We conducted an experiment to determine the effect of relative humidity (RH) during incubation on characteristics of hatched chicks from eggs produced by young broiler breeders. Eggs were collected for 6 consecutive d, every other week, in each of two trials from broiler breeder flocks at 26, 28, and 30 wk of age. The eggs were randomly distributed in machines according to RH treatments that were 43, 53, and 63% RH from set to pulling time at 21.75 and 22 d of incubation for Trials 1 and 2, respectively. The same dry bulb temperature (37.5 C) was used throughout incubation for both trials.

Body weight at hatch, but not BW at pull (removal from machine), increased significantly with increasing RH treatment. The BW at hatch and BW at pull increased with increasing hen age. Percentages of late dead and fertile hatchability were the highest for the 63% and 53% RH treatments, respectively. These data demonstrated that, although a high RH during incubation produced chicks with increased BW at hatch, this extra weight was greatly reduced by time of pull, which suggests a significant rate of evaporation even in the presence of high RH. Further, the high RH appears to have a detrimental effect on embryonic development, as evidenced by the increased percentage of late dead.

(Key words: hatchability, embryo mortality, incubation, relative humidity, broiler breeders)

INTRODUCTION

Young breeder flocks are often reported to produce eggs with low hatching potential, extended incubation periods, and chicks of low quality, as judged by mortality and growth. Hatching time has been shown to be significantly affected by hen age, with the middle-aged breeder showing a shorter incubation time in relation to that of younger flocks (Suarez et al., 1997). Also, mortality was significantly higher among chicks coming from a broiler breeder flock of 26 wk vs. 36 wk old (Wyatt et al., 1985).

The most obvious characteristic of eggs from young broiler breeders is low egg weight. Because chick weight is proportional to egg weight, small chicks are expected. Chick weight at hatch is heavily influenced by the weight of the egg from which it hatches (Morris et al., 1968; Hager and Beane, 1983; Whiting and Pesti, 1983; Burke, 1992; Suarez et al., 1997). Small chicks have higher surface area to weight ratios and are therefore more easily dehydrated than larger chicks. Dehydration has been reported to be associated with higher mortality of chicks from young breeders (Wyatt et al., 1985).

Dehydration can be influenced by relative humidity (RH) during incubation or hatching, as well as the length of time from hatching to removal from the hatcher (pull). Chick BW at hatch has also been reported to be influenced by time of removal from hatcher and setter humidity (Reinhart and Hurnik, 1984). Incubation at a lower RH has been reported by some authors to reduce chick BW, whereas an extended time between hatch and placement has been reported to exhibit a similar effect. The longer chicks remained in the hatcher posthatch, the greater the percentage weight loss before the chicks were placed into brooding pens (Hager and Beane, 1983; Reinhart and Hurnik, 1984).

Incubation conditions that result in the best hatchability have also been reported to elicit the best chick quality (Lundy, 1969). The optimal RH range has been reported to be quite wide, between 40 and 70% RH (Lundy, 1969), with the maximum hatchability obtained around 50% RH (Robertson, 1961a). Two trials were conducted to further investigate the effects of RH during incubation on hatchability and chick BW.

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1The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service of the products mentioned, nor criticism of similar products not mentioned.
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Abbreviation Key: RH = relative humidity.
MATERIALS AND METHODS

Hatching eggs were produced from donor flocks of Arbor Acres\textsuperscript{3} feather-sexable yield strain females mated to Arbor Acres\textsuperscript{3} yield strain males. Males and females were grown sex-separate in light-controlled facilities on an 8-h photoperiod. The feeding and BW program was as described by Walsh and Brake (1997), and details of house management were as described by Brake and Baughman (1989). At 20 wk (141 d) of age the birds were moved to slat-litter breeding pens and were photostimulated with a 14-h photoperiod. Males were equalized by BW and then distributed among the female pens to create 16 pens with six males and 60 females per pen.

Hatching eggs were collected daily, identified by date of collection and pen, and were stored at 18 C and 70% RH until sorted into RH incubation treatments and set into incubators. As appropriate for each trial in each experiment, eggs from the various pens were randomly distributed equally among the various RH treatments to eliminate any bias caused by pen or length of egg storage. Eggs had been stored for up to 6 d when set.

Machines used were Jamesway model 252B incubators. All machines were operated at 37.5 ± 0.5 C dry bulb temperature and either 26.7, 28.9, or 31.1 ± 0.5 C wet bulb temperatures. These wet bulb temperatures created the three RH treatments of 43, 53, and 63% RH, respectively. Machines were monitored twice daily for proper operation. At the time of transfer, all eggs were candled for evidence of live embryos. All eggs showing no evidence of a live embryo were removed for macroscopic examination to determine fertility or stage of embryo mortality. Only eggs with viable embryos were transferred to 30-egg wire pedigree baskets where they were allowed to hatch.

Trials 1 and 2 were conducted in spring and fall, respectively. In each trial eggs were collected from the donor flock at 26, 28, and 30 wk of age. In Trial 1, 430, 774, and 866 eggs were set per RH treatment (43, 53, and 63% RH) from the flock at 26, 28, and 30 wk of age, respectively. In Trial 2, 348, 467, and 480 eggs were set per RH treatment from the donor flock at 26, 28, and 30 wk of age, respectively.

In trial 1, hatching time and BW at hatch were monitored every 6 h from 19.75 to 21.75 d after transfer from the incubator to the hatching basket at 19 d of incubation. The chicks were weighed to the nearest 0.1 g, wing-banded at the time of hatch, and returned to the pedigree basket in the same machine. This procedure was performed to maintain uniform temperatures throughout the hatching process. Chicks were deemed to be hatched when they exhibited healed navels and dryness about the head and neck. Body weight was also determined at 21 d and pull time (21.75 d) for all chicks. Therefore, chicks that hatched before 21 d were weighed three times, whereas those that hatched at 21 and 21.75 d were weighed twice or once, respectively. At pull time, all unhatched eggs were opened and examined macroscopically to determine percentages of late mortality, pipped dead, and contaminated eggs. Only chicks that hatched prior to pull time were included in the calculation of weight loss after hatching.

Trial 2 was conducted in a manner similar to that of Trial 1 with the following exceptions. After transfer at 19 d of incubation, BW and hatching time were monitored every 8 h from 19.66 to 22.00 d. Chicks from eight, six, and six randomly selected pens were used for determination of BW and weight loss after hatching at 26, 28, and 30 wk of age, respectively.

The results for the incubation variables (BW at hatch, BW at pull, hatch time, weight loss from hatch to pull, and percentage weight loss from hatch to pull) were analyzed by ANOVA with the general linear model (GLM) procedure of PC SAS (SAS Institute, 1990); RH treatment and hen age were the main effects. The experiment was replicated twice using six different incubators. For trial and RH comparisons the incubator within trial variation was used as Error A, and for hen age comparisons the incubator by hen age interaction within each trial was used as Error B. For the embryo mortality analysis, percentages infertile, early dead, late dead, and pipped eggs, as well as fertile hatchability, were the dependent variables, and RH treatments and hen age were the main effects. These data were analyzed as categorical data using the general model (GENMOD) procedure of PC SAS. Means were partitioned using orthogonal contrasts. Statements of statistical significance were based upon $P \leq 0.05$ unless otherwise indicated.

RESULTS

The effects of RH treatment during incubation from set to pull on chick BW, hatching time, and weight loss from hatch to pull are shown in Table 1. The BW at hatch increased with percentage RH treatments, but this effect was not apparent at 21 d or at pull. Hatch time was not affected by RH treatment. Chick BW loss from hatch to pull for those chicks that hatched prior to pull, expressed on an absolute and percentage bases, was also not affected.

The effects of RH treatment during incubation from set to pull on percentage infertile, embryonic mortality, and fertile hatchability are shown in Table 2. Late embryonic mortality was affected ($P \leq 0.01$) by RH treatment with the highest mortality observed at 63% RH. Fertile hatchability

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\textsuperscript{3}Arbor Acres Farm Inc., Glastonbury, CT 06033.

\textsuperscript{3}Butler Manufacturing Co., Ft. Atkinson, WI 53538.
was increased by the 53% RH treatment compared with the other RH treatments. No other significant effects due to RH treatment were observed.

The effects of trial on percentage infertility, embryonic mortality, and fertile hatchability are shown in Table 2. Percentages of infertile (P ≤ 0.01) and early dead (P ≤ 0.01) were significantly higher in Trial 2, whereas percentage late dead (P ≤ 0.01) was greater in Trial 1.

The effects of hen age on percentages of infertile, embryonic mortality, and fertile hatchability are shown in Table 2. Percentages of infertile (P ≤ 0.01), early dead (P ≤ 0.01), late dead (P ≤ 0.01), and pipped dead were greatest at 26 wk of age and declined thereafter. There was a significant RH treatment × hen age interaction (P ≤ 0.01) for late deads (Figure 1). This interaction was apparently due to relatively high late dead mortality caused by the 63% RH treatment at 26 wk of age and quite low mortality caused by the 43% RH treatment at 28 wk of age. Fertile hatchability (P ≤ 0.01) was decreased at 26 wk when compared with later hen ages.

**DISCUSSION**

Chick BW at hatch, but not at 21 d or at pull, increased with increasing percentage RH (Table 1). This result agrees with that of Hamdy et al. (1991), who stated that chicks hatched from eggs incubated at 55% RH had a significantly higher BW than chicks hatched from eggs incubated at 45% RH, but disagrees with that of Robertson (1961b), who found no effect of RH on BW at hatch. Also, no differences in chick weight loss after hatching caused by RH treatment was found; which suggests that the additional weight due to RH condition is simply water that is rapidly lost even at the higher RH condition. This finding agrees with that of Swann and Brake (1990b) who stated that the combination of an early hatch and a long holding time in the hatchery had a more significant effect on the final BW of the chick than hatcher RH.

Chick BW at hatch and BW at pull increased significantly as hen age increased (Table 1). Egg weight increases with increasing hen age, and chick BW at hatch is heavily influenced by the weight of the egg from which it hatches (Morris et al., 1968; Hager and Beane, 1983; Whiting and Pesti, 1983; Burke, 1992; Suarez et al., 1997).

Percentage late dead embryos was significantly increased for the 63% RH treatment (Table 2), which confirms the findings of Davis et al. (1988). This increase could be caused by a decreased partial pressure of oxygen, because of additional water vapor in the air at the higher RH during the last stages of incubation when the requirements for oxygen are maximized. As stated by Tullett (1990), the oxygen requirement increases as incu-

**TABLE 1. Effects of relative humidity during incubation, trial, and hen age on chick BW, hatching time, and weight loss**

<table>
<thead>
<tr>
<th>Variable</th>
<th>43</th>
<th>53</th>
<th>63</th>
<th>1</th>
<th>2</th>
<th>26</th>
<th>28</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW at hatch (g)</td>
<td>39.4 ± 0.11</td>
<td>40.2 ± 0.11</td>
<td>41.2 ± 0.11</td>
<td>41.0 ± 0.10</td>
<td>39.6 ± 0.09</td>
<td>36.7 ± 0.12</td>
<td>40.1 ± 0.09</td>
<td>42.4 ± 0.09</td>
</tr>
<tr>
<td>BW at 21 d (g)</td>
<td>35.9 ± 0.31</td>
<td>38.9 ± 0.13</td>
<td>38.4 ± 0.30</td>
<td>36.8 ± 0.29</td>
<td>36.8 ± 0.10</td>
<td>33.5 ± 0.35</td>
<td>38.5 ± 0.16</td>
<td>39.2 ± 0.27</td>
</tr>
<tr>
<td>BW at pull (g)</td>
<td>35.9 ± 0.12</td>
<td>36.3 ± 0.11</td>
<td>37.9 ± 0.11</td>
<td>37.8 ± 0.09</td>
<td>35.8 ± 0.09</td>
<td>33.4 ± 0.13</td>
<td>36.4 ± 0.09</td>
<td>38.4 ± 0.10</td>
</tr>
<tr>
<td>Hatch time (d)</td>
<td>20.7 ± 0.01</td>
<td>20.6 ± 0.01</td>
<td>20.8 ± 0.01</td>
<td>20.7 ± 0.01</td>
<td>20.5 ± 0.01</td>
<td>20.7 ± 0.02</td>
<td>20.7 ± 0.01</td>
<td>20.5 ± 0.01</td>
</tr>
<tr>
<td>Weight loss (g)</td>
<td>3.6 ± 0.04</td>
<td>3.9 ± 0.03</td>
<td>3.5 ± 0.04</td>
<td>3.4 ± 0.03</td>
<td>3.9 ± 0.03</td>
<td>3.5 ± 0.05</td>
<td>3.8 ± 0.03</td>
<td>3.7 ± 0.03</td>
</tr>
<tr>
<td>Weight loss (%)</td>
<td>9.2 ± 0.10</td>
<td>9.7 ± 0.07</td>
<td>8.5 ± 0.10</td>
<td>8.3 ± 0.07</td>
<td>9.8 ± 0.07</td>
<td>9.4 ± 0.14</td>
<td>9.4 ± 0.08</td>
<td>8.7 ± 0.08</td>
</tr>
</tbody>
</table>

**TABLE 2. Effects of relative humidity during incubation, trial, and hen age on infertility, embryonic mortality, and fertile hatchability**

<table>
<thead>
<tr>
<th>Variable</th>
<th>43</th>
<th>53</th>
<th>63</th>
<th>1</th>
<th>2</th>
<th>26</th>
<th>28</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infertile (%)</td>
<td>7.4</td>
<td>8.3</td>
<td>7.3</td>
<td>4.8 a</td>
<td>11.0 a</td>
<td>8.9 a</td>
<td>6.5 b</td>
<td>6.8 b</td>
</tr>
<tr>
<td>Early dead (%)</td>
<td>8.2</td>
<td>7.1</td>
<td>8.5</td>
<td>6.9 a</td>
<td>8.3 a</td>
<td>8.9 a</td>
<td>7.2 b</td>
<td>6.7 b</td>
</tr>
<tr>
<td>Late dead (%)</td>
<td>3.0 b</td>
<td>2.5 b</td>
<td>4.5 A</td>
<td>0.6 b</td>
<td>1.8 b</td>
<td>5.5 A</td>
<td>0.2 c</td>
<td>2.7 b</td>
</tr>
<tr>
<td>Pipped (%)</td>
<td>0.9</td>
<td>0.5</td>
<td>0.8</td>
<td>0.8</td>
<td>0.5</td>
<td>1.1</td>
<td>0.5 b</td>
<td>0.7 b</td>
</tr>
<tr>
<td>Fertile hatchability (%)</td>
<td>86.6 b</td>
<td>89.1 A</td>
<td>86.3 b</td>
<td>87.4</td>
<td>87.2</td>
<td>82.6 b</td>
<td>89.3 A</td>
<td>88.2 A</td>
</tr>
</tbody>
</table>

a,b Means within a row that possess no common superscript differ significantly (P ≤ 0.05). Data subjected to categorical analysis and SE are, therefore, not generated.

A-C Means within a row that possess no common superscript differ significantly (P ≤ 0.01). Data subjected to categorical analysis and SE are, therefore, not generated.

1Relative humidity from set to pull at 21.75 d of incubation in Trial 1, or 22 d of incubation in Trial 2.

2Trial 1 was conducted in spring and Trial 2 in fall.
bation progresses. Water vapor is a gas and exhibits a partial pressure. Also, according to Swann and Brake (1990a), the embryo appears to have a limited ability to compensate for low water loss.

Percentages infertile, early dead, and late dead were significantly higher, and fertile hatchability was significantly lower when the broiler breeders were 26 wk of age as compared to 28 and 30 wk of age (Table 2). Percentage pipped was higher at 26 wk than at 28 wk of age only. With regard to early dead mortality, O’Sullivan et al. (1991) showed that early dead mortality decreased as hen age increased during the first weeks of production. The percentage late dead was not different due to hen age, which is supported by the findings of O’Sullivan et al. (1991) who found no change in the number of late dead embryos as hen age increased. Fertile hatchability was significantly increased for the 53% RH treatment in comparison with the other two RH treatments (Table 2). This result agrees with those of Robertson (1961a) who reported the range of RH for optimum hatchability to lie between 40 and 65% with the maximum hatchability obtained around 50%.

REFERENCES


