ANIMAL WELL-BEING AND BEHAVIOR

Effect of post-hatch transportation duration and parental age on broiler chicken quality, welfare, and productivity

Leonie Jacobs,[*,†,1] Evelyne Delezie,[*] Luc Duchateau,[†] Klara Goethals,[†] Bart Ampe,[*] Evelien Lambrecht,[‡] Xavier Gellynck,[‡] and Frank A. M. Tuyttens[*,†]

[*]*Animal Sciences Unit, Institute for Agricultural and Fisheries Research (ILVO), Scheldeweg 68, 9090 Melle, Belgium;* [†]*Faculty of Veterinary Medicine, Ghent University, Salisburylaan 133, 9820 Merelbeke, Belgium; and* [‡]*Faculty of Bioscience Engineering, Ghent University, Coupure links 653, 9000 Ghent, Belgium*

ABSTRACT Broiler chicks are transported to production sites within one to 2 d post-hatch. Possible effects of this transportation are poorly understood and could vary among chicks from breeder flocks of different ages. The aim of the present study was to investigate the effects of transportation duration and parental flock age on chick welfare, productivity, and quality. After hatch in a commercial hatchery, 1,620 mixed-sex chicks from 29-wk old (young) and 1,620 chicks from 60-wk old (old) breeders were subjected to transportation of 1.5 h or 11 h duration. After transportation, 2,800 chicks were divided among 100 pens, with each pen containing 28 chicks from one transportation crate (2 or 3 pens per crate). From the remaining chicks, on average 6 chicks (min 4, max 8) per crate (n = 228) were randomly selected and assessed for chick quality, weighed, and culled for yolk sac weighing (one d). Chicks that had not been assigned to pens or were not used for post-transportation measurements, were removed from the experiment (n = 212). Mortality, ADG, BW, and feed conversion (**FC**) of the experimental chicks were recorded until 41 d. Meat quality was measured for breast fillets (n = 47). No interaction effect of parental age and transportation duration was found for any variables. BW and yolk sac weight at one d were lower for chicks transported 11 h than 1.5 h and for chicks from young versus old breeders. The effect of parental flock age on BW persisted until slaughter. Additionally, parental age positively affected ADG until slaughter. Chick quality was lower in chicks from old versus young breeders. Chick quality and productivity were not affected by transportation duration. Mortality and meat quality were not affected by either parental age or transportation duration. To conclude, no long-term detrimental effects were found from long post-hatch transportation in chicks from young or old parent flocks. Based on these results, we suggest that 11 h post-hatch transportations under similar conditions do not impose long-term welfare or productivity risks.

Key words: broiler chick, post-hatch transportation, breeder flock age, animal welfare, productivity

2016 Poultry Science 95:1973–1979
http://dx.doi.org/10.3382/ps/pew155

INTRODUCTION

Early life environment and experiences are crucial for the development and performance of chicks later in life (Decuypere et al., 2001; Valros et al., 2008; Mitchell, 2009). Poultry are the only production animals that are transported very early in life, making this an important early life experience (EFSA, 2011). These so-called "day-old chicks" can in reality be up to 3 d old, because the time window between the first and last chick hatched within a flock is 24 to 48 h (Bautil et al., 2014). European legislation stipulates that these day-old broiler chicks may be transported for a maximum duration of 24 h within 72 h after hatch and may not be deprived of feed or water for longer than 72 h (EC No 1/2005). However, the spread in hatching moment may result in some chicks being deprived of feed and water for 48 h longer than others within the same flock. Such deprivation has been proven to negatively affect performance parameters (Decuypere et al., 2001).

Chicks are believed to sustain themselves without feed or water for 72 h after hatch by using reserves in their yolk sac (EFSA, 2011). However, the modern genetic lines with high metabolic rates, associated with faster growth, may deplete their energy reserves more quickly (EFSA, 2011). In line with this theory, Malik

Received December 2, 2015.
Accepted March 17, 2016.

[1]Corresponding author: jacobs.leonie@gmail.com

et al. (2010) found that fast-growing Lohmann chicks had a faster yolk uptake than a slow-growing layer line (Bovan males) when deprived of feed and water. Because transportation may exacerbate the depletion of reserves through excessive thermoregulatory demands and stress, the relation between the depletion of yolk sac reserves and transportation should be examined in order to determine the effect of transportation duration on chick welfare, health, and productivity (EFSA, 2011). The effect of pre-incubation and incubation factors such as parental flock age, egg storage, incubation temperature, and relative humidity (Tona et al., 2005; Bergoug et al., 2013a) also could influence the effect of transportation on chick welfare, quality, and productivity.

Recently, Bergoug et al. (2013b) investigated Ross chick quality and productivity in relation to duration of post-hatch transportation and parental age. Their results suggested a negative relation between breeder age and chick mortality, and a positive relation between breeder age and chick BW and quality. Transportation duration negatively affected BW until the chicks had reached the age of 21 d. However, in that study, the effect of breeder age could not be separated from other effects nor was it possible to discern the interaction between breeder age and transportation duration. The aim of the current study was to investigate the combined effect of post-hatch transportation duration and parental age on the welfare, productivity, and quality of broiler chicks from arrival at the production plant until slaughter age.

MATERIALS AND METHODS

This experiment (2014/232) was approved by the Ethics Commission for Experimental Use of Animals of the Institute for Agricultural and Fisheries Research (ILVO, Melle, Belgium).

Birds and Treatments

Eggs from a commercial hatchery (Vervaeke-Belavi NV, Tielt, Belgium) were collected on the same day from 2 flocks of Ross 308 breeder parents (kept under the same management conditions) of either 29-wk old ("young") or 60-wk old ("old"). Eggs had been stored for 4 d then incubated at the commercial hatchery according to standard practice in Belgium. The hatchery used a single-stage incubation program, in which eggs were disinfected, placed in the incubator for 18 d, candled, disinfected, and placed in the hatcher until 21 d. After the mixed-sex chicks hatched (they were not sex-separated post-hatch), hatchery personnel administered the vaccines and visually assessed the chicks for down appearance, anomalies, and cleanliness. Downgraded chicks were excluded from the experiment. Standard crates of 0.24 m^2 with a capacity of 90 chicks were used for transportation to the ILVO experimental farm. The chicks ($n = 3{,}240$) were divided over 36 transportation crates, with 90 chicks from either young or old breeders in each crate. These crates were alternately stacked and divided over one of the 2 transportation treatments. This resulted in 4 stacks of crates, with in all stacks an equal number of crates with chicks from young or old breeders, 2 stacks per transportation treatment.

Chicks were transported for either 1.5 h or 11 h, which respectively correspond to mean and maximum transportation durations in Belgium (L. Coghe, Vervaeke-Belavi NV, Tielt, personal communication), resulting in a 2×2 factorial setup. Commercial transportation conditions were reproduced by placing all crates in one fully loaded commercial semi-trailer with air conditioning (temperature between 28 and 30°C), together with commercial chicks intended for other farms. Numbered crates containing the experimental chicks were placed in 4 stacks on 2 carts in the truck, with the breeder-flock treatments alternately distributed over the 4 stacks.

Housing

After transporting the 3,240 chicks in 36 crates (9 crates per treatment, 90 chicks per crate), 2,800 unsexed chicks were placed in a single broiler housing unit. Remaining chicks were used for measurements ($n = 228$) or were taken out of the experiment ($n = 212$). Experimental chicks were housed in 100 pens (2m^2) on wood shavings. The content of each transportation crate was divided over 2 ($n = 8$ crates) or 3 pens ($n = 28$ crates), without mixing, resulting in 28 chicks from a single crate per pen (stocking density at slaughter age of ca. 35 kg/m^2). Commercial mash feed was provided ad libitum according to recommendations for Ross broilers in a commercial setting (starter, zero to 14 d; grower, 15 to 28 d; finisher, 29 to 41 d). Water was provided ad libitum in bell drinkers. Dynamic ventilation was used, with an air entrance located centrally at the roof with air extracted via both sides. The ventilation rate depended on the ambient temperature and age of the broilers to (1) maintain the temperature as close as possible to the optimal temperature schedule and (2) minimize the moisture, NH_3, and CO_2 content of the inside air. Ambient temperature in the housing unit was 33 to 35°C on d one and was reduced by 2.6°C every wk to 20 to 22°C at slaughter age (42 d), in line with recommendations for commercial settings. Chicks received 23 h of light per d from fluorescent lamps in the first wk, and then 18 h of light from 7 d onwards.

Measurements

The transportation crates were weighed and numbered immediately before transportation from hatchery to the research facility. Immediately after arrival at ILVO, all transportation crates were weighed again. On average 6 (min 4, max 8) randomly selected chicks per crate (n = 228) were marked, weighed individually, and checked for chick quality. Chick quality was scored on a zero to 100 scale according to Tona et al. (2003), with 100 being maximum quality. Criteria for chick quality included physical activity, dryness and cleanliness of down, retracted yolk, brightness and wideness of eyes, conformation and inflammation of legs, closure and color of the navel area, and remaining membrane and/or yolk (Tona et al., 2003). After assessment, these chicks were culled via cervical dislocation and then the yolk sac was removed from the abdomen through an incision and weighed individually.

BW and feed intake were recorded at pen level at 14, 28, and 41 d for 40 pens (10 pens per treatment, all 28 birds per pen). Feed conversion (**FC**; based on bird-days), ADG, and feed intake per bird were calculated for each interval and for the entire period (zero to 41 d). Researchers and caretakers were blinded for parental age treatment to avoid expectancy effects (Tuyttens et al., 2014). Mortality was recorded upon arrival and then daily until the end of the experiment.

At 41 d, broilers were transported to a commercial slaughterhouse. The next day, the birds were stunned electrically, slaughtered, and then their carcasses were immediately chilled at the slaughter plant (at 42 d). Meat quality was assessed on a sample of birds (n = 12 birds per treatment group, with the exception of one group in which 11 birds were sampled, thus n = 47) based on 5 parameters: pH, temperature, color, drip loss, and cooking loss. Approximately 5 h after slaughter, both breast fillets were removed from the carcasses. The right breast fillets were bagged and placed in a refrigerator (temperature 0.9 to 6.7°C). Left breast fillets were blotted dry and weighed, then measured for temperature (E514, Mingle Instrument GmbH Europe, Willich, Germany), pH (Portamess 910, Knick, Berlin, Germany), and color (Miniscan EZ colorimeter, HunterLab, Reston, VA) at 2 locations on the fillets. Subsequently, these fillets were placed in a plastic bag and hung for 24 h, blotted dry, and reweighed to determine drip loss. Temperature and pH were then measured again at 2 locations as above. After 24 h of cooling at the research facility (circa 29 h after slaughter), right breast fillets were blotted dry, weighed, and cooked in a warm water bath (80°C) for 40 minutes to a core temperature of 75 ± 0.5°C. Fillets were then blotted dry and reweighed to determine cooking loss.

Statistical Analysis

Data were analyzed using a mixed model (SAS 9.4, SAS Institute Inc., Cary, NC) with cage as random effect to study the effect of transportation duration, parental flock age, and their interaction on chick quality, mortality, weight, and feed uptake (pen level). Interaction effects remained in the model only when P-value was <0.10. The analyzed data were considered sufficiently normally distributed, based on the graphical evaluation of the residuals (histogram and QQ-plot).

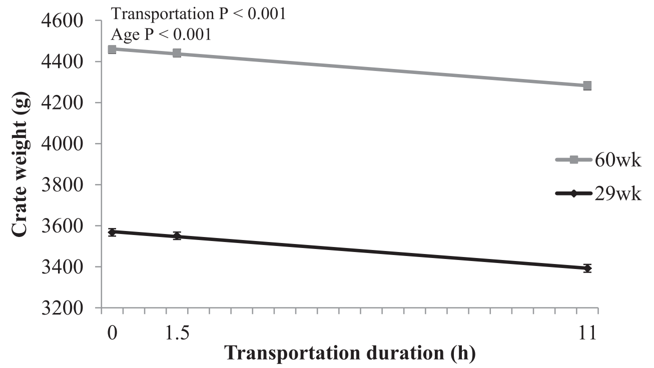

Figure 1. Mean transportation crate weight (g) with chicks from either young (29 wk) or old (60 wk) breeder flocks, at the hatchery (0 h), after short transportation (1.5 h; n = 36), and after long transportation (11 h; n = 18).

RESULTS

Crate Weights

Crate weights immediately after transportation were negatively affected by transportation duration ($P < 0.001$) and positively affected by parental age ($P < 0.001$; Figure 1). Crates with chicks from young breeders were on average 889 ± 20 g lighter than crates with chicks from old breeders. After 1.5 h transportation, crates weighed on average 17 ± 9.0 g less than before transportation; after 11 h transportation, they weighed 176 ± 9.2 g less. No interaction between transportation duration and parental age was found.

Chick Body Weight and Yolk sac Weight

Chick BW at 1 d ($P = 0.002$) and yolk sac weights ($P < 0.001$) were negatively affected by transportation duration. Chicks subjected to long transportation (11 h) were 1.40 ± 0.4 g lighter than chicks subjected to short transportation (1.5 h; Figure 2). After long transportation, yolk sacs were on average 1.23 ± 0.2 g lighter

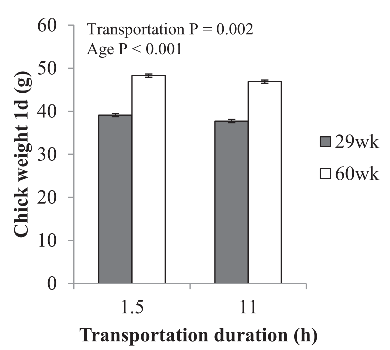

Figure 2. Mean individual chick weight at 1 d (g) from either young (29 wk) or old (60 wk) breeder flocks after short (1.5 h) or long (11 h) transportation (n = 228).

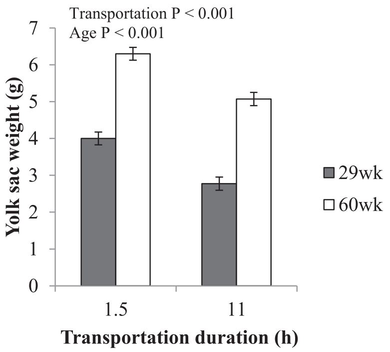

Figure 3. Mean yolk sac weight (g) of chicks from either young (29 wk) or old (60 wk) breeder flocks after short (1.5 h) or long (11 h) transportation (n = 228).

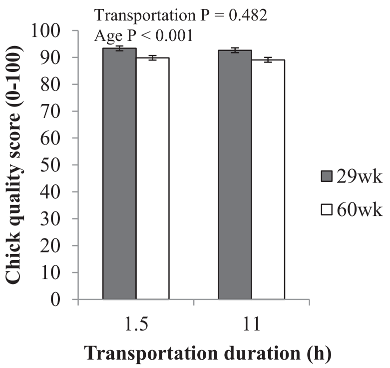

Figure 4. Mean chick quality score (0 to 100) from either young (29 wk) or old (60 wk) breeders after short (1.5 h) or long (11 h) transportation (n = 225).

than after short transportation (Figure 3). Chicks from young breeders were 9.2 ± 0.4 g lighter than chicks from old breeders ($P < 0.001$) and the yolk sacs were on average 2.30 ± 0.2 g lighter in chicks from young breeders in comparison to those from old breeders ($P < 0.001$). No interactions between parental age and transportation duration on BW and yolk sac weight were found.

Chick Quality Score

Chick quality score (0 to 100) was negatively affected by parental flock age ($P < 0.001$; Figure 4). Chicks from young breeders scored on average 3.56 ± 1 higher than chicks from old breeders. Most common abnormalities were navels that were not completely closed but not discolored (67% of the chicks) and a small amount of residual yolk in the navel opening (32% of the chicks). No abnormalities were found in chicks' activity, legs, or yolk retracted/swallowed. For chick quality, no effect was found for transportation duration, nor was there an interaction between transportation duration and age of breeders.

ADG, BW, FC

ADG in the first 28 d and until slaughter was positively affected by age of breeder flock ($P = 0.009$ at zero to 14 d, $P = 0.027$ at 15 to 28 d, $P = 0.017$ at zero to 41 d), with chicks from young breeders growing on average 4.2 ± 1 g less per d than chicks from old breeders (Table 1). No effect of transportation duration on ADG was found. Although transportation duration had a negative effect on BW at 1 d, no effect was found at later ages. BW was positively affected by parental flock age during the complete production phase ($P = 0.004$; Table 1), with a weight difference of 9.5 ± 0.3 g at one d, 55.4 ± 9.0 g at 14 d, 127.8 ± 29.4 g at 28 d, and 147.4 ± 35.0 g at 41 d. No interaction between transportation duration and age of breeders was found for BW. FC tended to be positively affected by parental flock age in the last 2 wk of the production phase (29 to 41 d; $P = 0.069$; Table 1), when chicks from young breeders had a FC of 0.04 ± 0.01 lower on average than the FC of chicks from old breeders. No interaction between transportation duration and parental flock age was found on ADG, BW, or FC.

Mortality (After Arrival and Cumulative)

Only one chick (from old breeders) died during (11 h) transportation, thus no statistical analysis was done for number of dead chicks on arrival. Mean cumulative mortality during the production phase was 3.2%, which was not affected by transportation duration or parental flock age. No interaction between transportation duration and age of breeders was found.

Meat Quality

No effect of transportation duration or parental flock age on meat quality was found. Fillet temperature and pH were on average 6.7 ± 0.1 and 5.5 ± 0.1 at 5 h after slaughter. Fillet lightness (L^*) was on average 54.8 ± 0.7, redness (a^*) 5.2 ± 0.2, and yellowness (b^*) 13.5 ± 0.3. Breast fillets lost 1.2 ± 0.1% weight after 24 h suspension and lost 18.1 ± 0.7% weight after cooking.

DISCUSSION

This study examined the effect of post-hatch transportation duration and parental flock age on chick quality, welfare, and productivity until slaughter. Parental flock age positively affected BW, yolk sac weight, and ADG, but negatively affected chick quality. We found that post-hatch transportation duration negatively affected chick BW and yolk sac weight. We hypothesized that chicks from parents of a different age would respond differently to a stressor (transportation). This hypothesis could not be confirmed; no significant interaction between parental flock age and transportation duration was found.

Table 1. ADG, feed conversion (FC), and BW during the production phase, measured per feed type (starter/grower/finisher), every 2 wk (14 d, 28 d, 41 d) for chicks from either young (29 wk) or old (60 wk) breeders after short (1.5 h) or long (11 h) transportation (n = 40 pens).

		29 wk		60 wk			*P*-value[1]
	Day	1.5 h	11 h	1.5 h	11 h	SEM	Parental age
ADG (g/day/bird)	0 to 14	21.0	21.0	24.2	24.2	0.59	0.009
	15 to 28	61.0	61.4	66.3	66.7	1.34	0.027
	29 to 41	102.5	100.1	104.0	102.5	1.04	NS
	0 to 41	60.5	60.2	63.9	63.5	0.74	0.017
FC	0 to 14	1.47	1.46	1.40	1.40	0.03	NS
	15 to 28	1.47	1.48	1.45	1.45	0.01	NS
	29 to 41	1.64	1.65	1.67	1.68	0.01	0.069
	0 to 41	1.55	1.55	1.55	1.55	0.01	NS
BW (g)	14	333.2	332.4	388.6	387.8	7.78	0.004
	28	1,188.5	1,192.4	1,316.3	1,320.2	25.5	0.012
	41	2,521.2	2,505.2	2,668.6	2,652.6	30.3	0.014

[1]Effects of transportation duration and of the interaction between parental age and transportation duration on ADG, FC, and BW were NS (P > 0.10).

Parental Age

Chicks from old breeders were heavier than chicks from young breeders throughout their lives, in line with the findings by Tona et al. (2004) and Willemsen et al. (2008). Chick weight is strongly correlated with initial egg weight (Wilson, 1991), which, in turn, is strongly correlated to breeder age, with heavier eggs from older breeders (Decuypere and Bruggeman, 2007; Koppenol et al., 2014). This weight difference was also reflected in ADG, which was higher for chicks from old breeders than for chicks from young breeders in the first 4 wk of production, but not different in the last 2 wk, resulting in a slaughter weight difference of 147 g. Even though high parental flock age tended to increase FC in wk 4 to 6, this tendency was not found for the whole production phase (wk one to 6; $P > 0.8$). To conclude, the weight difference found in day-old chicks cannot be compensated during production, and increases over time as weight gain was higher for day-old chicks from old breeders compared to those from young breeders.

The egg yolk (residue) contains nutrients and is utilized through uptake into the circulation or small intestine (Sklan, 2003). Early feeding (<24 h post-hatch) was shown to result in faster utilization of yolk sac nutrients and optimal development of intestines and organs (Bhanja et al., 2009). We found that chicks from young breeders had smaller yolk sac residues than chicks from old breeders. Decuypere et al. (2001) argued that small chicks (i.e., those from young breeders) should be fed as soon as possible after hatching due to their proportionally smaller yolk sac residues.

Chick quality score as developed by Tona et al. (2003) can be used as a qualitative predictor for broiler performance expressed as growth (Decuypere and Bruggeman, 2007; Willemsen et al., 2008). Many factors are known to influence chick quality, such as environmental factors during incubation, but also parental flock age (reviewed by Decuypere and Bruggeman, 2007). Tona et al. (2004) found fewer chicks with a perfect score from old breeders than from young breeders (93.7 versus 97.7% in chicks from non-stored eggs, 79.4 versus 96.9% in chicks from eggs stored for 7 d). In addition, Willemsen et al. (2008) found lower scores in chicks from older breeders. Both results are in line with the findings of the current study, in which chicks from old breeders generally had lower chick quality scores. Dissimilar chick quality scores due to parental age differences could be directly linked to egg quality (Decuypere and Bruggeman, 2007). Eggs from young breeders have better albumen quality and therefore higher chick quality scores, and although day-old chicks weigh less compared to chicks from old breeders, they have greater growth potential (Tona et al., 2004). This growth potential was not reflected in the current study, as ADG was not greater for chicks from young breeders than from old breeders.

Additionally, differences in chick quality scores could be related to storage of eggs (Tona et al., 2003). Egg storage during 7 d resulted in a deterioration in egg quality (especially albumen quality), and more so in eggs from old breeders than in those from young breeders (Tona et al., 2004; Decuypere and Bruggeman, 2007). In the current study, eggs were stored for 4 d, possibly resulting in lowered egg and chick quality, especially from the old breeders.

Both Willemsen et al. (2008) and van de Ven et al. (2012) argued that the correlation between the Tona score and broiler performance is meaningful only when a considerable percentage of suboptimal quality (second-grade) chicks are included. In the current study, chick quality showed little variation overall (SD = 7; data not shown), which is most likely due to the post-hatch selection made by hatchery workers (similar to Willemsen et al., 2008). Chicks with major abnormalities were culled by hatchery personnel, thus primarily high-quality (first-grade) chicks remained.

The scoring system comprises 8 indicators for quality, 3 of which focus on navel characteristics (closing and discoloration, remaining membrane, and remaining yolk). These naval characteristics are primarily determined peri-hatch. The number of abnormalities found in the current study is very similar to those found by Willemsen et al. (2008), with most of them related to the navel area. However, they found remaining membrane in the navel to be the most common abnormality (ca. 60% of abnormalities), while in our study naval closure was the most common abnormality (ca. 67% of abnormalities). Chick quality comprises mostly navel characteristics, and is relevant only when low-grade chicks are present in the sample. Therefore, it could be argued that chick quality as assessed using the Tona method is not a useful predictor for the impact of transportation or post-hatch performance in this study. A more suitable predictor for post-hatch performance (and impact of transportation) could be BW at 7 d, as it was found to be the best predictor for slaughter weight (Willemsen et al., 2008).

No effect of parental flock age on mortality was found. Hulet et al. (2007) showed a similar result, as they reported no effect of parental flock age (29 vs. 59 wk) on cumulative mortality in Cobb chicks.

Transportation Duration

After 1.5 h and 11 h transportation, chicks had lower BW than before transportation. Bergoug et al. (2013b) found similar weight differences between non-transported groups and 4 h and 10 h transportation groups, but no differences between both transportation groups. Any reduction in weight after transportation is likely due to delayed feed intake, as birds from the short transportation were fasted for >3 h and those from the long transportation for >12 h. Moreover, transportation may exacerbate the depletion of reserves through thermoregulatory demands and stress (EFSA, 2011). In an experiment on nutrient utilization in male chicks, researchers found that fasting chicks for 48 h at zero d resulted in depressed weight gain until 21 d (Batal and Parsons, 2002). A similar result was found in Ross PM3 birds (breeders) transported (and fasted) for 4 h and 10 h at zero d (Bergoug et al., 2013b). Gonzales et al. (2003) found fasting of >24 h to negatively affect final broiler weight. We did not find an effect of transportation duration (or fasting duration) on BW at 14 d, 28 d, and 41 d, suggesting that this negative effect from post-hatch transportation did not last until slaughter age.

No effect of transportation on ADG or FC was found in the current study, in line with the findings by Bergoug et al. (2013b) and by Gonzales et al. (2003) in studies on fasting times. Yolks were lighter after long transportation than after short transportation. These results are in line with expectations, as chicks were deprived of food and water for longer. Despite lower weights of the yolk sac after 11 h transportation, residue was still left, possibly suggesting that 11 h transportation did not negatively affect chicks in the long term.

The Tona score has been developed as an indicator of relative growth and thus broiler performance, which was not affected by post-hatch transportation in the current study. Even though Bergoug et al. (2013b) studied chick quality and post-hatch transportation, an association between both has not been reported.

No effect of transportation duration was found on mortality, which is in line with literature. In 3 experiments, Bergoug et al. (2013b) found no clear effect of transportation on mortality during the production phase. In addition, Almeida et al. (2006) found no relationship between fasting (for 12 h or 24 h) and mortality of Ross 308 males until slaughter age.

The meat quality characteristics pH, lightness, yellowness, and redness were very similar to values of 41 d-old Ross 308 broilers reported by Janisch et al. (2011). However, fillets of the current study had higher drip loss than reported in that study. Drip loss differences are possibly due to the difference in breast weights (ca. 170 g in the current study versus ca. 225 g in their study), as different fillet dimensions could mean a different surface area exposed to air, which could result in a different drip loss (Fanatico et al., 2007). Differences also could be due to methodological differences (we hung fillets for 24 h; they stored the meat in plastic containers for 61 h). A study with the same suspension time (Fanatico et al., 2007), but a different breed (Cobb) and slaughter age (63d) showed more comparable drip losses. Post-hatch transportation and parental flock age did not affect meat quality characteristics. This could be due to overruling effects of the 41 d production phase (Castellini et al., 2002; Michiels et al., 2012) and transportation to slaughter (Zhang et al., 2009).

In the current study, no interactive effects of transportation duration and parental age were found on chick quality, welfare, or productivity of broiler chickens. Long transportation lowered 1 d yolk and BW, compared to short transportation, but this effect on weight did not persist until slaughter age. No significant effect of transportation duration on chick quality was found. Chicks from old breeders showed reduced quality and a higher slaughter weight compared to chicks from young breeders. No significant effect of parental age or transportation duration on mortality or meat quality was found. No long-term detrimental effects were found for long (11 h) post-hatch transportation in chicks from young or old parent flocks. Based on these results, we suggest that 11 h post-hatch transportations under similar conditions do not pose long-term risks for broiler welfare or productivity.

ACKNOWLEDGMENTS

The authors thank The Federal Public Service (FPS) Health, Food Chain Safety, and Environment and The Environment, Nature, and Energy Department of the Flemish Government for funding the research (RT12/1 WELLTRANS). In addition, the authors thank Jordy Groffen, Sophie de Graaf, Lisanne Stadig, Anikó Molnár, Eva Van laer, Thijs Decroos, Dimitri van Grembergen, and the animal technicians of the poultry research facility at ILVO for help with the data collection. Similarly, the authors thank Vervaeke-Belavi NV for its cooperation, Johan Buyse, Jens Lesuisse, Astrid Koppenol (KU Leuven) for explanation of the chick measurements, and Miriam Levenson (ILVO) for English revisions.

REFERENCES

Almeida, J. G., S. L. Vieira, B. B. Gallo, O. R. A. Conde, and A. R. Olmos. 2006. Period of incubation and posthatching holding time influence on broiler performance. Rev. Bras. Cienc. Avic. 8:153–158.

Batal, A. B., and C. M. Parsons. 2002. Effect of fasting versus feeding oasis after hatching on nutrient utilization in chicks. Poult. Sci. 81:853–859.

Bautil, A., J. Buyse, and N. Everaert. 2014. Interactions between spread of hatch and delayed feed access with emphasis on the intestinal lipase activity. MSc Diss. KU Leuven, Leuven.

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. 2013a. 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.

Bergoug, H., M. Guinebretiere, Q. Tong, N. Roulston, C. E. B. Romanini, V. Exadaktylos, D. Berckmans, P. Garain, T. G. M. Demmers, I. M. McGonnell, C. Bahr, C. Burel, N. Eterradossi, and V. Michel. 2013b. Effect of transportation duration of 1–day-old chicks on postplacement production performances and pododermatitis of broilers up to slaughter age. Poult. Sci. 92:3300–3309.

Bhanja, S. K., C. A. Devi, A. K. Panda, and G. S. Sunder. 2009. Effect of post hatch feed deprivation on yolk-sac utilization and performance of young broiler chickens. Asian Australas. J. Anim. Sci. 22:1174–1179.

Castellini, C., C. Mugnai, and A. Dal Bosco. 2002. Effect of organic production system on broiler carcass and meat quality. Meat Sci. 60:219–225.

Decuypere, E., and V. Bruggeman. 2007. The endocrine interface of environmental and egg factors affecting chick quality. Poult. Sci. 86:1037–1042.

Decuypere, E., K. Tona, V. Bruggeman, and F. Bamelis. 2001. The day-old chick: a crucial hinge between breeders and broilers. World's Poult. Sci. J. 57:127–138.

EFSA. 2011. European Food Safety Authority. Scientific Opinion Concerning the Welfare of Animals during Transportation. EFSA Journal. 9:1966–2091.

Fanatico, A. C., P. B. Pillai, J. L. Emmert, and C. M. Owens. 2007. Meat quality of slow-and fast-growing chicken genotypes fed low-nutrient or standard diets and raised indoors or with outdoor access. Poult. Sci. 86:2245–2255.

Gonzales, E., N. Kondo, E. S. Saldanha, M. M. Loddy, C. Careghi, and E. Decuypere. 2003. Performance and physiological parameters of broiler chickens subjected to fasting on the neonatal period. Poult. Sci. 82:1250–1256.

Hulet, R., G. Gladys, D. Hill, R. Meijerhof, and T. El-Shiekh. 2007. Influence of egg shell embryonic incubation temperature and broiler breeder flock age on posthatch growth performance and carcass characteristics. Poult. Sci. 86:408–412.

Janisch, S., C. Krischek, and M. Wicke. 2011. Color values and other meat quality characteristics of breast muscles collected from 3 broiler genetic lines slaughtered at 2 ages. Poult. Sci. 90:1774–1781.

Koppenol, A., E. Delezie, J. Aerts, E. Willems, Y. Wang, L. Franssens, N. Everaert, and J. Buyse. 2014. Effect of the ratio of dietary n-3 fatty acids eicosapentaenoic acid and docosahexaenoic acid on broiler breeder performance, egg quality, and yolk fatty acid composition at different breeder ages. Poult. Sci. 93:564–573.

Malik, H. E. E., O. H. A. Ali, H. M. Elhadi, and E. A. Elzubeir. 2010. Residual yolk utilization in fast and slow-growing chicks, subjected to feed and water deprivation. Asian J. Biol. Sci. 4:90–95.

Michiels, J., L. Maertens, J. Buyse, A. Lemme, M. Rademacher, N. A. Dierick, and S. De Smet. 2012. Supplementation of guanidinoacetic acid to broiler diets: Effects on performance, carcass characteristics, meat quality, and energy metabolism. Poult. Sci. 91:402–412.

Mitchell, M. A. 2009. Chick transportation and welfare. Avian Biol. Res. 2:99–105.

Sklan, D. 2003. Fat and carbohydrate use in posthatch chicks. Poult. Sci. 82:117–122.

Tona, K., F. Bamelis, B. De Ketelaere, V. Bruggeman, V. M. Moraes, J. Buyse, O. Onagbesan, and E. Decuypere. 2003. Effects of egg storage time on spread of hatch, chick quality, and chick juvenile growth. Poult. Sci. 82:736–741.

Tona, K., V. Bruggeman, O. Onagbesan, F. Bamelis, M. Gbeassor, K. Mertens, and E. Decuypere. 2005. Day-old chick quality: Relationship to hatching egg quality, adequate incubation practice and prediction of broiler performance. Avian Poult. Biol. Rev. 16:109–119.

Tona, K., O. Onagbesan, B. De Ketelaere, E. Decuypere, and V. Bruggeman. 2004. Effects of age of broiler breeders and egg storage on egg quality, hatchability, chick quality, chick weight, and chick posthatch growth to forty-two days. J. Appl. Poult. Res. 13:10–18.

Tuyttens, F. A. M., S. de Graaf, J. L. T. Heerkens, L. Jacobs, E. Nalon, S. Ott, L. Stadig, E. Van laer, and B. Ampe. 2014. Observer bias in animal behaviour research: Can we believe what we score, if we score what we believe? Anim. Behav. 90:273–280.

Valros, A., R. Vuorenmaa, and A. M. Janczak. 2008. Effect of simulated long transportation on behavioural characteristics in two strains of laying hen chicks. Appl. Anim. Behav. Sci. 109:58–67.

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

Willemsen, H., N. Everaert, A. Witters, L. De Smit, M. Debonne, F. Verschuere, P. Garain, D. Berckmans, E. Decuypere, and V. Bruggeman. 2008. Critical assessment of chick quality measurements as an indicator of posthatch performance. Poult. Sci. 87:2358–2366.

Wilson, H. R. 1991. Interrelationships of egg size, chick size, posthatching growth and hatchability. World's Poult. Sci. J. 47:5–20.

Zhang, L., H. Y. Yue, H. J. Zhang, L. Xu, S. G. Wu, H. J. Yan, Y. S. Gong, and G. H. Qi. 2009. Transportation stress in broilers: I. Blood metabolism, glycolytic potential, and meat quality. Poult. Sci. 88:2033–2041.