Effects of a combined hatching and brooding system on hatchability, chick weight, and mortality in broilers

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ABSTRACT Chicks hatch over a time window of approximately 36 to 48 h and are removed from the hatchers only when the majority of the chicks has hatched. Consequently, chicks are exposed to prolonged posthatch holding periods and delays in feed and water access, leading to dehydration and impaired posthatch performance. It is questionable whether the physiological requirements of the hatchlings can be met with current hatching systems. An alternative system that may better match the requirements of the hatchlings is a system that combines the hatching and brooding phase, so that feed and water can be provided immediately after hatch. Such a system, named Patio, was developed in the Netherlands and tested from 2006 to 2008, to evaluate effects on hatchability and early performance of broilers. This paper describes the Patio system and the results from these tests. A total of 21 broiler production trials (780,686 eggs) in the Patio system were evaluated at 3 locations and compared with control hatches of eggs of the same parental flock in the hatchery. Hatchability in the Patio was on average 1.45, 1.83, and 1.86% higher at location 1, 2, and 3, respectively. However, in the calculation of the hatchability in the Patio, possible second grade chicks were included, whereas these were excluded in the calculation of hatchability in the hatchery. Additionally, in the hatchery, the hatching process was interrupted earlier than in the Patio, meaning that possible late hatching chicks remained in the flock in the Patio, but not in the hatchery. In 3 trials, the Patio chicks were 11.6 to 16.3% heavier at d 0, when the hatchery chicks were placed in the broiler house. Mean cumulative 7-d mortality was only assessed in the Patio and was 1.27, 1.09, and 1.43% at location 1, 2, and 3, respectively. The Patio system appears to function as an alternative to current hatching and brooding systems. Further studies are required to determine to what extent the higher hatchability is due to second grade and to late hatching chicks.

Key words: broiler, hatching system, hatchability, chick weight, delayed feeding

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INTRODUCTION

Hatching eggs are commonly incubated for 18 d in incubators, after which they are candled to verify the presence of an embryo inside the eggs. Following common practice, only the apparently fertile eggs are transferred to hatcher baskets and placed in hatcher cabinets for the last 3 d of incubation. Chicks hatch over a time window of approximately 36 to 48 h and are removed from the hatchers only when the majority of the chicks has hatched (Careghi et al., 2005). The variation in hatching time depends on factors such as age of the parent flock, egg handling, egg storage time, and incubation conditions (Decuypere et al., 2001). In addition, fixed management schedules at commercial hatcheries often leave little room for flexibility and thus the moment of chick collection has usually been set at 21.5 d. Consequently, a slight delay or a more pronounced variation in the moment of hatch may affect (and decrease) hatchability, because opening the hatchers too early means that eggs with viable chicks inside are wasted. On the other hand, postponing the moment of chick collection will lead to a higher percentage of chicks dehydrating and reduce chick quality (Bamelis et al., 2005; Tona et al., 2005).

After chick collection from the hatcher, further hatchery procedures, such as sexing, vaccination, packaging, and transportation, increase the time until placement in the broiler house and thus first feed and water intake, for part of the flock by up to 50 h or more (Sklan et al., 2000; Careghi et al., 2005). If long transporta-

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tion is involved, this period may be increased up to 72 h. Suboptimal conditions during transport and a delay in the moment of placement and the first feed and water intake are associated with higher early mortality in chicks and poults (Kingston, 1979; Carver et al., 2002; Chou et al., 2004) and impaired performance throughout the growout period (Halevy et al., 2000; Gonzales et al., 2003).

Although the first few days of the life of a chick are known to be crucial to later performance (Bruzual et al., 2000; Tona et al., 2005), it is questionable whether the physiological requirements of the hatchlings can be met with current incubation systems and hatchery management procedures. An alternative system that can potentially overcome the negative effects of variation in hatching time and deprivation of feed and water is a system that combines the hatching and brooding phase, in which feed and water can be provided immediately after hatch. In the period of 2002 to 2006, such a system was developed for broiler chicks. Thereafter, this system, named Patio (Vencomatic BV, Eersel, the Netherlands), was tested at 3 locations in the Netherlands from 2006 to 2008, to evaluate consequences on hatchability and later performance of broilers. This paper describes the Patio system and the results of these trials.

MATERIALS AND METHODS

At 3 locations, a total of 21 trials were evaluated in the Patio system (Table 1). At the first 2 locations (in total 18 trials), chicks were reared to an age of 7 to 14 d, after which they were transferred to a traditional broiler house. At both locations, bird density at the start of the trials varied between 55 and 90 birds/m^2. During the 3 trials carried out at the third location, the chicks remained in the system for the total growout period. Bird density at the start of each trial was about 22 birds/m^2, which is similar to the Dutch average bird density in broiler houses (KWIN, 2007).

The current paper describes the technical characteristics of the Patio system used at the third location. This system differs from the Patio system used at the first 2 locations mainly in terms of dimensions (Table 1), but also slightly in climate system. Data on hatchability of all 21 trials were compared with the results of control eggs that were simultaneously incubated until d 18 with eggs destined for Patio and hatched in hatcher cabinets. Records of early mortality were collected of chicks that hatched in Patio at all 3 locations. At location 3, weights of chicks that hatched in the Patio and control chicks that hatched in the hatchery were recorded at d 0, which was the day of placement in the broiler house for the control chicks.

Patio System Description

The Patio system was built into a well-insulated house (Figure 1) and was set up in 2 rows (A), each consisting of 6 identical levels (further referred to as Patio units) on top of each other. The rows were separated by a central corridor (B) and 2 corridors at each other side of the rows (C). The dimensions of 1 Patio unit were 47.80 m (length) × 2.34 m (width) × 0.75 m (height), mounting up to a living area for the chicks of 110 m^2 per unit. Based on a bird density of 22 birds/m^2, each unit housed up to about 2,450 birds, resulting in a capacity of 29,400 birds for the total Patio system. The bottom of each level consisted of a synthetic moveable belt (further referred to as conveyor floor) on which the chicks were housed (Figure 2). At the start of each trial, the conveyor floor was covered with wood shavings (1 kg/m^2).

In the center of each Patio unit, at a height of 0.45 m above the conveyor floor, a rail system was installed to hold egg trays during hatching (E in Figure 2). Egg trays containing 18-d incubated eggs were inserted at the front end of the system by means of an automatic elevator and a chord conveyor system. Eggs were positioned in the tray in a vertical position, with the air chamber up. At the side facing the central corridor between the 2 system rows, low-capacity drinking nipples (type 10025-2 360, Impex, Barneveld, the Netherlands) were provided. Next to the nipples, a feeding line (Vencomatic BV) was equipped with 1 feeding pan per 61 birds.

Climate System. Outside air entered an air conditioning room (9 × 2 × 1 m) through an adjustable inlet at the front of the building (Figure 1). In this room, air could be mixed with exhausted air from the Patio house (internal circulation) or with preheated fresh air from an air-air heat exchanger (capacity of 15,000 m^3/h). In addition, the air in the air conditioning room could be heated by a water-filled radiator system. From thi`s conditioning room, air entered the insulated attic of the Patio house. For situations in which no heating

Table 1. Characteristics of the 3 locations where the Patio system was tested during 2006 to 2008

Location	Period	Patio unit dimensions, m (length × width × height)	Total living area of complete Patio system (m^2)	Bird age at removal from Patio (d)	Bird density (no./m^2)
1	May to Nov. 2006	32.2 × 1.43 × 0.40	553	7 to 14	55 to 90
2	Feb. 2007 to Aug. 2008	32.2 × 1.43 × 0.40	553	7 to 14	65 to 90
3	March 2008 to Aug. 2008	47.8 × 2.34 × 0.75	1.320	44 to 46	17 to 22

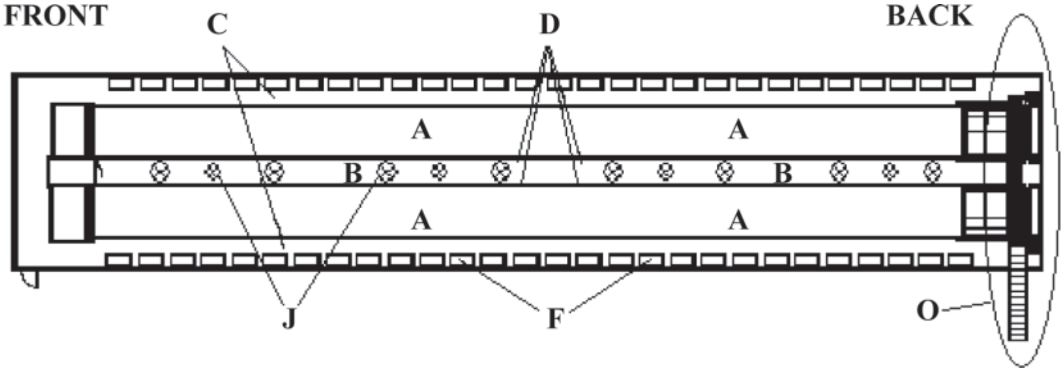

Figure 1. Schematic top view of the Patio system at location 3, consisting of 2 rows (A), with 1 central (B) and 2 outer corridors (C). Furthermore, the following items are indicated: position of the sensors used for control of the climate conditions (D), air inlet to outer corridors (F), exhaust fans (J), and the conveyor belt used for removal of the birds from the house (O).

was required, a bypass inlet directly allowed fresh air from outside to flow onto the attic. At the attic, air could be humidified by means of spray nozzles.

From the attic, the air entered the outer corridors of the Patio system through controllable openings in the ceiling (F in Figures 1 and 2). The air could be heated by a proportionally controlled warm water heating system, installed along the bottom side of the Patio system (G in Figure 2), thereby causing air movement and mixing in the outer corridors. Via air flow controlled balance valves (H), the air was distributed evenly over the Patio units. In this way, the temperature difference of the air entering the upper and lower Patio units was maximal 1°C.

Through a steel grid at the side of the central corridor between the 2 rows (I), air left the Patio units. From the central corridor between the 2 rows, air was removed via fans (J in Figures 1 and 2), thus creating negative pressure. In this way, air was drawn from the outer corridors over the birds toward the central corridor. The ventilation capacity was 180,000 m^3/h or about 6 m^3/h per bird, and the heating capacity was 120 kW or about 4 W per bird.

At high ventilation rates (indicating high inside temperatures), part of the air was drawn through the space between the upper and bottom side of the conveyor floor (K in Figure 2), thereby cooling the litter on the conveyor floor from below. This airflow was also controlled by balance valves, which were positioned at the side of the central corridor (L). Through the exhaust fans, the air was either removed from the house (M) or directed toward the air conditioning room via a duct (N) with a maximum capacity of 25,000 m^3/h. From this duct, part of the air could be directed toward the

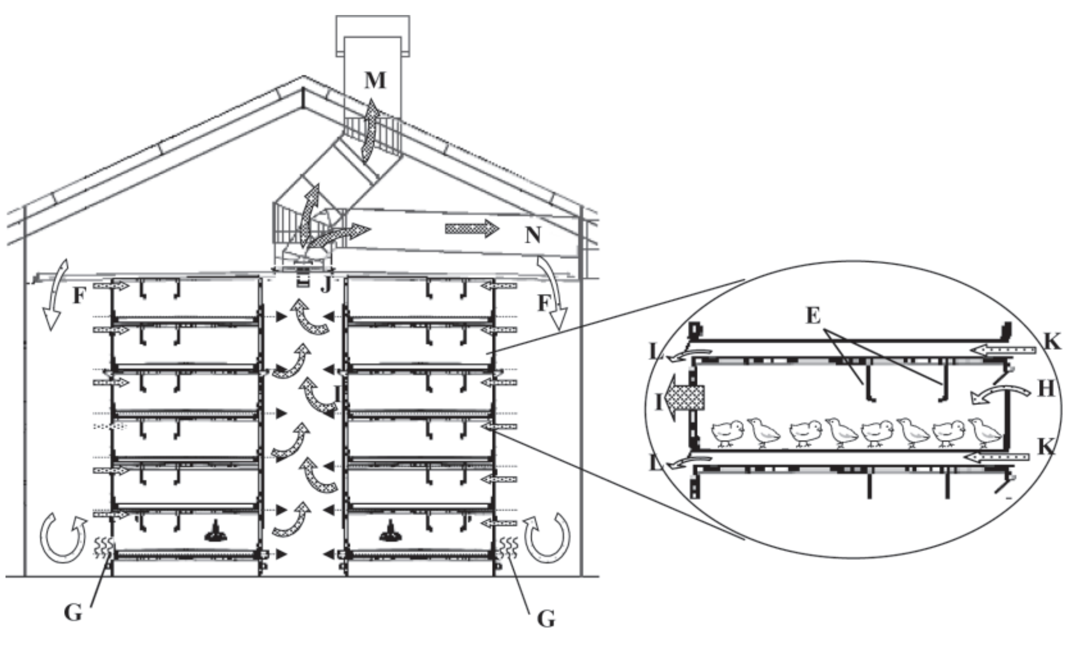

Figure 2. Schematic overview of the ventilation system in a Patio house at location 3: (left) front view of the entire house and (right) detail view of a Patio unit with egg tray holder (E), air inlet to outer corridors (F), water heating system (G), air inlet to the Patio unit (H), air outlet to the Patio unit (I), exhaust fan (J), airflow between conveyor floor (K), air outlet from space between conveyor floor (L), air outlet to outside air (M), and ducted return air connection (N).

heat exchanger to warm outside air entering the house, after which it was exhausted from the building.

Climate Control and Settings. Ventilation, heating, and humidifying were controlled by a computer system (Stienen BE, Nederweert, the Netherlands) using measurement data from 6 airflow sensors in the ventilation shafts and 1 CO_2 sensor, 4 temperature sensors, and 1 RH sensor positioned at a height of 4 m in the central corridor between the 2 rows (D in Figure 1). During hatch, climate set points were an air temperature of 34.5°C (observed air temperature surrounding the eggs about 35°C) and a minimum RH of 35%. The air was internally circulated until the CO_2 level reached 0.2%. From that moment on, a gradually increasing fraction of the air was taken from outside. After hatching, the temperature was decreased by 0.5°C per day during the first week and a gradual further decrease according to the recommendations of the breeding company (Cobb-Vantress, 2008). Minimum RH was increased to 45% and ventilation was increased with the growth of the birds or when the temperature in the Patio system was higher than the set point, or both.

Management of Eggs and Chicks

For all 3 locations, eggs produced by breeder flocks aged between 29 and 59 wk were obtained from commercial hatcheries in the Netherlands. At 18 d of incubation, eggs were removed from the incubator for candling and thereafter randomly assigned to be transferred to either a hatcher cabinet [Petersime, Zulte, Belgium (for location 1 and 3) and HatchTech, Veenendaal, the Netherlands (for location 2 and 3)] or to the Patio system. This means that the origin of the eggs, regarding parent flock, days of lay, storage duration, and apparent fertility was the same for both hatching systems. For eggs destined to hatch in the hatcher cabinet, conditions during candling followed standard procedures applied in the hatcheries. Infertile eggs were removed from the incubation trays, and apparently fertile eggs were transferred to hatcher baskets. In the event that high numbers of eggs were removed during candling, hatcher baskets were filled up with apparently fertile eggs from other trays, until they contained at least 120 eggs (at the hatcheries where control eggs for location 1 and 3 were hatched), or were not filled up (at the hatchery where control eggs for location 2 were hatched). After candling, the hatcher baskets with the eggs were placed in the hatcher cabinet for the last 3 d of incubation, during which a standard hatching program was used, with a set temperature starting at about 37°C and a minimum RH of about 50%.

For the eggs destined for Patio, the infertile eggs that were removed during candling were replaced by apparently fertile eggs from other trays. Thus, incubator trays containing 150 apparently fertile eggs were transported to the Patio in a climate-controlled truck at an air temperature of approximately 31°C. Upon receipt at the farm, the egg trays were inserted in the Patio system. The day of placement of the eggs in the Patio system was considered as d −3. Chicks started to hatch about 24 h after the eggs were inserted in the Patio. After hatch, chicks moved to the side of the egg tray or made their way through the opening in the egg tray underneath the eggshell and fell on the bedding, where feed and water were directly available. At d 0 or 1, egg trays with eggshells and unhatched eggs were removed from the system at the back (Figure 1). Chicks were raised at standard conditions of light and temperature, according to the guidelines of the breeding company. A commercially available broiler corn-wheat-soybean-based diet and water were provided ad libitum.

At an age of 7 to 14 d (location 1 and 2), or at slaughter age (location 3), birds were, level by level, removed from the system by moving the conveyor floor toward the back end of the system with a speed of circa 0.04 m/s. Here, the chickens moved onto a transverse conveyor belt (O in Figure 1), whereas the manure and litter fell down on another conveyor belt, which transported it to the manure storage. Via the transverse belt, broilers were conveyed to a loading platform (Ciemme Calabria, Cazzago San Martino, Italy), where they were distributed over transport containers, either to be transported to another poultry house or to the slaughter house.

Data Collection

When egg trays were removed from the system, the unhatched eggs were counted, and the number of hatched eggs was calculated as the total number of apparently fertile eggs minus the number of unhatched eggs. Hatchability in the Patio was calculated as the ratio of the number of hatched eggs to the number of apparently fertile eggs. In the hatchery, hatchability was calculated as the number of first grade chicks divided by the number of apparently fertile eggs. As a result, second grade chicks (nonmarketable chicks, showing physical anomalies, such as splayed legs, unhealed navels, unabsorbed yolk sac, or lacking alertness) were not included in the calculation of hatchability in the hatchery.

In each of the 21 trials in the Patio system, the numbers of dead broilers in the flock were recorded daily by the animal caretaker as a routine procedure. Cumulative 7-d mortality was calculated from the total number of birds that had died until d 7 divided by the total number of chicks present at d 0. No data are available on 7-d mortality of the control flocks in the broiler house. In 3 trials at location 3, within 6 h after the moment of placement of the hatchery birds in the broiler house, individual weights were collected of both Patio birds and hatchery birds.

Statistical Analysis

Hatchability results of eggs hatched in the Patio system and in the hatchery were analyzed in a GLM procedure (SAS Institute, 2004). The model was $Y_{ijkl} = \mu + T_i + C_j\ (T_i) + S_k + e_{ijkl}$, where Y_{ijkl} = hatchability; μ = overall mean; T_i = location (i = 1 to 3); C_j = trial nested within location (j = 1 to 9); S_k = hatching system (k = Patio or hatchery); and e_{ijkl} = residual error term. Before the analysis, hatchability data were transformed to arcsin square root. Hatchability data are presented as back-transformed least squares means.

Chick weights (n = 680) collected at location 3 were analyzed in a GLM procedure (SAS Institute, 2004). The model was $Y_{ijk} = \mu + C_i + S_j + e_{ijk}$, where Y_{ijk} = individual chick weight at d 0; μ = overall mean; C_i = trial (i = 1 to 3), S_j = hatching system (j = Patio or hatchery), and e_{ijk} = residual error term. Data on chick weights are presented as least squares means.

RESULTS AND DISCUSSION

Hatchability

Based on results of a total of 780,686 hatching eggs, hatchability in the Patio system was on average 1.45, 1.83, and 1.86% higher at location 1, 2, and 3, respectively, compared with control hatches in the hatchery (Table 2). Several factors may have contributed to this apparent difference in hatchability:

1) Part of the higher hatchability was probably due to the second grade chicks, which were removed in the hatchery before the number of chicks was computed by automated counting machines. In the Patio, hatchability was calculated as the ratio of the total number of hatched eggs to the total number of fertilized eggs, meaning that possible second grade chicks were included. To our knowledge, there is no scientific data available on mean percentages of second grade chicks at commercial hatcheries. Estimations of this percentage obtained through personal communication with several hatchery managers varied between 0.2 and 2.0%. It is known that the portion of second grade chicks varies with parental age, storage time, hatchery management, and incubation conditions (Lourens, 2002; Lourens et al., 2005).
2) The hatching process in the Patio system was not terminated by human intervention as it was in hatchery practice, when chicks were removed from the hatchers after approximately 21.5 d of incubation, and nonhatched eggs with potential viable chicks inside were wasted. In the Patio, egg trays were removed up to 6 h (location 1 and 3) or even 1 d later (location 2), and thus the higher hatchability may be partly due to chicks hatching after 21.5 d of incubation.
3) The hatchability from fertilized eggs really was higher in the Patio system compared with hatcher cabinets, which may be due to differences in climate conditions during hatching. The set point for air temperature during hatching of the control eggs in the hatchers was 36.5 to 37.0°C, whereas the temperature in the Patio was set at 34.5°C. During hatching, RH rose up to 90% in hatchers and remained around 40% in the Patio. Furthermore, in the hatchers, with capacities up to 28,800 chicken eggs, the volume of air per egg varied from 0.6 to 0.9 dm^3 depending on brand and type, whereas 4.4 to 7.3 (location 1 and 2) and 34.1 dm^3 (location 3) was available per egg in the Patio, depending on the Patio unit dimensions and the stocking density. In addition, air speed in the Patio was maximal 0.2 m/s, which is considered still air (Simmons et al., 2003). Air velocities in the hatchers were not determined, but it is known that in commercial incubation, high air velocities are required to remove the heat from the eggs effectively (Van Brecht et al., 2003). During the last phase of incubation, eggs produce considerable amounts of heat and effective heat removal from the eggs is crucial to prevent overheating and subsequent decreases in hatchability and chick quality (Lourens et al., 2005; Hulet et al., 2007; Leksrisompong et al., 2007). Combined with the lower set air temperature, the greater air volume in the Patio system may have enabled the heat dissipation from the eggs, even at a low air speed. Another possible factor that may have contributed to a difference in hatchability is the vertical position of the eggs

Table 2. Hatchability of apparently fertilized eggs in the Patio system and in the hatchery and 7-d mortality of chicks in the Patio system[1]

Location	Trials (n)	Hatching eggs (n)	Breed	Mean hatchability (%)[2] Patio	Control	Difference	7-d mortality in Patio (%)[3]
1	9	415,820	Ross 308/507/708	96.17 (95.58 to 96.71)	94.72 (94.05 to 95.36)	1.45**	1.27 (0.83 to 1.83)
2	9	246,966	Ross 308	97.60 (97.15 to 98.00)	95.76 (95.19 to 96.31)	1.83**	1.09 (0.72 to 1.73)
3	3	117,900	Cobb 500	95.53 (94.43 to 96.52)	93.67 (92.38 to 94.85)	1.86*	1.43 (0.91 to 2.34)
Total	21	780,686		96.49	94.75	1.73	1.21

[1]Control eggs originated from the same parent flock and were incubated simultaneously with eggs destined for the Patio system until d 18.

[2]Hatchability figures are back-transformed least squares means; 95% confidence limits in parentheses. The hatchability of control eggs hatched in the hatchery was based on at least 15,000 eggs per trial and was calculated after removal from second grade chicks.

[3]Raw mean 7-d mortality includes cull chicks; range in parentheses.

*$P \leq 0.05$; **$P \leq 0.01$.

in the Patio, which may facilitate the hatching process as was found in quail eggs (Mao et al., 2007), as opposed to the horizontal position of the eggs in the hatcher baskets. In addition, the relative silent environment in the Patio system may increase the possibility for embryos to communicate with each other, which has been shown to stimulate the hatching process in quail embryos (Vince, 1964).

Based on the results obtained in these trials, none of the factors can be excluded in the explanation of a possible difference in hatchability between the Patio and the hatchery. However, the results show that good hatchabilities can be achieved in a combined hatching-brooding system.

BW

At location 3, chick weights were collected in the Patio system and the broiler house at d 0. Birds hatched in the Patio system were 7.3 (16.3%), 7.0 (15.4%), and 5.5 g (11.6%) heavier in trials 1, 2, and 3, respectively ($P < 0.001$). These findings are in accordance with earlier reports on weight loss during posthatch holding of chicks before first access to feed and water. In broilers, BW loss up to 8% per 24 h occurs in this early posthatch period (Noy and Sklan, 1999a,b; Geyra et al., 2001; Bigot et al., 2003; Gonzales et al., 2003; Careghi et al., 2005). In hatchery practice, it may take up to 50 h until the first feed and water intake for the early hatched birds (Sklan et al., 2000; Careghi et al., 2005). The time until first feed and water intake for the chicks that hatched in the hatchery in the present study was not assessed, but it is likely that these birds had lost weight before being placed in the broiler house. In addition, the birds in the Patio system already had access to feed and water, and probably feed was present in their digestive tract or body growth had occurred at the moment of weighing at d 0 or both. In broilers, a weight gain of 6.91 to 15.03% in the first 48 h after clearing from the eggs was demonstrated when given immediate feed and water access, depending on the moment of hatching within the hatch window (Careghi et al., 2005).

Based on the present results, it is not known to what extent the observed differences in chick weight between birds that hatched in the hatchery and those that hatched in the Patio system resulted from weight loss of the hatchery birds or weight gain of the Patio birds, or both.

Chick Mortality

Mean cumulative 7-d mortality in the Patio was 1.27, 1.09, and 1.43% at location 1, 2, and 3, respectively (Table 2). These data are in accordance with results from a large epidemiological research study in the Netherlands during 2004 to 2006, in which the average mortality in the first week was 1.5% (Yassin et al., 2009). These figures agree with the mean 7-d mortality of 1.54% in a similar study on field data obtained from Norwegian broiler farms during 1996 to 1999 (Heier et al., 2002), and to the 1.55% mortality based on data collected from 38 broiler flocks at the research facilities of the University of Arkansas, Fayetteville (Tabler et al., 2004). It can be hypothesized that the early mortality in the Patio is not different from that in traditional broiler houses, although second grade chicks were not removed in a standard procedure in the Patio system as occurred in the hatchery. A possible reason for this observation could be that from the moment of hatching, climate conditions in the Patio system to a great extent corresponded to the recommendations for day-old chicks of the breeding company (Cobb-Vantress, 2008). The recommended conditions (temperature of 33°C, RH between 30 and 50%, and still air) were in contrast to the climate conditions in which the control birds in the hatchery hatched and remained until removal from the hatcher. Conditions during subsequent chick handling and transportation procedures, but also after placement in the broiler house, may not have been optimal for newly hatched birds. After hatch, the thermoregulatory system of chickens is limited (Nichelmann and Tzschentke, 2002) and warmth is a critical need to young birds. Early mortality in chickens and poults has been related to suboptimal truck temperatures and longer duration of transport from the hatchery to the farm (Carver et al., 2002; Chou et al., 2004). Low temperatures in the brooding phase lead to increased early mortalities in broiler chicks (Bruzual et al., 2000) and improper brooding conditions are a major important factor for decreased flock performance (Cobb-Vantress, 2008). Another factor, which can possibly explain the absence of increased mortality in birds hatched in the Patio system, is the immediate access to feed and water compared with the delay to which chicks in hatchery practice were exposed. Delays in the moment of first feed and water supply for the birds hatched in the hatchery were related to increased mortality in broiler flocks (Kingston, 1979; Carver et al., 2002; Chou et al., 2004).

In conclusion, combining the hatching and brooding phase in one system, as in the Patio, has proved to function as a promising alternative for current hatching and brooding systems, with regard to hatchability, early growth, and livability of broiler chicks. Further studies are required to determine to what extent the difference in hatchability is due to second grade chicks and to late hatchers, and to an actual higher hatching percentage.

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