PRODUCTION, MODELING, AND EDUCATION

Oviposition Pattern, Egg Weight, Fertility, and Hatchability of Young and Old Broiler Breeders[1]

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ABSTRACT Two experiments were conducted to investigate egg weight, fertility, hatchability, and embryonic mortality in relation to time of oviposition of young and old broiler breeder flocks. In experiment 1, eggs were collected from 2 flocks (34 and 59 wk) for 2 d at hourly intervals between 0700 and 1900 h. Most eggs were laid between 0700 and 1300 h, but eggs were laid later in the day by the old flock. Weights of early laid (C1) eggs were significantly greater than middle laid (Cs) and the late laid (Ct) eggs in the young flock, whereas late laid eggs (Ct) were significantly smaller than early laid (C1) and middle laid (Cs) eggs in the old flock. In experiment 2, eggs from experiment 1 were categorized as early laid first-in-sequence (C1) eggs (0700 to 0800 h), the mid-sequence (Cs) eggs (0900 to 1200 h), and the late laid terminal-in-sequence (Ct) eggs (1300 to 1700 h). These eggs were incubated to determine fertility, hatchability, and stage of embryonic mortality relative to oviposition time and flock age. Fertility declined with flock age, but there were no differences due to time of oviposition. There were no differences in hatchability of fertile eggs or embryonic mortality relative to time of oviposition (sequence position) or flock age. These results suggested that although there were differences in egg weight among eggs at different times of the day (different sequence positions), there were no differences in fertility, fertile hatchability, or embryonic mortality in naturally mated broiler breeders.

(*Key words*: broiler breeder, egg sequence, oviposition time, fertility, hatchability)

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INTRODUCTION

It has been well documented that a domestic hen can lay eggs on successive days, after which she may not lay for one or more days. Such a series of eggs laid on successive days has been termed a "sequence" or "clutch." Many of the egg-laying characteristics of commercial layers have been documented (Etches and Schoch, 1984; Bahr and Palmer, 1989; Zakaria, 2001; Johnston and Gous, 2003). Briefly, it has been reported that on a conventional lighting schedule of 14 h light and 10 h dark with lights off during normal night hours, the first egg (C1) of the sequence is generally laid in the morning, the last egg (Ct) is laid late in the afternoon or early evening, and a number of intermediate mid-sequence (Cs) eggs are laid between. In commercial layers, the C1 eggs have been reported to have larger yolks, more albumen, and greater percentage of shell than subsequent eggs in a sequence (Etches, 1996).

In contrast, studies of the egg-laying pattern of feed-restricted broiler breeder hens have been relatively limited. Brake (1985) found a significant interaction between time of oviposition and feeding time (0800 versus 1300 h) and stated that oviposition time was modified somewhat by feeding time. Furthermore, egg weight of early laid C1 eggs was previously reported to be greater than that of subsequent eggs in a sequence (Robinson et al., 1991; Novo et al., 1997), and egg specific gravity increased in the late laid Ct ovipositions (Brake, 1985; Novo et al., 1997). Specific gravity has been positively associated with increased hatchability (McDaniel et al., 1981; Bennett, 1992) but greater specific gravity is not accompanied by increased hatchability of late-in-day laid (Ct) eggs (McDaniel and Roland, 1977).

The C1 egg has been associated with reduced fertility in individually caged and artificially inseminated broiler breeders (Robinson et al., 1991; Goerzen et al., 1996) and in artificially inseminated turkeys (Bacon and Nestor, 1979).

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[1]The use of trade names in this publication does not imply endorsement of the products mentioned nor criticism of similar products not mentioned.

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Abbreviation Key: C1 = first egg of a sequence; Cs = intermediate midsequence eggs; Ct = last egg of a sequence.

Relatively poor fertility late in the production cycle could be, among other reasons, the result of a relatively greater percentage of C1 eggs. Therefore, an increased proportion of C1 eggs with increased breeder flock age (shorter sequence lengths) may negatively affect fertility and hatchability. Because hatchability has been demonstrated to be vitally important to the success of the broiler industry, it was of interest to study fertility, hatchability, and embryonic development in relation to sequence length (flock age related) and time of oviposition (egg position within various sequence lengths). This study was undertaken to investigate the hypothesis that fertility and hatchability would be depressed in relatively old, naturally mating broiler breeders when compared with relatively young broiler breeders, due to a higher incidence of first in sequence (C1) eggs.

TABLE 1. Effect of flock age on the predicted probability of oviposition occurring after a set time of day in experiment 1 as estimated by the Kaplan-Meier survivor function

	Survivor function S(t)		
Time (h)	Young flock (%)	Old flock (%)	SE
>700	90.94	92.61	6.76
>800	81.88	83.54	5.03
>900	61.97^{A}	70.88^{B}	3.97
>1000	36.38^{A}	54.20^{B}	3.89
>1100	23.68^{A}	40.31^{B}	4.28
>1200	13.76^{A}	26.65^{B}	5.08
>1300	6.88^{A}	15.23^{B}	6.58
>1400	3.84	4.37	9.96
>1500	1.85	0.90	15.13
>1600	0.52	0.22	24.87
>1700	0.00	0.00	—

^{A,B}Means within the same row with different superscripts differ significantly ($P < 0.001$).

MATERIALS AND METHODS

Experiment 1

To determine the appropriate times to gather eggs that fairly represented C1, Cs, and Ct eggs, an experiment was conducted to determine the oviposition pattern of broiler breeders. Two flocks of Ross 344 male × Ross 308 slow-feathering female broiler breeders at 34 wk (young) and 59 (old) wk of age were housed in 2 adjacent, 16-pen, two-thirds slat houses and subjected to the same nutrition and management programs. A total of 940 females and 87 males (young flock) and 759 females and 75 males (old flock) were present at the time of the experiment. There were 52 to 56 females with 5 to 6 males and 39 to 53 females with 3 to 6 males in each pen for the young and old flocks, respectively. Incandescent lights operated from 0330 h to 1930 h (daylight savings time) each day with additional natural daylight entering the house through open or translucent curtains, depending upon ambient temperature. The birds were fed at 0800 h daily.

Eggs were collected from the conventional hand-gathered nests filled with pine shavings from young and old flocks simultaneously for 2 consecutive days on an hourly basis from 0700 to 1700 h. Thus, these collection times corresponded roughly to oviposition time. An additional egg collection was carried out at 1915 h on the day prior to the first and second day of collection to remove any eggs in the nest boxes. This insured that there would be minimal eggs in the house overnight to interfere with the first collection of each day. On the first day, 1,192 nest-laid eggs were obtained from young (764 eggs) and old (428 eggs) flocks. Eggs were labeled according to flock, pen within the flock, date, and hour of egg collection. Eggs were individually weighed to the nearest 0.1 g and stored for 4 d at 18 to 20°C and about 65% relative humidity. On the second day, 1,213 hatching eggs (748 eggs from the young and 465 eggs from the old flocks) were again collected from the same broiler breeders and stored for 3 d. A total of 49 eggs were cracked during the process and excluded from the data set shown in Table 1. After examination of the egg laying pattern of the 2 flocks the early, middle, and late oviposition, times representing different egg positions in a sequence were determined to be 0700 to 0800 h, 0900 to 1200 h, and 1300 to 1700 h, respectively.

Experiment 2

After egg collection and storage, 900 hatching eggs representing the C1 eggs (0700 to 0800 h), Cs eggs (0900 to 1200 h), and Ct eggs (1300 to 1700 h) from the first day of egg collection from young (600 eggs) and old (300 eggs) flocks were distributed among 5 incubator trays.[3] Each tray held 6 flats of 30 eggs. Trays were used as a blocking variable to control for possible variability due to machine position effects on the incubation process. The C1 eggs (0700 to 0800 h) from the young flock were distributed randomly among 4 flats (about 6 eggs/flat) in each of the 5 incubator trays. The same steps (about 5 eggs/flat) were repeated for Ct (1300 to 1700 h) eggs. The remaining positions of each flat in each tray were randomly filled with Cs eggs collected from 0900 to 1200 h (4 to 5 eggs per flat for each hourly collection time). The same procedures were proportionately applied to eggs collected from the old flock, except that eggs were distributed between only 2 of the 6 flats in each incubation tray in a manner that fairly represented the total number of eggs available from each flock on each given day. To summarize, in each set of 5 incubator trays with 180 eggs that collectively represented a single day of collection, there were 120 eggs collected from the 34-wk-old flock in 4 flats (30 eggs/flat) and 60 eggs collected from the 59-wk-old flock placed in 2 flats and randomly assigned to different positions in each tray. By using the same egg distribution pattern, a second set of 5 incubator trays was used for the second day of collection.

The eggs collected on the first day were placed into one incubator[3] for 14 d of incubation at a controlled inter-

[3]NMC-1000 incubator, Natureform, Jacksonville, NC.

TABLE 2. Weight of eggs set in experiment 2 from early, middle, and late oviposition times of young (34-wk-old) and old (59-wk-old) broiler breeder flocks

	Young flock		Old flock	
Oviposition time	n[1]	Egg weight (g)	n[1]	Egg weight (g)
Early[2]	266	59.6 ± 0.3^{A}	141	68.8 ± 0.4^{A}
Middle[3]	1,013	57.5 ± 0.1^{B}	504	68.5 ± 0.2^{A}
Late[4]	200	57.9 ± 0.3^{B}	232	67.3 ± 0.3^{B}

[A,B]Means within a flock (column) with no common superscript differ significantly ($P < 0.01$).

[1]Number of observations for means ± SE shown.

[2]Eggs collected from 0700 to 0800 h represent C1 eggs in an oviposition sequence.

[3]Eggs collected from 0900 to 1200 h represent Cs eggs in an oviposition sequence.

[4]Eggs collected from 1300 to 1700 h represent Ct eggs in an oviposition sequence.

nal egg temperature of 37.8°C for the first day of incubation and 37.5 to 37.8°C for the remainder of the incubation period. Relative humidity was automatically controlled at 55%, and eggs were turned 48 times a day. Procedures for the second day of egg collection were identical to those used during the first day of egg collection, except that the eggs collected during the second day were placed in a second incubator due to capacity limitations at the time of the experiment. At 15 d of incubation all trays were removed from the 2 incubators and consolidated into a single incubator.[3] At 19 d of incubation, eggs were transferred to hatching baskets and returned to the same machine 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 broken out and examined macroscopically by a single experienced individual to determine fertility and stage of embryonic mortality. Eggs were classified as cracked (11 eggs were excluded from calculations), infertile, contaminated, early dead (embryos that died from 1 to 7 d of incubation), late dead (embryos that died from 8 to 20 d of incubation), and pipped (embryos pipped the shell). For purposes of statistical analysis the late dead and pipped embryos were combined.

Statistical Analysis

Differences in the time-course of oviposition across flocks in experiment 1 were quantified through the survivor function S(t), which was defined as the probability that, for a given bird, oviposition occurred after time t. The Kaplan-Meier estimate of the survivor function was obtained using the LIFETEST procedure of SAS software (SAS Institute, 1991) and is reported in Table 1. Survivor functions, commonly used for asymmetric time-to-event data in medicine, were used to investigate differences in oviposition time across flocks. Table 1 enabled comparison over the entire range of observed oviposition times, from 0700 to 1700 h, rather than simply at the mean or median. The effects of flock age and time of oviposition on egg weight in experiment 1 were analyzed by analysis of variance using the GLM procedures of SAS software (SAS Institute, 1991) with day of collection as a blocking variable. Differences among means were separated using least squares mean analysis and are reported in Table 2. Fertility, hatchability, and embryo mortality data from experiment 2 were subjected to categorical analyses using the odds ratio to estimate relative treatment differences of the effects of flock age and time of oviposition (C1, Cs, and Ct) and their interactions on fertility, hatchability, and embryonic mortality (SAS Institute, 1991). Day of collection was included as a blocking variable in the model, but only main effects of flock age and time of oviposition were presented due to an absence of a significant block effect (Table 3). Unless otherwise indicated, statements of statistical significance were based upon $P < 0.01$.

RESULTS AND DISCUSSION

Experiment 1

Flock age had a significant effect on the survival distribution function of time of oviposition ($P < 0.001$) in experiment 1 (Table 1). For birds in the young flock, the predicted probability of oviposition occurring before 1100 h was 76.32 ± 4.28% with a large peak during the 0800 to 1000 h collection times when the probability of oviposition having occurred increased sharply from 18.12 ± 5.03% to 63.62 ± 3.89%. In contrast to the young flock, the probability of oviposition occurring prior to 1100 h in the old flock was significantly lower at 59.69 ± 4.28% with a much less defined peak and broader distribution of the time of oviposition across multiple collection periods. The shift in the distribution of the time of oviposition with increasing flock age was also reflected by the probability of oviposition occurring during collection times between 0900 to 1400 h being significantly greater for the old flock in comparison to that of the young flock ($P < 0.001$). There were no differences between flocks for the probability of oviposition occurring after 1400 h.

The egg laying patterns of broiler breeders observed in this study were similar to the range reported for commercial layers (Etches and Schoch, 1984; Zakaria, 2001; Johnston and Gous, 2003) and illustrated how egg laying patterns of broiler breeders may be affected by flock age. These data provided the basis for selection of appropriate times to collect eggs that were laid early in the day to represent C1 eggs, eggs laid in the middle of the oviposition pattern to represent Cs eggs, and eggs laid later in the day to represent Ct eggs. These data showed that, under the conditions of this experiment, a very high percentage of C1 eggs would be laid from 0700 to 0800 h each day, whereas a relatively high percentage of Ct eggs would be laid from 1300 to 1700 h each day. The mid-sequence eggs would presumably be laid from 0900 to 1200 h.

TABLE 3. Fertility, hatchability, and embryonic mortality of eggs set in experiment 2

Variable and flock age (wk)	Oviposition time[1]			
	Early	Middle	Late	Total
	(%)			
Fertility				
34	99.61 (257)	98.51 (736)	98.52 (203)	98.75^{B} (1196)[2]
59	75.54 (139)	82.02 (228)	78.76 (226)	79.26^{A} (593)[2]
Hatchability of total eggs				
34	93.77	91.71	93.10	92.39^{B}
59	71.22	74.12	71.68	72.51^{A}
Hatchability of fertile eggs				
34	94.14	93.10	94.50	93.56
59	94.29	90.37	91.01	91.49
Early dead of fertile eggs				
34	3.13	4.41	3.00	3.90
59	1.90	5.88	5.62	4.89
Late dead of fertile eggs				
34	2.73	2.49	2.50	2.54
59	3.81	3.74	3.37	3.62

[A,B]Means within a column with no common superscript differ significantly ($P < 0.001$). There were no significant effects due to oviposition time or due to the interaction of flock age and oviposition time.

[1]Within oviposition time early (C1) represents eggs collected from 0700 to 0800 h, middle (Cs) represents eggs collected from 0900 to 1200 h, and late represents eggs collected from 1300 to 1700 h.

[2]Means for number of eggs set are shown in parentheses. There is no SE with categorical analysis.

Experiment 2

The mean egg weight relative to oviposition time and flock age in experiment 2 are shown in Table 2. The weight of the C1 eggs was significantly greater than that of Cs and Ct eggs from the young flock. In a slightly different manner the weight of the Ct eggs was significantly less ($P < 0.01$) than that of the C1 and Cs eggs in the old flock. Nevertheless, the C1 eggs weighed more than the Ct eggs for both flock ages. This was consistent with previous results obtained by Robinson et al. (1991), who used Indian River broiler breeder hens at 45 wk of age and reported that C1 eggs were significantly greater in weight than subsequent eggs in a sequence. Similarly, Novo et al. (1997) used eggs produced by Cobb 500 broiler breeder hens at 46 and 65 wk of age and found egg weight to decrease with time of day.

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 is a continuous increase in follicular (yolk) volume at ovulation (and thus egg weight) with increasing age, 2) the average follicular growth period tends to increase as sequence size decreases (flock aged), 3) the follicular growth period tends to decrease as egg position in a sequence increases from second to sixth, 4) follicular (yolk) volume also tends to be less in terminal (Ct) follicles in sequences of 2 to 5 eggs, and 5) the follicular growth period of the C1 egg is 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 longer to account for the differences in egg weight among the more numerous and smaller eggs of the young flock in the present study. In contrast, in the larger eggs from the presumably shorter sequence lengths of the older flock, only the Ct eggs were smaller. Inspection of the broader oviposition pattern for the older flock (Table 2) suggested that C1 and Cs eggs had similar rapid growth phases compared with the Ct eggs.

Fertility was significantly higher in the young flock in comparison to the old flock ($P < 0.001$) as expected (Table 3) but did not differ due to time of oviposition. These results were in general agreement with those reported by Novo et al. (1997) and Elibol et al. (2002). As a direct reflection of differences in fertility, hatchability of total eggs was higher for the young flock eggs than for the old flock ($P < 0.001$) but did not differ due to time of oviposition. However, there were no significant differences in hatchability of fertile eggs, early, or late embryonic mortality due to flock age or time of oviposition (Table 3).

The fertility of C1 eggs was not reduced in this study with naturally mated hens in contrast to the artificially mated turkeys of Bacon and Nestor (1979) and broiler breeders of Robinson et al. (1991). It was important to note that the previous study of Robinson et al. (1991) used an individual cage system as well. Robinson et al. (1991) classified eggs as "first-of-sequence" or "subsequent" eggs and reported 87.0% fertility for the first-in-sequence eggs vs. 89.56% for eggs in other sequence positions ($P < 0.10$). About 38% of total eggs came from the first-of-sequence eggs, which clearly demonstrated a high incidence of short sequence lengths. 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 our 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 on hatchability at 46 wk of age. Thus, the data would not support the hypothesis that a higher incidence of first in sequence (C1) eggs was responsible for the lower fertility and hatchability of the eggs from older broiler breeder flocks under natural mating conditions.

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