Research Note

Effects of egg position during late incubation on hatching parameters and chick quality

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ABSTRACT Chicken eggs are commonly incubated for 17 to 18 d in setters, after which they are transferred to the hatchery for the last 3 to 4 d of incubation. Whereas eggs are positioned vertically with the air cell up during the first incubation phase, they are placed horizontally for the hatching phase. It is unknown whether egg position in the last phase of incubation is of importance to the hatching process and chick quality. An experiment was conducted to investigate effects of egg position in the last 4 d of incubation on the hatching process and chick quality. The experiment consisted of 2 identical trials, where 300 fertile eggs per trial were transferred to a hatching cabinet at embryo day 17. Eggs were placed in 1 of 3 positions: with the air cell up (ACU), with the air cell down, or horizontally (HOR). Starting at embryo day 18, the following data were collected for each egg at 3-h intervals: time of internal pipping (IP), external pipping (EP), hatching, and position of EP. Approximately 6 h after hatch, BW, chick length, and chick quality based on the Pasgar score, were determined for each chick. In addition, residual yolk weight and yolk-free body mass were determined in every fourth chick that hatched. Time of IP was not affected by egg position, but EP occurred 5 h later in ACU eggs, and thus, the IP-EP interval was increased by 3 to 4 h in this group compared with the other egg positions. Hatching occurred 1 to 2 h earlier in HOR eggs than in the other 2 positions. Body weight, yolk weight, and yolk-free body mass were not affected by egg position. Chick length was 1 to 2 mm shorter and the Pasgar score was slightly lower in air cell-down eggs compared with ACU and HOR eggs, mainly caused by a high incidence of poor navel quality, red hocks, and red beaks. Hatchability was not affected by egg position. We concluded that egg position in the last phase of incubation affects the duration of the hatching process, and has small effects on chick quality.

Key words: hatching system, egg position, chick quality, hatching time

2011 Poultry Science 90:2342–2347
doi:10.3382/ps.2011-01467

INTRODUCTION

Hatching eggs are commonly incubated for 17 to 18 d in setters, during which they are positioned in a setter tray with the large end of the egg up. Because during this period eggs are turned regularly at an angle of 90° (Tona et al., 2005), they rest with their longitudinal axis at an angle of 45°. For the last 3 to 4d of incubation, eggs are transferred to hatcher baskets and placed in hatchers. In the hatcher baskets, eggs generally lay in a horizontal position (Bauer et al., 1990). Recently, an alternative hatching system was developed, named Patio (Vencomatic BV, Eersel, the Netherlands; van de Ven et al., 2009). The Patio is a multi-tiered housing system, which was developed to combine the hatching and brooding phase, so after hatch, chicks stay in this system for the remainder of the growing period. When using the Patio system, eggs at d 17 or 18 of incubation are not transferred to hatcher baskets, but remain in the upright position in the setter trays, which are placed in the Patio system. Consequently, in contrast to the horizontal egg position in traditional hatching systems, chicks in Patio hatch from eggs positioned with the large end up.

Egg position during the first part of incubation has been shown to influence hatchability in chickens and quails (Byerly and Olsen, 1931; Cain and Abbot, 1971; Bauer et al., 1990; Wilson et al., 2003; Mao et al., 2007; Moraes et al., 2008), primarily by affecting the proportion of embryos that have the head located in the large end of the egg, right under the air cell, which is considered the optimum position for hatching (Oppenheim, 1972). Positioning eggs with the small end up results in a higher percentage of embryos with the heads located in the small end of the egg, leading to lower hatchabil-

Received March 8, 2011.
Accepted July 16, 2011.
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ity compared with eggs that are placed horizontally or with the large end up (Byerly and Olsen, 1931; Cain and Abbot, 1971). In addition, positioning eggs with the small end up leads to lower chick quality at hatch (Bauer et al., 1990).

The studies mentioned above focused on effects of different egg positions during the first phase of incubation only, after which the eggs were transferred to a horizontal position for the hatching phase (Byerly and Olsen, 1931; Cain and Abbot, 1971; Bauer et al., 1990; Moraes et al., 2008), or the experiment was ended (Wilson et al., 2003). Effects of different egg positions in the last days of incubation are unknown, but may affect embryo movement and thus, the hatching process. In the current study we investigated the effects of egg position in the last 4 d of incubation on hatchability, hatching time, and chick quality.

MATERIALS AND METHODS

All procedures in this study were approved by the Animal Care and Use committee of Wageningen University, Wageningen, the Netherlands.

Experimental Design

The experiment consisted of 2 identical trials, conducted 1 wk after each other, with hatching eggs from the same commercial Cobb 500 broiler breeder flock. The breeder flock was aged 33 and 34 wk when eggs were obtained for trial 1 and 2, respectively. Eggs were stored for 6 d in trial 1 and 5 d in trial 2, and then incubated for 17 d in a multi-stage incubator (Petersime NV, Zulte, Belgium) at a constant machine temperature of 37.6°C and relative humidity of 53%. Eggs were placed in a vertical egg position with the air cell up, and turned hourly at an angle of 90°. After candling at embryo day (**E**) 17 (after 416 h of incubation), fertile eggs were collected from 1 setter trolley, weighed, and only eggs in the range of 51 to 56 g were transferred to a Plexiglas hatching cabinet (1.2 × 2.3 m), which provided room for 3 setter trays. Per trial, 300 eggs were randomly distributed over 3 setter trays (100 eggs per tray). Per tray, all eggs were placed in the same position, which was (1) vertical with the air cell up (**ACU**); (2) vertical with the air cell down (**ACD**); or (3) horizontal (**HOR**). The setter trays were placed next to each other in the hatching cabinet, about 30 cm above the floor of the cabinet, which was covered by wood shavings. The position of the egg trays in relation to one another was changed between the trials.

From E17 to E21.5, eggs were not turned, the set point of the air temperature remained constant at 35.0°C, and air speed was lower than 0.2 m/s, which is considered still air (Simmons et al., 2003). These conditions were based on set points commonly applied in the Patio system, and were shown to result in the highest hatchability in our preliminary (unpublished) trials.

Data Collection

From the moment the eggs were placed in the cabinet until the trial was ended at d E21.5, the temperature was logged every 5 min using 3 data loggers with an accuracy of 0.1°C (175-H2 Logger; Testo BV, Almere, the Netherlands) that were placed among the eggs on each of the setter trays, at a distance of approximately 1 cm from the eggs. In addition, 1 of the 3 loggers also measured relative humidity every 5 min. The data loggers were the same for both trials and were calibrated before the experiments started.

After 442 h of incubation (d E18), the measurements started at intervals of 3 h until hatching was finished at 505 and 496 h of incubation in trial 1 and 2, respectively. At each interval, all eggs were examined to determine the moment of internal pipping (**IP**), by use of a candling light, external pipping (**EP**), and hatching. In addition, the position of EP was registered and categorized in ring-shaped areas A, B, C, D, E, or F, each having the same width. Area A was located at the outermost large end of the egg, containing the air cell, and F was located at the small end of the egg.

When a chick had hatched, it fell down through one of the openings in the egg tray onto the wood shavings on the floor of the cabinet, which was divided into 3 separated compartments, 1 below each egg tray. Here, chicks were kept separately per treatment until measurements were performed 6 h later. At that moment, from each chick, the BW, chick length (measured from the top of the beak to the tip of the middle-toe excluding the nail; Hill, 2001), and chick quality were scored. Chick quality was measured using the Pasgar score (Boerjan, 2002). Based on this score, the quality of each chick was evaluated based on 5 criteria: (1) low alertness; (2) suboptimal navel condition; (3) red hocks (red or swollen hocks); (4) abnormal beak; and (5) large size of the residual yolk sac. For each of the 5 criteria, 1 point was subtracted from 10, with chicks scoring 10 being free of any abnormality and 5 being the lowest score.

In addition to the above-described measurements, every fourth chick that hatched was killed for measurements on residual yolk and yolk-free body mass (**YFBM**). Hatchability was determined as total number of eggs hatched divided by the total number of fertile eggs × 100.

Statistical Analyses

Data were analyzed with the SAS 9.1 software package (SAS Institute, 2004). Measurements on each individual egg or chick were treated as experimental unit in all analyses. Normally distributed data (BW, yolk weight, YFBM, chick length, and time of IP, EP, and hatch) were analyzed using the generalized linear model (GLM) procedure using the following model: $Y_{ij} = EP_i + trial_j + \text{interaction term} + e_{ij}$, where EP_i = egg position (ACU, ACD, or HOR), $trial_j$ = trial (1 or 2),

Table 1. Means ± SE at the moment of internal pipping (IP), external pipping (EP), hatching, and the interval between these moments, determined in eggs positioned air cell up (ACU), air cell down (ACD), or horizontally (HOR) during the last 4 d of incubation[1]

Item	n	IP	EP	Hatch	IP-EP interval	EP-hatch interval	IP-hatch interval
Trial							
Trial 1	289	461 ± 0.5[a]	478 ± 0.4[a]	492 ± 0.3[a]	17 ± 0.5[a]	14 ± 0.3[a]	31 ± 0.5[a]
Trial 2	294	452 ± 0.3[b]	468 ± 0.4[b]	481 ± 0.3[b]	16 ± 0.4[b]	13 ± 0.3[b]	29 ± 0.3[b]
Egg position							
ACU	194	457 ± 0.7	476 ± 0.6[a]	487 ± 0.6[a]	19 ± 0.6[a]	12 ± 0.3[b]	31 ± 0.5[a]
ACD	194	456 ± 0.6	471 ± 0.5[b]	486 ± 0.5[ab]	16 ± 0.5[b]	15 ± 0.3[a]	30 ± 0.5[ab]
HOR	195	456 ± 0.6	471 ± 0.6[b]	485 ± 0.5[b]	15 ± 0.6[b]	14 ± 0.3[a]	29 ± 0.5[b]
Trial × egg position							
Trial 1 × ACU	97	462 ± 0.9	481 ± 0.8	493 ± 0.6[a]	19 ± 1.0	12 ± 0.5	31 ± 0.8[a]
Trial 1 × ACD	95	460 ± 0.9	476 ± 0.7	491 ± 0.6[a]	16 ± 0.8	15 ± 0.4	31 ± 0.8[a]
Trial 1 × HOR	97	460 ± 1.0	476 ± 0.6	491 ± 0.5[a]	16 ± 0.9	15 ± 0.4	31 ± 0.9[a]
Trial 2 × ACU	97	451 ± 0.6	470 ± 0.6	481 ± 0.4[b]	19 ± 0.7	11 ± 0.5	30 ± 0.6[a]
Trial 2 × ACD	99	452 ± 0.5	467 ± 0.6	482 ± 0.4[b]	15 ± 0.6	15 ± 0.5	29 ± 0.6[ab]
Trial 2 × HOR	98	452 ± 0.5	466 ± 0.6	479 ± 0.4[c]	14 ± 0.6	13 ± 0.4	27 ± 0.5[b]
Source of variation (*P*-value)							
Trial		<0.001	<0.001	<0.001	0.019	0.025	0.044
Egg position		0.508	<0.001	<0.001	<0.001	<0.001	<0.001
Trial × egg position		0.068	0.304	0.006	0.304	0.103	0.025

[a–c]Different superscript letters within a column indicate a significant difference between treatment groups ($P \leq 0.05$).

[1]Data are expressed in hours, unless otherwise noted.

and e_{ij} = residual error term. Data on Pasgar score and hatchability were analyzed using the LOGISTIC procedure, using the same model (SAS Institute, 2004). Variation in hatching time parameters was tested for treatment effects using Levene's test for homogeneity of variance. Data are expressed as means ± SE, and differences were considered statistically significant at $P \leq 0.05$.

RESULTS

The egg weight at the moment of transfer to the hatching cabinet was 53.5 ± 0.06 g, and did not differ among treatments. The mean temperature was 34.5 ± 0.02°C during trial 1 and 34.8 ± 0.02°C during trial 2. The relative humidity was 22.7 ± 0.05% in trial 1, and 26.5 ± 0.05% in trial 2.

Hatching Parameters

Mean hatchability was 97.2%, and not affected by trial or egg position. The 17 unhatched eggs (11 from trial 1 and 6 from trial 2) were opened for macroscopic examination. Eleven embryos had already died before the start of the trial, 2 embryos showed malformations, and 4 embryos were malpositioned. No effect of egg position was noted on these parameters.

Internal pipping, EP, and hatch occurred about 10 h earlier in trial 2 than in trial 1 (Table 1). Egg position did not affect time of IP, but EP occurred approximately 5 h later in ACU eggs compared with ACD and HOR eggs ($P < 0.001$), which were not different from each other (Table 1). In line with these results, the IP-EP interval was increased in ACU eggs compared with ACD and HOR eggs ($P < 0.001$), whereas this interval did not differ between ACD and HOR eggs. Variation of time of EP and duration of the IP-EP interval differed among egg positions ($P = 0.028$ and $P = 0.018$, respectively), and was greatest in ACU eggs. Of all chicks, 99.5% pipped the eggshell at the large side of the egg (area A, B, or C). There was a small effect of egg position on the distribution of EP position ($P = 0.030$); in ACD eggs, a higher proportion of chicks pipped at area B (89.8%), compared with ACU (84.4%) and HOR (81.6%) eggs.

The EP-hatch interval was smaller in ACU eggs than in ACD and HOR eggs ($P < 0.001$), which were not different from each other. The IP-hatch interval was not affected by egg position in trial 1, but in trial 2, HOR eggs showed shorter IP-hatch intervals compared with the ACU ($P < 0.001$) and ACD eggs ($P = 0.002$). In trial 1, the moment of hatch did not differ among egg positions, but in trial 2, hatch occurred earlier in HOR eggs compared with ACU eggs ($P = 0.004$) and ACD eggs ($P = 0.002$).

Chick Quality

Body weight, yolk weight, and chick length were lower in trial 1 than in trial 2, whereas YFBM was higher in trial 1 than in trial 2 (Table 2). There were no effects of egg position on BW, yolk weight, or YFBM. Chick length was slightly shorter in chicks from ACD eggs compared with the ACU and HOR eggs ($P = 0.006$). The Pasgar score was lower in trial 2 than in trial 1, mainly explained by a higher incidence of red hocks in all egg positions (18% in trial 1 vs. 36% in trial 2). Chicks from ACD eggs had a lower Pasgar score than chicks from ACU eggs and HOR eggs ($P = 0.008$). The lower Pasgar score in ACD chicks was largely due to a high incidence of suboptimal navel score (36% in ACU, 51% in ACD, and 48% in HOR eggs), red hocks (29%

Table 2. Means ± SE of BW, yolk-free body mass (YFBM), yolk weight, chick length, and Pasgar score of chicks hatched from eggs positioned air cell up (ACU), air cell down (ACD), or horizontally (HOR) during the last 4 d of incubation

Item	BW (g)	YFBM (g)	Yolk weight (g)	Chick length (cm)	Pasgar score
Trial					
Trial 1	42.7 ± 0.08[b]	37.5 ± 0.15[a]	5.2 ± 0.11[b]	19.1 ± 0.03[b]	9.3 ± 0.04[a]
Trial 2	43.2 ± 0.07[a]	36.9 ± 0.12[b]	6.2 ± 0.10[a]	19.4 ± 0.02[a]	9.1 ± 0.05[b]
Egg position					
ACU	43.0 ± 0.10	37.2 ± 0.16	5.6 ± 0.13	19.2 ± 0.03[a]	9.3 ± 0.05[a]
ACD	42.8 ± 0.10	37.0 ± 0.16	5.8 ± 0.12	19.1 ± 0.03[b]	9.1 ± 0.06[c]
HOR	43.0 ± 0.10	37.3 ± 0.17	5.7 ± 0.13	19.3 ± 0.03[a]	9.2 ± 0.05[b]
Trial × egg position					
Trial 1 × ACU	42.9 ± 0.15	37.8 ± 0.25[a]	5.2 ± 0.20	19.1 ± 0.05	9.4 ± 0.07
Trial 1 × ACD	42.5 ± 0.14	36.9 ± 0.30[ab]	5.1 ± 0.14	19.0 ± 0.04	9.2 ± 0.07
Trial 1 × HOR	42.6 ± 0.14	37.6 ± 0.20[a]	5.2 ± 0.22	19.1 ± 0.05	9.4 ± 0.06
Trial 2 × ACU	43.1 ± 0.12	36.6 ± 0.23[b]	6.0 ± 0.17	19.4 ± 0.04	9.2 ± 0.08
Trial 2 × ACD	43.1 ± 0.13	37.0 ± 0.21[ab]	6.4 ± 0.16	19.3 ± 0.04	9.0 ± 0.08
Trial 2 × HOR	43.3 ± 0.13	37.0 ± 0.21[ab]	6.3 ± 0.16	19.4 ± 0.04	9.1 ± 0.07
Source of variation (P-value)					
Trial	<0.001	0.002	<0.001	<0.001	0.003
Egg position	0.401	0.341	0.731	0.006	0.008
Trial × egg position	0.226	0.026	0.458	0.818	0.442

[a–c]Different superscript letters with a column indicate a significant difference between treatment groups ($P \leq 0.05$).

in ACU, 29% in ACD, and 23% in HOR eggs), and abnormal beak score (2% in ACU, 9% in ACD, and 4% in HOR eggs).

DISCUSSION

Hatching Parameters

Before preparations for hatching start, avian embryos commonly lie on their left side with the neck curved under the air cell and the beak and anterior head region buried in the yolk between the legs (Oppenheim, 1972). Around d 17 to 18, embryos lift their head out of the yolk, position their head under the right wing, and bring the beak and right shoulder toward the air cell, which is considered the optimum hatching position (Oppenheim, 1972). In the present study, hatchability was high and not affected by egg position during the last 4 d of incubation. In addition, there were no effects of egg position on the occurrence of malpositions, and egg position did not greatly affect the position of external pipping, as all but 3 chicks (0.5%) pipped the eggshell at the region of the air cell. It was suggested that obtaining the right embryo position for hatching is mainly influenced by the need for oxygen and gravity (Byerly and Olsen, 1931), which was based on high incidences of malpositioned embryos in eggs placed with the air cell down, and in eggs placed air cell up but with the porous air cell region sealed with paraffin. From present data, it seems that gravity does not play a significant role after E17, because the embryo seems to be able to obtain the right hatching position irrespective of egg position during E17 to E21.

The IP-EP interval found in the present study was about 5 to 9 h longer compared with previous findings in eggs obtained from the same broiler breed with parent flocks 38 to 48 wk old, whereas the EP-hatch interval was comparable to those observed in these studies (Tona et al., 2003; De Smit et al., 2008; Everaert et al., 2008; Willemsen et al., 2010). The IP-EP interval was found to increase with longer egg storage time (Tona et al., 2003), however, despite a shorter storage time in the present study (5–6 d) compared with the 18-d stored eggs in the study of Tona et al. (2003), the IP-EP interval was about 5 h longer in the present study. Another possibility is that the longer IP-EP interval in the present study was related to a lower incubation temperature in the last phase of incubation (34.5–34.8°C) compared with the previous studies, where the set-point temperature was about 37.6°C in this phase (Tona et al., 2003; De Smit et al., 2008; Everaert et al., 2008; Willemsen et al., 2010). A lower incubation temperature during late incubation was associated with lower embryonic metabolism, resulting in a lower build-up of CO_2 in the air cell (Willemsen et al., 2011), which was shown to increase the length of the IP-EP interval (Visschedijk, 1968).

The IP-EP interval was 3 to 4 h longer in eggs positioned with the air cell up, which may indicate that embryos in these eggs encountered greater difficulty lifting their head from the yolk toward the air cell against gravity, compared with embryos in the other egg positions.

The EP-hatch interval was 2 to 3 h shorter in eggs positioned with the air cell up. It was suggested that the length of the EP-hatch interval is influenced by the availability of energy in this phase, such as yolk lipids or liver glycogen (Christensen et al., 2000; Everaert et al. 2008). There were no differences noted in residual yolk weight among egg positions, and no measurements on energy use were performed, so a relation between length of the EP-hatch interval and energy availability could not be assessed in this study. Possibly, embryos in ACU eggs found less difficulty moving their head during the process of external pipping compared with embryos in ACD eggs, and to a lesser extent in HOR eggs,

which probably encountered more pressure of their own BW during this process.

The hatching process started about 10 h earlier in trial 2 compared with trial 1. Factors that influence time of hatch are breeder age, storage time, and egg size (Decuypere and Bruggeman, 2007), which were kept similar in both trials. Incubation temperature is another important factor that affects hatching time (Decuypere and Bruggeman, 2007). Based on the assumption that the chick embryo needs a fixed amount of heat for full development, as suggested by Decuypere and Michels (1992), an air temperature difference of 0.3°C between the trials during the period from transfer until hatch (76 h in trial 1 and 65 h in trial 2) was unlikely to explain the difference of 10 h in hatching time. For both trials, eggs were incubated for 16 d in a multistage setter, at a constant set-point temperature of 37.6°C. Despite equal machine set points, temperature differences could occur at different positions within a setter (Van Brecht et al., 2003), and eggs for the 2 trials were obtained from different setter trolleys. The shorter hatching time in trial 2 suggests that these eggs could have been subjected to a higher temperature during d E0 to E16 at the level of the setter trolley.

Chick Quality

Egg position did not affect BW, yolk weight, or YFBM. The Pasgar score was highest in chicks hatched from ACU eggs, and lowest in chicks hatched from ACD eggs. The incidence of poor navel quality was highest in chicks from ACD eggs, followed by chicks from HOR eggs. In the current experiment, after emergence from the eggs, chicks had to crawl away from the egg and fall down through openings in the setter trays onto the litter. Chicks that hatched from ACD eggs emerged from the egg at the region of the air cell, facing the floor of the hatching cabinet. Possibly, remnants of the chorioallantoic arteries were torn as the chick fell down directly after it fractured the eggshell, thereby increasing the risk for unhealed navels and leaving a small scab of blood, which is the most common type of unhealed navel (Fasenko and O'Dea, 2008). High incidences of red hocks and red beaks in chicks from ACD eggs also point at a demanding hatching process. The length of chicks from ACD eggs was 1 to 2 mm shorter in comparison to chicks from the other egg positions. It must be noted that although differences in Pasgar score and chick length were statistically significant, they are small and relevance of these differences for later life is not clear.

Interestingly, despite equal initial egg weights, both body and yolk weights of chicks in trial 1 were 0.5 and 1.0 g lower, respectively, than in trial 2, whereas the YFBM was 0.6 g higher. These data point in the same direction as the earlier hatching time in trial 2, and suggest a higher incubation temperature from E0 to E16 for eggs in trial 2, as higher temperatures lead to lower YFBM and higher yolk weights at hatch (Molenaar et al., 2010). The Pasgar score was lower in trial 2 due to an increase in red hock incidence in chicks from each of the egg positions. Red hocks were associated with prolonged pushing of the hocks against the eggshell during the hatching process (Wilson, 2004). However, both the IP-EP interval and the EP-hatch interval were about 1 h shorter in trial 2 than in trial 1; thus, it seems unlikely that prolonged pushing of the hocks against the eggshell was the cause of the increased red hock incidence in trial 2. If the temperature from E0 to E16 was higher in trial 2, as suggested by the earlier hatching time and lower YFBM, then possibly the metabolism was increased in these embryos, and thereby the CO_2 pressure in the air cell at the end of incubation, stimulating the time of pipping (Visschedijk, 1968). Thus, these embryos may have been struggling more for quick access to the air cell and penetration of the eggshell, thereby pushing the hocks against the eggshell.

It is concluded that egg position in the last 4 d of incubation does not affect hatchability, but seems to affect the duration of the hatching process and chick quality.

ACKNOWLEDGMENTS

Louis Lemmens of Kuikenbroederij Van Hulst (Veldhoven, the Netherlands) is acknowledged for his help with egg collection. We thank Gerard van Kesteren (Vencomatic BV, Eersel, The Netherlands) for his technical assistance. The Southern Agriculture and Horticulture Organization (ZLTO, Den Bosch, the Netherlands) is acknowledged for partially funding the project.

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