MANAGEMENT AND PRODUCTION

Effects of floor eggs on hatchability and later life performance in broiler chickens

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ABSTRACT Two experiments were conducted in which effects of floor eggs, washed floor eggs, and clean nest eggs were investigated on incubation characteristics and performance in later life of broiler chickens. In both experiments, a young and an older breeder flock were used in a 3 × 2 factorial design during incubation. In the second experiment, male and female chickens were reared separately until d 35 of age in floor pens. During this grow out trial, an extra group was created in which chickens obtained from clean nest eggs were mixed with chickens obtained from floor eggs, meaning that grow out period was set up as a 4 × 2 × 2 factorial design with 4 egg types, 2 breeder ages, and 2 sexes. In both experiments, fertility and hatchability of fertile eggs were lower in floor and washed eggs than in clean nest eggs (hatchability: experiment 1: 74.4 vs. 70.6 vs. 92.6% for floor eggs, washed floor eggs and clean nest eggs, respectively, $P < 0.001$; experiment 2: 78.3 vs. 81.7 vs. 90.2%, respectively, $P < 0.001$). In experiment 2, BW at d 0 of chickens obtained from clean nest eggs was higher than that of chickens from floor eggs and washed floor eggs (41.5 vs. 40.4 and 40.3 g, respectively; $P < 0.001$). This difference disappeared during the grow out period and was absent at slaughter age at d 35 of age. Feed intake (FI), feed conversion ratio (FCR), and mortality during the grow out period were not affected by egg type. Incidence and severity of hock burns and footpad dermatitis were not affected by egg type or breeder age. Litter friability at d 35 of age tended to be lower in pens with chickens obtained from washed floor eggs compared to clean nest eggs. We conclude that incubation of floor eggs or washed floor eggs resulted in lower fertility and hatchability compared to clean nest eggs, but that performance during the grow out period was not affected.

Key words: broiler, floor eggs, incubation, hatchability, footpad dermatitis

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INTRODUCTION

The quality of the day-old chicken is important for the profitability of broiler production (Decuypere and Bruggeman, 2007). A good quality chicken starts with a good quality egg (Tona et al., 2005), meaning that eggs are clean, not broken, and not containing cracks (Khabisi et al., 2012). However, some of the eggs cannot fulfil these criteria, particularly when they are laid on the floor (De Reu, 2006). Floor eggs are more often dirty (Berrang et al., 1997), contain more bacteria on the eggshell (Berrang et al., 1997; De Reu et al., 2011), are more often broken, or contain more cracks than clean nest eggs (De Reu, 2006). Cracks are an ideal entrance route for penetrating bacteria (Ernst et al., 1998). Cracked eggs have been shown to result in lower hatchability, poorer chicken quality at hatch, and/or higher mortality in later life (Barnett et al., 2004; Khabisi et al., 2012) than intact eggs. Consequently, it is possible that floor eggs (with more cracks and more bacteria on the eggshell) will be more easily penetrated by bacteria (Smeltzer et al., 1979) before and during incubation, resulting in lower hatchability (Heier and Jarp, 2001) than clean nest eggs. Deeming et al. (2002) found evidence that the lower hatchability in floor eggs was caused by a higher microbial infection rate of the yolk sac in unhatched broiler embryos. However, data about effects of floor eggs on hatchability, chicken quality, and later life performance remain limited, although the economic impact of floor eggs can be considerable. The percentage of floor eggs, particularly in young breeder flocks, can be up to 20% (Cooper and Appleby, 1996; Sheppard and Duncan, 2011) and not incubating them can result in considerable losses for a breeder farm.

To potentially reduce negative effects on hatchability and chicken quality, floor eggs are often washed before incubation. Washing eggs reduces the bacterial

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contamination of the eggshell (Berrang et al., 1997; Hutchinson et al., 2006) immediately after washing, but in table eggs no effect of washing on bacterial penetration was found (Samiullah et al., 2013). During washing of eggs, the cuticle of the eggshell can be damaged and it has been suggested that this increases the risk of bacterial contamination of eggs (Alls et al., 1964; Gole et al., 2014), suggesting that washing eggs will not help to reduce the negative effects of floor eggs on bacterial contamination and consequently hatchability. However, data about consequences of incubating (washed) hatching floor eggs on hatchability and later life performance are very limited.

The aim of this study was to investigate effects of floor eggs and washed floor eggs on hatchability, chicken quality, and later life performance in broiler chickens.

MATERIALS AND METHODS

Experimental Design

Two experiments were conducted in which effects of egg type (floor eggs, washed floor eggs, or clean nest eggs) and breeder age on incubation characteristics and later life performance of broilers were investigated. The first experiment ended at the moment of hatch in which fertility, moment of embryonic mortality, and hatchability were determined. In the second experiment, the same variables were determined, but additionally chickens were reared until slaughtering at 35 d of age and BW, feed intake (**FI**), feed conversion ratio (**FCR;** total feed intake/total weight gain), and mortality were determined, as well as hock burns and foodpad dermatitis (**FPD**) incidence and litter friability. All experimental procedures were approved by the institutional Animal Use and Care Committee of the Animal Sciences Group (Lelystad, the Netherlands).

Experiment 1

The experiment had a 3 × 2 factorial design with egg type (floor eggs, washed floor eggs, or clean nest eggs) and broiler breeder age as factors. Eggs from 2 commercial Ross 308 broiler breeder flocks, aged 27 and 59 wk, were collected. From each flock, clean nest eggs and floor eggs were obtained. Floor eggs were laid in the litter on the floor and could contain manure on the eggshell. Obtained nest eggs were visually clean. Half of the floor eggs from both flocks were washed at one of the farms. Eggs were washed in a jet washer for approximately 5 min at a temperature between 40 and 45°C with tap water and the detergent Inciprop Egg (Ecolab, Nieuwegein, The Netherlands). The other half of the floor eggs were not washed and used as they were.

After collection, all eggs were transported to the hatchery of Wageningen University (Wageningen, The Netherlands) and incubated in one of two incubators (HatchTech, Veenendaal, The Netherlands) with a capacity of 1,408 eggs each. After arrival, all eggs were disinfected (fogging) with Desbest 400 (Frans Veugen Bedrijfshygiëne B.V., Nederweert, The Netherlands; active substances: hydrogen peroxide, acetic acid, and peracetic acid). Floor eggs (n = 792; n = 9 trays) and washed floor eggs (n = 652; n = 8 trays) were put together in one incubator, whereas the clean nest eggs (n = 1,032; n = 12 trays) were put in the other incubator. The washed floor eggs were put in the upper trays of the incubator, whereas the floor eggs were incubated in the lower trays. Eggs of both flock ages were placed on separate trays, and within each incubator and egg type, trays containing eggs of the 2 breeder flocks were alternately placed into the incubator.

On 5 eggs in each incubator Pt-100 thermistors were attached to the equator of the egg, using heat conducting paste (Dow Corning 240 heat Sink Compound, Dow Corning GmbH, Wiesbaden, Germany) and a small piece of tape. These thermistors were used to maintain eggshell temperature (**EST**) at 37.8°C throughout incubation for both incubators. EST was based on the median temperature of the 5 thermistors and incubator temperature was adjusted to maintain the EST at the required level (Lourens et al., 2006). Relative humidity was maintained between 55 and 60%. At d 7, 10, 14, and 18, eggs were candled and infertile eggs or eggs containing a dead embryo were removed. At d 18 of incubation, eggs containing a live embryo were moved to hatching baskets (per egg type and breeder age) and these baskets were placed back in the same incubators. From that moment onward, the incubator temperature was fixed at a constant value that corresponded to a constant EST of 37.8°C and EST was allowed to change. Relative humidity was maintained between 55 and 60%. At d 21.5 of incubation, all chicks were removed from the incubators and number of hatched chicks was counted per incubator tray, type of eggs, and breeder age. A break out analysis was performed on all eggs that were removed from the incubators at d 7, 10, 14, and 18, and eggs that did not hatch. These eggs were classified as unfertile or moment of dead as described by Lourens et al. (2006) and thereafter mortality was classified as early (d 0 to 3), middle (d 4 to 10), or late (d 10 to hatch).

Incubation (Experiment 2)

The incubation phase of experiment 2 was set up again as a 3 × 2 factorial design with egg type (floor eggs, washed floor eggs, clean nest eggs) and breeder flock age (30 and 50 wk; other flocks than in experiment 1) as factors. From both breeder flocks, 480 clean nest eggs and 780 floor eggs were obtained. Half of the floor eggs were washed, using the same procedure at described in experiment 1. On arrival of the eggs at the hatchery, they were disinfected with Desbest 400, as described for experiment 1. Eggs were incubated separately per egg type in one of three incubators (HatchTech, Veenendaal, The Netherlands). Per incubator, eggs of both flock ages were placed on separate trays, which were alternately placed in the incubator. At d 18 of incubation eggs were candled and fertile eggs were placed in hatching baskets, which were placed back in the same incubator. At d 21.5 of incubation, the incubation process was terminated and chickens were pulled from the incubators and number of hatched chicks was counted per incubator tray, type of eggs, and breeder age. A break out analysis was performed on all eggs that were removed from the incubators at d 18 and eggs that did not hatch. These eggs were classified as unfertile or moment of dead as described for experiment 1.

After pulling, chickens were classified as first or second grade chickens. A chicken was classified as first grade when it was clean and without deformities or lesions. Other chickens were classified as second grade. Thereafter, chickens were feather sexed and transported in cardboard boxes per type of egg and breeder age to the research accommodation of the Central Veterinary Institute (Lelystad, The Netherlands), where the grow out experiment was conducted.

Grow out (Experiment 2)

At the grow out facility, chickens were used in a 4 × 2 × 2 factorial design. Factors were egg type (floor eggs, washed floor eggs, clean nest eggs, and a mixture of chickens from floor eggs and clean nest eggs, named the mixed group), flock age (30 and 50 wk), and sex (males and females). Chickens were placed in floor pens (0.75 m^2) bedded with wood shavings (2 kg/m^2) per egg type, breeder age, and sex with 12 chickens per pen. Pens of the mixed groups consisted of 10 chickens obtained from clean nest eggs plus 2 chickens obtained from floor eggs, to simulate practical circumstances in which chickens from floor eggs and clean nest eggs are placed together in one broiler house. At placement of the hatchlings in the pens, 3 chickens per pen were randomly colored with UV spray. At d 11, the number of chickens per pen was reduced to 10, by removing maximal two of the colored chickens. In the mixed groups, chickens obtained from floor eggs were colored as well to ascertain that at d 11 these chickens were not removed. Each combination of egg type and breeder age was repeated 14 times (7 times with males, 7 times with females), meaning that in total 112 pens were used, which were divided in 7 blocks of 16 pens. Each block contained one pen of each combination of egg type, breeder age, and sex. Within each block, the 16 pens were randomly allotted to treatments.

All pens were situated in one broiler house, which was mechanically ventilated. Temperature at d 1 was set at 34°C, which was decreased to 20°C at d 28 of age and remained at that level until slaughter at d 35 of age. The first two days after placement, chickens received continuous light (24L:0D) and thereafter a light schedule of 18L:6D was used throughout the grow out period. Light intensity at pen level was 20 lux throughout the grow out period. All chickens received the same commercially available three phase diet. From d 1 to 11 chickens were provided a starter diet (ME: 2,975 kcal/kg, CP: 214 g/kg; dig. Lysine (Lys): 12.1 g/kg; dig. Methionine (Met): 6.1 g/kg; dig. Methionine plus Cysteine (M+C): 9.0 g/kg; 2.3 mm pellet), from d 12 to 28 a grower diet (ME: 3,010 kcal/kg, CP: 204 g/kg, dig. Lys: 10.9 g/kg; dig. Met: 5.4 g/kg; dig. M+C: 8.3 g/kg; 3.0 mm pellet), and from d 29 to 35 a finisher diet (ME: 3,035 kcal/kg, CP: 192 g/kg, dig. Lys: 9.8 g/kg; dig. Met: 4.9 g/kg; dig. M+C: 7.6 g/kg; 3.0 mm pellet). Both feed and water were available ad libitum throughout the grow out period. Chickens were vaccinated at the hatchery against Infectious Bronchitis (spray; Poulvac IB primer, Zoetis, Capelle aan de IJssel, The Netherlands), at d 14 against Newcastle Disease (spray; Nobilis Clone 30, MSD, Boxmeer, The Netherlands), and at d 21 against Gumboro (drinking water; Nobilis Gumboro D78, MSD, Boxmeer, The Netherlands).

Measurements Grow Out Period

At d 0 (placement), 11, 28, and 35 of age, chickens were weighed per pen. FI per pen was determined on the same days. Based on these measurements, BW gain in the different periods and FCR (not corrected for BW) were calculated. Mortality was registered on a daily basis.

At d 10, 28, and 35 of age, litter quality was visually scored by a panel of three persons. These persons scored friability/wetness of the litter in each pen on a 1 to 10 point scale (1 = completely caked/very wet litter and 10 = 100% friable/dry litter).

At d 35 of age, individual chickens were visually evaluated for hock burns (scale 0 to 4; Welfare Quality, 2009) and footpad dermatitis (scale 0 to 2; Berg, 1998) by the same experienced person. Both scores were averaged per pen.

Statistical Analyses

All data were analyzed with SAS (SAS 9.2, 2009) for each experiment separately. Fertility, moment of embryonic mortality, and hatchability of eggs were analyzed with a Generalized Linear Model (GLM) with egg type (clean nest egg, floor egg, washed floor egg) and breeder age (young, old) and their interaction as explaining factors. Incubation tray was used as the experimental unit.

Data from the grow out period of experiment 2 were analyzed with a GLM with block (1 to 7), egg type (clean nest egg, floor egg, washed floor egg, mixed group), breeder age (young, old), sex (females, males) and the 2 and 3-way interactions between egg type, breeder age, and sex as explaining factors. Preliminary analyses demonstrated a lack of significance for any of the variables tested for the 3-way interaction and the 2-way interactions between egg type × sex and between breeder age × sex. Consequently, these interactions were deleted from the model, meaning that only the interaction between egg type × breeder age remained in the model besides the main factors. Pen was used as the experimental unit for all performance variables, including measurements on individual chickens (hock burns, FPD).

Homogeneity of variance was tested for both means and residuals before analyses. Data are expressed as least square means (**LSMeans**) ± SEM. Differences between treatments were considered as significant at $P \leq 0.05$ and LSMeans were compared after correction with Bonferonni for multiple comparisons.

RESULTS

Experiment 1

No interaction between egg type (clean nest eggs, floor eggs, or washed floor eggs) and breeder age was found for any of the incubation variables (Table 1). Fertility of set eggs was higher in clean eggs than in floor and washed eggs (Δ = 10.3 and 8.8%, respectively; $P < 0.001$; Table 1). Percentage rotten eggs was higher in the floor eggs than in clean and washed eggs (Δ = 5.4 and 3.3%, respectively; $P < 0.001$). Hatchability of fertile eggs was higher in clean eggs than in floor and washed eggs (Δ = 18.2 and 22.0%, respectively; $P < 0.001$). When hatchability was calculated as percentage of set eggs, differences between clean eggs and floor or washed eggs, were even larger (Δ = 22.3 and 24.0%, respectively). This lower hatchability in floor and washed eggs was due mainly to higher mortality rate during the first 3 d of incubation, but smaller effects were found between d 4 and 10 and after d 10 as well.

Eggs from young broiler breeders (27 wk) had lower fertility (Δ = 13.3%; $P < 0.001$), higher late mortality (Δ = 5.3%; $P = 0.02$), and lower hatchability of set eggs (Δ = 15.3%; $P < 0.001$) than older broiler breeders (59 wk). Hatchability of fertile eggs tended to be lower in young breeders than in the older breeders (Δ = 8.0%; $P = 0.06$).

Experiment 2

Interactions between egg type (clean nest eggs, floor eggs, or washed floor eggs) and breeder age were found for early (d 0 to 3) and late (>10 d) mortality and for hatchability of fertile and set eggs. For all these variables, no effects of egg type were found in the young broiler breeders (30 wk), but in the older broiler breeders (50 wk), clean eggs resulted in lower early and late mortality and higher hatchability than floor and washed eggs (Table 2).

Percentage of rotten eggs was higher in the floor and washed egg than in the clean eggs (Δ = 3.1 and 2.1%, respectively; $P = 0.006$). Mortality between d 4 and 10 of incubation was higher in floor eggs than in clean eggs (Δ = 5.0%; $P = 0.03$), with washed eggs in between and not different from both other egg types.

No interaction between egg type and breeder age was found for BW, FI, FCR, and mortality during the grow out period until d35 of age (Table 3). At d 0 of age, BW of chickens obtained from clean eggs was higher than that of chickens obtained from floor and washed

Table 1. Effect of type of egg type (clean nest egg, floor egg, washed floor egg) and broiler breeder age (27 or 59 wk) on fertility, mortality, and hatchability (experiment 1; LSmeans).

	Fertility, % of set	Rotten, % of set	Mortality, % of fertile[1]			Hatchability, % of fertile	Hatchability, % of set
			Early	Middle	Late		
Egg type							
Clean	84.2[a]	0.0[b]	3.6[b]	1.9[b]	1.9[b]	92.6[a]	78.0[a]
Floor	73.9[b]	5.4[a]	13.0[a]	5.1[a,b]	7.6[a]	74.4[b]	55.7[b]
Washed	75.4[b]	2.1[b]	14.3[a]	7.9[a]	7.1[a,b]	70.6[b]	54.0[b]
SEM	1.8	0.7	2.0	1.3	3.8	3.1	3.1
Breeder age							
27	71.2[b]	2.8	10.1	6.0	8.2[a]	75.7	54.9[b]
59	84.5[a]	2.2	10.5	3.9	2.9[b]	82.7	70.2[a]
SEM	1.4	0.6	1.6	1.1	1.2	2.5	2.5
Egg type × Breeder age							
Clean × 27	79.4	0.0	4.7	2.4	2.2	90.7	72.0
Floor × 27	65.9	6.8	14.9	5.4	10.8	68.9	45.9
Washed × 27	68.3	1.7	10.7	10.2	11.6	67.5	46.9
Clean × 59	89.0	0.0	2.6	1.3	1.6	94.4	84.0
Floor × 59	82.0	4.0	11.0	4.8	4.4	79.9	65.5
Washed × 59	82.4	2.5	17.9	5.6	2.7	73.8	61.2
SEM	2.5	1.0	3.0	1.8	2.2	4.3	4.5
P-values							
Egg type	<0.001	<0.001	0.002	0.02	0.02	<0.001	<0.001
Breeder age	<0.001	0.68	0.88	0.18	0.02	0.06	<0.001
Egg type × Breeder age	0.39	0.46	0.17	0.54	0.26	0.58	0.65

[1]Early = d 0 to 3; Middle = d 4 to 10; Late = d 10 to hatch.
[a,b]LSmeans lacking a common superscript within a column and factor differ ($P < 0.05$).

Table 2. Effect of type of egg type (clean nest egg, floor egg, washed floor egg) and broiler breeder age (30 or 50 wk) on fertility, mortality, hatchability, and first grade chickens (experiment 2; LSmeans).

	Fertility, % of set	Rotten, % of set	Mortality, % of fertile[1]			Hatchability, % of fertile	Hatchability, % of set	1e grade chickens, %[2]
			Early	Middle	Late			
Egg type								
Clean	95.3[a]	0.0[b]	2.3	3.1[b]	4.3	90.2	86.0	99.1
Floor	86.7[b]	3.1[a]	7.6	8.1[a]	5.9	78.3	68.5	99.0
Washed	87.5[b]	2.1[a]	5.7	6.5[a,b]	6.2	81.7	72.2	99.4
SEM	1.6	0.5	0.9	1.3	1.2	2.4	2.5	0.6
Breeder age								
30	95.8[a]	0.8[b]	2.4	4.4	4.4	88.8	85.1	99.7
50	83.9[b]	2.7[a]	8.1	7.4	6.6	78.0	66.0	98.7
SEM	1.3	0.4	0.7	1.0	0.9	2.0	2.1	0.5
Egg type × Breeder age								
Clean × 30	98.0	0.0	1.9[b]	2.2	5.8	90.1[a]	88.3[a]	99.4
Floor × 30	94.9	1.8	3.3[b]	6.8	3.6	86.2[a,b]	82.0[a]	100.0
Washed × 30	94.5	0.6	2.1[b]	4.2	3.7	89.9[a]	85.1[a]	99.6
Clean × 50	92.6	0.0	2.9[b]	3.9	2.9	90.3[a]	83.6[a]	98.8
Floor × 50	78.6	4.4	12.0[a]	9.4	8.2	70.4[c]	55.1[b]	98.0
Washed × 50	80.4	3.7	9.3[a]	8.7	8.6	73.4[b,c]	59.3[b]	99.2
SEM	2.3	0.8	1.3	1.8	1.5	3.5	3.5	0.8
P-values								
Egg type	0.002	0.002	0.002	0.03	0.50	0.007	<0.001	0.85
Breeder age	<0.001	0.006	<0.001	0.06	0.12	<0.001	<0.001	0.13
Egg type × Breeder age	0.06	0.13	0.02	0.76	0.05	0.05	0.009	0.33

[1]Early = d 0 to 3; Middle = d 4 to 10; Late = d 10 to hatch.
[2]Percentage of hatched chickens; a chicken was considered as first grade when it was clean and without deformities or lesions.
[a–c]LSmeans lacking a common superscript within a column and factor differ ($P < 0.05$).

Table 3. Effect of type of egg type (clean nest egg, floor egg, washed floor egg, mixed group) and broiler breeder age (30 or 50 wk) on performance during the grow out period (experiment 2; LSmeans).

	BW d 0, g	BW d 11, g	BW d 28, g	BW d 35, g	FI d 0 to 35, g	FCR d 0 −35	Mortality d 0 – 35, %
Egg type							
Clean	41.5[a]	343[a]	1,764	2,509	3,587	1.45	4.5
Mixed	41.2[a]	337[a,b]	1,756	2,515	3,563	1.44	5.5
Floor	40.4[b]	337[a,b]	1,746	2,486	3,524	1.44	4.0
Washed	40.3[b]	334[b]	1,748	2,504	3,549	1.44	4.8
SEM	0.2	2	8	13	18	0.004	1.3
Breeder age							
30	36.8[b]	317[b]	1,708[b]	2,458[b]	3,471[b]	1.43[b]	5.0
50	44.9[a]	359[a]	1,799[a]	2,549[a]	3,640[a]	1.45[a]	4.4
SEM	0.1	2	6	9		0.003	0.9
Egg type × Breeder age							
Clean × 30	37.7	326	1,732	2,482	3,527	1.44	5.4
Mixed × 30	37.3	316	1,718	2,477	3,490	1.43	5.0
Floor × 30	36.0	315	1,697	2,438	3,440	1.43	3.3
Washed × 30	36.1	309	1,685	2,436	3,427	1.43	6.4
Clean × 50	45.4	360	1,795	2,537	3,647	1.46	3.6
Mixed × 50	45.1	359	1,794	2,553	3,636	1.45	6.1
Floor × 50	44.8	359	1,794	2,534	3,608	1.45	4.6
Washed × 50	44.4	359	1,810	2,573	3,671	1.45	3.3
SEM	0.3	3	12	19	25	0.005	1.8
P-values							
Egg type	<0.001	0.05	0.42	0.42	0.10	0.03	0.87
Breeder age	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.63
Egg type × Breeder age	0.18	0.08	0.07	0.14	0.09	0.90	0.56
Sex	0.73	0.002	<0.001	<0.001	<0.001	<0.001	0.02

[a,b]LSmeans lacking a common superscript within a column and factor differ ($P < 0.05$).

eggs, whereas this difference at d 11 of age was only significant between clean eggs and washed eggs with the floor eggs and mixed group in between and not different from both other groups. FCR between d 0 and 35 was 0.01 ($P = 0.03$) higher in the chickens obtained from clean eggs compared to the other three groups, but after correction with Bonferonni, this difference was no longer significant. Chickens obtained from older breeders had a higher BW at each measuring age and had a higher FI and FCR between d 0 and 35 than chickens

Table 4. Effect of type of egg type (clean nest egg, floor egg, washed floor egg, mixed group) and broiler breeder age (30 or 50 wk) on hock burns (score 0 to 4) and footpad dermatitis (score 0 to2) at d 35 of age and on litter friability (score 0 to 10) at d 10, 28, and 35 of age (experiment 2; LSmeans).

	Hock burn	Footpad dermatitis	Friability d 10	Friability d 28	Friability d 35
Egg type					
Clean	2.1	1.1	$8.3^{a,b}$	3.7	2.9
Mixed	2.1	1.1	8.5^{b}	3.5	2.8
Floor	2.1	1.3	8.2^{a}	3.7	2.7
Washed	2.3	1.3	$8.4^{a,b}$	3.4	2.5
SEM	0.05	0.07	0.07	0.12	0.11
Breeder age					
30	2.2	1.3	8.4	3.6	2.6^{b}
50	2.2	1.1	8.4	3.6	2.9^{a}
SEM	0.03	0.05	0.05	0.09	0.08
Egg type × Breeder age					
Clean × 30	2.1	1.3	8.3	3.8	2.8
Mixed × 30	2.2	1.3	8.5	3.6	2.7
Floor × 30	2.2	1.3	8.3	3.6	2.5
Washed × 30	2.2	1.4	8.4	3.4	2.4
Clean × 50	2.1	1.0	8.3	3.6	3.0
Mixed × 50	2.1	1.0	8.5	3.6	3.0
Floor × 50	2.1	1.2	8.2	3.7	2.8
Washed × 50	2.3	1.3	8.5	3.5	2.6
SEM	0.07	0.10	0.10	0.17	0.16
P-values					
Egg type	0.08	0.15	0.02	0.33	0.05
Breeder age	0.88	0.08	0.82	0.79	0.03
Egg type × Breeder age	0.42	0.77	0.76	0.78	1.00
Sex	<0.001	0.48	0.12	<0.001	0.07

[a,b]LSmeans lacking a common superscript within a column and factor differ ($P < 0.05$).

obtained from the young breeders. Male chickens were heavier than females chickens from d 11 onward and had a higher FI, a lower FCR, and a higher mortality rate between d 0 and 35 of age (all $P < 0.05$; data not shown).

No interactions between egg type and breeder age were found for percentage chickens with hock burns or FPD and friability of the litter at different ages. Friability of the litter was lower (worse) in floor egg pens compared to mixed egg pens ($\Delta = 0.3$; $P = 0.02$; Table 4), with the other two groups in between and not different from both other groups. At d 35 of age, friability of the litter was lowest in the washed egg groups and highest in the clean eggs groups, but after correction for Bonferroni this difference was no longer significant.

Friability of the litter at d 35 of age was higher (better) in pens of chickens obtained from older breeders compared to younger breeders ($\Delta = 0.3$; $P = 0.03$). Male chickens had more hock burns and lower friability of the litter at d 28 of age than female chickens (data not shown).

DISCUSSION

This study was designed to investigate consequences of incubating floor eggs on hatchability and later life performance. Both experiments demonstrated a reduced fertility and hatchability in floor eggs and washed floor eggs, which is in agreement with Heier and Jarp (2001). They concluded from an epidemiologic study that incubating floor eggs in the hatchery reduced the hatchability of the total flock by 1.07%. Assuming this difference in flock hatchability due to floor eggs and a 20% lower hatchability in floor eggs than in clean nest eggs, it can be calculated that approximately 5% of all eggs delivered to the hatchery would have been floor eggs. Another explanation could be that the percentage of floor eggs would be lower than the proposed 5%, but that floor eggs negatively affect hatchability of clean eggs, e.g., by bacterial cross-contamination. Cooper and Appleby (1996) demonstrated in young broiler breeder hens (27 to 28 wk of age) a percentage of floor eggs of 5%, whereas Sheppard and Duncan (2011) demonstrated a considerably higher percentage of floor eggs (13.3%) in broiler breeder hens of 35 to 44 weeks of age. However, in the latter study, flock size was very limited with 10 hens per pen, which might have affected the percentage of floor eggs. Based on these data, it appears reasonable that delivering floor eggs to the hatchery can result in at least 1% lower flock hatchability. The approximately 20% lower hatchability in floor eggs compared to clean nest eggs in the current study is a bit higher than found by Tullett (1990) who indicated a difference of 10 to 15% in hatchability.

The difference in fertility can probably be explained by a complete lack of embryonic development after the start of incubation, meaning that, after candling at d 18 of incubation, no visual distinction could be made between infertile eggs and fertile eggs with early dead germs. The lower hatchability of floor eggs and washed floor eggs was due to a (non-significant) higher mortality in each stage of incubation. Because the percentage of rotten eggs was (numerically) higher in floor and washed eggs than in clean nest eggs, it appears that the increased embryonic mortality in floor and washed eggs can be partially explained by a higher bacterial penetration in these eggs, resulting in a higher embryonic death at each stage of incubation. Deeming et al. (2002) demonstrated that floor eggs resulted in a higher percentage of bacterial yolk sac contamination (43 vs. 11% in clean nest eggs), causing the death of embryos at approximately d 18 of incubation, even when the eggshell was intact. This suggests that bacteria indeed can pass the intact eggshell and consequently can negatively affect development and survival of embryos for example by infection of the yolk sac. The (numerically) higher percentage of rotten eggs in floor and washed eggs, increases the risk that other eggs will be contaminated after explosion of these rotten eggs. This can further increase the negative effects of contaminated eggs on overall hatchability and chicken quality.

In experiment 1, no interactions were found between egg type and breeder age, but the young breeder flock had lower fertility and hatchability, whereas in experiment 2, the negative effects of floor eggs and washed eggs on fertility and hatchability were found mainly in the old flock. These results suggest that breeder flock itself, rather than breeder flock age seems to determine effects of floor eggs on fertility and hatchability.

At hatch, BW of the chickens was lower in the floor and washed eggs than in the clean nest eggs. As floor eggs often have more cracks (De Reu, 2006) than clean nest eggs and washed eggs (partly) lose the cuticle, eggshell conductance can be affected, resulting in higher egg weight loss (Board and Halls, 1973) and consequently lower chicken BW at hatch (Burton and Tullett, 1983; Meir et al., 1984). So, it can be suggested that the lower BW at hatch might be explained by the higher egg weight loss during incubation. The difference in BW disappeared during the grow out period and at d 35 no difference was found for BW, FI, FCR, and mortality rate among treatment groups. It appears that hatchability is lower in floor eggs and washed eggs than in clean nest eggs, but once the chicken has hatched from floor and washed eggs, the quality is not different from chickens originating from clean nest eggs. This was also demonstrated by the lack of difference in percentage of second grade chickens at hatch.

The percentage of chickens affected by hock burns and FDP was not affected by egg type. The most important factor causing FDP is considered to be wet litter (Shepherd and Fairchild, 2010) and in turn an important factor for wet litter is intestinal health, related to diet composition (De Jong et al., 2012). Because in the current study hardly any effect was found of treatments on litter friability, no large effects on FDP and hock burns could be expected. However, although effects among treatment groups were not large and no effects on BW, FI, and FCR were found, chickens obtained from washed eggs demonstrated numerically the poorest litter friability and highest scores for hock burns and FDP. It can be speculated that bacterial contamination of hatching eggs and consequently chickens at hatch, still has a small effect on intestinal development, later resulting in higher moisture content of the feces and litter.

It can be concluded that incubation of floor eggs or washed floor eggs results in lower fertility and hatchability compared to clean nest eggs, but that performance during the grow out period is not affected.

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