Factors Affecting Ostrich Egg Hatchability

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ABSTRACT Ostrich eggs often have low hatchability (HATCH) rates because they do not lose sufficient weight during incubation. Because egg size, eggshell porosity and thickness (THICK), and length of preincubation egg storage are known to affect egg weight loss during incubation (EWL) and HATCH of chicken eggs, these factors were examined using ostrich eggs.

The effects of eggshell porosity (number of large pores per cm² of shell; LP); and THICK on EWL and HATCH were assessed by categorizing the eggs as having either low, intermediate, or high LP or low, intermediate, or high THICK. Mean EWL was higher (P < 0.05) in eggs of the high LP group when compared with eggs in either the low or intermediate LP groups that lost similar amounts of weight during incubation. Mean HATCH was also higher (more than 25%; P < 0.10) in eggs with high LP when compared with the HATCH found in eggs having low LP. Eggs from the intermediate LP group had an intermediate HATCH response. Moreover, numbers of LP were positively correlated to both EWL (r² = 0.64; P < 0.0001) and HATCH (r² = 0.25; P < 0.03). Inverse relationships existed between THICK and HATCH according to the order (P < 0.05): eggs of low THICK, highest mean EWL and HATCH > eggs of intermediate THICK, intermediate mean EWL and HATCH > eggs of highest THICK, lowest mean EWL and HATCH. Shell thickness was not correlated to either EWL or HATCH.

The influence of egg size on mean LP, THICK, EWL, HATCH, and chick weight (CWT) was assessed. Although THICK was unaffected by egg size, higher LP (P < 0.10), EWL (P < 0.05), and HATCH (P < 0.10) were found in medium-sized eggs when compared with either small or large eggs. The CWT was associated with egg size (P < 0.05) according to the order: large eggs, highest CWT > medium eggs, intermediate CWT > small eggs, lowest CWT. Neither EWL nor HATCH was affected by length of preincubation egg storage. Collectively, our findings suggest that 1) ostrich eggs that possess low LP and increased THICK hatched poorly, 2) intermediate-sized eggs hatch best, 3) large eggs produced large chicks, and 4) ostrich eggs can be stored under conditions typically used in the poultry industry for a minimum of 10 d without negatively impacting HATCH.

(Key words: ostrich, egg, hatchability, egg weight, preincubation time)

INTRODUCTION

Although ostriches have been domesticated for more than 100 yr, the bulk of a scanty literature describing artificial incubation practices for ostrich eggs centers around popular reports (e.g., Brake and Rosseland, 1991; Anonymous, 1992; Stewart, 1993) and studies under natural incubation conditions (e.g., Bertram and Burger, 1981; Jarvis et al., 1985; Swart et al., 1987; Swart, 1988; Swart and Rahn, 1988). Deeming et al. (1993) reported that scientific investigation into the conditions required for the artificial incubation of ostrich eggs has been very poor, a situation that has hampered the development of the industry worldwide.

Hatching success of ostrich eggs in artificial incubators is considerably below that found in wild ostriches (Hurxthal, 1979; Bertram and Burger, 1981), which suggests that the hatchability of artificially incubated ostrich eggs can be improved by identifying and altering factors inherent to eggs or associated with current incubation practices that preclude maximum hatchability. It is reasonable to expect that many of the factors known to influence incubation success in eggs of domestic fowl also affect ostrich egg hatchability. These factors include length of egg storage, preincubation environmental conditions, egg size, shell thickness and porosity, and incubation criteria (e.g.,
temperature, humidity, and frequency of egg turning) (Rahn et al., 1979; Board, 1980; Tullett, 1984; Wilson, 1991; Fasenko et al., 1992).

Two of the above factors, shell thickness and porosity, greatly influence eggshell conductance, or G, which has been defined as the quantity of a given gas diffusing in a unit of time through the pores of an eggshell (Ar et al., 1974; Rahn et al., 1979). The G value serves as an estimate of the functional ability of an eggshell to 1) resist water vapor passage (it predicts egg weight loss in the form of water during incubation) and 2) permit embryonic respiration. The G value estimates an eggshell’s ability to exchange the vital gases, O2 and CO2 (Paganelli, 1980).

A common problem for ostrich producers is an unacceptably high incidence of death in fully developed embryos during the last several days of incubation. Necropsy results reveal that a significant amount of this late embryonic mortality appears to stem from suffocation in edematous embryos (Satterlee et al., unpublished data). In a preliminary report, Satteneini and Satterlee (1994) found that ostrich eggs that are thick shelled or of low porosity do not hatch well. It seems likely that such eggs would suffer from a low G. Subsequent to this 1994 report, Christensen et al. (1996) calculated a G value for ostrich eggs and found it to be much lower than would be predicted for eggs with such a large egg mass. Thus, it seems plausible that the observation of poor hatchability in artificially incubated, compared to naturally incubated, ostrich eggs could be a logical consequence of compromised G, particularly in thick-shelled eggs (presumably having longer pore lengths) or eggs possessing low numbers of pores (presumably having reduced pore areas available for gaseous diffusion).

In the present study, we attempted to confirm and amplify our initial findings (Satteneini and Satterlee, 1994) through further investigation of the effects of egg size and the length of preincubation storage on incubation egg weight loss, hatchability, and chick weight at hatch. In addition, the relationships between eggshell thickness and the number of eggshell pores on egg weight loss and hatchability were also examined.

**MATERIALS AND METHODS**

**Animals, Husbandry, and Egg Incubation**

Ostrich eggs were collected from four trios (3 to 4 yr of age) of purebred blue neck and blue × black neck ostrich crosses from the LSU Agricultural Center’s Idlewild Research Station (Clinton, LA) during a 5-mo period (March 4, 1997 to August 21, 1997) near the middle of the breeding season. Birds were fed 1 kg/bird per d of a pelleted ratite breeder ration3 (22% CP, 2860 kcal DE/kg of feed) and water was supplied for *ad libitum* consumption. Each trio was housed in a fenced pen (0.4 hectare) that contained a small covered nesting area (20.9 m²). Scrapes (sand substrate) were routinely checked (three to four times daily) for the presence of eggs. Eggs laid on a given day (the majority of which were laid in late afternoon just before dusk) were put in insulated containers (cooled with ice packs to approximately 18 C) prior to transport to the LSU Poultry Science Department the following morning within 12 h postoviposition. Eggs were randomly assigned to one of two egg storage length treatments: short (< 5 d; n = 38) or long (> 5 d, but ≤ 10 d; n = 35) at 18 C and 69% RH. The influence of length of preincubation storage on egg weight loss and hatchability (HATCH) was determined.

Prior to incubation in a NatureForm NMC 2000 incubator4 at a temperature of 36.3 C and 20% RH (range: 16 to 25% RH), eggs were individually identified. During early incubation, a small number of eggs were observed to be contaminated and were removed from the study. Our subjective impression was that the incidence of contamination varied by season, with higher rates of contamination occurring during periods of greater precipitation. Fertility was determined by candling eggs at Day 7 of incubation. Infertile eggs were removed from the incubator at this time. Eggs were turned every hour throughout the incubation period that was typically around 40 d (i.e., the time at which internal pipping occurred as determined by candling). When eggs exhibited evidence of internal pipping, they were transferred to a hatcher (a separate NatureForm NMC 2000 incubator) maintained at 36 C and 30% RH until hatching. Eggs that did not hatch by Day 47 were removed from the hatcher and the contents examined.

Egg shells and hatching shards from hatched eggs, as well as like materials from manually opened eggs that did not hatch, were individually stored in plastic bags. Bags were marked with the original bird number identification in order to associate subsequently collected egg data with treatment applications.

**Egg Weight Loss During Incubation**

Egg weight loss (EWL) during incubation was determined by the following formula: EWL (%) = ((egg weight<sub>Day 1</sub> - egg weight<sub>Day 40</sub>/egg weight<sub>Day 1</sub>) × 100. Egg weight on Day 1 was determined at the time of setting eggs.

**Egg Size**

The influence of egg size on the mean number of large pores per cm² of shell surface area (LP), egg shell thickness (THICK), EWL, hatchability (HATCH), and chick weight at hatching (CWT) was determined by assignment of eggs.

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3Cloverbrand Feeds, SF Services, Inc., Little Rock, AR 72119.
4NatureForm Hatchery Systems, Jacksonville, FL 32218.
to one of three egg size categories: small, \(\leq 1,450\) g; medium, \(> 1,450\) g, but \(\leq 1,650\) g; or large, \(> 1,650\) g.

**Eggshell Porosity**

An estimate of an individual egg’s LP was determined by averaging pore counts obtained from discretionary sampling at five independent \(1\) cm\(^2\) sites on an egg’s surface. Four sites were chosen approximately equidistant along the equator and one site was chosen that approximated the center of the air-cell. To better visualize and facilitate a more accurate counting of LP, each selected site was dyed with a food-grade blue dye before counts were made using a dissection microscope. A clear dichotomy of pore size, small and large, was observed. As we were uncertain that the small pores were patent, only large pores were counted. The eggs were categorized as having either low (\(< 7\)), intermediate (\(> 7, \text{but} \leq 10\)), or high (\(> 10\)) LP.

**Eggshell Thickness**

An estimate of overall THICK was obtained by averaging THICK measurements made at the same five shell sites used to determine LP. A slip-clutch micrometer\(^5\) was used to make individual THICK estimates to the nearest 0.01 mm. The influence of THICK on EWL and HATCH was examined by categorizing the eggs as having either low (\(< 1.7\) mm), intermediate (\(> 1.7, \text{but} \leq 1.9\) mm), or high (\(> 1.9\) mm) THICK.

**Chick Weight**

Chick weights (CWT) were determined at hatching using an electronic pan balance that was accurate to 0.01 g. The relationship between egg size and chick weight was studied as described above.

**Statistical Analyses**

Because only 73 eggs were available for this study, we conducted a series of independent statistical analyses for each of the four treatment categories (egg shell porosity, egg shell thickness, egg size, and storage length groups) as they independently affected selected variables. Consideration of these four categories in a factorial arrangement of treatments (3 \(\times\) 3 \(\times\) 3 \(\times\) 2) would be prohibitive given the small sample size.

Differences in means from treatment categories (i.e., low, intermediate, or high) of LP or THICK on EWL and HATCH were assessed by one-way ANOVA using a completely randomized design (CRD) (Steele and Torrie, 1980). Where appropriate, category means were again separated by Duncan’s New Multiple Range Test. Pearson correlation coefficients and their probabilities of significance (\(P\)-values) were calculated between the following variables: LP with EWL, LP with HATCH, THICK with EWL, and THICK with HATCH. Differences in the three egg size treatment categories (small, medium, and large) on mean LP, THICK, EWL, HATCH, and CWT were also detected by one-way ANOVA using a CRD and, where appropriate, category means were again separated by Duncan’s New Multiple Range Test. A one-way ANOVA using a CRD was also used to assess treatment effects of length of preincubation egg storage (short vs long storage) on EWL and HATCH.

**RESULTS AND DISCUSSION**

**General Observations**

After removal of contaminated and infertile eggs, 73 fertile eggs were available for study. Overall EWL (Days 0 to 40 of incubation) averaged 13.2% (range: 6.5 to 23.0%) and mean HATCH was 68.5%.

**Number of Large Pores and Egg Shell Thickness**

Similar to the report of Satteneni and Satterlee (1994), there were positive relationships between LP and EWL during the first 40 d of incubation and between LP and HATCH (Figure 1; Table 1) and negative relationships

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TABLE 1. Pearson correlation coefficients (r) and probabilities of their significance (P-values) for correlations between the number of eggshell large pores per cm² of eggshell surface or eggshell thickness with egg weight loss during the first 40 d of incubation and hatchability in ostrich eggs

<table>
<thead>
<tr>
<th></th>
<th>Large pores (no.)</th>
<th>Eggshell thickness (mm)</th>
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<tr>
<td></td>
<td>r</td>
<td>P</td>
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<tr>
<td>Egg weight loss (%)</td>
<td>0.64</td>
<td>0.0001</td>
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<tr>
<td>Hatchability (%)</td>
<td>0.25</td>
<td>0.03</td>
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between THICK and EWL and between THICK and HATCH (Figure 2). Although the latter negative relationships clearly demonstrated differences in EWL and HATCH by THICK treatment categories (ANOVA), when all eggs were examined for correlations between THICK and EWL (r = −0.14, P = 0.26) or HATCH (r = −0.16, P = 0.18), relationships were not significant.

It is generally held that eggshell conductance (G) is directly proportional to the area of the pores available for diffusion (approximated by LP) and inversely proportional to the length of the diffusion path (i.e., the length of the pores through the eggshell; estimated by THICK) (Ar et al., 1974; Rahn et al., 1979). Thus, G not only determines the functional ability of eggshells to resist water vapor passage, but is also a good indicator of an eggshell’s ability to permit the exchange of vital gases (supply of O2 to the embryo and removal of CO2 from the embryo) (Paganelli, 1980). We therefore conclude that thick-shelled ostrich eggs, which presumably have longer pore lengths and eggs possessing low numbers of pores, and thus a reduction in total pore area, hatch poorly because such eggs likely suffer from a reduced G (Rahn et al., 1979).

Indeed, a lower than expected G in ostrich eggs (compared to what would be predicted for eggs with such a large egg mass) has been reported (Christensen et al., 1996). This finding may explain why ostrich embryos experience a high incidence of death during the last several days of incubation. Necropsy findings of a significant amount of late embryonic mortality in ostrich eggs appeared to be associated with suffocation of embryos within eggs whose physical characteristics suggest that they likely suffered from a compromised G (Satterlee, unpublished results). Support for this hypothesis was found by Meir and Ar (1996) who found that HATCH was dramatically improved in early laid goose eggs having low mass specific G by artificially increasing G by drilling of one or more holes through the eggshell into the air cell during the last trimester of incubation.

**Egg Size Effects**

Within a flock of chickens, turkeys, or ducks, intermediate-sized eggs hatch better than their small or large counterparts (Rendel, 1943; Brunson and Godfrey, 1953; Morris et al., 1968; Petersen, 1984; Connor, 1986; Wilson, 1991), and this appears to be the case in ostrich eggs as well. In the present study, egg size affected HATCH, as well as two characteristics that are known to affect HATCH (LP and EWL), in a manner consistent with the concept that intermediate-sized eggs hatch best (Table 2). Specifically, LP and EWL were greater (P < 0.10 and P < 0.05, respectively) in medium-sized ostrich eggs than in small or large eggs. Because G is directly proportional to the area of the pores available for diffusion (Rahn et al., 1979), the medium-sized eggs, which had a greater number of LP, would be expected to possess an enhanced ability to lose water and breathe (exchange vital gases) during incubation. Enhancement of G would not only explain the finding of higher EWL in medium-sized eggs but also its ultimate translation into greater HATCH (P < 0.10; Table 2). Collectively, these data support the findings of Deeming (1995), who found that poor EWL or reduced G was associated with enhanced embryonic mortality.

The mean EWL in medium-sized eggs (14.7% of initial egg mass; Table 2) falls near the center of the range of 13.5 to 15.6% reported by Swart et al. (1987) for ostrich eggs hatched under natural conditions. Our present egg size findings on HATCH also lend support to earlier ob-

**FIGURE 2.** Mean (±SE; vertical bars) egg weight loss (Panel A) and hatchability (Panel B) of fertile ostrich eggs with varying shell thickness (THICK)(a,bP < 0.05). Sample size was n = 8, 34, and 31, respectively, for the low, medium, and high THICK groups.
survations on the relationship between these same two variables (Satteneni and Satterlee, 1994).

The finding that THICK was unaffected by egg size (Table 2) was not unexpected. To the authors’ knowledge, no consistent relationship between these two variables within an avian species has been reported.

In domestic fowl, there is a strong positive correlation between the weight of an egg and the weight of the chick hatched from it (Wilson, 1991). Table 2 clearly demonstrates that this relationship also exists in ostriches (i.e., heavier chicks were associated with larger eggs and vice-versa). Chick weight as a percent of egg weight is also known to be fairly constant across species (Wilson, 1991). Ranges of 62 to 76%, 60 to 70%, and 53 to 62% have been reported for chickens, turkeys, and waterfowl, respectively. Herein, ostrich chick weight as a percent of initial egg weight ranged from 53 to 70%. This range compares favorably with the range (56 to 69%) recently reported by Wilson et al. (1997).

**Length of Preincubation Egg Storage**

Many ostrich producers are concerned that the practice of preincubation egg storage might negatively affect hatchability. Storing ostrich eggs at 18°C and 69% RH up to 10 d did not alter EWL (short storage, ≤5 d, 13.0 ± 0.6% vs long storage, >5 d but ≤10 d, 13.3 ± 0.7%) or HATCH (short storage, ≤5 d, 63.2 ± 7.9% vs long storage, >5 d but ≤10 d, 74.3 ± 7.5%) (Table 3). This is not surprising when one considers how ostrich eggs are incubated in the wild. Ostrich adults (males and females incubate the eggs) are capable of incubating up to 22 eggs (Bertram, 1979b) per nest (scrape). The scrapes of wild ostriches usually contain the eggs of three or more hens (Bertram, 1979a). Because oviposition in ostriches occurs approximately at 2-d intervals and because both the “major” hen (greatest contributor of eggs) and several “minor” hens lay eggs in each nest, the eggs laid early in a nest typically wait 2.5 to 3 wk before incubation begins (Bertram and Burger, 1981). Not only is this preincubation period substantially longer than that used herein, but the conditions of egg “storage” in the wild would be much more harsh (e.g., eggs are frequently left unattended and exposed to the sun). Nevertheless, hatching success of eggs in the wild is considerably higher than that found in artificial incubators (Hurxthal, 1979; Bertram and Burger, 1981). Although the present egg storage results support our previous report (Satteneni and Satterlee, 1994) as well as the data cited in Bertram and Burger (1981), a recent study by Wilson et al. (1997) appears to conflict with these findings. Overall, Wilson et al. (1997) found that hatchability declined linearly with storage time. However, examination of their results in 3-d intervals of storage showed no significant differences in hatchability within the range of storage length used in the present study. The results of the present study are more closely in keeping with the study cited in Bertram and Burger (1981) who found that storage for approximately 8 d resulted in a numerical increase in hatchability over storage for approximately 3 d.

**Summary**

Additional research is needed to further delineate important factors affecting hatchability of ostrich eggs. Very little is known about the interaction of factors intrinsic to the ostrich egg and those of artificial incubation. Once these interactions are known, steps can be taken to maximize hatchability through nutritional intervention, genetic selection, and alteration of current artificial incubation and other management practices.

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