# Effects of different types of dark brooders on injurious pecking damage and production-related traits at rear and lay in layers

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**ABSTRACT** Injurious pecking (IP) remains one of the major welfare challenges in housing of laying hens worldwide due to the negative consequences it inflicts on animal welfare and economy. One potential solution to reduce IP is the use of dark brooders as the primary heat source during rearing. The objective was to investigate effects of rearing layer chicks with different management strategies and size allowances of dark brooders on IP and production-related traits during rear and lay. Groups of 100 to 103 Isa Warren chicks were reared either with one of 4 brooder types ($n = 4$ per treatment) or with whole-house heating (control: $n = 6$). Brooders were either large (54 $cm^2$/chick) or small (72 $cm^2$/chick) and kept at a fixed height or periodically lifted. Plumage and skin condition were scored at age 6, 16, and 28 weeks. The birds were weighed at age one, 16, and 28 weeks. Data on egg production and mortality were registered daily from wk 16 until 27 wk of age. Minor differences between brooder treatments were found but with no clear trend pointing to a specific brooder treatment being superior. In contrast, major differences in IP damage were found between birds reared with or without brooders. Brooder birds had a better plumage condition throughout the experiment ($P < 0.001$) and fewer wounds during lay ($P < 0.001$). Mortality due to cannibalism in the brooder treatments tended to be lower during rear ($P = 0.066$) and was lower during lay ($P < 0.001$). There was no treatment effect on body weight on d 7 ($P = 0.48$). Brooder birds laid fewer floor eggs ($P < 0.001$) and had higher total egg production ($P < 0.001$). We conclude that an automatic system lifting the brooders regularly may be skipped, and a size allowance of 54 $cm^2$ per chick is sufficient, leaving the design of brooders simple and cheap. Rearing layer chicks with dark brooders can be a successful method of reducing prevalence of IP and floor eggs, whereby mortality is reduced, leading to improved welfare, egg quality, and production performance.

**Key words:** dark brooder, cannibalism, egg production, injurious pecking damage, laying hen

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## INTRODUCTION

Injurious pecking (**IP**) remains one of the major welfare challenges in the housing of laying hens worldwide. It consists of either severe feather pecking, i.e., pulling or plucking the feathers of conspecifics, causing damage to the plumage in terms of broken feathers and loss of feathers (Bilcik and Keeling, 1999), or cannibalistic pecking where skin and underlying tissue are being pinched off (Yngvesson and Keeling, 2001). Different types of cannibalistic pecking have been identified: vent pecking, toe pecking, comb pecking, and cannibalistic pecking to the feathered parts of the body (Savory, 1995; Buitenhuis et al., 2003). Both the latter type of cannibalism and vent pecking have been found to be linked to severe feather pecking (Cloutier et al., 2000; Potzsch et al., 2001; Lambton et al., 2015). Floor-laying behavior, where the cloacal membranes of the birds are more visible to other birds during oviposition, has also been suggested to be associated with vent pecking (Savory, 1995). However, this was not confirmed by Gunnarsson et al. (1999), who found vent pecking to be independent of both prevalence of floor eggs and feather pecking.

Apart from being associated with poor welfare in terms of pain (Gentle and Hunter, 1990) and increased fear (Vestergaard et al., 1993; Jones et al., 1995), IP is also linked to increased mortality (Yngvesson et al., 2004). Victim birds risk being killed during cannibalistic attacks, but cannibalism may also indirectly cause death, as wounds caused by cannibalistic pecks may become infected, causing prolonged suffering and, in worst case, death of the infected bird (Fossum et al., 2009). The outcome of high mortality levels is a reduction in flock size leading to decreased total egg production


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for that flock and thus negative economic consequences for egg producers. Ultimately, high mortality levels result in a less sustainable production, as the average lifespan per bird will be reduced. In addition, feather pecking may itself have economic consequences, as the damage to the feathers reduces the insulation power of the plumage, causing increased feed consumption (Leeson and Morrison, 1978; Tauson and Svensson, 1980; Herremans et al., 1989; Blokhuis and van der Haar, 1992). Feather pecking also has been related to decreased egg production. Huber-Eicher and Sebö (2001) found mean number of eggs per d in a flock to be negatively affected by feather pecking rate at age 32 wk, though not at age 22 or 50 weeks.

To reduce IP and thus the negative consequences it has on animal welfare and economy in the egg industry, solutions to prevent IP are essential, especially with the trend towards banning or omitting beak trimming in Northern Europe, as pecking with intact beaks can further increase risk of IP and aggravated damage due to pecking (Hartcher et al., 2015; Sepeur et al., 2015; Riber and Hinrichsen, 2017). One potential solution is the use of dark brooders as the primary heat source during rearing of layer chicks. In previous experiments, the use of dark brooders has shown promising results in regards to prevention of IP (Johnsen and Kristensen, 2001; Jensen et al., 2006; Gilani et al., 2012). Based on a series of experiments, Riber (2007) proposed that the reason dark brooders reduce the risk of development of feather pecking is that brooders prevent mixing of active and inactive chicks during the sensitive period for food and dust recognition. Brooders both have a synchronizing effect on the activity of the chicks (Riber et al., 2007) and separate active chicks from inactive chicks (Jensen et al., 2006). The effects of brooders on growth and egg production have received limited or no attention in previous studies. These are important parameters for farmers, who are still hesitating to implement brooders and have expressed concern whether chicks will learn to leave the brooder to find feed and water and to find their way back again when in need of heat.

Brooders resemble the broody hen in the brooding posture, providing a dark and warm shelter. In Red Junglefowl, the broody hen will terminate one out of 5 brooding bouts by leaving the brooding posture with chicks still under her (Sherry, 1981). Raising the brooders periodically may simulate the active role played by the broody hen in initiating some of the activity bouts of young chicks. Size allowance per chick under the brooders may play an important role for how well the brooders function to synchronize activity and separate active and inactive chicks. The objective of the present experiment was to optimize the design of dark brooders by examining short- and long-term effects on IP damage and production-related traits of rearing layer chicks with different management strategies and size allowances of dark brooders. The different management strategies consisted of either keeping the brooders at a fixed height or raising the brooders for short periods during the first 4 critical d, when chicks have to learn to find food and water. Two different size allowances of brooders were applied. We hypothesized that birds reared with the largest size allowance and periodically lifted brooders would have less damage to the plumage and skin caused by IP, have a lower mortality rate, a higher body weight at one wk of age, and a higher body weight uniformity at 16 and 28 wk of age. A lower mortality would affect the total egg production positively.

## MATERIALS AND METHODS

### *Animals and Housing Conditions*

Isa Warren layers ($n$ = 2254) were obtained from a commercial hatchery (TopÆg Aps, Viborg, Denmark) as day-old, non-beak-trimmed female chicks and transported to the experimental poultry facility at AU Foulum (Tjele, Denmark). Upon arrival, the chicks (100 to 103 per group) were randomly placed in one of 22 pens that were assigned to one of 2 different experimental conditions; Brooder (B) and Control (C). Under condition C, no brooders were used. Instead the primary heat source was water-heated radiators fixed to the outer walls of the house, heating the ambient room temperature to 34 °C during the first 3 d and then lowered half a degree each d until 20 °C was reached on d 28. Under condition B, water-heated brooders (one per pen, placed centrally; MHJ Agroteknik A/S) were used as the primary heat source for the chicks. The ambient room temperature, provided by water-heated radiators fixed to the outer walls of the house, was kept at 24 °C on d zero and one, 22 °C on d 3 and 4, and then kept constant at 20 °C. The temperature under the brooders was kept at 34 °C during the first 3 d and then lowered half a degree each d until 20 °C was reached on d 28. Upon arrival, chicks were placed under the brooders. The settings were otherwise the same for the 2 experimental conditions.

Sixteen groups were housed under experimental condition B and 6 under condition C. Pens under condition B were randomly assigned to one of 4 treatments that differed in the size of the brooder (large or small) and in the management of the height of the brooders (movable or fixed). Hence 4 types of brooders/management combinations were tested: SM (small and movable), SF (small and fixed), LM (large and movable), and LF (large and fixed). The large brooders measured 120 cm × 60 cm, corresponding to an average available area under the brooder of 72 $cm^2$ per chick, whereas the small brooders measured 90 cm × 60 cm (54 $cm^2$ per chick).

The movable brooders were raised for 10 min every 4 h on d one to 4, whereas the fixed brooders were maintained at the same height during brooding. The time interval between raising the brooders was chosen based on knowledge from studies of brooding Red

Junglefowl and domestic laying hens. Each cycle of brooding and activity may on average last between 20 and 35 min (Wood-Gush et al., 1978; Sherry, 1981; Riber et al., 2007), with observations of maximum durations up to 71 min (unpublished data). Since only one out of 5 brooding bouts are not terminated by the chicks themselves, but by the broody hen, a time interval of 4 h between raising the brooders was chosen. The active periods have been reported to last between 5 and 20 min (Wood-Gush et al., 1978; Sherry, 1981; Riber et al., 2007). Consequently, the duration of lifting the brooders was set to 10 minutes. During the first wk, the chicks become increasingly independent of the broody hen, and the duration of the brooding bouts may rapidly decline (Sherry, 1981). Also, in previous experiments, we have found daily mortality of layer chicks during the first wk to peak around 4 d of age (unpublished data). Based on this, we chose to terminate raising of brooders on d 5. To compensate for size of the chicks, the regular height position of the brooder was adjusted at d 29, from 16 cm at the beginning up to 25 cm. All brooders were permanently raised to 2.0 m on d 41. In order to minimize pen-effect, all groups were reallocated over the 22 pens at 44 d of age.

Each pen measured 2 m × 4 m, resulting in a stocking density of 12.5 to 12.9 birds/m$^2$, which is around 2/3 of that used for brown barn pullets under commercial conditions in Denmark. When pullets were 113 to 114 d old, all groups were reduced to 50 individuals per pen to maintain the stocking density (6.25 birds/m$^2$) around 2/3 of that used under commercial conditions for barn hens during the laying period under the European legislation (9 birds/m$^2$; EU Council Directive, 1999). From d zero, pens were provided with 7 automatic water nipples and 2 round feeders (251 cm feeder space, totally). In addition, chicks were fed on paper during the first 4 days. Seventy-cm-high white sheets of hard plastic were attached to the bottom sides of the pens to prevent visual contact between individuals from neighboring pens. Bedding was provided in the form of an approximately 5-cm-deep layer of wood shavings, and birds were fed a commercial diet (DLG, Denmark) according to their rearing stage that was provided ad libitum.

At d 18, each pen was provided with 2 wooden perches with rounded edges (2,000 mm × 57 mm × 38 mm; L × H × W; at 1 m height). In addition, at d 114, each pen was provided with 6 nest boxes (40 cm × 30 cm × 34 cm; W × D × H) inside the pens and 4 additional wooden perches (800 mm × 57 mm × 38 mm; L × H × W) arranged in a ladder layout, providing easy access to the nest boxes. In each pen, half of the nest boxes contained wood shavings as nesting material, and the other half had Astroturf as flooring material. Mortalities or birds culled for health reasons (such as retarded growth and behavioral signs indicative of illness) were recorded daily, and these birds were not replaced. A computerized system (Skov A/S) allowed control of light and ventilation, which followed commercial standard practices, e.g., the lighting program followed the standard suggested in the ISA Warren management guide (Hendrix Genetics).

All procedures involving animals were approved by the Danish Animal Experiments Inspectorate in accordance with the Danish Ministry of Justice Law no. 382 (June 10, 1987) and Acts 333 (May 19, 1990), 726 (September 9, 1993), and 1016 (December 12, 2001). This study was part of a larger project that also evaluated the effects of dark brooders on time budget and fearfulness of layers (Riber and Guzman, 2016). The birds removed, when the group size was reduced to 50 birds/pen, were mainly those that had been tested for fearfulness.

## Data Collection

***Injurious Pecking Damage.*** Plumage and skin conditions were determined according to the scoring method proposed by Bilcik and Keeling (1999) at 3 different ages: 6, 16, and 28 weeks. Twenty hens from each pen were selected randomly and individually scored at 6 and 16 wk of age, and at 28 wk of age, all hens were individually scored. For the scoring of the plumage, the body was divided into 11 regions: head, upper neck (back side of the neck), back (part between the wings), rump, tail, belly (abdomen), breast, under neck (front side of the neck), primary feathers of the wings, coverts of the wings, and legs. Each body part was given a score from 0 (best) to 5 (worst) (Table 1). Slightly different criteria were used for scoring flight feathers (tail and primaries) compared to feathers on the rest of the body because of the different types of feathers and damage associated with being forcefully removed. The scores given to the 11 body parts of a hen were summed to provide a whole body index, ranging from 0 to 55. During the scoring of the skin, the 11 body parts described above plus the comb were evaluated after a different scale ranging from 0 (no injuries) to 4 (large wound; Table 1), resulting in a body index ranging from 0–48.

***Production-related Traits.*** For the collection of data on body weight, 2 different protocols were used. At zero and 7 d of age (Phase I), the average body weight of the chicks within each pen was measured. Briefly, the chicks from each group were placed together in one of 2 plastic boxes and weighed. The total weight of all chicks in each pen was divided with the number of chicks in the pen, whereby the average body weight per chick was obtained. On day 0, the weighing took place immediately before placing the chicks in their respective pens. At 16 and 28 wk of age (Phase II), the individual body weight of all birds within each pen was measured. The birds were individually captured and weighed on a digital scale (0.1 g sensitivity). After being weighed, birds were housed temporarily in transport crates. Once all birds within each pen were weighed, they were gently released into their respective pens. Body weight

**Table 1.** Description of scoring method used to evaluate the plumage and skin damage.

| Score | Body feathers | Wing-primary and tail feathers | Skin |
|---|---|---|---|
| 0 | Intact feathers | Intact feathers | No injuries or scratches |
| 1 | Some feathers scruffy, up to 3 missing feathers | Few feathers separated but none broken or missing | <5 pecks or scratches |
| 2 | More damaged feathers, >3 feathers missing | A lot of feathers separated and/or a few broken or missing | ≥5 pecks/scratches or 1 wound, <1 cm diameter |
| 3 | Bald patch <5 cm diameter or <50% of area | All feathers separated, a lot of broken or missing feathers | Wound >1 cm in diameter but <2 cm |
| 4 | Bald patch >5 cm diameter or >50% of area | Most of the feathers missing or broken | Wound >2 cm in diameter |
| 5 | Completely denuded area | Almost all feathers missing | – |

A different scale is used for wing-primary and tail feathers compared to feathers on the rest of the body. Modified from Bilcik and Keeling (1999).

uniformity, expressed as the proportion of individuals having a body weight within the range of 10% below and 10% above the mean body weight, was calculated per pen at 16 and 28 wk of age.

Mortality was recorded daily with a registration of whether the cause of death was likely to be cannibalism. A similar categorization was used for the birds culled for health reasons. Data on mortality were then split into 2 groups according to the cause of mortality: a) mortality due to cannibalism and b) mortality from causes other than cannibalism. Following that, each group of data was divided into 3 age periods: a) First-week Mortality (FMo), i.e., the total number of dead birds during the first wk, b) Rearing Mortality (RMo), i.e., total number of dead birds from 8 to 112 d of age, and c) Laying Mortality (LMo), i.e., total number of dead birds from 113 to 189 d of age. As a result, the mortality data were arranged in 6 data sets according to cause of mortality and age.

Eggs were collected daily for 71 d from onset of lay, which occurred at 16.8 wk of age, to 10.2 wk after point of lay. Floor eggs were collected 2 to 3 times daily during the period of 19 to 24 wk of age in an attempt to reduce the prevalence. The total numbers of eggs found in nest boxes and laid on the floor were recorded daily for each pen. From the daily registrations of egg production, the following were calculated with pen as replicate: a) daily egg production, i.e., the average number of eggs laid per hen per d calculated for each wk, b) prevalence of floor eggs, i.e., the percentage of total number of floor eggs of the total number of eggs per pen, and c) the total egg production, i.e., the total number of eggs laid.

## *Statistical Analysis*

The data on the plumage and skin conditions were subjected to repeated measurements analysis using the mixed procedure with treatment (SM, SF, LM, LF, and C), age (6, 16, and 28 wk), and the interaction between treatment and age as fixed effects. Pen was included as random effect. Data on the skin condition were log-transformed to obtain a better fit with the model assumptions, and when necessary heteroscedasticity under Linear Mixed Models was corrected by specifying the variance structure of the errors. Stepwise reduction of the models was conducted, and non-significant interactions and main effects were removed from the model. Data on plumage and skin conditions were subjected to analysis in the SAS® statistical program (SAS, 2000). All other models were fitted using the NLME, GLM, and GLMER R library through an interface implemented in InfoStat (Di Rienzo et al., 2015). Means of significant main effects were compared using Fisher's protected least significant difference (**LSD**) (alpha = 0.05). One of the 4 SM groups had to be removed from all statistical analyses, as we discovered the presence of a rooster in the group when the birds were 85 d old.

Body weight was analyzed using mixed model ANOVA with treatment (SM, SF, LM, LF, and C) as fixed effects and age (Phase I: d zero and 7; Phase II: wk 16 and 28) as repeated measure. Pen was included as random effect. Different protocols were used for Phases I and II, and therefore data from each phase were analyzed separately. Body weight uniformity per pen was calculated from the data on body weight collected in Phase II. Differences in body weight uniformity were determined by a mixed model ANOVA with treatment (SM, SF, LM, LF, and C) as fixed effect and age (wk 16 and 28) as repeated measure. Pen was included as a random effect.

The 6 data sets on mortality were analyzed separately using one-way ANOVA with treatment (SM, SF, LM, LF, and C) as fixed effect. Due to null occurrences, FMo due to cannibalism could not be statistically analyzed. Daily egg production was analyzed using a mixed model ANOVA with treatment (SM, SF, LM, LF, and C) as fixed effect and age (wk 18 to 27) as a repeated measure. Pen was included as a random effect. Bonferroni correction was chosen to counteract the problem of multiple comparisons in the analysis of daily egg production. Prevalence of floor eggs and total egg production were analyzed using the Generalized Linear Mixed Model (GLMM). A Gaussian error distribution with an identity-link function was used on prevalence of floor eggs with treatment (SM, SF, LM, LF, and C) as fixed effect. A Poisson error distribution with a log-link function was used for the analysis of total egg

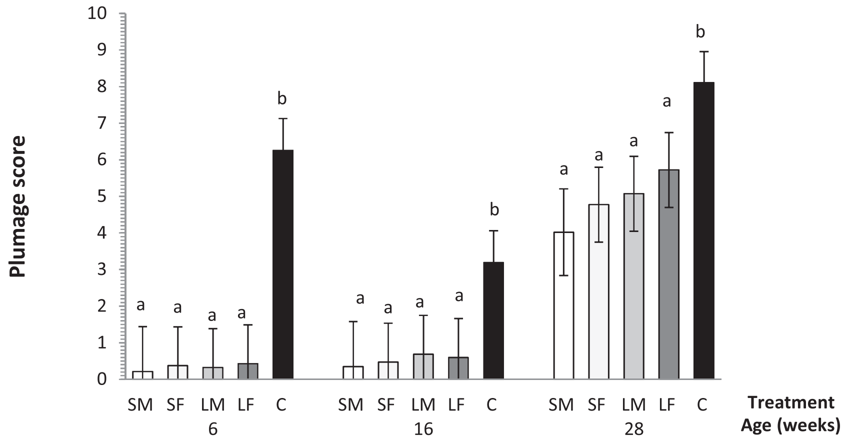


**Figure 1.** Plumage condition of 6-, 16-, and 28-week-old laying hens from the 4 brooder treatments and the control (SM: small and movable; SF: small and fixed; LM: large and movable; LF: large and fixed; and C: Control). [a-b]Bars with no common letter differ significantly ($P < 0.05$). Based on the scoring method described by Bilcik and Keeling (1999).

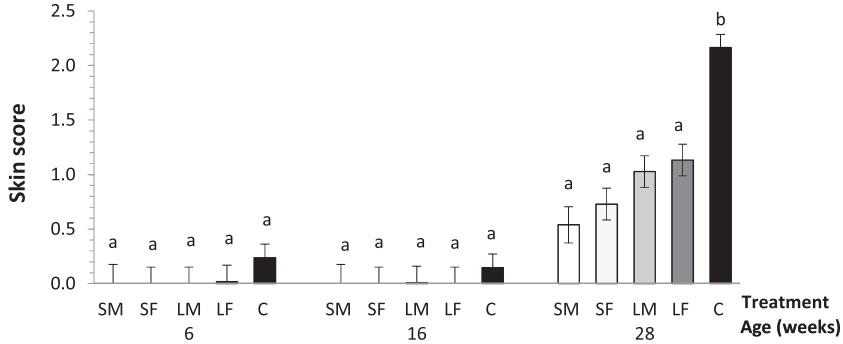


**Figure 2.** Skin condition of 6-, 16-, and 28-week-old laying hens from the 4 brooder treatments and the control (SM: small and movable; SF: small and fixed; LM: large and movable; LF: large and fixed; and C: Control). [a-b]Bars with no common letter differ significantly ($P < 0.05$). Based on the scoring method described by Bilcik and Keeling (1999).

production with treatment (SM, SF, LM, LF, and C) as fixed effect.

## RESULTS

The results on plumage and skin condition are summarized in Figures 1 and 2, respectively. There were significant interactions between treatment and age for plumage ($F_{8,1713} = 7.36$; $P < 0.0001$) and skin condition ($F_{8,1713} = 6.8$; $P < 0.0001$). For the brooder birds, no differences were found between treatments or ages. In the control groups, plumage damage was significantly worse at all ages and skin damage at age 28 wk, compared to the brooder treatments.

No differences were found between treatments on average body weight during any of the d in Phase I ($F_{4,16} = 0.90$; $P = 0.48$). During Phase II, there were significant interactions between treatment and age on body weight ($F_{4,2834} = 5.09$; $P = 0.004$; Figure 3) and body weight uniformity ($F_{4,16} = 3.55$; $P = 0.029$; Figure 4). At 16 wk of age, no differences in body weight uniformity were detected and LF and control birds were heavier than birds from SF, whereas at wk 28, LF and control birds were lighter and less uniform than birds from SM.

The results on mortality are summarized in Table 2 for the different causes, age periods, and treatments. No differences were found between treatments for mortality due to causes other than cannibalism during the first wk and the remaining rearing period (FMo: $F_{4,16} = 0.24$; $P = 0.91$; RMo: $F_{4,16} = 1.08$; $P = 0.40$). Mortality was higher in control birds than in brooder birds during the laying period (LMo), both mortality due to IP and other causes, whereas no differences were found between brooder treatments (IP: $F_{4,16} = 3.99$; $P = 0.02$; other causes: $F_{4,16} = 8.33$; $P = 0.0008$). During rearing, mortality due to cannibalism did not differ between brooder treatments, whereas it tended to be higher for control birds compared to brooder birds (RMo: $F_{4,16} = 2.73$, $P = 0.063$). The first incidence of mortality due to cannibalism was detected in a control group at 25 d of age.

No effect of treatment was found on the daily egg production ($F_{36,144} = 1.54$; $P = 0.16$). Prevalence of floor eggs and total egg production were significantly affected by treatment ($Deviance_{4,16} = 0.22$; $P < 0.0001$ and $Deviance_{4,16} = 180.21$; $P < 0.0001$, respectively). The prevalence of floor eggs did not differ between

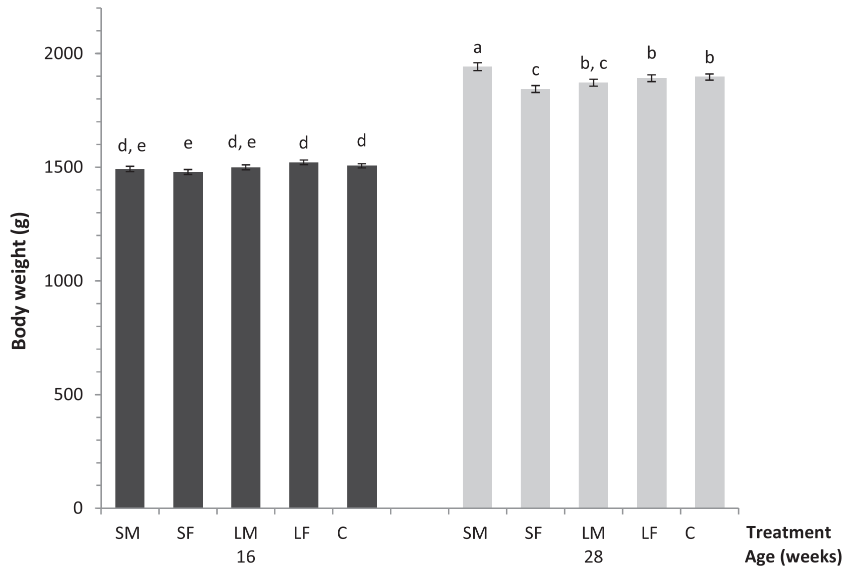


**Figure 3.** Body weight (g, mean ± SE) of 16- and 28-week-old laying hens from the 4 brooder treatments and the control (SM: small and movable; SF: small and fixed; LM: large and movable; LF: large and fixed; and C: Control). [a-d]Bars with no common letter differ significantly ($P < 0.05$).

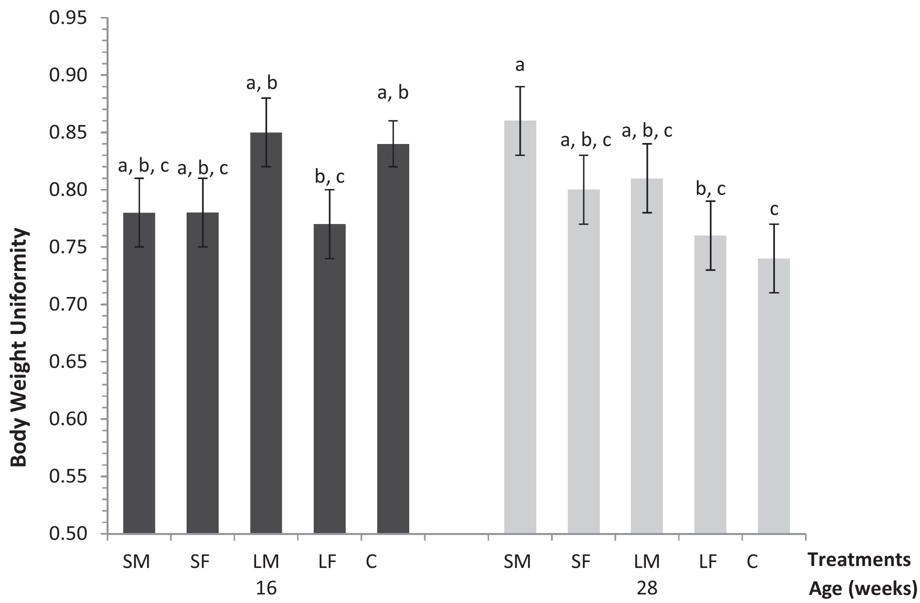


**Figure 4.** Body weight uniformity (mean ± SE) of 16- and 28-week-old laying hens from the 4 brooder treatments and the control (SM: small and movable; SF: small and fixed; LM: large and movable; LF: large and fixed; and C: Control). [a-c]Bars with no common letter differ significantly ($P < 0.05$).

brooder treatments, but brooder birds laid significantly fewer floor eggs than control birds (Figure 5). LM had a higher total egg production than SM, LF, and control birds. LF also had a lower egg production than SF, but all brooder treatments had a higher total egg production compared to control birds (Figure 6).

## DISCUSSION

We found no clear differences among the 4 types of brooders in size allowance of brooder allocated per chick or whether brooders were raised for short periods during the first 4 critical d when chicks have to learn to find food and water. The few measured parameters, where we found minor differences among the brooder treatments, were body weight at age 16 and 28 wk, body weight uniformity at age 28 wk, and total egg production. However, there was no clear trend pointing to a specific type of brooder being either superior or inferior. Our results suggest that an automatic system lifting the brooders at regular patterns may be skipped and that the small size allowance, i.e., 54 $cm^2$ per layer chick, may be used, leaving the design of the brooders simple and as cheap as possible.

We speculate whether lifting the brooders more often than every 4 h would be beneficial, bearing in mind that

**Table 2.** Percentages of mortality (mean ± SE) due either to causes other than cannibalism or cannibalism at different age periods (FMo, RMo, and LMo) for the 4 brooder treatments (SM, SF, LM, and LF)[1] and the control (C).

| Causes of death | FMo (0 to 7 d of age) | | | | | RMo (8 to 112 d of age) | | | | | LMo (days 113–199 of age) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SM | SF | LM | LF | C | SM | SF | LM | LF | C | SM | SF | LM | LF | C |
| Causes other than cannibalism | 4.5 ± 1.8 | 3.9 ± 1.6 | 2.9 ± 1.6 | 5.0 ± 1.6 | 3.6 ± 1.3 | 0.0 ± 0.6 | 1.3 ± 0.5 | 0.8 ± 0.5 | 1.1 ± 0.5 | 1.3 ± 0.4 | $0.0 \pm 1.1^{b}$ | $0.5 \pm 1.0^{b}$ | $1.0 \pm 1.0^{b}$ | $0.0 \pm 1.0^{b}$ | $5.7 \pm 0.8^{a}$ |
| Cannibalism | | | | | | $0.0 \pm 2.6^{b}$ | $0.0 \pm 2.2^{b}$ | $0.8 \pm 2.2^{b}$ | $1.9 \pm 2.2^{b}$ | $7.7 \pm 1.8^{a}$ | $6.0 \pm 7.0^{b}$ | $4.5 \pm 6.1^{b}$ | $7.5 \pm 6.1^{b}$ | $5.5 \pm 6.1^{b}$ | $29.3 \pm 5.0^{a}$ |

[1]SM: small and movable; SF: small and fixed; LM: large and movable; LF: large and fixed.
[a-b]Values within an age period and cause of death with no common bold letters differ significantly ($P < 0.05$). *Italic* letters show tendencies ($P < 0.10$).

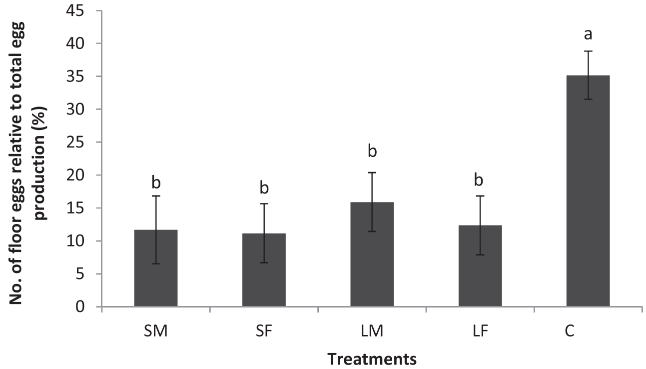


**Figure 5.** Percentage of floor eggs per pen for the 4 brooder treatments and the control (SM: small and movable; SF: small and fixed; LM: large and movable; LF: large and fixed; and C: Control) from point of lay to 27 wk of age. [a,b]Bars with no common letter differ significantly ($P < 0.05$).

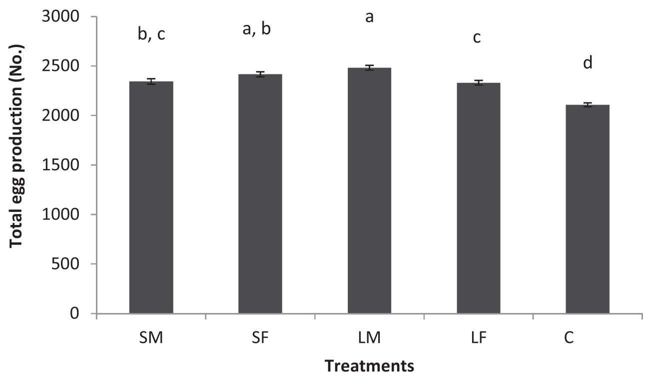


**Figure 6.** Total egg production over 71 d per pen for the 4 brooder treatments and the control (SM: small and movable; SF: small and fixed; LM: large and movable; LF: large and fixed; and C: Control) from point of lay to 27 wk of age. [a-d]Bars with no common letter differ significantly ($P < 0.05$).

it would also increase the risk of disturbing a natural pattern of activity. Regarding the size allowance, some flexibility is probably to be expected, as under natural conditions, the sizes of clutches laid by domestic fowl may range from one to 11 eggs (McBride et al., 1969), forcing chicks in larger broods to cope with limitations of space available during brooding. It would have been interesting to examine how size allowance affected the degree of synchronization of behavior in the present experiment.

We found major differences in many of the measured parameters between chicks reared with and without dark brooders as the primary heat source. The results from the present experiment show that brooder birds develop less IP, resulting in improved plumage condition during both the rearing and laying periods, as well as improved skin condition during the laying period. This is in accordance with the behavioral observations reported in Riber and Guzman (2016), where we found that during the observation period (zero to 6 wk of age), brooder birds expressed less feather pecking behavior than control birds. The results confirm the positive effects of brooders on plumage and skin conditions found in previous studies. Both Jensen et al. (2006)

and Johnsen and Kristensen (2001) found that rearing layer chicks with dark brooders in small groups (15 to 45 birds; ISA Warren and Lohman Brown) has a reducing effect on prevalence of feather pecking behavior and cannibalistic incidences during rear and early lay. Similarly, Gilani et al. (2012) found in an on-farm study (Columbian Blacktail) that the use of brooders resulted in improved feather cover during the laying period.

Neither body weight nor mortality differed between brooder and control birds at one wk of age, showing that chicks are capable of using the brooders to regulate their body temperature to an optimum without compromising survival and growth. The concern that farmers have expressed, regarding whether chicks will learn to leave the brooder to find feed and water and to find their way back again when in need of heat, was therefore unfounded. At 16 and 28 wk of age, there were minor differences between treatments in body weight but no clear difference between brooder and control birds. Gilani et al. (2012) found that brooder birds ended up slightly heavier than control birds at the end of the rearing period, whereas we found no difference in body weight between brooder and control birds at the end of the rearing period, except that birds from one of the brooder treatments (SF) were slightly lighter. In accordance with Gilani et al. (2012), we found no effects of treatment on body weight uniformity at the end of the rearing period. Interestingly, a significant drop from 16 to 28 wk of age in body weight uniformity was found for the control birds, which may be linked to the high mortality rate within these groups.

The higher mortality for the control birds compared to brooder birds is in accordance with the results found by Jensen et al. (2006) in an experimental study in which mortality due to cannibalism summed for the period zero to 23 wk of age was found to be higher in control birds compared to brooder birds. In the study by Jensen et al. (2006), the outbreak of cannibalism coincided with the point of lay, whereas in the present study, cannibalism started very early during the rearing period (25 d of age). Gilani et al. (2012), on the other hand, did not find a significant difference in mortality between brooder and control birds at the end of rear in an on-farm study. Gilani et al. (2012) found that the main causes of mortality were yolk sack infection and smothering, with the latter causing a high mortality rate in one replicate of the controls (11.8%). Whereas the yolk sac infection is unlikely to be linked to the presence/absence of brooders, prevalence of smothering may indeed be affected by brooder treatment, as brooders have been found to reduce fearfulness in layers (Riber and Guzman, 2016), which is likely to reduce the risk of smothering incidences (Bright and Johnson, 2011). Thus, there is growing evidence that brooders do have long-lasting positive effects on survival, reducing the risk of cannibalism and other causes of mortality.

Wounds were mainly found on the feathered parts of the body and the cloacal region (data not presented), and previous studies have found cannibalistic pecks to these 2 target areas to be correlated with feather pecking. Our results are in accordance with this, as both skin and plumage conditions were poorer in the control birds. However, floor eggs were also considerably more prevalent for control birds than for brooder birds, suggesting a possibility of a link between the high occurrences of both cannibalism and floor-laying behavior. However, this suggestion is in conflict with the results found by Gunnarsson et al. (1999) who found vent pecking to be independent of the prevalence of floor eggs. More research is needed to clarify the causes of vent pecking, especially on the possibility of a link to floor-laying behavior.

The higher proportion of floor eggs in the control groups was an unexpected result. However, a possible explanation may be linked to the use of brooders as alternatives to perches. Already from d 9 and with increasing prevalence until the final behavioral observations on d 42, brooder birds were observed resting on top of the brooders (Riber and Guzman, 2016). In contrast, during the period of behavioral observations, the use of perches was infrequent in all of the treatments (unpublished data). Thus, the brooder birds perched from an early age, which may (partly) account for the difference in prevalence of floor eggs between control and brooder birds. According to Gunnarsson et al. (1999), access to perches at no later than at 4 wk of age decreases the prevalence of floor eggs during the period from point of lay until 35 wk of age. Therefore, the brooders may have had an additional function to being a source of heat and a shelter, i.e., training the birds in 3-dimensional use of their environment.

The experiment was intended to last until the birds would be around 60 wk of age, but due to the early outbreak of cannibalism in the control groups, we decided to end the study prematurely. The cause of the outbreak remains unclear, but 3 factors may have been responsible or played a significant role. First, the quality of the batch of day-old chicks used for the experiment seemed suboptimal. Upon arrival from the hatchery, the chicks looked slightly weak (judged by the appearance and activity level), creating a poor starting point. This is supported by the higher than normal level of mortality during the first week. Unfortunately, we did not get an autopsy of the birds, which otherwise could have clarified the reason for this apparent suboptimal quality. Second, we exposed the birds to many disturbances involving handling during the first 2 mo, including weighing, rotation of groups, fear testing (see Riber and Guzman, 2016), and assessment of plumage and skin condition. Third, the lower use of 3-dimensional space in the control birds during the first 6 wk may have increased the risk of development of vent pecking, as Gunnarsson et al. (1999) found that early access to perches decreases the prevalence of vent pecking during the production period. The combination of a weak starting point, a series of stressful events, and the low perch use during the first 6 wk of age may have triggered the development of IP in control birds. However, the brooder birds were of the same origin, and they were exposed to the exact same procedures, but they did not develop IP until later and to a much lesser extent. Therefore, rearing layer chicks with brooders appears to result in birds that are more robust. Indeed, the fear testing showed that control birds also react more fearfully in tonic-immobility tests, open-field tests, and novel-object tests during the rearing and laying periods (Riber and Guzman, 2016).

## CONCLUSIONS

We conclude that an automatic system lifting the dark brooders regularly may be skipped, and a size allowance of 54 $cm^2$ per layer chick is sufficient, leaving the design of brooders simple and as cheap as possible. Rearing with dark brooders as the primary heat source was found to be superior compared to rearing with traditional heating, as brooders had both short- and long-term positive effects on welfare and production-related traits, resulting in improved plumage and skin condition, lower mortality, fewer floor eggs, and thus better egg quality, as well as higher total egg production. Thus, to reduce IP in the egg-laying industry and the negative consequences it has on animal welfare and economy in the egg-industry, application of brooders during rearing of layer chicks appears to be a promising solution.

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