, and reliable indicator of the physiological response of a post-hatch chick to common brooding management and would, therefore, be a useful indicator of future performance.

Key words: Broiler, brooding, chick, glucose, liver glycogen, refractive index

Introduction

Broiler breeder age influences the hatchability and performance of broiler offspring. Decreased hatchability and increased mortality during the first 7 d of brooding have been observed in broiler offspring from immature breeders (McNaughton *et al*., 1978; Vieira and Moran, 1999). The first 7 d mortality patterns in these birds peak at Day 3 or 4 and decline by Day 7 (Keirs, unpublished observation), and respective daily patterns show a progressive loss of BW in birds that eventually die. Progeny of young hens are often subjectively labeled as "poor quality", "dehydrated", or "starved" without the evaluation of associated baseline physiological parameters. The reasons behind first 7 d mortality in broiler chicks are controversial. Noble *et al*. (1986) reported that high mortality and decreased development of broiler embryos from very young breeder hens are associated with a reduction in yolk lipid mobilization. However, elevated cholesterol and depressed glucose levels have also been found in the sera of newly hatched chicks from these very young parents (Latour *et al*., 1996).

Within the first 2-3 d after hatching, chicks experience a transition from yolk-derived lipid to dietary-based carbohydrate as the primary source of energy (Vieira and Moran, 1999). The intake of high carbohydrate diets soon after hatching increases blood glucose levels and decreases the chick's reliance upon gluconeogenesis (Donaldson and Christensen, 1991). However, under commercial conditions, chicks may be subjected to a delay in access to carbohydrate which increases the possibilities of ketosis and dehydration (Vieira and

Moran, 1999). Reduced growth and increased early mortality among chicks held without access to food and water have been associated with dehydration and a shortage of available energy (Vieira and Moran, 1999). The delayed placements of chicks for 24 and 48 h after hatching retard subsequent broiler performance up through market age (Nir and Levanon, 1993).

Warriss *et al.* (1993) suggested that significant increases in plasma protein concentration and numerical increases in blood osmolality were indicative of dehydration in broilers during prolonged transport at slaughter age. Relationships between hematocrit (HCT) and refractive index (RI) have been reported to be inconsistent under different conditions (Boyd, 1981; Chamblee and Morgan, 1982; Chamblee *et al.*, 1989), however, RI measurements provide a very rapid and direct method for determining serum protein concentration when extreme accuracy is not essential (Grant and Kachmar, 1976). In a review of published data on plasma protein concentration (i.e. plasma RI) and packed cell volume (i.e. HCT) during dehydration, Boyd (1981) stated that a greater increase in plasma protein concentration was usually observed, with the interpretation of those data being limited by the absence of baseline values. Nevertheless, BW loss consistently reflected dehydration.

Peebles *et al.* (1999) described temporal changes and associations among the moisture and organic contents of broiler embryo and extra-embryonic tissues throughout incubation in an effort to predict more accurately the effects that changes in the incubational environment have on embryonic composition and metabolism. Similarly, the objectives of the current study were to establish temporal changes and relationships among growth and various tissue and organ systems in post-hatch broiler progeny from young parents, before and after subjection to transport and delayed brooding placement. No research to-date has established relationships among these physiological parameters during this critical period. Therefore, in an attempt to begin to redress this, time-dependent changes in various somatic, visceral, and blood parameters and their relationships were assessed from the hatching process at a commercial hatchery through early brooding at a distant brooding facility in non-sexed post-hatch broiler chicks from 29-wk-old breeder hens. Chick BW, relative liver weight (RLW), liver glycogen content (LGLY), kidney pathology score (KPS), body fat loss score (BFLS), rectal temperature (RT), HCT, RI, and plasma glucose (GLU) were determined at various times between hatch and 72 h post-hatch. Plasma RI was used as a rapid and direct estimate of plasma protein concentration and level of chick hydration.

Materials and Methods

General: At hatch (21 d of incubation), 16 hatching trays representing each vertical level of a single vertical row, were taken from a single hatcher unit in a broiler hatchery for chick physiological parameter analyses. The trays contained chicks hatched from eggs laid on the same day by a common flock occupying the same house. All eggs in all 16 trays were also collected at the same time of day. All chicks (Cobb x Cobb) were hatched from eggs laid by broiler breeder hens at 29 wk of age. For all the following determinations chicks were randomly selected from each tray. In each tray, the BW of 18 chicks was determined. Of those 18 chicks, 10 were used for determination of RT. The 10 chicks were then bled for determination of HCT, RI, and GLU. A total volume of approximately 120 µL of blood from each chick was collected into heparanized capillary tubes via toe prick for determination of the three aforementioned blood parameters. Of the 10 chicks bled in nine of the 16 trays, two were killed for determination of RLW. All other chicks were killed after being bled. At 6 h post-hatch, BW and RT were obtained from eight chicks from each of the 16 trays. Of those eight chicks, two chicks were bled for determination of HCT, RI, and GLU. After being bled, the two chicks in each of the 16 trays were then killed for determination of RLW, and livers from one of the two chicks were used for determination of LGLY.

Six chicks from two of the 16 trays were then subjected to transport (2 h) for delivery to a laboratory brooding facility at 12 h post-hatch. Temperatures in the hatchery and transport vehicle were 24.5 ± 2°C and 23.9 ± 2°C, respectively. The birds were housed and brooded in each of two pens, labeled to correspond to the two original hatcher trays, in a common brooder unit. Each pen measured 24.5 cm x 17.5 cm and had wire mesh flooring. Pen temperatures were maintained at 32.2 ± 1°C and ad libitum food and water were provided to all chicks throughout the remainder of the experiment. All birds were provided a standard starter diet formulated to meet or exceed National Research Council (1994) specifications. For all the following determinations chicks were randomly selected from each pen. The BW and RT of six chicks at 24 h, four chicks at 48 h, and two chicks at 72 h were obtained in each of the two pens. Furthermore, of those chicks, two were bled at each of the three time periods for determination of HCT, RI, and GLU. The two chicks in each tray were then sacrificed after being bled for determination of RLW, LGLY, KPS, and BFLS.

Liver Weight and Glycogen Content Quantitation: The weights of whole fresh livers from each chick were expressed as a percentage of total wet BW to provide relative liver weight. Liver samples (approximately 0.25 g) from the same lobe of each liver were used for determination of liver glycogen concentration (mg glycogen / g wet liver) based on a modification of the assay described by Dreiling *et al.* (1987). The

Table 1: Means (± SEM) for BW, relative liver weight (RLW), liver glycogen content (LGLY), kidney pathology score (KPS), and body fat loss score (BFLS) at 0 (hatch), 6, 24, 48, and 72 h post-hatch

Hours Post-Hatch	BW(g)	RLW(%)	LGLY(mg/g)	KPS	BFLS
0[1]	37.3^{c}±0.39	2.12^{bc}±0.139	-	-	-
6[1]	37.9^{c}±0.44	1.87^{c}±0.104	0.10^{b}±0.299	-	-
24[2]	38.0^{c}±1.32	2.49^{bc}±0.294	1.59^{b}±0.708	1.25±0.144	2.00[3]
48[2]	48.7^{b}±1.42	2.71^{b}±0.294	4.91^{a}±0.724	1.50±0.144	1.00[3]
72[2]	65.2^{a}±1.63	4.03^{a}±0.294	2.36^{ab}±0.724	1.00±0.144	1.00[3]

$^{a-c}$Means within parameter and treatment among ages with no common superscript differ significantly ($P \leq 0.05$).
[1]N=16 replicate units for the mean of each parameter within time period, except for RLW where N=9 at 0 hours.
[2]N=2 replicate units for the mean of each parameter within time period.
[3]SEM not provided because of lack of variability within age groups.

Table 2: Means (± SEM) for rectal temperature (RT), hematocrit (HCT), plasma refractive index (RI), and plasma glucose (GLU) at 0 (hatch), 6, 24, 48, and 72 h post-hatch

Hours Post-Hatch	RT(°C)	HCT(%)	RI(g/dL)	GLU(mg/dL)
0[1]	36.3^{b}±0.24	33.1±0.71	2.87^{bc}±0.048	213±9.0
6[1]	36.4^{b}±0.25	33.1±1.06	2.78^{c}±0.064	196±12.5
24[2]	38.6^{a}±0.76	37.0±2.99	3.72^{a}±0.172	264±34.7
48[2]	39.5^{a}±0.84	27.5±2.99	3.19^{b}±0.172	301±48.8
72[2]	40.2^{a}±0.99	27.0±2.99	2.97^{bc}±0.172	275±34.7

$^{a-c}$Means within parameter and treatment among ages with no common superscript differ significantly ($P \leq 0.05$).
[1]N=16 replicate units for the mean of each parameter within time period.
[2]N=2 replicate units for the mean of each parameter within time period.

modification involved a predetermination of the efficiency of extraction of glycogen from liver samples. Based on this predetermination, values were derived after a double extraction which allowed for a 95% average extraction efficiency.

RT, HCT, RI, and GLU Determinations: Rectal temperature (°C) was determined by inserting A YSI series 400 temperature probe[6], connected to a Nist Traceable digital thermometer[7], approximately 1 cm into each chick via the rectum. Hematocrit, expressed as percentage blood packed cell volume, was determined through the use of capillary tubes that were centrifuged in an IEC MB centrifuge[8], and were then read with a micro-capillary reader. Refractive index (g protein/dL) was determined by optical observation after dispensing 25 µl of plasma between the measuring prism and cover plate of a Model 10406 TS meter[9]. Plasma glucose concentrations, expressed in mg / dL, were determined by dispensing 10 µL of plasma onto a test slide inserted into an Ektachem DT-60 module analyzer[10] according to the procedures of Elliott (1984) and as described in detail by Latour *et al.* (1996).

Gross Kidney Pathology and Body Fat Loss Scoring: Visual gross KPS and BFLS scoring were subjective and were made by the same individual observer. The KPS scoring system was: 1=normal, 2=swollen with urates, 3=nephrosis, and 4=urates in hock joints, heart, and other vital organs. The BFLS scoring system was: 1=fat normal with ivory color, 2=fat regression with pink color, and 3=absence of fat.

Statistical analysis: Individual sample data within each replicate unit were averaged prior to analysis. Differences in numbers of sub-samples and replicates at each time period for all parameters were accounted for in the analysis of the effects of bird age. Least-squares means were compared in the event of significant global effects (Steel and Torrie, 1980). The Mixed Model in SAS® (Littell *et al.*, 1996) was used to evaluate the effects of time. Correlations among the 0 and 6 h time period measurements were determined by Pearson Product Moment Correlation (Steel and Torrie, 1980). These correlations were calculated independently because of replication differences. Correlation analyses between measurements at 24, 48, and 72 h were performed across these three time periods using partial correlations that were computed adjusting for age effects using the GLM procedure in SAS® (2000). Statements of significance were based on $P \leq 0.05$ unless otherwise stated.

Results

There were no mortalities in any of the replicate pens between 24 and 72 h post-hatch. Chick BW ($P \leq 0.0001$), RLW ($P \leq 0.0004$), LGLY ($P \leq 0.03$), RT ($P \leq 0.0006$), and RI ($P \leq 0.001$) changed significantly with time after hatch (Table 1 and 2). Chick BW increased between 24 and 48 h, and increased again between 48 and 72 h. Chick RLW was higher at 48 h compared to that at 6 h, but was highest at 72 h compared to all other previous time periods. However, LGLY was higher at 48 h compared to that at both 6 and 24 h post-hatch (Table 1). The RT of chicks was greater between 24 and 72 h compared to

Table 3: Correlation coefficients[1] among BW at 0 h (hatch) (BW-0), BW at 6 h post-hatch (BW-6), relative liver weight at 0 h (RLW-0), rectal temperature at 0 h (RT-0), rectal temperature at 6 h (RT-6), hematocrit at 6 h (HCT-6), plasma refractive index at 0 h (RI-0), and plasma glucose at 0 h (GLU-0)

	BW-0	RLW-0	RT-0	RT-6
BW-6	0.61 P≤ 0.01	-	-	-
HCT-6	-	0.67 P≤ 0.05	-	-
RI-0	-0.63 P≤ 0.01	-	0.54 P≤ 0.03	-
GLU-0	-	-	-	0.72 P≤ 0.002

[1]N = 16 replicate units for each correlated parameter, except for RLW-0 where N=9.

Table 4: Correlation coefficients[1] among BW, relative liver weight (RLW), liver glycogen content (LGLY), body fat loss score (BFLS), rectal temperature (RT), hematocrit (HCT), plasma refractive index (RI), and plasma glucose (GLU) between 24 and 72 h post-hatch

	BW	RLW	LGLY	BFLS	HCT	RI
BW	-	0.88 P ≤ 0.02	-	-	-0.81 P ≤ 0.05	-0.85 P ≤ 0.03
RT	0.95 P ≤ 0.004	-	-	-0.82 P ≤ 0.04	-0.88 P ≤ 0.02	-0.82 P ≤ 0.04
HCT	-0.81 P ≤ 0.05	-	-	0.98 P ≤ 0.0004	-	82 P ≤ 0.04
GLU	-	-	0.90 P ≤ 0.04	-	-	-

[1]N = 6 replicate units for each correlated parameter.

that at both 0 and 6 h (Table 2). Furthermore, RI was greatest at 24 h, and RI at 48 h was higher than that at 6 h post-hatch (Table 2).

At hatch (0 h), RI was negatively correlated with BW (P ≤ 0.01) but was positively correlated with RT (P ≤ 0.03). Body weight at hatch was positively correlated with BW at 6 h post-hatch (P ≤ 0.01), and RLW at hatch was positively correlated with HCT at 6 h (P ≤ 0.05). Also, GLU at hatch and RT at 6 h were positively correlated (P ≤ 0.002) (Table 3).

Between 24 and 72 h, BW was positively correlated with RLW (P ≤ 0.02) and RT (P ≤ 0.004), and was negatively correlated with HCT (P ≤ 0.05) and RI (P ≤ 0.03). Hematocrit was positively correlated with BFLS (P ≤ 0.0004) and RI (P ≤ 0.04), but was negatively correlated with RT (P ≤ 0.02). Chick RT was negatively correlated with BFLS (P ≤ 0.04) and RI (P ≤ 0.04), and LGLY and GLU were positively correlated (P ≤ 0.04) (Table 4).

Discussion

Keirs *et al.* (2002) observed that under adequate brooding conditions, 85% of broiler chicks from 29-wk-old hens gained nearly 10% in BW over the first 24 h. The BW of these same chicks nearly doubled at Day 4 and tripled at Day 6. The contents of yolk sacs in the body cavities of newly hatched chicks provide them with important nutrients during the first few days of hatching, but these are rapidly diminished and are almost completely depleted by the third day. Delayed access to food and water increases the possibility that broiler chick performance will be adversely affected (Vieira and Moran, 1999). Furthermore, Pinchasov (1991) has even suggested that broiler chicks may lose BW during their first 24 h of life despite the immediate provision of food and water.

Gonzales *et al.* (2003), on the other hand, demonstrated that broiler BW at 7 and 42 d of age was not influenced when fasting had a maximum duration of 12 h. However, fasts longer than 18 h significantly impaired both 7 and 42 d BW without affecting feed conversion or mortality. Chamblee *et al.* (1992) also noted that chicks that had been hatched for 24 h, whether kept in the hatchery continuously or in the hatcher for 12 h and then on litter under conventional brooding conditions for an additional 12 h, exhibited non-significant differences in BW and yolk sac weights. Absorption of the yolk sac by the chicks preceded the initiation of their growth. Furthermore, Chamblee *et al.* (1992) reported that deutectomy (yolk sac removal) within 6 h of hatching, resulted in a significant decrease in BW of the chicks for at least 15 d, and significant increases in BW were not observed until the chicks had been on litter for 36 h (48 h post-hatch). Having feed and water available had no affect on their body or yolk sac weights during the first 24 h. Similarly, in this study, although the chicks were subjected to the stresses of the hatching and delivery processes and food and water deprivation during the first 12 h post-hatch, a significant positive correlation was maintained between BW at hatch and at 6 h, and the chicks did not exhibit a significant change in BW through 24 h. Nevertheless, they did experience significant growth by 48 h, at which time they had been provided food, water, and a warm brooding environment for 36 h. Under these conditions, significant growth continued through the remainder of the study (72 h).

There were concurrent nadirs in the RLW and LGLY of the birds from the present investigation at 6 h post-hatch. Furthermore, like BW, LGLY did not exhibit a significant increase until 48 h after hatch. This was followed by a significant increase in RLW at 72 h. In conjunction with a numerical decrease in liver weight after a 24 h post-hatch holding time, Nir and Levanon

(1993) reported that the total fat and ash contents of the livers were significantly depressed. Upon investigating the potential effects of transport vibration on glycogen reserves in broiler chickens, Warriss *et al.* (1997) concluded that vehicle vibration was unlikely to be the major cause of liver glycogen depletion seen in transported broilers. However, it has been shown that LGLY can be exhausted in birds raised under reduced environmental temperatures (Siegel, 1980), and in earlier work, Warriss *et al.* (1993) also demonstrated that both a feed withdrawal period (10 h) and either 2, 4, or 6 h of transport caused the loss of LGLY in market-age broilers. Liver weight was decreased in birds subjected to feed withdrawal or transport for either 4 or 6 h, whereas GLU was decreased only by the feed withdrawal period. Neither the feed withdrawal period nor the 2, 4, or 6 h of transport significantly affected BW. Although the chicks in the current investigation had available yolk stores, unlike market-age broilers, results from the aforementioned studies would suggest that the nadirs in LGLY and RLW prior to 48 h may have resulted in part from food and water deprivation in the absence of a warm brooding environment during the first 12 h post-hatch. Conversely, after considering the results from the other previously described studies, it would not be expected that the BW of the birds in this investigation were adversely affected by the regime to which they were subjected during the first 12 h post-hatch. The results of Chamblee *et al.* (1992) would also suggest that had food and water been available during this period, the birds may still not have experienced a gain in BW before 48 h.

Peebles *et al.* (1999) demonstrated that relationships between the relative dry matter weights of the livers and bodies of broiler embryos changed with day of age during incubation. Similarly, although chick BW and RLW were positively correlated between 24 and 72 h in this study, changes in BW and RLW were not coordinated between the three consecutive time periods examined within that interval of time, and despite the fact that both BW and LGLY increased significantly between 24 and 48 h, there was a 24 h delay before there was an associated significant increase in RLW. Nevertheless, the peak in LGLY at 48 h revealed that the chicks were able to store glycogen in the liver during feed intake. Christensen *et al.* (2003) concluded that improved livability of faster growing turkey embryos observed after prolonged egg storage may be due to better utilization of carbohydrate. The accelerated growth in these broiler chicks between 24 and 72 h post-hatch was similarly associated with an improved availability and utilization of carbohydrate, in that while GLU levels were maintained at a static level, glycogen was being stored in the liver. The positive correlation between GLU and LGLY between 24 and 72 h would lend further evidence that these birds were experiencing a state of positive energy balance during that time.

Liver glycogen reserves are converted to GLU and provide the chick with an immediate energy source. However, at hatch, the chick has a limited supply of LGLY (Donaldson, 1995; Hazelwood, 2000). If feed is not consumed immediately, chicks may undergo gluconeogenic metabolism on available substrates for the conversion of glycerol and amino acids to LGLY and then to GLU (Donaldson, 1995; Klasing, 1998; Hazelwood, 2000). It has been shown that broiler chick growth may be facilitated by supplemental gluconeogenic nutrients during the early transition from fat to carbohydrate-based nutrient uptake during brooding (Keirs *et al.*, 2002). The maintenance of GLU prior to feed intake may, therefore, have been afforded in part through gluconeogenic metabolic processes; however, at 48 and 72 h when the birds had access to feed for at least 36 h, the birds were apparently able to accumulate LGLY and sustain GLU without the need for further gluconeogenic activity.

Excessive morbidity and mortality of chicks from young parents during the first 7 d of brooding can be associated with loss of fat, muscular regression, and nephritis with nitrogenous waste present as urates (Keirs, unpublished observation). It has also been suggested that the inability of birds that had been nutrient-restricted during the early post-hatch period, to attain the weights of those fed early (Misra, 1978; Hager and Beane, 1983; Wyatt *et al.*, 1985; Nir and Levanon, 1993) likely involves a depression in muscle development (Elliot *et al.*, 1943). These conditions are suggestive of increased metabolic gluconeogenesis. Nevertheless, the lack of any significant change in KPS between 24 and 48 h would indicate that any gluconeogenic activity prior to 48 h had little pathological impact on the chicks. A numerical decrease in BFLS between 24 and 48 h would suggest that body fat depots were probably being reestablished after the birds had been provided food and water for 36 h. A significant negative correlation between BFLS and RT and a significant positive correlation between BFLS and HCT between 24 and 72 h would further indicate that body fat levels were influenced by the metabolic status of the bird at that time.

Zhou *et al.* (1998) found that whole blood viscosity and HCT were decreased in broilers subjected to food and water withdrawal for 39 h while maintained at 20°C. However, it was suggested that whole blood viscosity and HCT initially decrease before increasing with duration of food and water withdrawal past 39 h. Moreover, Koike *et al.* (1983) have reported that water deprivation for 24 h or more increased HCT in chickens. The RI of the birds in the current investigation reached their maximum level by 24 h post-hatch. Because an elevated RI is indicative of dehydration (Warriss *et al.*, 1993), these data suggest that the chicks were

dehydrated at 24 h post-hatch although they had access to water for 12 h. By 48 h (access to water for 36 h), hydration became evident with a significant decrease in RI. Deaton *et al.* (1969) have shown that broilers reared between 1 and 8 wk of age at a temperature of 7.2ºC had significantly higher HCT and plasma protein levels than those reared at 32°C. Also, between 24 and 72 h, there was a significant positive correlation between HCT and RI in this study. The earlier results of Deaton *et al.* (1969) would, therefore, support the negative correlations found between RT and HCT, and between RT and RI, between 24 and 72 h in this study. Accordingly, the peak in RI at 24 h may be in part a result of the lower (non-brooding) temperatures experienced by the chicks at the hatchery and during transport within the first 12 h prior to brooding.

The associations between HCT and RI during dehydration are not always consistent (Boyd, 1981; Chamblee and Morgan, 1982; Chamblee *et al.*, 1989). The lack of a significant change in HCT in association with RI at 24 h may also be because RI is a more precise indicator of changes in blood osmolality than is HCT. Longer and more extreme environmental changes like those described by Deaton *et al.* (1969) may be necessary to elicit changes in HCT. A positive correlation between RLW at hatch and HCT at 6 h post-hatch was found, but no physiological basis for this relationship or its possible impact in these birds can be provided. Regardless of the fluctuations in RLW, LGLY, and RI, RT increased progressively between 0 and 72 h, with a significant increase between 6 and 24 h. Although the chick is essentially poikilothermic at hatch, it has been demonstrated that hatchlings are able to maintain their core body temperatures at about 6°C above ambient temperature (Tazawa and Rahn, 1987). Therefore, the chicks in this study were able to exceed this level when held at an ambient temperature of approximately 24°C during the 12 h prior to brooding. The positive correlation between RT and RI at hatch may reflect associated increases in rates of metabolism and plasma protein synthesis from the livers of hatchlings, and also supports the contention that the chicks were capable of maintaining and possibly even experiencing increases in core body temperature despite dehydration following food and water deprivation for the first 12 h after hatch. Food consumption (Geran and Rashotte, 1997) and increased brooding temperatures at 12 h further enabled the birds to experience a significant increase in RT by 24 h post-hatch. The significant positive correlation between GLU at hatch and RT at 6 h also suggests that increased GLU at hatch can cause a positive response in metabolic rate up to 6 h later. Nevertheless, the significant increase in RT between 6 and 24 h may have been augmented by the availability of food and water and warm brooding temperatures for the final 12 h of the 24 h period. Furthermore, Warriss *et al.* (1997) have noted that transport vibration for 3 h increased the body temperatures of market-age broilers. The plateau in RT, after its significant increase between 6 and 24 h, was maintained through 72 h. This was associated with significant increases in BW between both 24 and 48, and 48 and 72 h. These temporal relationships in conjunction with a highly significant positive correlation between RT and BW between 24 and 72 h underscores a close association between metabolic rate and growth in these post-hatch chicks. Tona *et al.* (2004) have suggested a link between level of embryo metabolism measured in terms of heat production and later growth potential through 7 d post-hatch in broiler offspring within various broiler breeder lines. These current data would further suggest that metabolic level, as measured by RT, has an immediate positive relationship to growth rate between 24 and 72 h in broiler chicks from young parents. The negative correlation that existed between BW and RI at hatch, and the negative correlations that HCT and RI had with both BW and RT between 24 and 72 h, indicate that dehydration may exhibit concurrent negative associations with both growth and metabolism at various times during the early growout period. While chicks experienced increases in BW and RT through 72 h, dehydration, as indicated by increased RI at 24 h, may have retarded the metabolic and growth rates of these birds. Incomplete fatty acid catabolism can lead to a reduction in the production of metabolic water essential to tissue hydration (Hammond, 1944). The negative correlations that HCT and RI had with RT between 24 and 72 h would likewise suggest that a reduced metabolism could negatively influence chick hydration as well as growth rate. The cause and effect relationships between environmental and body temperatures, metabolic rate, tissue hydration, food and water intake, and growth in the post-hatch chick require further detailed examination.

There is a close relationship between HCT and RI, and between 24 and 72 h RI and HCT were similarly correlated to both BW and RT, however, HCT did not exhibit any coordinated changes with BW or RT with time. These results put in to question the reliability of HCT as a means by which to accurately monitor and predict the hydration status, metabolic rate, and growth potential of chicks from young parents during the first 72 h of post-hatch life. Plasma refractive index was the only blood parameter that changed significantly over time and fluctuated oppositely to that of BW between 24 and 72 h. Furthermore, RI increased significantly between 6 and 24 h when chicks failed to gain BW. These associated changes with time and the maintenance of consistent negative correlations between RI and BW at hatch and between 24 and 72 h post-hatch indicate that RI may be a sensitive, practical, and reliable indicator of the physiological response of a post-hatch chick to common

brooding management and would, therefore, be a useful indicator of future performance.

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