The Effects of Suboptimal Eggshell Temperature During Incubation on Broiler Chick Quality, Live Performance, and Further Processing Yield

N. S. Joseph,* A. Lourens,† and E. T. Moran Jr.*[1]

*Department of Poultry Science, Auburn University, Auburn, AL 36849-5416; and †Department of Applied Poultry Research, Animal Sciences Group, Lelystad, The Netherlands

ABSTRACT Different incubation conditions can cause eggshell temperature (EST) to deviate from optimum. Two experiments were performed to determine the effect of low EST at the start of incubation and high EST at the end of incubation on hatchability, chick quality, 6-wk live performance, and breast meat yield of broiler chickens. In each experiment, 1,800 eggs from a single flock were divided and set into 2 setters. From 0 to 10 d of incubation, one setter was set to attain an EST of 36.6°C (considered low), whereas the other was set to 37.8°C (the control temperature). Using an infrared thermometer, EST was measured daily on a sample of eggs to ensure treatment intentions. On d 11 of incubation, the temperature of the low EST setter was increased to 37.8°C in synchrony with the other setter until transfer. On d 18 of incubation, eggs from both setters were combined into 2 equal groups and transferred to hatchers. The EST in one hatcher was set to 37.8°C (control) and in the other to 39.5°C (considered high) until 21 d of incubation. Hatched males were placed in battery cages (Experiment 1) or floor pens (Experiment 2) and reared on common feeds to 1 or 6 wk of age, respectively. Low EST in the first 10 d of incubation reduced hatchability, increased BW and chick yield, and reduced 1-wk gain compared with the control EST. Throughout rearing, BW was reduced for low EST chicks compared with control EST chicks; consequently, carcass, fillet, and tender weights were also reduced. High EST in the hatcher increased hatchability, and reduced BW, chick yield, and 1-wk gain compared with control EST in the hatcher. By 3 wk of age, there was no difference in BW between chicks in high EST and control EST treatments. Subsequent carcass and processing yields were also similar. Incubation at the control EST of 37.8°C, particularly from 0 to 10 d, resulted in the best performance overall.

Key words: broiler, incubation, eggshell temperature, body weight, processing yield

2006 Poultry Science 85:932–938

INTRODUCTION

Chicken embryos are poikilothermic, relying on an external source (hen or incubator) to provide heat to develop and maintain normal metabolic functions (Romijn and Lokhorst, 1955; Tazawa et al., 1989). Consequently, it is important to incubate eggs at a temperature that optimizes hatchability, which is defined as 37.5 to 37.8°C (Lundy, 1969). In incubation trials, however, air temperature is often used as the treatment applied to the eggs (French, 1997). The limitation to this approach is that air temperature is not always equal to internal egg temperature and can vary independently (Meijerhof and van Beek, 1993).

Internal egg temperature is the temperature experienced by the embryo; it is therefore more influential on embryonic development and hatchability than air temperature. The difficulty in measuring internal egg temperature is that it requires destruction of the eggshell, which can affect embryonic development. Eggshell temperature (**EST**), therefore, can be used as a nondestructive method of measuring internal egg temperature. In practice, the average EST may be close to 37.8°C, but deviations of over 4°C can be found, depending on location in the incubator and embryonic age (Lourens, 2001). The lowest EST readings are often found at the start of incubation in multistage incubators, whereas high EST readings are not uncommon in both single-stage and multistage incubators in the latter part of incubation. Large EST fluctuations have an obvious impact on hatchability and chick quality (Lourens, 2001), but so do slight deviations of less than 1°C from 37.8°C EST (Lourens et al., 2005). The total impact of EST deviations on economic returns to the poultry industry may exceed these effects by affecting posthatch broiler performance and processing yields (Lundy, 1969; Wilson, 1991; Lourens and van Middelkoop, 2000). Therefore, a trial was conducted to examine the effects of low EST in the setter, high EST in the hatcher, and their combination on chick quality, live performance, and processing yields of broiler chickens.

Received October 30, 2005.
Accepted January 13, 2006.
[1]Corresponding author: moranet@auburn.edu

Table 1. Schedule of eggshell temperature treatments (°C) during incubation

	Incubation period		
Treatment	0 to 10 d	11 to 18 d	19 to 21 d
Control	37.8	37.8	37.8
Control:high			39.5
Low:control	36.7	37.8	37.8
Low:high			39.5

MATERIALS AND METHODS

The Auburn University Institutional Animal Care and Use Committee approved the experimental protocol. For replication purposes and to minimize incubator variability, the experiment was conducted twice using the same incubators. Both experiments were used to determine hatchability, embryonic mortality, and chick yield at hatch. For the first experiment, the focus was on embryonic development and early chick quality, whereas the second experiment focused on live performance up to 6 wk of age and subsequent processing yields.

Experiment 1

Eighteen hundred Ross × Ross 308 eggs were obtained from a breeder flock at 31 wk of age, weighed by groups of 15, and set into 2 single-stage setters (Natureform NMC-2000, 1,980 egg capacity, Natureform Hatchery Systems, Jacksonville, FL). Eggs were placed in alternate spaces on the trays to increase airflow. Using an infrared thermometer (Braun Thermoscan Plus Type 6013, The Gillette Company, Boston, MA), EST was measured daily on 8 sample eggs from each incubator to ensure treatment intentions. Sample eggs located toward the center of the incubator or along the sides were selected from alternating rows in each setter. The thermometer was placed against the side of the egg on a predetermined spot. A mean EST was calculated for each incubator and the machine operating temperature was adjusted accordingly. When not in use, the thermometer was stored inside one of the incubators to keep it warm. For the first 10 d of incubation, one incubator was set to attain an EST of 36.7°C to represent the "low" treatment, whereas the other was set to 37.8°C representing the control temperature (Table 1). On d 11 of incubation, the temperature in the low EST incubator was increased to 37.8°C in synchrony with the other incubator until egg transfer. On d 18 of incubation, those eggs deemed infertile by candling were removed. The remaining eggs from each group were weighed and transferred to hatch baskets. One-half of the eggs from each setter were combined and placed in each of 2 hatchers (Natureform Hatchery Systems). The EST in one hatcher was set to 37.8°C, and the other to 39.5°C to represent the "high" treatment. The hatcher temperature treatments were applied from d 19 to 21 of incubation. There were 4 EST treatments in total. The control treatment was 37.8°C EST for the entire incubation period; control:high was 37.8°C EST in the setter followed by 39.5°C in the hatcher; low:control was 36.7°C EST in the first 10 d of incubation followed by 37.8°C thereafter; and low:high was 36.7°C EST in the first 10 d in the setter, then 37.8°C from d 11 to 18, and finally 39.5°C in the hatcher (Table 1).

On d 21 of incubation, the chicks were examined for abnormalities and classified as either saleable (healthy) or culls (splayed legs, unhealed navels, etc.). Saleable chicks were weighed, feather-sexed, and vaccinated for Marek's disease. Unhatched eggs were opened to macroscopically determine fertility and embryonic mortality (early, middle, late deads, and internal and external pipped). Twelve male chicks from each temperature treatment were euthanized with CO_2 gas to determine yolk sac weight, yolk-free BW, and body length at hatch. Body length was determined by placing the chick face down on a flat surface and straightening the left leg. A ruler was used to measure the length of the bird from the tip of the beak to end of the middle toe on the left leg.

For determination of chick quality, 624 male chicks were placed by treatment in 52 battery cages (0.04 m^2/chick) providing 13 replicate cages per setter and hatcher temperature treatment. Water and a common corn-soybean meal starter ration (3,070 kcal of ME/kg, 22.5% CP) were supplied ad libitum under continuous lighting. At 1 wk of age and termination of the experiment, the chicks were weighed; 1 chick from each cage was randomly chosen for dissection to determine BW, body length, heart and liver weights.

Table 2. Mean eggshell temperature of hatching eggs incubated at 2 setter temperatures from 0 to 10 d and 2 hatcher temperatures from 19 to 21 d of incubation[1]

Setter temperature	Hatcher temperature	Mean eggshell temperature (°C)		
		0 to 10 d	11 to 18 d	19 to 21 d
Control	Control	37.8[a]	38.0	38.1[b]
	High			39.4[a]
Low	Control	36.6[b]	37.9	38.1[b]
	High			39.4[a]
SEM		0.05	0.05	0.05
Setter × Hatcher		***	NS	***

[a,b]Means within a column with no common superscript differ significantly.

[1]Values represent the least square means of 2 trials, each with 8 temperature readings per incubator every day.

NS: $P > 0.05$, ***$P \leq 0.001$.

Table 3. Hatchability and embryonic losses from eggs incubated at 2 setter temperatures from 0 to 10 d of incubation and 2 hatcher temperatures from 19 to 21 d of incubation[1]

Source	Hatchability (% eggs)		Embryonic death[2] (% fertile)			Pipped (% fertile eggs)	
	All chicks	Saleable chicks	Early	Middle	Late	Internal	External
Setter temperature							
Control	91	87	2.7	0.2	2.4	0.8	0.9
Low	87	81	2.8	0.5	2.0	1.4	2.4
Hatcher temperature							
Control	88	84	2.4	0.3	2.6	1.5	2.0
High	90	84	3.0	0.4	1.8	0.8	1.3
SEM	0.7	0.9	0.41	0.14	0.34	0.24	0.31
Setter	**	***	NS	NS	NS	NS	***
Hatcher	*	NS	NS	NS	NS	*	NS
Setter × Hatcher	NS	NS	NS	NS	NS	*	NS

[1]Setter temperatures: control = 37.8 ± 0.05°C, low = 36.6 ± 0.05°C. Hatcher temperatures: control = 38.1 ± 0.05°C, high = 39.4 ± 0.05°C. From 11 to 18 d of incubation all eggs were incubated at ~38.0°C. Values represent the least square means of 2 trials, each with 30 replicate trays of 15 eggs at the start of experimentation.

[2]Embryonic death is the cessation of development occurring from 0 to 7 d of incubation (early), 8 to 14 d of incubation (middle), and 15 to 21 d of incubation before pipping (late).

NS: $P > 0.05$; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Experiment 2

This experiment used 1,800 eggs originating from a Ross × Ross 308 flock of the same age as in the first experiment. The temperature treatments and methodology for measuring EST were also identical to those in Experiment 1. Eight embryos from each setter treatment were dissected on d 10 and 18 of incubation to measure embryo weight and body length. Embryos were excised from the extraembryonic membranes before they were weighed.

Upon removal from the hatcher, chicks were processed and a subsample of 12 male chicks from each setter and hatcher treatment was dissected as in Experiment 1. For determination of live performance and processing yields, 800 male chicks were placed in 32 floor pens (0.02 m^2/chick), providing 8 replicate pens for each setter and hatcher temperature treatment. Birds were reared under continuous lighting with feed and water supplied ad libitum. Chicks were fed common corn-soybean meal rations throughout rearing. The starter ration (3,070 kcal of ME/kg, 22.5% CP) was fed from 0 to 21 d of age and the

Table 4. Chick quality parameters measured at hatch from broilers incubated at 2 setter temperatures from 0 to 10 d of incubation and 2 hatcher temperatures from 19 to 21 d of incubation[1]

Source	BW[2] (g)	Chick yield[2] (%)	Yolk-free BW[3] (g)	Yolk sac weight[3] (g)	Body length[3] (mm)
Setter temperature					
Control	39	67	35.5	3.0	168
Low	40	71	35.1	4.3	163
Hatcher temperature					
Control	40	70	35.9	3.7	165
High	39	68	34.7	3.6	165
SEM	0.1	0.1	0.34	0.13	1.4
Setter × Hatcher					
Control	40[b]	69[c]	36.8[a]	2.9	168
Control:high	38[c]	66[d]	34.3[b]	3.1	167
Low:control	41[a]	71[a]	35.0[b]	4.4	163
Low:high	40[b]	70[b]	35.1[ab]	4.1	163
SEM	0.2	0.2	0.47	0.19	1.9
Setter	***	***	NS	***	**
Hatcher	***	***	**	NS	NS
Setter × Hatcher	***	***	**	NS	NS

[a–d]Means within a column with no common superscript differ significantly.

[1]Setter temperatures: control = 37.8 ± 0.05°C, low = 36.6 ± 0.05°C. Hatcher temperatures: control = 38.1 ± 0.05°C, high = 39.4 ± 0.05°C. From 11 to 18 d of incubation, all eggs were incubated at 38.0°C.

[2]Values represent the least square means of 2 trials, each with 30 replicate trays of 15 eggs at the start of experimentation. Body weight includes the weight of the yolk sac and chick yield is the ratio of whole BW to egg weight, expressed as a percentage.

[3]Yolk-free BW, body length, and yolk sac weight data represent the least square means of 2 trials, each with 12 replicates of male chicks.

NS, $P > 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$.

Table 5. Chick quality at 1 wk of age of broilers incubated at 2 setter temperatures from 0 to 10 d of incubation and 2 hatcher temperatures from 19 to 21 d of incubation[1]

Source	BW (g)		Body length (mm)	Heart weight (g)	Liver weight (g)
	Final	Gain			
Setter temperature					
Control	144	106	238	1.15	7.9
Low	138	98	232	1.17	7.3
Hatcher temperature					
Control	147	107	235	1.15	7.9
High	135	97	235	1.17	7.3
SEM	3.2	3.1	2.3	0.043	0.33
Setter × Hatcher					
Control	154[a]	115[a]	242[a]	1.17	8.4
Control:high	134[b]	96[b]	234[ab]	1.14	7.4
Low:control	139[ab]	98[b]	229[b]	1.14	7.4
Low:high	137[b]	97[b]	235[ab]	1.21	7.2
SEM	4.5	4.4	3.3	0.061	0.47
Setter	NS	NS	NS	NS	NS
Hatcher	*	*	NS	NS	NS
Setter × Hatcher	*	*	*	NS	NS

[a,b]Means within a column with no common superscript differ significantly.

[1]Body weight values represent the least square means of 13 replicate cages of 12 chicks at 1 d of age. Body length and organ weight data represent the least square means of 13 replicates of individual chicks.

NS: $P > 0.05$; *$P \leq 0.05$.

grower ration (3,150 kcal of ME/kg, 20% CP) from 22 to 42 d of age. Feed consumption and individual BW for each pen were determined at 21 and 42 d of age. Mortality was recorded daily. At 42 d of age birds were cooped, held for 12-h, and then slaughtered in the poultry processing plant at the university. Following stationary immersion in slush-ice water for 3 h, the carcasses were drained and abdominal fat pads were removed. Experienced personnel removed breast fillets and tenders 24 h postmortem using stationary cones.

Statistical Analyses

The experimental unit was the group of 15 eggs during incubation, the battery cage for chick quality data, and the floor pen for the live performance and processing data. Eggs from each setter treatment were blocked by location in the hatcher. Birds from each treatment were blocked by location in the rearing facility. The data were analyzed by 2-way ANOVA for setter temperature and hatcher temperature using the GLM procedure in SAS (SAS Institute, 2001). Hatch data were transformed to arc sine values before analysis. Tukey's honestly significant difference was used to separate differences between treatment means. Significance implied a *P*-value equal to or less than 0.05.

RESULTS AND DISCUSSION

Eggshell Temperature

Mean EST readings that were used to ensure treatment objectives are presented in Table 2. For the first 10 d of incubation, mean values for control EST and low EST were as intended. From 11 to 18 d of incubation, when no temperature treatments were in place, the mean EST in both setters did not significantly differ. The temperature difference between hatcher treatments was less than intended, although mean values for control EST and high EST were significantly different. Other studies have found significant impacts on embryonic development with smaller temperature differences (Romanoff, 1935, 1936; French, 2000). Eggshell temperature is influenced by the amount of heat produced by the embryo and the amount of heat transferred between the egg and the environment (Meijerhof and van Beek, 1993). Eggshell temperature treatments were achieved by altering the machine temperature daily. Lourens et al. (2005) found that the consequence of a low EST during the first week of incubation was that a higher machine temperature was required thereafter to bring EST up to 37.8°C. Nichelmann et al. (1998) demonstrated that metabolic rate increased with incubation temperature. Thus, the low EST was believed to lower the embryo's metabolic rate and resulting heat production. A high EST of 38.9°C during the last week of incubation also required a higher machine temperature than an EST of 37.8°C (Lourens et al., 2005). As Janke et al. (2002) found, once internal egg temperatures reached 40°C at d 20, the metabolic rate of embryos decreased within 30 min.

Hatchability and Chick Quality

Setter and hatcher EST significantly affected hatchability (Table 3). Low EST in the setter reduced both total and saleable hatches compared with the control EST. In other studies, a significant drop in hatchability occurred with continuous exposure to a 36.5°C machine temperature (Romanoff, 1935) but not with a 36.8°C machine temperature (Michels et al., 1974). Eggshell temperature may have been lower than 37.8°C in the former study, whereas in the latter, EST may have decreased to 37.8°C. High hatcher EST increased total hatchability compared with the control EST. The difference was mainly in the number of culled

Table 6. Live performance of broilers at 3 and 6 wk of age incubated at 2 setter temperatures from 0 to 10 d of incubation and 2 hatcher temperatures from 19 to 21 d of incubation[1]

Source	BW (g)		Feed conversion[2]	Mortality (%)
	Final	Gain		
	0 to 21 d of age (27 ± 2.3°C and 72 ± 7.0% RH)[3]			
Setter temperature				
Control	936	897	1.34	2.3
Low	891	851	1.34	1.8
Hatcher temperature				
Control	911	871	1.35	2.6
High	916	877	1.34	1.5
SEM	5.9	6.3	0.011	0.50
Setter × Hatcher				
Control	926	887	1.37[a]	1.7[ab]
Control:high	946	908	1.31[b]	2.9[ab]
Low:control	895	855	1.33[ab]	3.5[a]
Low:high	887	847	1.37[a]	0.0[b]
SEM	7.3	7.8	0.016	0.72
Setter	***	***	NS	NS
Hatcher	NS	NS	NS	*
Setter × Hatcher	NS	NS	**	*
	21 to 42 d of age (23 ± 3.2°C and 69 ± 12.1% RH)			
Setter temperature				
Control	3,103	2,167	1.79	0.9
Low	3,014	2,115	1.77	0.6
Hatcher temperature				
Control	3,060	2,147	1.78	0.6
High	3,057	2,136	1.79	0.9
SEM	16.1	15.1	0.016	0.46
Setter × Hatcher				
Control	3,100	2,173	1.79	0.6
Control:high	3,107	2,161	1.79	1.2
Low:control	3,021	2,120	1.76	0.6
Low:high	3,008	2,110	1.78	0.6
SEM	22.8	21.4	0.023	0.65
Setter	***	*	NS	NS
Hatcher	NS	NS	NS	NS
Setter × Hatcher	NS	NS	NS	NS

[a,b]Means within a column and main effect with no common superscript differ significantly.

[1]Setter temperatures: control = 37.8 ± 0.05°C, low = 36.6 ± 0.05°C. Hatcher temperatures: control = 38.1 ± 0.05°C, high = 39.4 ± 0.05°C. From 11 to 18 d of incubation all eggs were incubated at 38.0°C. Values are the least square means of 8 pens each having 25 chicks at the start of experimentation.

[2]Feed conversion (feed to gain) values were corrected for mortality.

[3]Average temperature and relative humidity ± standard deviation.

NS: $P > 0.05$; *$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.

chicks because hatchability of saleable chicks was similar for both treatments. Previous reports stated that moderate changes in hatcher temperature had no affect on hatchability because full-term embryos were less sensitive to temperature fluctuations than were young embryos (Romanoff, 1935; Lundy, 1969; Wilson, 1991; French, 2000). However, Romanoff (1935) observed that the percentage of weak or crippled chicks increased with higher hatcher temperatures in agreement with the present study.

Embryonic losses before the pipping stages of emergence were similar irrespective of high or low EST. Fewer deaths at internal pipping were observed with high EST compared with control EST in the hatcher. Also, a significant setter and hatcher EST interaction on internal pip losses was found (0.7, 0.8, 2.2, and 0.7 ± 0.34% for control, control:high, low:control, and low:high, respectively). Mortality, after external pipping, increased with incubation at low EST in the setter, whereas hatcher EST had no effect.

Chick quality data at hatch are presented in Table 4. Low setter EST increased BW, whereas high hatcher EST reduced BW compared with the controls. The combination of setter and hatcher EST also affected BW. Chicks in the low:control EST treatment had the highest BW and chicks in the control:high EST treatment had the lowest BW compared with the other 2 treatment groups. Chick yield followed the same pattern, indicating that eggs in the low:control EST treatment lost the least amount of weight during incubation. These results contradict the findings of Michels et al. (1974) who found no differences in chick yield in response to low incubation temperature. Body weight variability at hatch (when egg weight is constant) is often the result of differences in moisture loss or residual yolk sac weight (Tullett and Burton, 1982). In the present study, after subtracting yolk sac weight from BW, control EST chicks weighed the same as low EST chicks. Therefore, whole BW differences between these 2 treatments may be explained by differences in yolk sac weight. Alternatively, hatcher EST affected yolk-free BW, not residual yolk sac weight. Low setter EST reduced body length, whereas hatcher EST had no effect, perhaps because of longer expo-

Table 7. Carcass and breast meat yield of broilers at 6 wk of age incubated at 2 setter temperatures from 0 to 10 d of incubation and 2 hatcher temperatures from 19 to 21 d of incubation[1]

	Carcass without abdominal fat[2]		Abdominal fat[3]		Fillets[4]		Tenders[4]	
Source	Weight (g)	Live wt (%)	Weight (g)	Carcass wt (%)	Weight (g)	Carcass wt (%)	Weight (g)	Carcass wt (%)
Setter temperature								
Control	2,149	68.8	46	2.09	511	23.7	110	5.11
Low	2,065	68.6	46	2.19	475	23.2	105	5.07
Hatcher temperature								
Control	2,104	68.7	46	2.12	491	23.3	107	5.08
High	2,110	68.7	47	2.17	495	23.6	108	5.10
SEM	9.1	0.09	0.7	0.030	3.9	0.09	0.8	0.028
Setter	***	NS	NS	*	***	**	***	NS
Hatcher	NS	NS	NS	NS	NS	NS	NS	NS
Setter × Hatcher	NS	NS	NS	NS	NS	NS	NS	NS

[1]Setter temperatures: control = 37.8 ± 0.05°C, low = 36.6 ± 0.05°C. Hatcher temperatures: control = 38.1 ± 0.05°C, high = 39.4 ± 0.05°C. From 11 to 18 d of incubation all eggs were incubated at 38.0°C. Values represent the least square means of approximately 20 carcasses from each of 8 replicated pens.

[2]Carcass without neck and giblets after 4 h of slush-ice chilling followed by removal of abdominal fat, expressed on an absolute basis and relative to the full-fed live weight.

[3]Depot fat removed from the abdominal cavity, expressed on an absolute basis and relative to the chilled carcass.

[4]Fillets and tenders correspond to the major and minor pectoral muscles, respectively, and are expressed on an absolute basis and relative to the chilled carcass.

NS: $P > 0.05$; *$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.

sure time to setter EST treatments (10 d) compared with hatcher EST treatments (3 d). Based on previous research, a lower than optimal temperature during the first 10 d of incubation likely slowed the rate of embryonic development (Moreng and Bryant, 1954), producing chicks that were smaller in frame size. Lourens et al. (2005) found comparable results.

After 1 wk posthatch, the setter temperature effect on BW had dissipated, whereas chicks from the high hatcher EST still weighed less than the controls (Table 5). Incubating eggs at the constant control EST resulted in the highest BW gain compared with the other setter and hatcher treatments. Body length, heart and liver weights did not differ by the main effects. Body length of control EST chicks was larger than the body length of low:control EST chicks, whereas control:high and low:high EST treatments were intermediary in this respect.

In response to the initial live performance data, embryo weight and length at d 10 and 18 of incubation were determined in the second experiment. On d 10 of incubation, low EST embryos weighed less than control EST embryos (3.6 and 4.9 ± 0.18 g, respectively; $P \leq 0.001$). Body length was also significantly reduced (5.0 and 5.5 ± 0.08 mm for low and control EST, respectively; $P \leq 0.001$). On d 18 of incubation, BW was still reduced (27 and 30 ± 0.6 g for low and control EST, respectively; $P \leq 0.05$), as was body length (94 and 99 ± 0.9 mm for low and control EST, respectively; $P \leq 0.001$). According to Geers et al. (1982, 1983), embryos initially incubated at low temperatures followed by an optimal temperature exhibit compensatory growth during incubation and within the first week posthatch. The authors found that dry embryo weights in the low temperature group were similar to controls on d 19 of incubation. Data from the present study would suggest that compensatory growth did not occur because wet embryo weights were still reduced with low setter temperature on d 18 of incubation. In another study, the effect of low EST during the first week of incubation on chick weight persisted at 1 wk posthatch when the trial was terminated, and no compensatory growth was observed (Lourens et al., 2005).

Live Performance and Processing Yield

At 3 and 6 wk of age, chicks incubated at a low setter EST weighed less than those incubated at an optimal setter EST (Table 6); BW gain was likewise reduced. Other reports found that chicks incubated at a low temperature recovered during rearing and reached similar weights as controls (Michels et al., 1974; Geers et al., 1982, 1983; Kuhn et al., 1982; Decuypere, 1984). These reports attributed the compensatory growth to greater heat production (Geers et al., 1983; Decuypere, 1984) and a higher concentration of triiodothyronine in chicks incubated at low temperature (Kuhn et al., 1982). It has to be realized that low machine temperature treatments as described in these experiments are commonly applied in commercial hatcheries to avoid overheating the eggs, and that these "cold-incubated chicks" may actually represent incubation at 37.8°C EST. Hatcher EST did not affect posthatch BW, which was in agreement with observations from a previous experiment (Joseph, 2004). The high hatcher EST treatment reduced mortality at 3 wk of age compared with the control EST treatment; mortality was the same by 6 wk of age. The interaction of setter and hatcher EST treatments altered feed conversion and mortality at 3 wk of age. By 6 wk of age, the low setter EST was the only treatment to adversely affect any of the live performance parameters. Results are comparable to findings by Lourens and van Middelkoop (2000), who incubated eggs from 2 different broiler strains at 50 wk of age at different EST profiles and concluded that any deviation away from 37.8°C decreased both hatchability and posthatch performance.

Low EST decreased carcass weight and increased abdominal fat pad yield compared with control EST in the setter (Table 7), whereas hatcher EST had no effect on any processing parameter measured. Reduced fillet weight, yield, and tender weights were also observed in the low EST treatment. Poults subjected to a low setter temperature during early embryonic development had fewer myofibers and delayed myogenin expression compared with poults incubated at a normal setter temperature (Maltby and Stickland, 2003). Because myofiber number is believed to be fixed at hatch, fewer fibers may limit posthatch growth potential. Further research on myogenic regulatory factors and muscle differentiation may offer an explanation for the results observed in this study. The combination of setter EST and hatcher EST affected all processing parameters similarly.

The effects of EST on embryonic development determine the influence that EST can have on the posthatch chick. This research demonstrated that a low EST of 36.6°C in the first 10 d of incubation, which may arise in practice, reduced embryonic weight, hatchability, and early chick quality. Furthermore, compensatory growth did not occur up to 6 wk of age and subsequent carcass and breast meat yields were reduced. Presumably, posthatch growth was stunted because of slowed development in ovo including myogenesis. A high EST of 39.5°C in the hatcher increased total hatchability with the difference attributed to more culls. Although BW and gain were reduced initially, this EST did not affect overall live performance or processing yields. This study found that maintaining an EST of 37.8°C throughout incubation, but especially from d 0 to 10, optimized hatchability, live performance to 6 wk of age, carcass weight, and breast fillet yield. Researchers studying both incubation and broiler performance should be aware of the effect of low or high EST in their experiments, because it may have a larger impact on results than other factors that are studied (e.g., machine temperature). As days to market age decrease, economic returns in the broiler industry can be improved when more attention is paid to the control of EST and hence, embryonic development.

ACKNOWLEDGMENTS

Aviagen Inc. deserves many thanks for donating the eggs for these experiments and for their technical input. The authors would also like to acknowledge Jin Fung Chen and Jaume Galobart Cots for their assistance with the trials.

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