PRODUCTION, MODELING, AND EDUCATION

Influence of Egg Shell Embryonic Incubation Temperature and Broiler Breeder Flock Age on Posthatch Growth Performance and Carcass Characteristics

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ABSTRACT A study was conducted to examine the posthatch growth performance of high-yielding broilers when eggs were incubated at 3 different embryo temperatures from 2 flocks of breeders at different ages (different egg size). Two thousand, four hundred eggs from 2 broiler breeder flocks (29 and 57 wk of age) of the same high-yielding strain (Cobb × Cobb) were incubated in the same incubator for 16 d at 37.5°C. Following candling, the eggs from the 2 flocks were transferred into 3 hatcher cabinets at starting temperatures of 36.5°C (low, L), 37.6°C (middle, M), and 38.7°C (high, H) and adjusted to achieve a shell temperature of 37.5°C (L), 38.6°C (M), and 39.7°C (H) using an infrared thermometer. All chicks were taken off at 21 d of incubation, randomized into floor pens, and reared for 44 d. Body weights, feed intake, and feed conversion were determined at 21, 35, and 44 d of age. Body weight of birds from the H treatment was significantly less at 21, 35, and 44 d compared with the M birds. Birds in the L group weighed significantly less at 35 and 44 d compared with the M birds. Progeny from the older breeder flock had significantly greater BW at 1, 21, and 35 d of age, but had only numerically greater BW at 44 d when compared with birds from the younger flock. Feed conversion for the H birds was significantly higher from 0 to 21 d of age compared with the M and L birds. Broilers from the 29-wk-old breeder flock had lower cumulative feed conversion values than the birds from the 57-wk-old flock. No significant differences in mortality were observed. Posthatch performance appears to be affected by hatcher environment as determined by embryo shell temperature.

Key words: egg shell temperature, posthatch growth, broiler, hatcher, breeder

2007 Poultry Science 86:408–412

INTRODUCTION

The importance of maintaining the correct embryonic temperature during incubation of broiler eggs has been shown to be more important than the incubator temperature settings. Previous work from the laboratory of one of the authors (R. Meijerhof) has demonstrated that embryos frequently become overheated during incubation, even when the incubator is operating correctly (i.e., within a narrow temperature set point range; Meijerhof and van Beek, 1993; Hulet and Meijerhof, 2001). The result of overheating is lower hatchability and reduced chick quality (Hagger et al., 1986; French, 2000). Problems with machine maintenance, incubator cooling, airflow patterns, and other conditions may cause embryos to overheat (French, 1997). Mauldin and Buhr (1995) showed how a minor maintenance problem that affected temperatures in different parts of an incubator (creating areas that were outside the proper temperature range) could result in decreased hatchability.

Optimum incubation temperature is often defined as that required to achieve maximum hatchability (Wilson, 1991). Although optimum incubation temperature for poultry is between 37 and 38°C, this range overlooks the differential between incubator temperature and embryonic temperature. During early incubation, embryonic temperature is close to incubator temperature. However, from mid-incubation onwards, metabolic heat production from the embryo increases embryonic temperature above that of the incubator. The difference between late embryonic temperature and incubator air temperature is dependent upon thermal conductivity, which in turn, is mostly influenced by the air velocity over the eggs (Meijerhof and van Beek, 1993). Meijerhof (2005) reported a 2°C difference between the highest and lowest shell temperatures within commercial incubators at 17 d of incubation. Significant metabolic heat from the embryo begins around d 4 and, by d 9, results in embryo temperatures significantly greater than incubator air temperature. Therefore, removal of heat from the embryo, rather than just distri-

Received June 16, 2006.
Accepted July 29, 2006.
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Table 1. Effects of embryo shell temperature during incubation on posthatch broiler BW (g)

	Embryo shell temperature,[1] °C			
Age (d)	37.5	38.6	39.7	SEM
1	41.1[c]	42.2[b]	43.1[a]	0.60
21	715.1[a]	714.8[a]	669.5[b]	5.80
35	1,722.5[b]	1,756.7[a]	1,663.6[c]	8.86
44	2,213.8[b]	2,263.3[a]	2,165.7[c]	9.77

[a–c]Means within a row with no common superscripts differ significantly ($P < 0.05$).

[1]Each value is the mean of 8 pens (34 birds/pen).

bution of the air within the incubator, becomes a critical factor influencing hatchability. The uniformity of the air velocity within the incubator will depend on the ease with which the air is able to pass across the pores of the eggshells to dissipate heat. The number and size of shell pores and shell thickness are factors that influence the ability to dissipate heat and are directly related to egg size. French (1997) stated that as egg mass increases, thermal conductance does not increase proportionally. Therefore, larger eggs should have greater difficulty losing metabolic heat produced by the embryo. Physical conditions or design of the incubator can also influence thermal conductivity. For example, failure to properly fasten air-directing curtains in a multistage incubator often results in air passing around the eggs rather than over them.

To date, the extent of the rise in embryonic temperature and the impact on broiler performance has been difficult to measure. Additionally, almost all of the published work on incubation temperature and posthatch performance reported only incubator air temperatures. Hill (D. Hill, Hatch Tech USA, personal communication, 1999) routinely found high embryo temperatures of between 39 and 41°C within different commercial hatcheries, as well as differences of 2 to 3°C within an incubator.

Bruzual et al. (2000) investigated the effects of broiler breeder age (26, 28, and 30 wk) and incubator relative humidity (43, 53, and 63% RH) on embryonic growth between 16 and 21 d of incubation in young breeders and demonstrated that broiler breeder age affects embryogenesis and chick hatching BW. Those authors found that hatching broiler chick BW at 21 d was lower for 26-wk-old breeders compared with 28- and 30-wk-old breeders, and the lowest RH reduced wet embryo weight. Young hens produce eggs with thicker eggshells and therefore, longer eggshell pores. However, it is recognized that hatchability is lower in eggs from pullets entering lay than in eggs laid later in life (Shanawany, 1984; Mauldin, 1989). Maximum hatchability is often observed during midlay when shell thickness is lowest and porosity is greatest (Peebles and Brake, 1987). The BW at hatch is greater with increasing hen age (Bruzual et al., 2000). Thin-shelled eggs displayed a greater increase in weight with greater breeder age and greater weight loss during incubation. Eggs from the younger flock had higher weight loss during incubation regardless of shell thickness (Roque and Soares, 1994).

Table 2. Effects of breeder hen age (29 vs. 57 wk of age) during incubation on posthatch broiler BW (g)

	Age of breeder hens,[1] wk		
Age (d)	29	57	SEM
1	38.5[b]	46.2[a]	0.60
21	674.6[b]	730.8[a]	5.80
35	1,689.2[b]	1,745.7[a]	8.86
44	2,206.3	2,225.7	9.77

[a,b]Means within a row with no common superscripts differ significantly ($P < 0.05$).

[1]Each value is the mean of 12 pens (34 birds/pen).

The present study was conducted to evaluate the effect of different embryonic temperatures and egg size on subsequent broiler growth performance and carcass characteristics.

MATERIALS AND METHODS

To improve hatchability, embryonic temperature during the different phases of the incubation process must be optimized. Because embryo temperature cannot be measured without destroying the egg, the temperature of the eggshell is used to indirectly measure the relative embryonic temperature. The most practical and accurate means to measure eggshell temperature is with an infrared fever thermometer. The Thermoscan (Braun, Kronberg, Germany) with an accuracy of ±0.17°C is a practical instrument for such measurements, provided the instrument is used according to the manufacturer's recommendations.

Two thousand four hundred eggs from high-yielding broiler breeder flocks (Cobb × Cobb) at 2 ages (29 and 57 wk of age) were incubated in a Buckeye incubator (Chickmaster Inc., Medina, OH) for 16 d at 37.5°C dry bulb and 29.4°C wet bulb. After candling on d 16, one-third of the fertile eggs from both breeder flocks were transferred into separate hatchers that maintained shell temperatures of 37.5°C (low, **L**), 38.6°C (middle, **M**), and 39.7°C (high, **H**). Shell temperature was adjusted daily by measuring 25 eggs on 3 different trays and taking the average temperature to adjust the incubator. Individual eggshell temperature was determined with the infrared thermometer placed halfway between the blunt and pointed end of the eggs at approximately 1 cm below the air cell of the egg (Meijerhof, 2005). Incubator air temperatures were approximately 1°C lower than the embryo temperatures. Wet bulb temperature was adjusted for the H and L treatments to be equal to the wet bulb temperature for the M treatment eggs. After hatching, chicks from each temperature-breeder flock age treatment combination were randomized into pens with 8 replicate pens and 34 birds per pen (n = 1,632 birds).

Each pen was prepared with pine shavings, nipple drinkers, and a tube feeder. An egg flat filled with starter feed was used as a supplemental feeder during the first 5 d. Brooding was accomplished using primary heat from

Table 3. Effects of embryo shell temperature during incubation on posthatch broiler feed conversion (g/g)

	Embryo shell temperature,[1] °C			
Age (d)	37.5	38.6	39.7	SEM
1 to 21	1.56[b]	1.55[b]	1.60[a]	0.26
22 to 35	1.75[a]	1.72[b]	1.70[b]	0.01
36 to 44	2.91	2.67	2.64	0.07
0 to 44	1.91	1.86	1.87	0.01

[a,b]Means within a row with no common superscripts differ significantly ($P < 0.05$).

[1]Each value is the mean of 8 pens (34 birds/pen).

Table 5. Effects of embryo shell temperature during incubation on posthatch broiler mortality (%)

	Embryo shell temperature,[1] °C			
Age (d)	37.5	38.6	39.7	SEM
1 to 21	2.21	2.55	3.99	0.41
22 to 35	1.68	2.19	1.52	0.35
36 to 44	2.70	2.06	2.05	0.32
0 to 44	6.43	6.66	7.35	0.62

[1]Each value is the mean of 8 pens (34 birds/pen).

hot water radiation along with 1 heat lamp per pen as supplemental heat for the first 2 wk. Room temperatures were 31°C at 1 d of age and decreased gradually by 3°C/wk until they reached 20°C. Room temperature was then maintained at 20°C until the end of the experiment. Day-old chicks were provided equal amounts of a crumbled corn-soybean meal–based starter diet that was calculated to contain 3,014 kcal of ME/kg and 21.64% CP. At 23 d, the chicks were fed a pelleted grower diet (3,093 kcal of ME/kg and 19.85% CP). A pelleted finishing diet (3,168 kcal of ME/kg and 18.18% CP) was fed from 36 to 44 d. Feed and water were offered ad libitum throughout the study.

Birds were weighed at 0, 21, 35, and 44 d of age. Dead chicks were removed and recorded daily for each pen and expressed as percentage of initial bird placement. Birds were processed (10 males and 10 females) from each treatment (60 birds total) and the following carcass parameters were measured: BW, carcass yield, breast meat, legs, wings, back, neck, and abdominal fat pad, carcass yield, and the weight of all parts as a percentage of live weight and carcass weight. All animal handling protocols were approved by the PSU Animal Care and Use Committee.

The experiment was a 3 × 2 factorial arrangement of treatments, consisting of 3 embryo temperatures and 2 ages of breeder flocks with 8 replicates per treatment. The data were analyzed by ANOVA using the GLM procedure of SAS (SAS Institute, 1985). Duncan's multiple range test (Duncan, 1955) was used to determine significant differences between treatment means. Level of significance was $P \leq 0.05$ unless otherwise indicated. Percentage data were subjected to an arcsine square root of the percentage data transformation before analysis (Snedecor and Cochran, 1974).

RESULTS AND DISCUSSION

Eggs incubated at 39.7°C (H) resulted in heavier chick weights at hatch when compared with the M or L chicks (Table 1). However, birds incubated at the H temperature had significantly lower BW at 21, 35, and 44 d of age when compared with chicks from M eggs (incubated at 38.6°C). The chicks incubated at the L temperature weighed significantly less than those incubated at the M temperature. When compared with chicks from the other 2 treatments, the chicks from the H temperature treatment were noticeably sluggish at placement, preferring to sit under the heat lamps rather than eat and drink. As a result, the chicks from the H temperature did not consume feed during the first 8 h posthatch. At 44 d, the H temperature birds weighed almost 100 g less (Table 1) than the M temperature birds and weighed 48 g less than the L temperature treatment birds. Although the M chicks were significantly heavier than the L chicks at hatch, the difference was eliminated by d 21 when the birds were fed a feed containing an antibiotic. When the grower and finisher diets were fed, the M birds again had greater BW at 35 and 44 d of age. It is not known whether stress or perhaps a subliminal infection (slightly higher mortality) was responsible for the weight gain difference or lack of development of the supply organs to provide continual growth. These results differed from previous research showing the relationship between hatching weight and BW at subsequent ages. Wilson (1991) stated that the consensus is that larger hatching eggs result in larger chicks, which therefore result in larger broilers at market age. However, it should be noted that differences in incu-

Table 4. Effects of breeder hen age (29 vs. 57 wk of age) during incubation on posthatch broiler feed conversion (g/g)

	Age of breeder hens,[1] wk		
Age (d)	29	57	SEM
1 to 21	1.55[b]	1.58[a]	0.26
22 to 35	1.71	1.74	0.01
36 to 44	2.59[b]	2.93[a]	0.07
0 to 44	1.85[b]	1.92[a]	0.01

[a,b]Means within a row with no common superscripts differ significantly ($P < 0.05$).

[1]Each value is the mean of 12 pens (34 birds/pen).

Table 6. Effects of breeder hen age (29 vs. 57 wk of age) during incubation on posthatch broiler mortality (%)

	Age of breeder hens,[1] wk		
Age (d)	29	57	SEM
1 to 21	1.84[b]	4.06[a]	0.41
22 to 35	2.50[a]	1.00[b]	0.35
36 to 44	2.06	2.54	0.32
0 to 44	6.25	7.42	0.62

[a,b]Means within a row with no common superscripts differ significantly ($P < 0.05$).

[1]Each value is the mean of 12 pens (34 birds/pen).

Table 7. Effects of embryo shell temperature during incubation on posthatch carcass characteristics

Carcass characteristic	Embryo shell temperature,[1] °C 37.5	38.6	39.7	SEM
Live weight, g	2,136.7	2,176.6	2,095.1	28.28
Carcass weight, g	1,598.4	1,601.1	1,545.7	20.48
Breast meat, g	344.3	356.3	347.2	4.90
Thigh, g	290.1	289.9	282.1	4.74
Drum, g	230.6	239.8	228.5	4.02
Abdominal fat, g	48.1	42.7	41.8	1.58
Yield, %	74.88	73.61	73.78	0.27
Breast, % of carcass	21.62	22.29	22.48	0.23

[1]Each value is the mean of 20 birds.

bation (yolk sac size), management, environment, and disease could greatly influence the weight of a broiler at market age.

Breeder hen age had a significant effect on 1-d-old chick weight in that chicks from the oldest breeder flock weighed 7.65 g more than the chicks from the younger breeder flock (Table 2). This agreed with research conducted by Proudfoot et al. (1982), in which 2 different sized eggs resulted in 1-d-old chick weights that were significantly different. Chicks from the larger eggs had significantly greater BW at market age (49 d). However, in our study, significant differences were noted in BW between the 2 treatment groups at all measurement points. The birds from the older breeder flock were significantly heavier at 21, 35, and 44 d of age when compared with the birds from the younger flock.

No overall significant differences in feed conversion at market age were found between birds subjected to different embryonic temperature treatments. However, chicks incubated at the H temperature had significantly poorer feed conversion at 21 d of age than the chicks from the L or M groups (Table 3). Because BW were significantly different between temperature treatments, feed conversion adjusted to a 2-kg BW would result in differences of 0.05 and 0.07 in cumulative feed conversion, respectively, between the M birds (1.75) and H (1.80) and L (1.82) broilers.

Chicks hatched from the older breeder flock (57 wk) had significantly greater cumulative feed conversion values compared with chicks from the younger breeder flock

Table 8. Effects of breeder hen age (29 vs. 57 wk of age) during incubation on post hatch carcass characteristics

Carcass characteristic	Age of breeder hens,[1] wk 29	57	SEM
Live weight, g	2,147.6	2,124.7	28.28
Carcass weight, g	1,592.1	1,571.3	20.48
Breast meat, g	353.4	345.1	4.90
Thigh, g	287.9	286.9	4.74
Drum, g	236.3	229.7	4.02
Abdominal fat, g	42.9	45.5	1.58
Yield, %	74.16	74.02	0.27
Breast, % of carcass	22.27	21.99	0.23

[1]Each value is the mean of 20 birds.

(Table 4). Previous work comparing breeder age and chick weight on subsequent feed conversion has yielded variable results. Proudfoot et al. (1982) found better efficiency in chicks from larger eggs, whereas others found either no effect or the opposite effect (Proudfoot and Hulan, 1981; Wyatt et al., 1985; Hearn, 1986). It should be noted that breeder flock, breeder age, and egg size effects are all confounded statistically and cannot be separated in this study.

Incubation temperatures had no subsequent effect on broiler mortality (Table 5). However, mortality of chicks from the younger breeder flock was lower than in the older flocks in the period from 1 to 21 d, but higher from 22 to 35 d (Table 6). Data from previous studies have been inconsistent regarding mortality. Hearn (1986) found significantly higher mortality from very young breeder flocks, whereas Proudfoot and Hulan (1981) found no difference in mortality between chicks from different age breeder flocks.

No significant differences were observed in carcass characteristics due to incubator temperature (Table 7) or breeder hen age (Table 8).

In conclusion, evidence is presented that the embryonic temperature during the last 5 d of incubation can significantly affect posthatch growth and performance. Understanding how and why this happens could be extremely important to the poultry industry for commercial hatching practices. Broilers from older Cobb breeder flocks had greater BW and lower feed conversion values than birds from the younger breeders. No significant differences in carcass characteristics were found in this study resulting from either incubation temperature or breeder flock age.

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