Effect of hatch location and diet density on footpad dermatitis and growth performance in broiler chickens

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Primary Audience: flock supervisors, hatchery staff, researchers, extension services, veterinarians

SUMMARY

The effect of hatch location and diet density on the prevalence of footpad dermatitis and growth performance in broiler chickens was studied. Broilers (Ross 308), incubated at 2 different hatch locations but originating from the same parent stock, were subjected to 2 feeding programs differing in energy content (2,750 vs. 2,950, 2,850 vs. 3,050, 2,900 vs. 3,100, and 2,900 vs. 3,100 kcal/kg for starter, grower I, grower II, and finisher diets, respectively) in a 2 × 2 factorial design (6 replicates per treatment combination). Broilers were housed under conditions and managed according to Dutch practice. Hatch location did not affect hatching results nor the prevalence and severity of footpad dermatitis, but did affect BW gain, feed, and water intake. A significant interaction was found between hatch location and feeding program; broilers fed the low-energy (LE) program had a better performance when hatched at Location 2 than at Location 1, whereas performance was similar for the high-energy (HE) broilers hatched at both locations. Broilers fed the LE program had similar BW gain but a higher feed conversion due to a higher feed intake as compared to broilers fed the HE program. In addition, moisture content of the litter in the pens with LE birds was higher than in pens with HE birds. As a result, broilers fed the LE program had more footpad dermatitis and hock burns at d 36 as compared to broilers fed the HE program. It is concluded that the HE feeding program is preferred to prevent footpad dermatitis and hock burn, and with respect to growth performance. The differences in growth performance between the 2 hatch locations merit further study but indicate the importance of the incubation and hatching environment and posthatch handling in relation to the growth performance of broilers on-farm.

Key words: broiler, diet density, hatch location, footpad dermatitis, performance

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DESCRIPTION OF THE PROBLEM

Footpad dermatitis (**FPD**), also called footpad lesions or pododermatitis, is a welfare and economic concern in broiler chickens (e.g., [1, 2]). Severe FPD is in general considered to be painful for the birds [3], and because of its association with litter quality it also reflects other welfare aspects [4]. Wet litter is generally considered to be the most important factor causing FPD in broiler chickens [2]. Many factors contribute to the quality of the litter in broiler houses, either directly or by having an effect on broiler health or behavior. Examples are outside and house temperature and humidity, season, chicken breed, light program, light distribution, water pressure and line height,

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type of drinking system, type and depth of litter, and various nutritional factors [2, 5].

In a previous study on the prevalence of FPD in Dutch fast growing broiler chickens, it was found that farm management played a significant role in the prevalence of FPD [6]. Surprisingly, large differences were found between broilers from different hatcheries or even from different hatch locations of the same hatching company. From that particular study it could, however, not be determined if differences between hatcheries could be associated with differences related to the parent stock management confounded with hatch location or to specific conditions at the hatch location, or both [6]. Recently, it has been shown that breeder feed restriction programs (skip-a-day or every-day feeding) and incubation temperature programs affected histomorphological traits of footpads and may therefore have an effect on the risk to develop FPD [7]. However, in another study no relationship was found between incubation conditions and FPD [8]. It is therefore important to further elucidate why different FPD scores were found between hatcheries.

Nutrition is considered to be an important factor in the development of FPD, either by having an effect on feces consistency and thus on litter quality, or by improving skin health or skin strength [2, 5]. Nutritional factors that may have an effect on FPD are mineral levels (Na, K, Cl, Mg, Ca), levels and sources of protein, vitamin levels, use of nonstarch polysaccharide enzymes in wheat based diets, diet density [2], and feed form [5]. For example, excess levels of sodium or potassium increase water intake which leads to wet litter [9] and some feed ingredients like soybeans have high potassium levels and thus have similar effects on litter quality [10]. High levels of CP or feeding diets unbalanced in CP levels lead to wet droppings and increased risk for FPD [2]. In a study that examined the effects of diet density, 2 density levels were applied with equal protein:energy ratio. Broilers raised on the low-density diet had significantly less FPD compared with broilers fed the high-density diet [11]. Diet density also seemed one of the factors causing differences in FPD scores between feed companies in a previous study [6]. As a follow up, feed companies related to farms with contrasting FPD scores in that particular study were asked to provide the feed formulation used during the time of that study. Information received by these feed companies indicated that low FPD scores seemed to be linked to low-density diets and vice versa. However, if diet density indeed affects FPD in broiler chickens, then this should be further studied in a controlled experiment.

Aim of the current study was therefore to study if diet density affects FPD and growth performance in broiler chickens. Broilers were fed either a high- or a low-density feeding program with a difference in ME of about 200 kcal/kg for each feeding phase. In addition, as a first step to further elucidate the effect of hatchery on FPD in broiler chickens [6], broilers originating from the same parent stock were incubated at 2 locations of one hatching company that had different incubator types and applied different hatching management.

MATERIALS AND METHODS

Animals and Housing

The study was carried out between October and November 2012 at the research facilities of Schothorst Feed Research, Lelystad, The Netherlands. One-day-old broiler chickens (21,600 Ross 308 as hatched) were housed in 24 identical pens of 47.5 m^2 in 2 identical, climate controlled rooms until slaughter at 37 d age. Twelve pens per room were randomly assigned to the present study and treatments were equally divided over both rooms and over rows within a room. Each room was divided by a central corridor with 8 pens on both sides. Pens not assigned to the current study were used for another study (using broilers of the same batch) [1]. Per pen, 900 broilers were housed (19 chicks/m^2 at placement). White wood shavings (1 kg/m^2) were used as bedding material. Each pen had 11 feeder pans and 2 drinking lines with 72 nipples with drip cups. Environmental temperature was gradually reduced from 33°C at d 1 to 19°C at d 37. Lights were continuously on at d 1 and 2, and on d 37. From d 3 to 36 an intermittent lighting schedule was provided of 4L:4D and 4 periods of 3L:1D per 24 h. Light was off from 23:00 to 03:00, 06:00 to 07:00, 10:00 to 11:00, 14:00 to 15:00, and 18:00 to 19:00 hrs. Light intensity was 20 lux at animal height. Birds were vaccinated according to commercial practice, i.e., Infectious Bronchitis primer at d 1 at the

hatchery, Newcastle Disease at d 14, and Gumboro at d 22.

Treatments

Four treatments were applied in a 2×2 factorial design with 6 replicates per treatment combination: Hatch Location 1 or 2 (i.e., H1 and H2) and high-energy (**HE**) or low-energy (**LE**) feeding program, see below for details.

Hatch location. Broilers in the current study hatched from eggs incubated at 2 different locations (H1 and H2) of one hatching company. Both are commercial large scale single stage broiler hatcheries that have a weekly production of approximately 1.2 to 1.6 million broilers and are different in many aspects, such as incubator type (Pas Reform B.V., Zeddam, The Netherlands; and Petersime N.V., Zulte, Belgium) and specific management. H1 (Petersime incubators) was located 100-km northwest of H2 (Pas Reform incubators). Hatching eggs of one parent stock flock of 49 wk age were collected in a time period of 3 d. Per day, first grade hatching eggs were split into 2 similar batches and allotted to be incubated in one of the 2 hatcheries. In this study only first grade eggs weighing more than 50 g were used, and all second grade eggs such as floor eggs, misshapen eggs, double yolk eggs, and eggs with cracks, holes, dirt, or debris were excluded. Eggs were transported to both hatch locations in the afternoon of the third day, stored during 4 d and subsequently placed in the incubators at both hatch locations. Egg storage management was similar for both hatcheries (storage temperature between 16 and 18°C and RH between 60 and 70%). Eggs were incubated according to the hatcheries' best practices, and no deviations from optimal had been observed. One-day-old chicks were transported to the study farm on the same day for H1 and H2 in one climate-controlled lorry under similar climatic conditions (transport route from H2 via H1 to the study farm). Crates were marked per hatch location and 1-day-old chicks were placed in the pens simultaneously.

Study diets. Birds received a commercial multiphase diet, i.e., starter from d 0 to 10, grower I from d 10 to 18, grower II from d 18 to 28, and finisher from d 28 to 37. All diets were pelleted (3-mm die), except the starter diets (crumbles). In the starter phase (0 to 10 d) a complete diet was provided. From grower I phase onwards the ration consisted of a complement diet plus whole wheat. At the study facility, complement grower I, grower II, and finisher diets were mixed with 15, 20, and 30% whole wheat, respectively. Half of the treatment groups were fed a HE ration and half of the treatment groups were fed a LE ration, hereinafter indicated with HE program and LE program. Composition of the complement diets and the rations in the different feeding phases are provided in Tables 1 and 2. The feeding programs differed only in energy content, the HE diets were about 200 kcal/kg higher than the LE diets (Table 2) in each feeding phase; protein, vitamin, and mineral contents of both feeding programs were equal. Complement diets were produced and supplied (in bulk) by a commercial feed company in The Netherlands.

Measures

Hatching results. At the day of hatch, dead in shell were opened to determine true fertility and the timing of embryonic mortality by visual appraisal as described by Lourens et al. [12], for both hatch locations. Chicks were assigned second grade by the presence of any sign of suboptimal development as described by [13]. One-day-old chick weight was determined by weighing 2 crates (180 chicks) per pen at placement.

Litter quality. On d 14, 21, and 36 litter was sampled per pen. From every pen 3 samples were collected from the same locations relative to the water line and feeder line. A plastic round tube (diameter = 5.5 cm) was used to punch the samples from the top of the litter to the floor. Samples were immediately stored at −20°C and analyzed by Wageningen UR Livestock Research for moisture content (drying during 24 h at 105°C).

Footpad dermatitis and hock burn. Per pen, 20 males and 20 females were randomly selected at 21 and 36 d age and inspected. Footpad dermatitis was scored for both feet according to the 'Swedish' classification, i.e., score 0: no lesions or very small discoloration; score 1: discoloration but no deep lesion; score 2: deep lesion with ulcers or scabs, bumble foot [14]. Hock burns were scored for both hocks according to [15], with a score ranging from 0 (no hock burn) to 4 (large black spot).

Table 1. Composition and calculated contents of the study supplemental diets. Analyzed contents are shown between parentheses.

Period (Days)		Starter (d 1 to 10)[2]		Grower I (d 10 to 18)		Grower II (d 18 to 29)		Finisher (d 29 to 37)	
Diets[1]		HE	LE	HE	LE	HE	LE	HE	LE
Wheat	%	25.00	42.43	25.00	25.00	25.00	25.00	15.00	20.04
Corn	%	34.12	19.97	28.16	33.51	27.48	33.28	33.44	34.99
Soybean meal	%	28.09	24.97	27.77	26.97	27.91	27.06	29.57	28.35
Sunflower meal	%		2.50						
Rapeseed meal (00)	%	3.00	3.00	8.00	8.00	8.00	8.00	10.00	10.00
Fishmeal	%	1.50	1.50						
Soy lecithin	%	1.35		1.00	1.00	1.15		0.49	
Animal fat	%	2.00	1.18	4.51		6.53	1.98	7.00	1.00
Palm oil	%	0.91	0.33	1.74	1.69	0.57	1.30	1.22	2.31
DL-Methionine	%	0.25	0.23	0.25	0.24	0.25	0.24	0.27	0.26
L-Threonine	%	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.11
Lysine 50	%	0.32	0.39	0.41	0.43	0.43	0.45	0.49	0.52
Limestone	%	0.84	0.81	0.58	0.58	0.91	0.87	1.00	1.00
Monocalcium phosphate	%	0.91	0.94	0.54	0.52	0.36	0.41	0.27	0.28
Salt	%	0.09	0.12	0.15	0.15	0.16	0.16	0.17	0.17
Premix I		1.00	1.00	1.18	1.18				
Premix II						0.81	0.81	0.93	0.93
NSP-enzyme		0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Phytase enzyme				0.02	0.02	0.02	0.02	0.02	0.02
Coccidiostat (Maxiban)		0.50	0.50	0.59	0.59				
Coccidiostat (Salinomycine)						0.31	0.31		
		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutrients									
ME broiler	kcal/kg	2,950	2,750	3,048	2,812	3,110	2,860	3,117	2,831
CP	g/kg	218 (217)	220 (223)	220 (214)	220 (214)	220 (223)	220 (219)	229 (224)	229 (228)
Crude fat	g/kg	75 (74)	45 (49)	103 (96)	59 (58)	113 (111)	65 (68)	119 (117)	66 (69)
Crude fiber	g/kg	26 (24)	31 (33)	31 (31)	32 (30)	31 (33)	32 (34)	33 (34)	34 (33)
Crude ash	g/kg	57 (56)	58 (60)	54 (55)	54 (53)	51 (54)	51 (52)	53 (54)	53 (53)
Dig lysine	g/kg	11.6	11.6	12.0	12.0	12.1	12.1	13.0	13.0
Dig methionine	g/kg	5.5	5.4	5.4	5.4	5.4	5.4	5.8	5.8
Dig M+C	g/kg	8.5	8.5	8.5	8.6	8.5	8.5	9.0	9.0
Dig threonine	g/kg	7.5	7.5	7.7	7.7	7.7	7.7	8.1	8.1
Dig tryptophan	g/kg	2.3	2.3	2.3	2.3	2.3	2.3	2.4	2.4
Starch	g/kg	389 (368)	403 (377)	353 (345)	387 (358)	348 (318)	385 (355)	328 (307)	368 (345)
Available calcium	g/kg	10.7	10.7	9.8	9.8	9.3	9.3	9.9	9.9
Calcium	g/kg	9.4 (9.3)	9.4 (10.0)	7.9 (8.5)	7.9 (8.2)	7.4 (8.2)	7.4 (7.8)	7.6 (8.0)	7.6 (7.8)
available P	g/kg	4.4	4.4	3.8	3.8	3.4	3.4	3.5	3.5
Phosphorus (P)	g/kg	6.2 (6.3)	6.2 (6.8)	5.3 (5.5)	5.3 (5.6)	4.9 (5.3)	4.9 (5.1)	4.8 (5.1)	4.8 (5.1)
Sodium	g/kg	1.5 (1.5)	1.6 (1.9)	1.7 (2.0)	1.7 (1.8)	1.5 (1.7)	1.5 (1.9)	1.7 (1.8)	1.7 (1.7)
Potassium	g/kg	8.3	8.2	8.5	8.5	8.5	8.5	8.9	8.9

[1]Dig = Digestible; NSP = Nonstarch polysaccharide.

[2]HE = High-energy feeding program; LE = Low-energy feeding program.

Growth performance. BW was determined at d 37 by weighing all remaining birds per pen. Body weights at d 10, 18, and 28 were determined using an automated weighing plateau in the pen [16]. Feed intake and water intake were determined per pen per feeding phase (d 0 to 10, 10 to 18, 18 to 28, and 28 to 37). Mortality was recorded daily per pen.

Statistical Analysis

Fertility, embryo mortality, and hatchability of first and second grade chicks were analyzed using a generalized linear mixed model procedure for a binomial distribution with a logit link function. The generalized linear mixed model model produced log transformed values for the means, and back transformed means were used for further discussion. Embryo mortality and hatchability were analyzed as percentage of the fertile eggs, with incubator tray as study unit. The significance of differences between means was determined with the PDIFF option of the LSMEANS statement of Genstat software (Genstat Release 15.2). The model used was:

$$Y = \mu + \text{Hatchery}_i + \text{error}_i$$

Table 2. Calculated contents of the study diets/rations (supplemental diet + wheat).

		Starter (d 1 to 10)[2]		Grower I (d 10 to 18)		Grower II (d 18 to 29)		Finisher (d 29 to 37)	
		HE	LE	HE	LE	HE	LE	HE	LE
Percent supplemental diet		100	100	85	85	80	80	70	70
Percent whole wheat		0	0	15	15	20	20	30	30
Calculated nutrients									
ME broiler	kcal/kg	2,950	2,750	3,050	2,849	3,100	2,900	3,100	2,900
CP	g/kg	218	220	204	204	198	198	193	194
Crude fat	g/kg	75	45	90	53	94	56	89	52
Crude fiber	g/kg	26	31	30	31	30	30	30	31
Crude ash	g/kg	57	58	48	48	44	44	41	42
Dig lysine[1]	g/kg	11.6	11.6	10.6	10.6	10.2	10.2	9.9	9.9
Dig methionine	g/kg	5.5	5.4	4.9	4.8	4.7	4.6	4.5	4.5
Dig M+C	g/kg	8.5	8.5	7.8	7.8	7.6	7.6	7.4	7.4
Dig threonine	g/kg	7.5	7.5	6.9	6.9	6.6	6.6	6.4	6.4
Dig tryptophan	g/kg	2.3	2.3	2.1	2.1	2.1	2.1	2.0	2.0
Starch	g/kg	389	403	387	415	394	423	402	430
Available Ca	g/kg	10.7	10.7	8.4	8.4	7.5	7.5	7.0	7.0
Ca	g/kg	9.4	9.4	6.8	6.8	6.0	6.0	5.4	5.4
oP	g/kg	4.4	4.4	3.4	3.4	3.0	3.0	2.8	2.8
P	g/kg	6.2	6.2	5.0	5.0	4.5	4.5	4.3	4.3
Na	g/kg	1.5	1.6	1.5	1.5	1.2	1.2	1.2	1.2
K	g/kg	8.3	8.2	7.9	7.9	7.6	7.6	7.5	7.5
Cu	mg/kg	15.0	15.0	15.5	15.5	15.5	15.5	15.9	15.9
J	mg/kg	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Fe	mg/kg	80	80	80	80	60	60	50	50
Mn	mg/kg	80	80	80	80	60	60	60	60
Zn	mg/kg	100	100	100	100	80	80	80	80
Se	mg/kg	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Co	mg/kg	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vitamin A	IU/kg	12,000	12,000	12,036	12,036	11,953	11,953	10,015	10,015
Vitamin D3	IU/kg	3,500	3,500	3,511	3,511	2,988	2,988	2,504	2,504
Vitamin E	IU/kg	100	100	100	100	60	60	60	60
6-Phytase	phytase units	350	350	425	425	440	440	455	455
Endo-1,4-beta-xylanase	endo-pentosanase units/kg	2,182	2,182	2,202	2,202	2,182	2,182	2,195	2,195
Nicarbazin	mg/kg	50	50	50	50	0	0	0	0
Narasin	mg/kg	50	50	50	50	0	0	0	0
Salinomycine	mg/kg	0	0	0	0	69	69	0	0

[1]Dig = Digestible.

[2]HE = High-energy feeding program; LE = Low-energy feeding program.

Where:

Y: Response parameter
μ: General mean
Hatchery: Effect of hatch location (i = 1, 2)
error: Error term

The further study was carried out as a 2 × 2 factorial trial, with feeding program (high or low dietary energy program; HE or LE) and hatchery location (Location 1 or 2; H1 or H2) as factors, pen as study unit, and room and row within the room as blocking factors. Data were first analyzed for outliers (Doornbos test [17]). Significant outliers (i.e., observed value with residual outside the range of 2.5* SE of residuals) were excluded from the dataset prior to statistical analysis. Data were statistically analyzed by ANOVA using the following model:

$$Y_{ijklm} = \mu + Room_i + Block_j + Diet_k + Hatchery_l + Diet * Hatchery_{kl} + error_{ijklm}$$

Where:

Y: Response parameter
μ: General mean
Room: Effect of climate room (i = 1,2)

Table 3. Hatching results and chick quality of chicks of 2 different hatch locations (H1 and H2, see description in the Methods section).

	H1	H2	SEM	*P*-value
Hatching results				
Cracks[1] (%)	0.83	0.83	0.11	1.000
Rots[1] (%)	0.33	0.25	0.08	0.580
Infertiles[1] (%)	11.26	11.21	0.42	0.956
Embryonic mortality[2]	*5.88*	*6.21*	*0.33*	*0.630*
Early (d 1 to 2)	0.66	0.72	0.12	0.847
Blood ring (d 3)	1.37	1.37	0.18	1.000
Eye present (d 4 to 10)	1.00[A]	1.46[B]	0.13	0.069
Feathers present (d 11 to 17)	0.37	0.52	0.09	0.383
Large yolk remains outside body (d 18 to 20)	1.38	1.09	0.17	0.319
Ready to hatch (d 21)	1.10	1.05	0.16	0.843
Dead and second grade chicks	0.15	0.19	0.06	0.681
First grade chicks	93.97	93.60	0.33	0.810

[1]Expressed as percent eggs set.

[2]Expressed as percent fertile eggs.

[A,B]Different superscripts within a row indicate a tendency ($0.05 \leq P \leq 0.10$).

Block: Effect of row within room (j = 1,2)
Diet: Effect of dietary energy level (k = 1,2)
Hatchery: Effect of hatch location (l = 1,2)
Diet∗Hatchery: Interaction effect between diet and hatchery
Error: Error term

Effects with $P \leq 0.05$ were considered to be statistically significant, whereas $0.05 < P \leq 0.10$ were considered trends. All analyses were performed using Genstat Release 15.2, VSN International Ltd.

RESULTS AND DISCUSSION

Incubation of eggs, from the same parent stock and collected simultaneously, at 2 different locations of one hatching company did not result in different hatching results (Table 3). Weights of the 1-day-old chicks at placement did also not differ (H1: 44.9 ± 0.4 g; H2: 45.0 ± 0.2 g). However, during the growth period, broilers from a different hatch location differed in feed and water intake and in BW gain (Table 4). With respect to BW gain, there was a significant interaction between hatch location and diet density (Table 4). Broilers fed the LE program had a significantly higher BW gain at d 37 when hatched at H2 as compared to broilers hatched at H1. In addition, a tendency for an interaction was found for feed intake; feed intake was highest for broilers fed the LE program and hatched at H2 as compared to broilers fed LE program and hatched at H1 or broilers fed the HE program (Table 4). FCR and water intake were significantly higher for the LE program as compared to the HE program (Table 4). Water:feed ratio and mortality were not affected by feed program and hatch location.

The finding of our previous study that broilers hatched at the 2 hatch locations differed with respect to prevalence of FPD [6] could not be confirmed in the current study, although numerically the results were in the same direction (more FPD at H2) (Table 5). There were also no differences in litter DM content, thus moisture level, between H1 and H2 (Table 6). Although there is some evidence that hatching conditions and breeder feed programs may affect the morphological aspects of feet, and thus might affect the risk to develop FPD [7], others have found opposite results with respect to incubation conditions [8]. Thus, the effect of breeder feeding programs or diets and incubation conditions on the risk to develop FPD clearly merits further study.

It is generally known that pre-incubation conditions (such as egg storage conditions, egg size, egg weight, age of breeders, etc.), incubation conditions (temperature, humidity, ventilation, turning, concentration of gases, etc.), and posthatch handling affect chick quality and later performance (see [18] for a review). In the

Table 4. Effect hatch location and diet density on technical performance results from 0 to 37 d age.

	BW gain (g)	Feed intake (g)	FCR	Water intake (mL)	Water: feed ratio	Mortality (%)
Treatment[1]						
LE H1	1,990[b]	3,335[b]	1.677	5,624	1.687	2.6
LE H2	2,128[a]	3,500[a]	1.645	5,822	1.663	2.6
HE H1	2,080[a]	3,293[b]	1.584	5,547	1.685	1.9
HE H2	2,099[a]	3,324[b]	1.584	5,649	1.700	2.6
LSD	84.8	101.4	0.04	156.6	0.05	0.68
P-value diet ∗ hatch location	0.05	0.06	0.26	0.38	0.32	0.11
Diet						
LE	2,059	3,417[a]	1.661[a]	5,723[a]	1.675	2.6
HE	2,089	3,309[b]	1.584[b]	5,598[b]	1.692	2.3
LSD	59.9	71.7	0.029	110.8	0.039	0.48
P-value	0.30	0.005	<0.001	0.03	0.37	0.19
Hatch location						
H1	2,035[b]	3,314[b]	1.631	5,586[b]	1.686	2.3
H2	2,113[a]	3,412[a]	1.615	5,736[a]	1.681	2.6
LSD	59.9	71.7	0.029	110.8	0.039	0.48
P-value	0.014	0.010	0.265	0.011	0.801	0.19

[a,b]Different superscripts within a column indicate a significant treatment effect ($P \leq 0.05$).

[1]LE = Low-energy feeding program; HE = High-energy feeding program; H1 and H2 = Hatch location.

Table 5. Effect of diet density and hatch location on the average score for hock burns and footpad dermatitis at 21 and 36 d age.

	d 21		d 36	
	Hock burn score[2]	FPD score[2]	Hock burn score[2]	FPD score[2]
Treatment[1]				
LE H1	0.91	0.75	1.81	1.09
LE H2	1.00	0.94	1.72	1.29
HE H1	0.96	0.63	1.48	0.84
HE H2	0.90	0.57	1.48	0.90
LSD	0.19	0.36	0.30	0.29
P-value diet ∗ hatch location	0.23	0.31	0.62	0.51
Diet				
LE	0.96	0.84[A]	1.76[a]	1.19[a]
HE	0.93	0.60[B]	1.48[b]	0.87[b]
LSD	0.13	0.25	0.21	0.21
P-value	0.65	0.06	0,01	0.004
Hatch location				
H1	0.94	0.69	1.64	0.96
H2	0.95	0.76	1.60	1.09
LSD	0.13	0.25	0.21	0.21
P-value	0.85	0.59	0.65	0.21

[a,b]Different superscripts within a column indicate a significant treatment effect ($P \leq 0.05$).

[A,B]Different superscripts within a column indicate a tendency ($0.05 \leq P \leq 0.10$).

[1]LE = Low-energy feeding program; HE = High-energy feeding program; H1 and H2 = Hatch location; LSD = Least significant difference.

[2]For hock burns and footpad dermatitis (FPD), the average score per treatment is presented.

Table 6. Effect of hatch location and diet density on DM content (grams per kilogram) of the litter sampled at 14, 21, and 36 d age.

	d 14	d 21	d 36
Treatment[1]			
LE H1	665	596	515
LE H2	643	576	527
HE H1	672	616	589
HE H2	673	623	593
LSD	53	36	44
P-value diet ∗ hatch location	0.54	0.28	0.76
Diet			
LE	654	586[b]	521[b]
HE	672	619[a]	591[a]
LSD	37	26	31
P-value	0.31	0.014	<.001
Hatch location			
H1	668	606	552
H2	658	599	557
LSD	37	26	31
P-value	0.56	0.59	0.60

[a,b]Different superscripts within a column indicate a significant treatment effect ($P \leq 0.05$).

[1]LE = Low-energy feeding program; HE = High-energy feeding program; H1 and H2 = Hatch location; LSD = Least significant difference.

current study, pre-incubation conditions were equal for H1 and H2, and only incubation conditions and posthatch handling differed between H1 and H2. No effects were found on hatching results, which could be expected because incubation conditions may have differed at both locations since for example different types of incubators were used [18]. However, growth performance differed between H1 and H2 and interacted with feeding program. This is an interesting finding that merits further study; as various factors such as incubating conditions (temperature, humidity, concentration of gases, etc.) and posthatch handling might have been different between both hatch locations, it is necessary to study these independently to unravel the underlying mechanisms.

Litter quality was significantly affected by feeding program. Pens with broilers fed the HE program had a significantly lower litter moisture content at 21 and 36 d age (Table 6). Differences in litter quality between the diet treatments were also reflected in the scores for FPD and hock burns (Table 5). Birds fed the LE program tended to have a higher (thus worse) FPD score at 21 d age and significantly higher (worse) hock burns and FPD score at 36 d age as compared to birds fed the HE program.

Based on the FPD scores per feed company from our previous study [6] and information on feed formulations as provided by most of these companies, we predicted that birds fed the LE program would have better FPD scores than birds fed the HE program. However, we found the opposite results. This might be explained by the fact that the diets as applied here only differed in energy and raw fat content and not with respect to the other nutrient content (e.g., protein, amino acids, vitamins, and minerals). Broilers fed the LE program increased their feed intake, resulting in a higher intake of e.g. proteins and minerals. Excess protein intake should be excreted which will be accompanied by increased water intake, resulting in wet litter which increases the risk for FPD and hock burns [2, 9, 10, 19]. An increased intake of minerals (Ca, Na, K) also results in an increased water intake and moisture content of the droppings and thus an increased risk of wet litter and FPD [9, 20]. The litter in pens with broilers fed the HE program had a lower moisture content as compared to the pens with broilers fed the LE program which indeed confirms earlier studies indicating that moisture content in the litter is an important risk factor for FPD [2]. It has been shown that broilers raised at 2 diet density levels with equal protein:energy ratio showed less FPD when raised on the low density diet as compared to being raised on the high density diet [11]. This indicates that LE diets potentially may decrease the risk for FPD on the condition that the diet formulation is adapted (adjusted to the lower energy level) to prevent excessive intake of protein and minerals. Also in the study of [11] BW gain was not affected by diet density.

An economic calculation was performed for feeding program and hatch location based on the technical performance results of the current study (Table 7). Lowest margin was found for broilers fed the LE program and hatched at H1; highest margin was found for broilers fed the LE program and hatched at H2. Margins of broilers fed the HE program were equal for both hatch locations and a bit lower as compared to LE/H2 broilers.

Table 7. Calculated economic results (in € cent per broiler placed) for the different combinations of hatch location and diet density[1].

	LE[2]		HE[2]	
Parameter	H1[2]	H2[2]	H1[2]	H2[2]
Live weight (g)	2.036	2.173	2.125	2.144
Feed conversion	1,677	1,645	1,584	1,584
Economic results				
Gross income (sale of birds) (A)	165,95	176,73	174,07	174,37
One-day-old chickens (B)	33,00	33,00	33,00	33,00
Feed costs (C)	102,38	107,32	105,81	105,99
Total variable expenses (D)	18,10	18,12	18,11	18,11
Gross margin [A-(B+C+D)]	**12,11**	**18,29**	**17,14**	**17,27**

[1]Calculations were based on reference values for Dutch broiler farms according to [21], a return price of €0,835/kg broiler delivered at slaughter, a feed price of €0.315/kg for the LE program, a feed price of €0.3308/kg for the HE program (feed prices according to indications of manufacturer), and a wheat price of €0.20/kg.

[2]LE = Low-energy feeding program; HE = High-energy feeding program; H1 and H2 = Hatch location.

CONCLUSIONS AND APPLICATIONS

1. Incubation and hatching broiler eggs from one parent stock at 2 hatch locations from one company did not result in differences in hatching results or FPD scores, but did result in a different BW gain, feed, and water intake.
2. Differences between hatch locations were mainly due to an interaction with feed program; growth performance of broilers fed the HE feed program were similar for both hatch locations, but significant differences in BW gain, feed, and water intake were found between hatch location when broilers were fed an LE feed program.
3. Providing broilers with an LE feed program resulted in more FPD and a worse feed conversion as compared to broilers that were fed a HE feeding program, taking into account that the diets were not isonitrogenous.
4. Therefore, with respect to FPD and growth performance, a HE feed program is preferred over a LE feed program when feeding nonisonitrogenous diets. The differences in growth performance between the 2 hatch locations merit further study but indicate the importance of the incubation and hatching environment and posthatch handling in relation to the performance of broilers on-farm.

REFERENCES AND NOTES

1. de Jong, I. C., H. Gunnink, and J. van Harn. 2014. Wet litter not only induces footpad dermatitis but also reduces overall welfare, technical performance, and carcass yield in broiler chickens. J. Appl. Poult. Res. 23:51–58.

2. Shepherd, E. M., and B. D. Fairchild. 2010. Footpad dermatitis in poultry. Poult. Sci. 89:2043–2051.

3. Michel, V., E. Prampart, L. Mirabito, V. Allain, C. Arnould, D. Huonnic, S. Le Bouquin, and O. Albaric. 2012. Histologically-validated footpad dermatitis scoring system for use in chicken processing plants. Br. Poult. Sci. 53:275–281.

4. Haslam, S. M., T. G. Knowles, S. N. Brown, L. J. Wilkins, S. C. Kestin, P. D. Warriss, and C. J. Nicol. 2007. Factors affecting the prevalence of foot pad dermatitis, hock burn and breast burn in broiler chicken. Br. Poult. Sci. 48:264–275.

5. de Jong, I. C., T. Veldkamp, and J. Van Harn. 2013. Management tools to reduce footpad dermatitis in broiler chickens. Pages 78–83 in Proc. of the 19th Eur. Symp. on Poult. Nutr. Working Group 2: Nutrition of the European Federation of Branches of the World Poultry Science Association, Potsdam, Germany.

6. de Jong, I. C., J. van Harn, H. Gunnink, V. A. Hindle, and A. Lourens. 2012. Footpad dermatitis in Dutch broiler flocks: Prevalence and factors of influence. Poult. Sci. 91:1569–1574.

7. Da Costa, M. J., E. O. Oviedo-Rondon, M. J. Wineland, J. Wilson, and E. Montiel. 2014. Effects of breeder feeding restriction programs and incubation temperatures on progeny footpad development. Poult. Sci. 93:1900–1909.

8. Oviedo-Rondon, E. O., M. J. Wineland, S. Funderburk, J. Small, H. Cutchin, and M. Mann. 2009. Incubation conditions affect leg health in large, high-yield broilers. J. Appl. Poult. Res. 18:640–646.

9. Cengiz, O., J. B. Hess, and S. F. Bilgili. 2012. Influence of graded levels of dietary sodium on the development

of footpad dermatitis in broiler chickens. J. Appl. Poult. Res. 21:770–775.

10. Cengiz, O., J. B. Hess, and S. F. Bilgili. 2012. Feed enzyme supplementation does not ameliorate foot pad dermatitis in broiler chickens fed on a corn-soyabean diet. Br. Poult. Sci. 53:401–407.

11. Bilgili, S. F., M. A. Alley, J. B. Hess, and M. Nagaraj. 2006. Influence of age and sex on footpad quality and yield in broiler chickens reared on low and high density diets. J. Appl. Poult. Res. 15:433–441.

12. Lourens, A., R. Molenaar, H. van den Brand, M. J. W. Heetkamp, R. Meijerhof, and B. Kemp. 2006. Effect of egg size on heat production and the transition of energy from egg to hatchling. Poult. Sci. 85:770–776.

13. van de Ven, L. J. F., A. V. van Wagenberg, K. A. Uitdehaag, P. W. G. G. Koerkamp, B. Kemp, and H. van den Brand. 2012. Significance of chick quality score in broiler production. Animal 6:1677–1683.

14. Berg, C. C. 1998. Foot-Pad Dermatitis in Broilers and Turkeys–Prevalence, Risk Factors and Prevention. Swedish Univ. of Agric. Sci., Uppsala, Sweden.

15. Welfare Qualilty. 2009. The Welfare Quality Assessment Protocol for Poultry (Broilers, Laying hens). Welfare Quality Consortium, Lelystad, The Netherlands.

16. Opticon DWS-20, Opticon Agri-Systems, Venlo, The Netherlands.

17. Jonge de, H. 1964. Inleiding Tot de Medische Statistiek Deel II Klassieke Methoden. Wolters–Noordhof NV, Groningen. The Netherlands.

18. Bergoug, H., C. Burel, M. Guinebretiere, Q. Tong, N. Roulston, C. E. B. Romanini, V. Exadaktylos, I. M. McGonnell, T. G. M. Demmers, R. Verhelst, C. Bahr, D. Berckmans, and N. Eterradossi. 2013. Effect of pre-incubation and incubation conditions on hatchability, hatch time and hatch window, and effect of post-hatch handling on chick quality at placement. World's Poult. Sci. J. 69: 313–334.

19. Nagaraj, M., C. A. P. Wilson, J. B. Hess, and S. F. Bilgili. 2007. Effect of high-protein and all-vegetable diets on the incidence and severity of pododermatitis in broiler chickens. J. Appl. Poult. Res. 16:304–312.

20. Enting, H., J. De Los Mozos, A. Gutierrez del Alamo, and P. Perez de Ayala. 2009. Influence of minerals on litter moisture. Pages 47–52 in Proc. of the 17th Symp. on Poult. Nutr., Edinburgh, UK.

21. Wageningen UR Livestock Research. 2014. KWIN Veehouderij 20140–2015. Wageningen UR Livestock Research, Lelystad, The Netherlands.

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