PRODUCTION, MODELING, AND EDUCATION

The effects of oviposition time on egg weight loss during storage and incubation, fertility, and hatchability of broiler hatching eggs[1]

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ABSTRACT An experiment was conducted to determine the effect of time of oviposition, generally representing different positions in the normal egg laying sequence, on egg weight loss during storage and incubation, and on fertility and fertile hatchability of eggs from mid-lay (42 wk) and old (67 wk) broiler breeders. A total of 1,800 eggs (900 eggs per flock age) were collected during 10 consecutive days between 0830 and 1830 h each day. The eggs were individually marked, weighed, and stored for 1 to 10 d before incubation was initiated. Egg weight remained less from collection through incubation for eggs from the mid-lay flock than those from the old flock. Fresh weight of early laid (first-in-sequence; C1) eggs was significantly greater than that for the middle-of-day laid (mid-sequence; Cs), or late-in-day laid eggs (terminal-in-sequence; Ct). Percentage of egg weight loss during storage did not differ significantly between the mid-lay and old flocks but percentage of weight loss in the mid-lay flock was greater during incubation. Egg weight loss during storage of eggs from the middle-of-day laid (Cs) eggs was significantly greater than for early laid (C1) eggs, which was greater than for the late-in-day laid (Ct) eggs. Fertility was significantly decreased due to flock age but not due to oviposition time. Fertile hatchability was also significantly decreased due to flock age, but there was no significant effect of oviposition time. Early and late dead embryos increased with flock age, but there was no significant effect of oviposition time. It was concluded that there was no effect of oviposition time on fertility or fertile hatchability even though there were significant differences in egg weight and egg weight loss during storage due to oviposition time.

Key words: oviposition time, egg storage, broiler breeder, egg weight loss, hatchability

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INTRODUCTION

Domestic hens lay eggs on successive days, followed by a pause of one or more days during which no eggs will be laid. Eggs laid on successive days have been called a sequence or clutch of variable length. Furthermore, the time interval between successive ovipositions in each sequence has been reported to vary from about 24 to 29 h depending on the sequence length, with longer sequences attributed to a shorter interval between eggs. In this respect, it has been commonly observed that the sequence length was longer in younger hens that laid smaller eggs. This implied that as the hen aged, the length of the sequence was shortened and egg weight increased (Etches and Schoch, 1984; Bahr and Palmer, 1989; Zakaria, 2001; Johnston and Gous, 2003).

In a previous report (Zakaria et al., 2005), the majority of eggs from a relatively young (34 wk) broiler breeder flock were produced primarily between 0700 and 1300 h when feeding was at 0800 h, with the greatest numbers for a single hour being between 0900 and 1000 h. In an older (59 wk) flock under similar conditions, eggs were more evenly distributed between 0700 and 1500 h. Furthermore, egg weight of early laid (**C1**) eggs was significantly greater than mid-sequence (**Cs**) and late laid (**Ct**) eggs in the young broiler breeder flock, whereas the late (Ct) eggs were significantly smaller than early (C1) and middle (Cs) eggs in the old broiler breeder flock. Similarly, egg weight of the first-in-sequence (C1) eggs was reported to be greater than that of subsequent eggs in a sequence in broiler breeders (Robinson et al., 1991; Novo et al., 1997).

The first-in-sequence (C1) eggs have been associated with reduced fertility in individually caged and arti-

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ficially inseminated broiler breeders (Robinson et al., 1991; Goerzen et al., 1996) and in artificially inseminated turkeys (Bacon and Nestor, 1979). Although Fasenko et al. (1992) did not find differences in fertility relative to egg position in a sequence, they reported lower fertile hatchability in first-in-sequence eggs compared with subsequent eggs in a sequence in individually caged and artificially inseminated broiler breeders. On the other hand, Zakaria et al. (2005) found no differences in fertility and fertile hatchability among eggs of different sequence positions in naturally mated broiler breeders.

Brake et al. (1997) reviewed the changes in egg components associated with egg handling and storage and concluded that the factors that could affect hatchability varied by age of flock, age of egg, ambient temperature, strain, and handling procedures. Fasenko et al. (1991) further stated that nest holding time and method of egg storage affected postoviposition and preincubation embryonic growth. Oviposition time may also affect hatchability. The objective of the present study was to examine the effect of breeder flock age and oviposition time on egg weight, egg weight loss during both storage and incubation, fertility, hatchability, and embryonic mortality of broiler hatching eggs.

MATERIALS AND METHODS

Birds and Management

Two flocks of Ross 344 male × Ross 308 slow-feathering female broiler breeders at 42 wk of age (mid-lay) and 67 wk of age (old) were housed in 15 pens each of 2 adjacent two-thirds slat curtain-sided houses and were subjected to the same nutrition and management programs. An average of 54 females with 6 males or 46 females with 5 males was present in each pen of the mid-lay and old flocks, respectively, at the time of experiment. Incandescent lights operated from 0330 to 1930 h (daylight saving time) each day with additional natural daylight entering each house through open or translucent curtains, depending upon ambient temperature. The birds were fed at 0800 h daily and water was available for ad libitum consumption from 0700 to 1500 h daily.

Experimental Design

All eggs were removed from the nest boxes in each of the 15 pens at 1900 h on the day before the first egg collection and during each day of the experiment. A total of 1,800 eggs (900 eggs per flock age) were collected during 10 consecutive days starting at 0830 h and terminating at 1830 h each day. Two eggs were randomly selected from all of those collected from each of the 15 pens at 0830, 1100, and 1800 h each day from the mid-lay flock to be used for incubation. Eggs collected at 1030 and 1300 h were not used. Thus, the 30 eggs collected at 0830, 1100, and 1800 h generally represented early (C1), middle (Cs), and late (Ct) eggs, respectively. In a similar manner, eggs were collected at 0930, 1130, and 1830 h each day from the old flock to be used for incubation. Eggs collected at 1100 and 1330 h were not used. Thus, the 30 eggs collected at 0930, 1130, and 1830 h generally represented early (C1), middle (Cs), and late (Ct) eggs, respectively, in the old flock. The slight modification of time of collection between the 2 flock age groups was required to provide sufficient numbers of eggs in the old flock based upon knowledge of the pattern of egg production and the actual count of eggs present during the first 2 d of this experiment. A 10-d period was selected so as to include the full range of egg storage periods that might reasonably be encountered during normal commercial practice. Thus, eggs collected during the first day were stored for 10 d and those collected on the 10th day were stored for 1 d. All eggs were individually identified by pen number, flock age, and date of collection before being weighed to the nearest 0.01 g. Eggs from each day of egg collection were transferred to a cooler (14 to 16°C and 65% RH) 2 h after collection.

A total of 1,800 eggs representing the 3 daily oviposition times from 10 d of egg collection from the mid-lay (900 eggs) and old (900 eggs) broiler breeders were distributed randomly among 10 incubator trays (180 eggs per tray), with both flock ages and all oviposition times uniformly represented in each tray. The 10 trays were randomly placed into a single Natureform NMC-2000 incubator (Natureform International, Jacksonville, FL) to 18 d of incubation at an internal egg temperature of 37.8°C for the first 24 h of incubation and 37.5 to 37.8°C thereafter as determined by the method of Leksrisompong et al. (2007). Relative humidity was automatically controlled at 55% and eggs were turned through a 90° angle 48 times daily through 18 d of incubation. At 18 d of incubation, all eggs were weighed individually and then transferred to hatching baskets and returned to the same machine at 36.8°C to complete the hatching process. The number of chicks hatched from each tray was counted at 21.5 d of incubation. All unhatched eggs were then opened and examined macroscopically by a single experienced individual to determine fertility or stage of embryonic mortality, or both. Eggs were classified as cracked (11 eggs were excluded from calculations), infertile, early dead (embryos died 1 to 7 d of incubation), and late dead (embryos died 8 to 21 d of incubation). For purposes of statistical analysis, the middle dead, late dead, and pipped embryos were combined into the 8 to 21 d late dead group.

Statistical Analysis

The effects of flock age and time of oviposition on egg weight and egg weight loss during storage and incubation were analyzed by ANOVA using the GLM procedure of SAS Institute (1991) with day of collection as a block. Differences among means were separated using least squares mean analysis. Fertility, fertile hatchability, and embryo mortality data were subjected to categorical analyses using the odds ratio method to estimate relative treatment differences of the effects of flock age, time of oviposition [early (C1), middle (Cs), and late (Ct)], and their interactions on fertility, fertile hatchability, and embryonic mortality (SAS Institute, 1991). Unless otherwise indicated, statements of statistical significance were based upon $P < 0.01$.

RESULTS AND DISCUSSION

The effects of flock age, oviposition time, and their interaction on egg weight at collection, during storage before setting, and during incubation are shown in Table 1. As expected, egg weight at collection, during storage before setting, and during 18 d of incubation was less for the mid-lay than for the old flock. Weight of early laid (C1) eggs was significantly greater than for the middle (Cs) eggs or late (Ct) eggs. However, there was an interaction between flock age and oviposition time for egg weight at collection, during storage before setting, and during incubation for early (C1), middle (Cs), and late (Ct) oviposition times. Inspection of the data of Table 1 revealed this interaction to have been due to the late laid (Ct) eggs from the old flock being smaller than the middle laid (Cs) eggs of the older flock, but this was not the case for the mid-lay flock, whereas early laid eggs were the largest in all cases. These data confirmed and extended previous findings (Zakaria et al., 2005) that egg weight decreased as time of oviposition (position in a sequence) advanced in 2 Ross 308 flocks aged 34 and 59 wk. This was consistent with the results obtained by Robinson et al. (1991), who used Indian River broiler breeder hens at 45 wk of age and reported that early (C1) eggs were significantly greater in weight than subsequent eggs in a sequence. Similarly, Novo et al. (1997) utilized eggs produced by Cobb 500 broiler breeder hens at 46 and 65 wk of age and found egg weight to decrease with later time of oviposition. The effect of aging and the relationships of sequence length and egg position on ovarian follicular development of commercial layers has been studied in detail by Zakaria et al. (1983, 1984a,b) and Zakaria (1999a,b). These studies indicated 1) there was a continuous increase in follicular (yolk) volume at ovulation (and thus egg weight) with increasing age, 2) the average follicular growth period increased as sequence size decreased (flock aged), 3) the follicular growth period decreased as egg position in a sequence increased from second to sixth, 4) follicular (yolk) volume tended to be less in terminal (Ct) follicles in sequences of 2 to 5 eggs, and 5) the follicular growth period of the C1 egg was longer than for Ct follicles. Based on these considerations, it could be suggested that the rapid growth phase of Ct follicles was shorter and the rapid growth phase of C1 follicles was longer to account for the differences in the egg weight among the more numerous and smaller eggs

Table 1. Egg weight at collection, after storage before setting, and at transfer after 18 d of incubation from early, middle, and late oviposition times of 42-wk-old and 67-wk-old broiler breeder flocks

Variable	Egg weight (g)		
	Collection[1]	Setting[2]	Transfer[3]
Flock age (wk)			
42	63.7 ± 0.2^{B}	63.4 ± 0.2^{B}	57.4 ± 0.2^{B}
67	68.2 ± 0.2^{A}	67.9 ± 0.2^{A}	61.7 ± 0.2^{A}
Oviposition time			
Early[4]	67.8 ± 0.2^{A}	67.5 ± 0.2^{A}	61.3 ± 0.2^{A}
Middle[5]	65.1 ± 0.2^{B}	64.8 ± 0.2^{B}	58.7 ± 0.2^{B}
Late[6]	65.0 ± 0.2^{B}	64.7 ± 0.2^{B}	58.7 ± 0.2^{B}
Age × oviposition time			
42 wk			
Early	65.9 ± 0.3^{D}	65.6 ± 0.3^{D}	59.5 ± 0.3^{D}
Middle	62.3 ± 0.3^{E}	62.0 ± 0.3^{E}	56.1 ± 0.3^{E}
Late	62.9 ± 0.3^{E}	62.6 ± 0.3^{E}	56.7 ± 0.3^{E}
67 wk			
Early	69.7 ± 0.3^{A}	69.4 ± 0.3^{A}	63.2 ± 0.3^{A}
Middle	67.9 ± 0.3^{B}	67.5 ± 0.3^{B}	61.4 ± 0.3^{B}
Late	67.1 ± 0.3^{C}	66.8 ± 0.3^{C}	60.6 ± 0.3^{C}

[A–E]Means ± SE for 900 eggs from each flock age in a column with different superscripts differ significantly ($P < 0.01$).

[1]Egg weight at collection.

[2]Egg weight before setting at the end of storage period of 1 to 10 d at 14 to 16°C and 65% RH.

[3]Egg weight at 18 d of incubation before transfer to hatching baskets.

[4]Early oviposition time of 0830 to 0930 h generally represented first-in-sequence (C1) eggs in a laying sequence.

[5]Middle oviposition time of 1100 to 1130 h generally represented mid-sequence (Cs) eggs in a laying sequence.

[6]Late oviposition time of 1400 to 1800 h generally represented terminal-in-sequence (Ct) eggs in a laying sequence.

Table 2. Percentage of egg weight loss after storage before setting, after 18 d of incubation, and the combined total loss from early, middle, and late oviposition times of 42-wk-old and 67-wk-old broiler breeder flocks

	Egg weight loss (%)		
Variable	Setting[1]	Transfer[2]	Total[3]
Age (wk)			
42	0.45 ± 0.01	9.45 ± 0.07^{A}	9.86 ± 0.07^{A}
67	0.47 ± 0.01	9.14 ± 0.07^{B}	9.57 ± 0.07^{B}
Oviposition time			
Early[4]	0.47 ± 0.01^{B}	9.17 ± 0.09	9.59 ± 0.09
Middle[5]	0.52 ± 0.01^{A}	9.31 ± 0.09	9.79 ± 0.09
Late[6]	0.41 ± 0.01^{C}	9.41 ± 0.09	9.78 ± 0.09
Age × oviposition time			
42 wk			
Early	0.43 ± 0.02	9.37 ± 0.13	9.76 ± 0.13
Middle	0.53 ± 0.02	9.48 ± 0.13	9.96 ± 0.13
Late	0.41 ± 0.02	9.49 ± 0.14	9.87 ± 0.14
67 wk			
Early	0.50 ± 0.02	8.96 ± 0.13	9.42 ± 0.13
Middle	0.51 ± 0.02	9.16 ± 0.13	9.69 ± 0.13
Late	0.41 ± 0.02	9.32 ± 0.13	9.62 ± 0.13

$^{A–C}$Means ± SE for 900 eggs from each flock age in a column with different superscripts differ significantly ($P < 0.01$). The absence of superscripts indicates the absence of significant effects.

[1]Egg weight loss at the end of the storage period at 14 to 16°C and 65% RH for 1 to 10 d before setting in the incubator.

[2]Egg weight loss at 18 d of incubation before transfer to hatching baskets.

[3]Total egg weight loss relative to egg weight at collection.

[4]Early oviposition time of 0830 to 0930 h generally represented first-in-sequence (C1) eggs in a laying sequence.

[5]Middle oviposition time of 1100 to 1130 h generally represented mid-sequence (Cs) eggs in a laying sequence.

[6]Late oviposition time of 1400 to 1800 h generally represented terminal-in-sequence (Ct) eggs in a laying sequence.

of the young flock in the present study. In contrast, the larger eggs from the shorter sequence lengths of the older flock, the Cs and Ct eggs, were smaller.

The effects of flock age, oviposition time, and their interaction on percentage of egg weight loss during storage before setting, incubation, and total (combined) are shown in Table 2. Percentage of egg weight loss during storage before setting did not differ significantly between the mid-lay and the old flocks, but percentage of weight loss in the mid-lay flock was greater during incubation as reflected by the transfer and total egg weight loss. Egg weight loss in relation to oviposition time differed during egg storage before setting but did not differ during incubation. In this respect, weight loss during storage of eggs from the middle (Cs) oviposition time was significantly greater than for eggs from the early (C1) oviposition time, which was, in turn, greater than for eggs from the late (Ct) oviposition time. There were no significant interactions.

According to Peebles and Brake (1987), shell thickness was the lowest and porosity the greatest during the mid-lay age period. It has been well documented that mid-sequence eggs (Cs) comprise most of the eggs produced by mid-lay hens (Etches and Schoch, 1984; Bahr and Palmer, 1989; Zakaria, 2001). Higher relative porosity may explain, in general, why egg weight loss of the mid-lay flock or mid-sequence eggs (Cs) was greater than that of the old flock. Weight loss may be explained by liberation of water as a result of deterioration of the albumen with subsequent passage of unbound water through the eggshell as influenced by variation in albumen quality due to flock age, storage time, and storage conditions (Brake et al., 1997; Lapao et al., 1999; Tona et al., 2003).

The effects of flock age, oviposition time, and their interaction on fertility, fertile hatchability, and embryo mortality are shown in Table 3. As expected, fertility was significantly decreased due to flock age but not due to oviposition time, or the interaction of flock age and oviposition time. Fertile hatchability was also significantly decreased due to flock age, as expected, but there was no significant effect of oviposition time or the age × oviposition time interaction (Table 3). As was the case for fertile hatchability, late dead embryos increased with flock age, whereas early dead embryos exhibited a similar numerical trend ($P < 0.10$) but there was no significant effect of oviposition time. This was consistent with the report of Elibol and Brake (2004), who found that fertile hatchability was much better from a 29-wk-old broiler breeder flock than from a 68-wk-old flock because of decreased mortality at all stages of embryo development. However, in the present study, there was a significant interaction of flock age × oviposition time for percentage early dead, which was due to increased early dead embryos during the early C1 oviposition time of the mid-lay flock but a decrease in early dead embryos during the same period in the old flock (Table 3). Albumen quality varies with flock age and length of egg storage (Brake at al., 1997) and probably played some role in this interaction.

Reports have previously stated that hatchability decreased with increased egg weight (Wilson, 1991; Ogunshile and Sparks, 1995; French, 1997), but the significantly larger early (C1) eggs of the present study did not exhibit a significant decrease in fertile hatchability. Elibol and Brake (2008) found that fertile hatchability was decreased in larger eggs, about 69 g in comparison with about 63 to 66 g, obtained from a flock of 51- to 57-wk-old Ross 308 broiler breeders. Perhaps the difference in egg weight due to time of oviposition found in the present study was not sufficiently great to induce the effect. Increased embryonic mortality associated with greater egg weight, especially late deads, has been explained on the basis of difficulties in losing embryonic metabolic heat during the latter stages of incubation (French, 1997; Elibol and Brake, 2008). This may explain the increased late deads in the considerably larger eggs (~4.5 g) of the older flock versus mid-lay flock of the present study as opposed to the slightly larger eggs (~2.7 g) due to early oviposition time. Evidently, there may be a threshold difference in egg weight required to observe a significant difference in hatchability and this may depend upon egg management, incubation conditions, and age of flock.

In this study, percentage egg weight loss at 18 d of incubation before transfer and total egg weight loss during storage and incubation from old hens was significantly less than for eggs from mid-lay hens (Table 2). The fact that weight loss was higher in the mid-lay flock would be consistent with greater porosity (Peebles and Brake, 1987) and better fertile hatchability (Table 3). The percentage weight loss approached 10% (Table 2) under conditions of this study, which was slightly less than the weight loss of 10.9 to 11% associated with the highest hatchability in 27- to 60-wk-old Cobb broiler breeders (Tona et al., 2001), but the fertile hatchability was acceptable in the present study nonetheless (Table 3).

The fertility of early laid eggs (C1) was not reduced in this study with naturally mated hens in contrast to artificially mated turkeys (Bacon and Nestor, 1979) and broiler breeders (Robinson et al., 1991) but was in close agreement with other findings (Zakaria et al., 2005). It was important to note that the previous study of Robinson et al. (1991) used an individual cage system where about 38% of the eggs were first-in-sequence (C1) eggs, which clearly demonstrated a high incidence of short sequence lengths (poor egg production). Robinson et al. (1991) reported 87.0% fertility for the first-in-sequence eggs versus 89.6% fertility for eggs in other sequence positions. Similarly, Bacon and Nestor (1979) classified eggs as "first of the clutch," including clutch lengths of only one egg, and "other clutch position." In agreement with the present findings, Novo et al. (1997) collected eggs at 2-h intervals between 0800 and 1800 h from 13,900 commercially housed hens and did not find significant differences in fertility and embryonic mortality relative to time of oviposition at 46 and 65 wk of age, or differences in hatchability at 46 wk of age. Thus, although poor fertility may be observed in early

Table 3. Fertility, fertile hatchability, and embryonic mortality of eggs from 42-wk-old and 67-wk-old broiler breeders that were stored for 1 to 10 d before incubation

Variable	Fertility[1] (%)	Fertile hatchability (%)	Early dead (%)	Late dead (%)
Age (wk)				
42	96.0^{A}	91.9^{A}	4.1^{y}	3.1^{B}
67	77.3^{B}	85.7^{B}	5.9^{x}	8.4^{A}
Oviposition time				
Early[2]	86.6	88.2	4.6	6.5
Middle[3]	87.4	90.3	4.9	4.4
Late[4]	85.9	87.5	5.8	6.2
Age × oviposition time				
42 wk				
Early	95.3	89.4	6.0^{A}	3.2
Middle	97.3	93.2	3.4^{B}	2.7
Late	95.3	92.9	2.8^{B}	3.2
67 wk				
Early	77.8	86.9	3.2^{B}	9.9
Middle	77.6	87.5	6.4^{A}	6.1
Late	76.4	82.1	8.8^{A}	9.1

^{x,y}Means for 900 eggs from each flock age in a column with different superscripts approach significance ($P < 0.10$). There is no SE with categorical analysis. The absence of superscripts indicates the absence of significant effects.

^{A,B}Means for approximately 900 eggs from each flock age in a column with different superscripts differ significantly ($P < 0.01$). There is no SE with categorical analysis. The absence of superscripts indicates the absence of significant effects.

[1]Percentage of fertile hatchability, early, and late dead embryos calculated based on number of fertile eggs.

[2]Early oviposition time of 0830 to 0930 h generally represented first-in-sequence (C1) eggs in a laying sequence.

[3]Middle oviposition time of 1100 to 1130 h generally represented mid-sequence (Cs) eggs in a laying sequence.

[4]Late oviposition time of 1400 to 1800 h generally represented terminal-in-sequence (Ct) eggs in a laying sequence.

laid (C1) eggs under some conditions, especially with artificial insemination, this effect was not observed in the natural mating conditions of the present study. It was concluded that there was no effect of oviposition time on fertility or fertile hatchability even though there were significant differences in egg weight and egg weight loss during storage due to oviposition time.

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