Improving utilization of nests and decreasing mislaid eggs with narrow width of group nests

Hongya Zheng[1,2], Baoming Li[1,2,3*], Gang Chen[1,2,3], Chaoyuan Wang[1,2,3]

(1. *College of Water Resources and Civil Engineering, China Agricultural University, Beijing 100083, China*;
2. *Key Laboratory of Agricultural Engineering in Structure and Environment, Ministry of Agriculture, Beijing 100083, China*;
3. *Beijing Engineering Research Center for Livestock and Poultry Healthy Environment, Beijing 100083, China*)

Abstract: Provision of nest boxes is necessary for laying hens, especially in non-cage systems. This study investigated the effects of nest width on nest utilization and mislaid eggs. Hy-Line Browns hens were transferred from conventional cages to perchery pens at 12 weeks of age. Two experiments were conducted to mutually verify the hypothesis that narrowing group nests would improve nest utilization and reduce mislaid eggs. In experiment 1, group nests of 150 cm wide in two pens were partitioned at intervals of 50 cm and 37 cm, respectively. In experiment 2, partition panels were removed after acclimation. The number of mislaid eggs and nest eggs in each pre-set section were compared. Results indicated that narrowing group nests had positive effects on improving usage uniformity and efficiency of group nests. Nest eggs were more evenly distributed on the egg belt in both narrowed group nests, which was indicated by the significant decrease of variance among different sections (p<0.001). The proportion of mislaid eggs decreased by 3.5% in 37 cm treatment (p<0.05) and 4.7% in 50 cm treatment (p<0.001), respectively. As expected, reuse of the 150 cm group nests after removal of partition panels lowered the usage uniformity of group nests. A growth of three percentage points was found for the proportion of mislaid eggs after removing the partition panels in 50 cm treatment. The present results indicated that it is the width of the nest box that works for a better use of group nests. In conclusion, adding partition panels at intervals of 50 cm and 37 cm in group nests both are effective on nest usage and decreasing the occurrence of mislaid eggs.

Keywords: group nest, nest width, utilization, mislaid eggs, hen house, non-cage system, bird welfare
DOI: 10.25165/j.ijabe.20181101.3167

Citation: Zheng H Y, Li B M, Chen G, Wang C Y. Improving utilization of nests and decreasing mislaid eggs with narrow width of group nests. Int J Agric & Biol Eng, 2018; 11(1): 83–87.

1 Introduction

Laying hens are highly motivated for nests[1-4] even if they have no prior experience of nesting cues[5]. They feel frustrated when nest sites are out of access[1], and they will overcome increasing resistance for nest entrance[6]. Therefore, provision of nests is thought as an improvement for birds' welfare to fulfill pre-laying behaviors. For all alternative systems promoted in Directive 1999/74/EC[7], every seven hens should have at least one nest or a maximum of 120 hens sharing at least 1 m^2 of group nest.

Unequal utilization of nest has several problems. For group nests, which are commonly used in non-cage systems in commercial production, the width ranges from 1 m to 3 m[8] and each nest often accommodates dozens of birds simultaneously during oviposition. However, preference for nest site seems obvious both in experiments and in production. Hens are reported to prefer nests in corners[9,10], at the end in a row[11] or integrated in the aviary rather than wall nests[12]. Meanwhile, birds have nest sharing preference called gregarious nesting[13,14], which involves a hen alternatively choosing the occupied nest site other than an unoccupied one, or with more than one hen cramming into one individual nest reported by producers. Multiple occupations may result in abrasion on feather loss because of trampling and scraping from top hens[15], increased aggression between individuals for favored nests[16], more cracked eggs because of birds squeezing and egg stacking, and more floor laying when birds are not competitive for nests they preferred[10].

Floor laying is a major problem in non-cage system[10,17,18]. The proportion of mislaid eggs ranged from 0.7% to 18.4% in three-tiered aviary systems[19] and from 4.68% to 28.7% in non-cage systems[17]. Floor eggs require additional egg collecting[17,18] and have a risk of contamination[19]. For layer breeders, floor eggs even cannot be used for incubation[20,21], which causes a big economic loss because they are major resource of dirty eggs reported by Abrahamsson and Tauson[19,22]. Laying hens have a strong nest preference[2,6]. Properties of nest boxes, including structure, nesting material and position, have significant impacts on nest use[23-26]. To reduce the prevalence of floor eggs, enhancing the attractiveness of nests is very important. Nest size is another important factor. Previous studies showed that small nests were more attractive than large ones[8,27], with more eggs, fewer nest visits per egg and longer nest visit durations were recorded in smaller nests. However, it is hard to tell which dimension parameter of the nest affects the nest use.

Received date: 2017-01-05 **Accepted date:** 2017-08-16

Biographies: Hongya Zheng, PhD candidate, research interests: housing system and welfare for laying hens, Email: zhycau@cau.edu.cn; **Gang Chen**, Master, Associate Professor, research interests: housing system and equipment, Email: Chengang@cau.edu.cn; **Chaoyuan Wang**, PhD, Associate Professor, research interests: animal environment control and welfare, Email: gotowchy@cau.edu.cn.

***Corresponding author**: **Baoming Li**, PhD, Professor, research interests: animal housing, environment, equipment and animal welfare. Key Laboratory of Structure and Environment in Agricultural Engineering, Ministry of Agriculture, China Agricultural University, Beijing 100083, China. Tel: +86-10-62736904; Email: libm@cau.edu.cn.

The objective of this study was to investigate the effects of width on nest utilization efficiency of group nests and mislaid eggs. It was hypothesized that decreasing the width of group nests by adding partition panels would be effective. To verify increasing the width of that group nests would have opposite effects, impacts of removing partition panels were also investigated. It was anticipated that more eggs would be laid inside nests and nest eggs would be distributed more evenly on the egg belt after division treatment, and the positive effects would disappear after the removal of partition panels.

2 Materials and methods

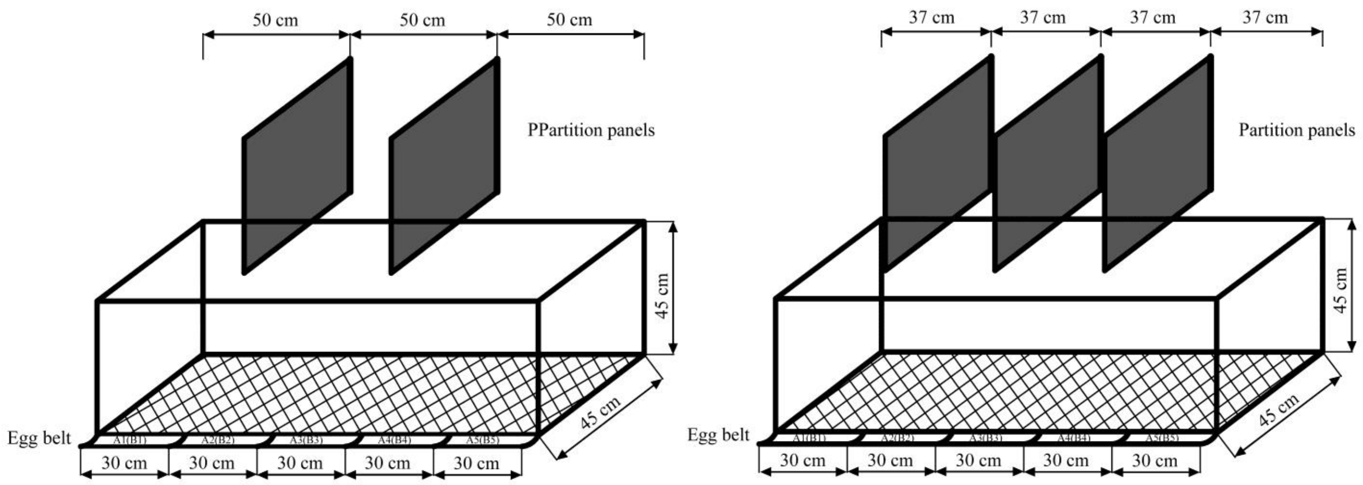
2.1 Animals and husbandry

Laying hens of Hy-line Brown were obtained from a commercial farm, which used conventional cages for production. Hens were transferred into two perchery pens which were placed in separate rooms at the end of 12 weeks. Each pen measured 4.5 m (L) × 1.5 m (W) × 2.6 m (H) and consisted of two-tier nests (the upper one and the lower one), stair-step perches, one netting floor and two elevated platforms for drinking, feeding and other daily activities. All birds were acquainted with nests and other resources inside the pen before experiments. They could feed and drink ad libitum. Light schedule was 16L : 8D (30-min dim LED light served for hens to get on perches and it was turned on 10 min before the main light out). Average temperature was maintained between 19.8℃ and 20.1℃ in the two rooms during the experimental period.

2.2 Experiment design

In experiment 1, 179 hens were allocated into two pens with group nests for oviposition before treatment. One consisted of 78 hens at the stocking density of 8.8 birds/m^2 and the other consisted of 101 hens, 11.3 birds/m^2. Group nests with two tiers (the upper and the lower) were used before treatment and each tier measured 150 cm (W) × 45 cm (D) × 45 cm (H). There total nest area was 1.35 m^2 in each pen. Experiment 1 started at the age of 42 weeks and lasted 4 weeks. Egg information about the location and quantity was recorded for one week and was used as baseline data. After that, group nests were trisected at interval of 50 cm (50 cm division treatment, 50D) in the 78-hen pen or divided into quarters at interval of 37 cm (37 cm division treatment, 37D) in the 101-hen pen. The material of the partition panels was the same for all nests. Entrances for the nest were set in the middle of each section. Two weeks were guaranteed for adaption. The same information of eggs was collected in the following week as the treatment data.

Experiment 2 began 14 weeks later after experiment 1 when the hens were completely adapted to the partitioned group nests. In experiment 2, 42 hens were left in 50D and 71 hens were left in 37D because of mortality-culling and requirements for another experiment, at the stocking density of 4.9 birds/m^2 and 8.1 birds/m^2. At the age of 60 weeks, egg information was recorded for one week as baseline data and partition panels in both groups were removed after that (removal of 50 cm partition panels, 50R; removal of 37 cm partition panels, 37R), to verify that broadening group nests would have opposite effects on promoting utilization efficiency of group nests. In the following two weeks, all birds were allowed to acclimate to the transformation. In the same manner as experiment 1, in the fourth week, data for treatment was collected. Detailed information of treatment in both experiments was shown in Figure 1.



a. 50D and 50R treatments

b. 37D and 37R treatments

Figure 1 Schematic representations of nest transformation in two experiments

2.3 Data collection and statistical analysis

Egg collection was manually operated daily at 17:00 when all eggs were laid. The egg belt was divided into five equal sections sequentially. The divided egg belt was labeled from A1 to A5 on the upper nest, and from B1 to B5 on the lower one, shown in Figure 1. Information of eggs included the total number of eggs in or out of nests and number of nest eggs in different divided sections was also recorded.

Egg distribution in each section and the ratio of mislaid eggs were presented as a percentage, divided by the number of eggs inside the nests and the number of total eggs per day, respectively. Proportions were subjected to arcsine transformation to stabilize the variance for the statistical model. Comparisons between the baseline record and treatment record were analyzed using one way ANOVA for each section, otherwise were subjected to non-parametric analysis of variance (Mann-Whitney U Test). Data was analyzed using IBM SPSS Statistics 20.0 (SPSS, I. (2011); IBM SPSS statistics for Windows, version 20.0; New York: IBM Corp). Effects were perceived as significant when p<0.05. To discuss the uniformity of nest utilization, variance of egg proportions among sections was assessed by standard deviation (SD), which was calculated daily and was presented as the mean and standard error for each treatment, with a smaller SD meaning greater uniformity.

3 Results and discussion

3.1 Egg distribution and mislaid eggs in experiment 1

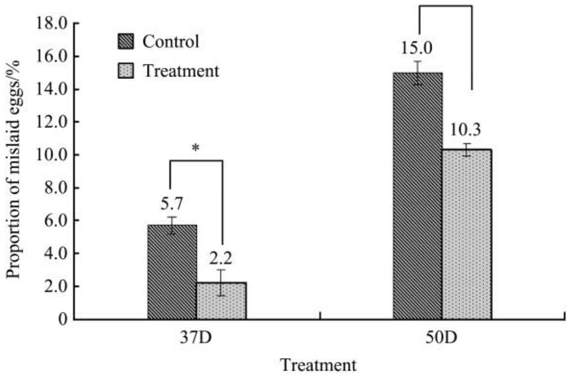
Proportions of eggs in each section were significantly affected after adding partition panels, indicating that utilization of group nests could be improved by narrowing transformation. Variances of egg-proportion ranged from 0.0 to 14.2% for 37D after treatment in different sections, and this value ranged from 0.8% to 12.4% for 50D. Narrowing group nests resulted in a decrease of egg-proportion for preferred corners. Egg-proportion decreased by 28.1% for 37D and 38.4% for 50D in sections of A1, A2, B1 and B2. Proportion of eggs in those sections before treatment reached as much as 82.1% in 37D and 80.4% in 50D (Table 1). Correspondingly, an increase of egg proportion in the majority of other sections was found. Comparisons of SD showed that narrowing group nests dramatically improved uniformity of nest utilization in both tiers (p<0.05). An increased number of safe and alternative nesting sites for hens were thought as the prime possibility. Nesting area in the corner was chosen by a majority of hens, as reported by Lundberg and Keeling[10]. It was also found in the present research before the treatment, possibly because of its safety[10,13], or by imitation and the presence of hens or eggs. As shown by Riber[13], hens are likely to choose a nest site which is already occupied, and Appleby et al.[28] also found that most hens were apparently gregarious rather than solitary in their nesting behavior. The material of division treatment was the same with the nest itself, which did not make divided compartments distinguished from each other. Hens might regard all compartments as the same and reselected their preferred nest site. Besides, there was a possibility that social order existed for individuals in the present group size. As suggested by Pagel and Dawkins[29], hierarchy formation varies with group sizes, and it only will be established when the chances of meeting the same individual repeatedly is high. In the present perchery system, individuals had a high probability of repeatedly meeting the same penmate, especially in the nest box area, where there was increasing feather pecking and aggressive pecking with advancing age[30]. So division treatment just provided vulnerable hens more optional nesting sites without direct competition with the high ranking ones. Or for hens of lower ranking order, they might have the same preference for nest site with others but were forced to lay egg in other sites.

Table 1 Proportions of nest eggs in different pre-set sections before and after division treatment and SD values among sections of the same tier (Mean±S.E.)

Treatment	Egg collection regions											
	Location	A1	A2	A3	A4	A5	SD	B1	B2	B3	B4	B5	SD
37 cm division	Before /%	29.4±0.9	16.8±1.2	5.7±1.5	1.9±0.7	5.2±0.7	10.4±0.2	25.0±1.5	10.9±0.8	1.2±0.5	1.1±0.4	2.7±0.4	9.3±0.5
	After /%	15.2±0.7	13.1±1.2	8.5±1.3	12.3±1.6	8.7±0.9	3.8±0.6	14.8±2.0	10.9±1.7	8.8±1.6	4.3±0.6	3.3±0.6	5.2±0.6
	p-value	<0.001	0.055	0.182	0.001	0.012	<0.001	0.002	0.992	0.007	0.001	0.398	<0.001
50 cm division	Before /%	18.9±0.8	24.5±2.3	8.7±1.7	0.9±0.6	3.4±1.0	9.3±0..9	19.9±1.2	17.1±1.4	2.5±1.3	1.2±1.2	2.8±1.2	8.3±0.7
	After /%	8.9±1.1	15.3±1.5	17.3±1.1	14.6±1.1	9.4±1.6	4.5±0.	7.5±1.0	10.3±1.3	10.0±1.0	4.8±0.9	2.0±0.5	3.9±0.2
	p-value	<0.001	0.007	0.002	<0.001	0.029	<0.001	<0.001	0.009	0.001	0.044	0.453	<0.001

Note: A1 to A5 were pre-set egg collection regions for the upper nest, and B1 to B5 for the lower nest. Effects were perceived as significant when p<0.05, each value was the mean of 7 daily records.

As shown in Figure 2, the proportion of mislaid eggs obviously decreased by 3.5% in 37D (p<0.05) and 4.7% in 50D (p<0.001). There was no significant difference for egg production during experiment 2 (92.5%±1.2% for control, 91.0%±1.9% for treatment in 37D; 93.8%±0.5% for control, 92.1%±0.8% for treatment in 50D). It was believed that the decrease of mislaid eggs was affected by increased nests sites, which ensured hens of lower-ranked order could find their place for oviposition.



Note: * indicates significant difference (p<0.05), ** indicates extremely significant difference (p<0.001) of treatment effect.

Figure 2 Mean proportions of mislaid eggs before and after division treatments

Division treatment did not significantly affect the total proportion of eggs in the upper nest and lower nest in 37D, but there was a detectable increase of 9.0% (p<0.05) for the upper nest and an equivalent decrease for the lower nest in 50D. Hens preferred to lay eggs on the upper place[10] or favor nest boxes in the upper tier[31]. Compared to the lower nest, the upper one was of fewer disturbances. Hens preferred to lay eggs in quiet and private space[32]. Besides, such an increased use of the upper nest might also be impacted by aging. An increasing ratio of nest eggs in the upper tier was found during production.

3.2 Egg distribution and mislaid eggs in experiment 2

As expected, nest utilization and the ratio of mislaid eggs were obviously impacted by removal of partition panels. With regard to the nesting site, preference for corners rebounded in 37R. Proportions of eggs significantly increased by 24.0% at A1 (p<0.001) and 29.5% at B1 (p<0.001) (Table 2), with egg distributions in other sections including A3, A4, A5 and B4 significantly decreased simultaneously (p<0.05). Comparison of SD showed a remarkable decrease of uniformity of nest utilization after treatment for 37R (p<0.001). The impact of removing partition panels away in 50R was less obvious. Corner preference was only found in A5 after treatment, with egg proportion increasing by 12.2% (Table 2). Distributions of eggs in different sections were different from the beginning of experiment 1 after removal treatment, especially in 50R. The location of egg stacking changed from one side to the other side. Current results revealed that site selection of the nest could be changed by structure alteration in width.

During the period of experiment 2, no significant changes of laying rates were found from the baseline record (84.5%±3.1% for control, 75.4%±0.4% for treatment in 37R; 78.7%±1.1% for control, 75.6%±1.3% for treatment in 50R). A decrease of the laying rate could result from aging, because hens were in their late laying period. Besides, hens also suffered severe feather pecking during that time, which stimulated high levels of fearfulness. Several studies reported that birds with higher fearfulness had lower egg production[34-36].

Table 2 Proportions of nest eggs in different sections before and after division treatment and SD values among sections of the same level (Mean±S.E.)

Treatment	Egg collection regions												
	Location	A1	A2	A3	A4	A5	SD	B1	B2	B3	B4	B5	SD
37 cm division	Before /%	14.9±3.0	14.0±2.3	18.0±2.3	16.6±2.2	14.3±2.8	5.4±0.7	6.1±2.4	2.1±1.4	1.0±0.6	8.3±1.3	4.7±1.5	4.0±0.4
	After /%	38.9±1.6	11.6±2.6	1.7±1.2	1.2±1.2	1.2±0.7	14.8±0.5	35.6±3.6	6.4±1.6	0.0	1.2±0.7	2.3±2.8	13.5±1.5
	p-value	<0.001	0.500	<0.001	<0.001	0.002	<0.001	<0.001	0.075	0.394	0.001	0.244	<0.001
50 cm division	Before /%	7.5±1.0	14.2±3.0	22.7±2.1	24.1±1.9	14.8±1.9	7.8±0.6	1.5±1.1	3.7±0.9	2.2±0.9	4.5±0.9	4.9±1.5	2.6±0.4
	After /%	8.6±0.5	7.3±1.9	16.8±1.3	30.9±2.4	27.0±1.4	10.0±0.9	0.3±0.3	0.6±0.4	0.9±0.9	4.0±0.5	3.7±1.1	2.2±0.3
	p-value	0.339	0.076	0.035	0.047	<0.001	0.058	0.340	0.018	0.297	0.599	0.549	0.370

Note: A1 to A5 were pre-set egg collection regions for the upper nest, and B1 to B5 for the lower nest. Effects were perceived as significant when $p<0.05$, each value was the mean of 7 daily records.

The total proportion of eggs in the nest had no big change, but the removal of partition panels resulted in a decrease of 23.2% for the utilization of the upper nest in 37R. There was a visible reduction of nest utilization ($p<0.05$) and an equivalent increase of 3.0% for the mislaid eggs in 50R (Figure 3). Preference for nests of the upper tier was consistent during production. Removal of partition panels resulted in fewer available nest sites for hens, increasing competition for favored sites and pecks between individuals. Severe feather pecks and aggression pecks were reported to mostly occur near the nest boxes[30]. In experiment 2, the number of birds in both groups was fewer than 80, in which size birds were found having territorial behavior by McBride and Foenander[33], suggesting an existed hierarchy between individuals. Lower-ranked hens or vulnerable hens might not be allowed to lay eggs in the site they preferred, which could account for an increase of mislaid eggs in 50R. Furthermore, the rebound ratio of mislaid eggs in 50R and the unevenness of nest utilization proved our anticipation that it was the width of nests affecting nest usage.

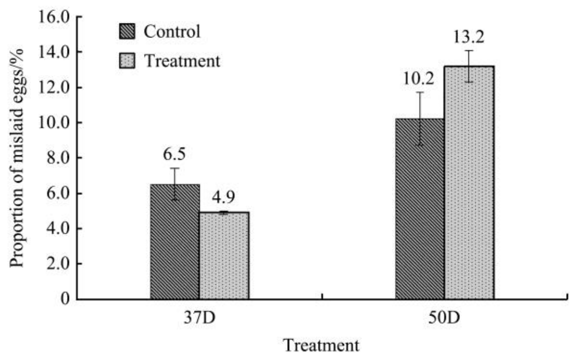


Figure 3 Mean proportions of mislaid eggs before and after removal treatments

4 Conclusions

Division treatment of group nests and removal treatment of partition panels together proved our hypothesis that the decrease in the width of group nests by adding partition panels was effective to improve utilization of group nests and reduce mislaid eggs. Division treatments at intervals of either 37 cm or 50 cm were found having more positive effects than group nests of 150 cm width in the present study. The improved utilization of nest use and reduced mislaid eggs are likely to be the result of increased optional nest sites for all birds, especially for the birds of lower-ranked order.

Acknowledgements

This study was financially supported by the Developing Key Equipment for Digital Management and Monitoring Environment in Animal Production Modern Agricultural Industry Technology System (2013AA10230602) and the Special Fund for Cultivation and Evolution of Beijing Innovative Base (Z171100002217018).

[References]

[1] Baxter M R. The welfare problems of laying hens in battery cages. Vet Rec, 1994; 134: 614–619.
[2] Cooper J J, Appleby M C. Demand for nest boxes in laying hens. Behav Processes, 1996; 36(2): 171–182.
[3] KeeIing L J. Nesting, perching and dustbathing. In: Perry G C (Ed.), editor. Welfare of the laying hen. Oxfordshire: CABI. 2004; pp. 203–213.
[4] Barnett J L, Tauson R, Downing J A, Janardhana V, Lowenthal J W, Butler K L, et al. The effects of a perch, dust bath, and nest box, either alone or in combination as used in furnished cages, on the welfare of laying hens. Poult Sci, 2009; 88(3): 456–470.
[5] Cooper J J, Appleby M C. Nesting behaviour of hens: effects of experience on motivation. Appl Anim Behav Sci, 1995; 42(4): 283–295.
[6] Kruschwitz A, Zupan M, Buchwalder T, Huber-Eicher B. Nest preference of laying hens (*Gallus gallus domesticus*) and their motivation to exert themselves to gain nest access. Appl Anim Behav Sci, 2008; 112(3-4): 321–330.
[7] Directive E U. Council directive 1999/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens. Official Journal of the European Communities, 1999; (L 203): 53–57.
[8] Ringgenberg N, Fröhlich E K F, Harlander-Matauschek A, Würbel H, Roth B A. Does nest size matter to laying hens? Appl Anim Behav Sci, 2014; 155: 66–73.
[9] Riber A B, Nielsen B L. Changes in position and quality of preferred nest box: Effects on nest box use by laying hens. Appl Anim Behav Sci, 2013; 148(3-4): 185–191.
[10] Lundberg A, Keeling L J. The impact of social factors on nesting in laying hens (*Gallus gallus domesticus*). Appl Anim Behav Sci, 1999; 64(1): 57–69.
[11] Clausen T, Riber A B. Effect of heterogeneity of nest boxes on occurrence of gregarious nesting in laying hens. Appl Anim Behav Sci, 2012; 142(3-4): 168–175.

[12] Lentfer T L, Gebhardt-Henrich S G, Fröhlich E K F, von Borell E. Nest use is influenced by the positions of nests and drinkers in aviaries. Poult Sci, 2013; 92(6): 1433–1442.
[13] Riber A B. Development with age of nest box use and gregarious nesting in laying hens. Appl Anim Behav Sci, 2010; 123(1–2): 24–31.
[14] Riber A B. Nest sharing under semi-natural conditions in laying hens. Appl Anim Behav Sci, 2012; 136(1): 44–49.
[15] Appleby M C, Smith S F. Design of nest boxes for laying cages. Br Poult Sci, 1991; 32(4): 667–678.
[16] Meijsser F M, Hughes B O. Comparative analysis of pre-laying behaviour in battery cages and in three alternative systems. Br Poult Sci, 1989; 30: 747–760.
[17] Gunnarsson S, Keeling L J, Svedberg J. Effect of rearing factors on the prevalence of floor eggs, cloacal cannibalism and feather pecking in commercial flocks of loose housed laying hens. Br Poult Sci, 1999; 40(1): 12–18.
[18] Appleby M C. Factors affecting floor laying by domestic hens: A review. Worlds Poult Sci J, 1984; 40(03): 241–249.
[19] Abrahamsson P, Tauson R. Performance and egg quality of laying hens in an aviary system. J Appl Poult Res, 1998; 7(3): 225–232.
[20] Hodgetts B. Dealing with dirty hatching eggs. MAFF information for flock farms and hatcheries: Hatch handout, 1981; No. 17.
[21] Kirk S, Emmans G C, McDonald R, Arnot D. Factors affecting the hatchability of eggs from broiler breeders. Br Poult Sci, 1980; 21(1): 37–53.
[22] Abrahamsson P, Tauson R. Aviary systems and conventional cages for laying hens: Effects on production, egg quality, health and bird location in three hybrids. Acta Agriculturae Scandinavica A-Animal Sciences, 1995; 45(3): 191–203.
[23] Struelens E, Tuyttens F, Janssen A, Leroy T, Audoorn L, Vranken E, et al. Design of laying nests in furnished cages: influence of nesting material, nest box position and seclusion. Br Poult Sci, 2005; 46(1): 9–15.
[24] Struelens E, van Nuffel A, Tuyttens F, Audoorn L, Vranken E, Zoons J, et al. Influence of nest seclusion and nesting material on pre-laying behaviour of laying hens. Appl Anim Behav Sci, 2008; 112(1-2): 106–119.
[25] Stämpfli K, Buchwalder T, Fröhlich E K F, Roth B A. Influence of front curtain design on nest choice by laying hens. Br Poult Sci, 2012; 53(5): 553–560.
[26] Stämpfli K, Roth B A, Buchwalder T, Fröhlich E K F. Influence of nest-floor slope on the nest choice of laying hens. Appl Anim Behav Sci, 2011; 135(4): 286–292.
[27] Buchwalder T, Fröhlich E K F. Assessment of colony nests for laying hens in conjunction with the authorization procedure. Appl Anim Behav Sci, 2011; 134(1-2): 64–71.
[28] Appleby M C, McRae H E, Duncan I J H, Bisazza A. Choice of social conditions by laying hens. Br Poult Sci, 1984; 25(1): 111–117.
[29] Pagel M, Dawkins M S. Peck orders and group size in laying hens: 'futures contracts’ for non-aggression. Behav Processes, 1997; 40(1):13–25.
[30] Nicol C J, Gregory N G, Knowles T G, Parkman I D, Wilkins L J. Differential effects of increased stocking density, mediated by increased flock size, on feather pecking and aggression in laying hens. Appl Anim Behav Sci, 1999; 65(2): 137–152.
[31] Appleby M C, Hogarth G S, Hughes B O. Nest box design and nesting material in a deep litter house for laying hens. Br Poult Sci, 1988; 29(3): 215–222.
[32] Cronin G M, Barnett J L, Hemsworth P H. The importance of pre-laying behaviour and nest boxes for laying hen welfare: A review. Anim Prod Sci, 2012; 52(6-7): 398–405.
[33] McBride G, Foenander F. Territorial behaviour in flocks of domestic fowls. Nature, 1962; 194: 102.
[34] Lee Y P, Craig J V, Dayton A D. The social rank index as a measure of social status and its association with egg production in White Leghorn pullets. Applied Animal Ethology, 1982; 8(4): 377–390.
[35] Carey J B, Kuo F L, Anderson K E. Effects of cage population on the productive performance of layers. Poult Sci, 1995; 74(4): 633–637.
[36] Sefton A E, Crober D C. Social and physical environmental influences on caged Single Comb White Leghorn layers. Canadian Journal of Animal Science, 1976; 56(4): 733–738.