Laying pattern parameters in broiler breeder hens and intrasequence changes in egg composition

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ABSTRACT: The aim of the study was to analyze the pattern of oviposition time in laying sequences in broiler breeder hens and to determine a relationship between egg position in the sequence and egg quality. The sequences were described using mean oviposition time (hour) within a sequence, mean lag of oviposition time between successive ovipositions, and mean and cumulative lag of oviposition for a sequence. Egg weight, percentage of egg components and shape index were determined for successive eggs in a sequence. The 2-, 3-, 4-, 5- to 6- and 7- to 9-egg sequences were considered. The light/dark regime was 16 h/8 h (05:00 a.m. to 09:00 p.m.). Hens laid the first egg in a sequence about 3.5 h after the beginning of the photoperiod. With increasing sequence length, the first egg was laid sooner after the beginning of the photoperiod and the intervals between successive ovipositions shortened. This suggests that when planning the frequency of egg collection in a flock of broiler breeder hens, one should account for changes in the egg sequence length during the production period. No significant relationship between egg position in the sequence and quality of egg components was observed.

Keywords: broiler breeder hens; egg sequence; laying pattern; egg composition

In wild birds it is difficult to study the pattern of oviposition in terms of sequence size and intrasequence variation in egg quality because of, among other things, seasonal changes. In domestic birds the asynchronous cycle of ovulation and oviposition has been well documented. A domestic hen produces a sequence of ovulations on successive days, occurring slightly later each day, until the total lag exceeds 8 to 10 h. At this stage no ovulation occurs, a pause day is introduced and the last ovulation becomes the terminal egg in the sequence (Johnston and Gous, 2003).

Laying hens are characterized by a greater number of eggs laid in longer sequences in comparison with broiler breeder hens. Most often, 3- or 4-egg sequences separated by one-day intervals are observed in broiler breeder hens (Gumulka and Kapkowska, 1996; Zuidhof et al., 2007).

To date, the time pattern of oviposition in a conventional photoperiod of 16 h light and 8 h dark and its various modifications has been analysed mainly in laying hens (Naito et al., 1989; Miyoshi et al., 1997; Johnston and Gous, 2003). Moreover, in laying hens the effect of genotype on oviposition time under the same photoperiod conditions was shown (Campo et al., 2007; Tůmová et al., 2007, 2009). There are few published data about the time pattern of oviposition in broiler breeder hens. Recently, Lewis et al. (2004) recorded the mean oviposition time for in-lay birds kept under different photoperiod conditions (8 h–16 h light) and revealed differences in oviposition time between laying hens and broiler breeders. Therefore, we decided to examine the oviposition time in broiler breeder hens. The data may be useful in practice, among other things for determining the frequency of egg collection. Moreover, individual variability in oviposition time in broiler breeders may have a cognitive aspect.

Some researchers demonstrated a relationship between egg position in the sequence and hatchability of eggs from broiler breeder hens (Robinson et al., 1991a; Fasenko et al., 1992). However, Zakaria et al. (2005, 2009) reported no effect of oviposition time on hatchability of fertile eggs.

In domestic fowl, the effect of oviposition time on egg quality parameters has been investigated mainly in laying hens (Arafa et al., 1982; Yannakopoulos et al., 1994; Tůmová and Ebeid, 2005; Tůmová et al., 2007, 2009). In a few studies a relationship between egg position in the sequence and egg weight and shell strength was determined (Abdallah and Harms, 1997; Lewis et al., 2004). Previous research on broiler breeder hens also examined the effect of egg position in the sequence on shell quality (Yannakopoulos et al., 1994; Gumulka et al., 2005), which significantly influenced hatchability. It would be interesting to determine whether the weight of egg and its components changes with egg sequence length in broiler breeders.

The aim of the study was to analyze the oviposition time pattern in broiler breeder hens and to determine the relationship between egg position in the sequence and egg quality, as expressed by egg weight, egg components and shape index.

MATERIAL AND METHODS

Data were obtained from 86 Arbor Acres broiler breeders. Birds were purchased at the age of 19 weeks from a private owner of a breeding flock. During rearing and egg production periods microclimate, feeding and photoperiod conditions recommended by a primary breeding company for broiler breeder hens were applied.

The study was carried out at the Experimental Station of the Agricultural University in Krakow, Poland. Hens were housed in individual cages. Hen house climate conformed to the standards for broiler breeder parent stocks.

A photoperiod of 8 h light: 16 h dark was used until 22 weeks of age and was increased to 15 h light at 25 weeks of age. From 30 weeks of age, a photoperiod of 16 h light:8 h dark (05:00 a.m. to 09:00 p.m., 24 h light/dark cycle) was applied.

Birds were subjected to restricted feeding with daily administration of feed. At 19 weeks of age, the body weight of birds averaged 1 985.7 ± 22.0 g and was in accordance with the recommendations for Arbor Acres stock. Within the first week of bird purchase, 100 g feed/day was used. Then the ration was determined individually based on weight gains and laying percentage. Dietary ration was increased to the maximum ration (160 g at 32 weeks of age) by about 5 g feed/week, which was less than the recommended ration of 7.5 g/week. This was due to the individual cage housing system used. After this period, the diet was reduced by about 2 g per two weeks. From 54 weeks of age to the end of the productive period, hens had a mean daily intake of 142 g feed.

Hens started egg production at 27 weeks of age on average (189.9 ± 0.8 days) and had an average body weight of 3 136.9 ± 20.6 g.

Cages for hens were linked to a computer registration system (Agroboss S.C., Poland). It contained a system recorder linked to reed relay sensors placed in cages. Oviposition was automatically recorded with information about cage number, day and time. Data on oviposition time were collected daily for individual hens from the beginning of laying period (27 weeks of age) up to 64 weeks of age. For the purpose of this paper only the records gathered during the peak of egg production are presented (31–38 weeks of age).

Based on the data recorded by the computer system, mean oviposition time (hour) within a sequence for sequences of different length was calculated. In addition, the mean lag of oviposition time between successive ovipositions and mean lag for sequences were calculated. Lag was defined as an interval (h) between successive ovipositions in the same egg sequence minus 24 h (Lillpers and Wilhelmson, 1993). Lag between the first and last oviposition in a sequence was defined as cumulative lag.

From the data, examples of egg sequences with oviposition outside the photoperiod, i.e. before the start (05:00 a.m.) or after the end (09:00 p.m.), were selected. The data were defined in the paper as out-of-lay rhythm. For these data, previously mentioned traits were calculated. The individual pattern of successive ovipositions for some hens is also presented.

The eggs were collected several times during the photoperiod and stored for 12 h at 4°C. The short and long diameters of the eggs were measured with a digital calliper (0.001 mm) to determine egg shape index. Moreover, egg weight (0.01 g) and weight of individual components (yolk, albumen and shell) were evaluated. Shell weight included shell membrane weight. The values obtained were used to calculate the percentage of egg components in egg weight as well as egg shape index. The formula for calculating the shape index was (breadth/length) × 100 (Yannakopoulos and Tservenigousi, 1986). Shell quality was also assessed. The results were presented in a paper by Gumulka et al. (2005).

We evaluated data for 63 hens in which oviposition was recorded only during the photoperiod (05:00 a.m. to 09:00 p.m.) and in 2- and 2-plus egg sequences. The 2-, 3-, 4-, 5- to 6- and 7- to 9-egg sequences were considered. For the last two sequences, the results were analyzed together for eggs laid 5th and 6th, and for those laid 7th, 8th and 9th. During the peak of egg production, 9-plus egg sequences were recorded. These were not included in data analysis because of large differences in sequence lengths and small number of sequences. The oviposition time for 190 egg sequences was assessed.

One-way analysis of variance (ANOVA) and Tukey's test for comparison of means were used for statistical calculations (SAS Institute, 2001).

RESULTS AND DISCUSSION

Despite the fact that the rhythm of egg production in birds has been analysed in detail, there are few data for broiler breeder hens. During the rearing period, birds investigated in this study had similar weight gains to those recommended by a breeding stock producer and showed normal egg production. This leads us to suggest that they were suitable for studying the rhythm of egg production. Thus, the birds were reared and managed in a manner to closely simulate industry conditions and the results obtained would likely be comparable to an industry operation.

In the present experiment, the number of egg sequences noted for the whole production period of 37 weeks averaged 58.2 ± 2.0. A greater mean number of sequences (63.0) was recorded by the present authors in an earlier study (Gumulka and Kapkowska, 1996). The number of eggs laid in the longest sequence averaged 17.6 ± 2.0 eggs, with one 38-egg sequence being recorded. Literature data for the longest sequence in broiler breeder hens range from 13.6 to 27.8 (Robinson et al., 1991b; Gumulka and Kapkowska, 1996; Zuidhof et al., 2007). Hens laid their first egg in a sequence about 3.5 h after the beginning of the photoperiod (Table 1). In laying hens, Miyoshi et al. (1997) found that the first egg in a sequence was already laid about 1.5 h after lights on. Lewis et al. (2004) reported that in commercial crossbreeds of laying hens, the mean oviposition time was about 1 h earlier in comparison with broiler breeder hens.

The present observations demonstrated that with increasing sequence length the first egg was laid increasingly sooner after lights on. Compared to 2-egg sequences, these eggs were laid 1.5 h earlier in 5- to 6-egg sequences and 2.3 h earlier in 7- to 9-egg sequences (Table 1). In long sequences, time intervals between subsequent ovipositions within the sequence were shortened. Mean oviposition lag was the highest for 2-egg sequences and tended to decrease with sequence length.

Miyoshi et al. (1997) observed an oviposition pattern in laying hens similar to that presented in this paper. However, the mean lag between successive ovipositions in sequences was lower than that noted in our study, except for the last eggs in sequences. In two Leghorn hen lines, Luc et al. (1996) estimated the mean lag for sequences as 1.04 and 1.32 h. In our experiment, mean lag for all sequences exceeded 2 h but we did not consider very long sequences of more than 10 eggs. However, mean lag values for the sequences analyzed in this study were similar to those calculated by Johnston and Gous (2003) based on predicted ovulation times using a mathematical model of the ovulation cycle of the laying hen. Therefore, it may be appropriate to use a mathematical model of the ovulatory cycle of laying hens to estimate egg production in a flock of broiler breeder hens as well.

Variability of the egg sequence length was observed in the poultry flock, which may be due to the differences in the length of open period for LH release or dynamics of ovarian follicle maturation. The reasons for differences in sequence length among hens subjected to the same photoperiod program have not been well explained. It may be suggested that in some hens daily photoperiod is not synchronized with the ovulatory cycle. Johnston and Gous (2007) point to variation that exists within a population of laying hens in sequence characteristics, particularly in mean sequence length and prime sequence length, both within and between indi-

Table 1. Mean time (h) of within sequence oviposition and lag (h) in broiler breeder hens under a 16L:8D photoperiod (lights-on from 05:00 a.m. to 09:00 p.m.) ($\overline{x}$, (SD))

Position of egg in sequence	Number of sequence (n)	Oviposition time (h)	Lag between successive ovipositions	Mean lag for sequence	Cumulative lag
1	21	09:58 (1:40)			
2		14:02 (1:47)	4:03 (1:26)	4:03 (1:26)	4:03 (1:45)
1	41	08:56 (0:29)			
2		11:37 (1:20)	2:42 (1:06)		
3		15:35 (1:04)	3:58 (0:56)	3:20 (1:11)	6:40 (1:07)
1	31	08:38 (0:42)			
2		10:39 (0:51)	2:02 (0:40)		
3		13:04 (1:15)	2:02 (1:02)		
4		15:44 (1:06)	2:45 (1:00)	2:18 (0:57)	6:49 (0:46)
1	59	08:08 (1:14)			
2		09:34 (1:09)	1:27 (0:37)		
3		10:49 (1:09)	1:16 (0:36)		
4		12:20 (1:16)	1:29 (0:45)		
5–6		15:05 (1:45)	2:53 (0:58)	1:46 (0:59)	7:05 (0:24)
1	38	07:28 (1:01)			
2		08:51 (1:14)	1:26 (0:59)		
3		09:52 (1:04)	1:05 (0:47)		
4		10:25 (2:09)	0:40 (0:24)		
5		11:03 (1:07)	0:38 (0:23)		
6		11:50 (1:29)	0:50 (0:20)		
7–9		13:51 (2:08)	2:00 (1:22)	1:06 (0:56)	6:39 (1:03)

lag: oviposition interval – 24 h

viduals. According to the authors one of the reasons for the irregular laying pattern of some individuals is internal ovulation that is difficult to reveal in commercial production conditions. Despite the use of restricted feeding, disturbances in egg laying are more frequent in broiler breeder hens compared to laying hens. These include oviposition outside the photoperiod. In this study, for cognitive purposes, we characterized parameters of the sequences in which such events were observed (Tables 2 and 3). Some hens laid successive eggs in a sequence with high lag values. This more frequently concerned short (2- or 4-egg) sequences. For these sequences, high values of mean cumulative lag were recorded. Pyrzak and Siopes (1989) considered that oviposition time in long sequences and the last oviposition in the sequence are better controlled at the physiological level than for eggs laid in short sequences and at the start of sequence. The results lead us to conclude that egg collection at the initial period of reproduction in broiler breeder hens should precede the beginning of the photoperiod. Egg collection should be performed more often than in the second half of the reproductive period when the sequence length decreases.

Egg weight variation with laying order and sequence length is typical of wild and domestic birds. In wild birds, intrasequence variation in egg weight could result from nutritional constraints such as breeding experience, year, territory quality (Vińuela, 1997) or

Table 2. Mean time (h) of within sequence oviposition and lag (h) in broiler breeder hens under a 16L:8D photoperiod (lights-on from 05:00 a.m. to 09:00 p.m.) ($\overline{x}$, (SD))– out of laying rhythm

Position of egg in sequence	Number of sequence (n)	Oviposition time (h)	Lag between successive ovipositions	Mean lag for sequence	Cumulative lag
1	10	07:30 (4:17)			
2		15:26 (5:09)	7:56 (3:46)	7:56 (3:46)	7:56 (3:46)
1	15	09:09 (2:10)			
2		12:17 (2:28)	3:08 (1:37)		
3		18:19 (2:31)	6:02 (2:42)	4:35 (2:38)	9:10 (2:29)
1	12	07:24 (2:28)			
2		10:18 (2:10)	2:53 (1:04)		
3		12:58 (2:34)	2:45 (1:44)		
4		17:28 (2:45)	4:29 (3:09)	3:22 (2:11)	10:07 (3:07)
1	10	07:22 (2:19)			
2		09:18 (2:09)	1:56 (0:42)		
3		11:04 (2:14)	1:46 (0:47)		
4		12:59 (2:34)	2:05 (1:06)		
5–6		16:32 (2:58)	3:30 (1:52)	2:17 (1:22)	9:17 (1:21)
1	8	06:36 (1:34)			
2		08:05 (1:36)	1:28 (0:59)		
3		08:37 (1:17)	0:35 (0:58)		
4		09:37 (1:25)	0:58 (0:43)		
5		10:34 (2:07)	0:57 (0:29)		
6		11:34 (2:28)	1:01 (0:22)		
7–9		14:26 (3:29)	2:51 (1:58)	1:19 (0:59)	7:50 (0:56)

lag: oviposition interval – 24 h

Table 3. Individual pattern of successive ovipositions (h) in sequences of broiler breeder hens in which some eggs were laid during darkness (photoperiod 16L:8D – lights-on from 05:00 a.m. to 09:00 p.m.)

	Position of ovipositions in sequence								
Hens	1	2	3	4	5	6	7	8	9
A	00:54	12:23							
B	09:11	09:58	21:45						
C	07:22	10:14	11:50	21:49					
D	04:23	06:03	08:54	12:53	14:18				
E	04:01	06:05	08:05	08:14	12:00	17:40			
F	05:46	08:12	08:04	08:29	09:55	11:01	20:29		
G	04:51	05:58	08:28	09:09	09:35	09:37	09:58	11:44	
H	04:47	06:13	07:32	08:43	08:50	09:04	10:16	11:48	14:43

Table 4. Percentage of eggs components laid in sequences in broiler breeder hens ($\bar{x}$, SD)

Position of eggs	Number of eggs (n)	Egg weight (g)	Yolk (%)	Albumen (%)	Shell (%)	Shape index (%)
1	20	63.5 (4.1)	28.2 (1.8)	63.0 (1.5)	8.6 (1.0)	76.4 (3.6)
2		61.0 (4.2)	28.3 (1.8)	62.8 (1.6)	8.8 (0.9)	74.9 (3.0)
1	40	66.3 (3.8)	28.2 (1.7)	63.4 (1.7)	8.5a (0.9)	76.2 (7.2)
2		65.2 (3.8)	27.9 (1.3)	63.2 (2.2)	8.8ab (0.8)	74.9 (3.5)
3		64.3 (3.3)	28.4 (1.5)	62.6 (1.5)	8.9b (0.7)	74.6 (3.1)
1	30	65.3 (4.1)	27.9 (1.3)	63.2 (1.6)	8.8 (0.8)	75.0 (3.2)
2		65.0 (3.5)	28.2 (1.4)	62.8 (1.2)	8.9 (0.8)	75.5 (5.2)
3		64.6 (3.4)	28.2 (1.5)	62.7 (1.4)	9.1 (0.6)	75.4 (3.1)
4		64.9 (3.4)	27.8 (1.4)	63.1 (1.4)	9.1 (0.6)	74.7 (2.6)
1	59	65.5 (3.7)	27.9 (1.7)	63.4 (1.8)	8.7 (0.6)	74.6 (3.2)
2		65.0 (3.7)	28.4 (1.6)	62.8 (1.7)	8.8 (0.7)	76.0 (3.2)
3		63.9 (3.8)	28.4 (1.8)	62.7 (1.8)	8.9 (0.8)	76.0 (3.0)
4		64.5 (4.2)	28.2 (1.9)	62.9 (1.7)	8.9 (0.6)	75.6 (3.8)
5–6		64.9 (3.6)	28.0 (1.8)	63.0 (1.7)	9.0 (0.7)	75.4 (3.1)
1	38	63.9 (5.3)	28.6 (2.1)	62.4 (2.2)	9.0 (0.5)	74.3 (2.6)
2		63.1 (4.0)	29.1 (1.7)	61.6 (1.9)	9.2 (0.7)	75.2 (2.7)
3		62.2 (5.2)	29.2 (2.6)	61.7 (2.7)	9.0 (0.5)	75.5 (3.1)
4		61.7 (4.5)	29.1 (1.6)	61.9 (2.2)	8.9 (0.6)	75.5 (2.6)
5		62.3 (4.5)	28.9 (1.5)	62.1 (1.8)	9.0 (0.6)	75.3 (3.0)
6		62.9 (4.7)	28.6 (1.5)	62.9 (1.9)	8.5 (10.0)	74.2 (3.9)
7–9		62.4 (3.3)	28.8 (1.4)	62.3 (1.7)	8.8 (0.7)	74.8 (3.0)

[a,b]means followed by different superscript letters in the same column are different using Tukey's test at $P < 0.05$

could be an adaptive trait (Williams et al., 1993). In some birds with sexual dimorphism, intrasequence variation in egg weight was associated with the sex of embryos (Blanco et al., 2003). In domestic fowl, the weight of eggs laid successively in a sequence was observed to decrease (Abdallah and Harms, 1997; Miyoshi et al., 1997). In the present experiment, eggs laid first were the heaviest for all sequences analysed. However, the differences were not significant. Numerous studies have indicated that eggs laid in the morning were significantly heavier than those collected in the afternoon (Novo et al., 1997; Zakaria et al., 2005, 2009; Tůmová et al., 2007, 2009). As has been previously documented, the first eggs in a sequence are laid in the morning.

In the present observations, no significant differences in the weight and percentage of yolk and albumen in egg weight in relation to the position of sequence were observed (Table 4). Only a tendency was noted, in which higher weight of the first eggs in a sequence was connected with higher weight and percentage of albumen. Higher yolk weight was also detected for eggs laid in short (2- to 3-egg) sequences. Likewise, Yannakopoulos et al. (1994) did not note a significant effect of daily oviposition time on yolk or albumen weight, but the analysis was performed on eggs from laying hens of the same weight. According to the authors, hen age is a factor markedly influencing the weight of internal egg components. On the other hand, in experiments with laying hens, Miyoshi et al. (1997) found that albumen weight was higher for the first egg in a sequence and it decreased subsequently. In previous observations of Arafa et al. (1982), yolk weight was decreasing gradually in eggs laid by laying hens in the afternoon and the differences in the percentage of yolk between the eggs laid early in the morning and late in the afternoon were 1.5%. On the other hand, the authors did not find any trend for the weight or percentage of albumen. By contrast, in recent studies Tůmová et al. (2009) did not show the effect of oviposition time on yolk weight in three genetic groups of laying hens. Moreover, in albumen quality characteristics only Haugh units score declined significantly with egg collection time. However, in a study by Tůmová and Ebeid (2005) yolk percentage was lower in eggs laid in the afternoon and no significant effect of oviposition time on Haugh units was recorded.

In the present study, shell percentage in egg weight in 3- to 4- and 5- to 6-egg sequences was higher for the last egg in a sequence compared to the other eggs, but significant ($P \leq 0.05$) differences were found only for shell percentage in 3-egg sequences.

In the literature there are no data on the influence of egg position in a sequence on shape index. Our observations did not reveal any changes in the shape of eggs laid as the last in the sequence in comparison with the first. Similarly, in a report by Tůmová et al. (2009) the shape index of eggs laid by laying hens did not change with collection time. However, it was demonstrated (Arafa et al., 1982; Gumulka et al., 2005) that eggs laid in the afternoon were characterized by thicker shells and were less deformed.

CONCLUSIONS

Broiler breeder hens with good production laid the first egg in a sequence about 3.5 h after the beginning of the 16-h photoperiod. Moreover, mean lag for a sequence was the highest for the 2-egg sequences and decreased as the sequences increased. When planning the frequency of egg collection in a flock of broiler breeder hens, one should account for changes in egg sequence length during the production period.

No relationship between egg position in a laying sequence and quality of egg components in broiler breeder hens was observed.

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Received: 2009–08–26
Accepted after corrections: 2009–12–17

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