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2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

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Determination of Minimum Horizontal Distance between Laying-Hen Perches

Kai Liu, Hongwei Xin, Timothy Shepherd, Yang Zhao

Department of Agricultural and Biosystems Engineering, Iowa State University, Ames, IA, 50011, USA.

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Abstract. The objective of the study was to determine minimum horizontal distance (HD) between perches for laying hens using qualitative and quantitative behavioral analysis. A real-time monitoring system was developed to record hen's perching behaviors, such as the number of perching hens, perching duration, perching trips, and the pattern of perch occupancy. Three groups of sixteen W-36 laying hens (68 weeks old at test onset) with prior perching experience were used. For each group, hens were kept in an enriched wire-mesh floor pen (1.2×1.2×1.2m) equipped with two parallel perches (15 cm perch space/hen). The HD between the perches were varied sequentially at 60, 40, 30, 25, 20, and 15 cm; then varied again in a reversed order. The minimum HD that led to no significant change in hen's perching behavior was determined. Results showed that reduction of HD to 25 cm did not significantly restrain hen's perching behavior; however, HD <25 cm significantly reduced the proportion of perching hens. When HD was insufficient, more perching trips occurred during the 45 min prior to dark period, indicating increase in perching competition. Meanwhile, hens perched interlacing with one another and tended to perch outwards from the opposite perch or hens during dark period, which might be a strategy to use the perch more efficiently. Horizontal distance of 60 cm increased the perching duration and reduced the perching trips during light period; however these two behavioral responses were not affected by HD <60 cm. Therefore, 25 cm is suggested as the minimum HD between laying-hen perches, 30 cm being preferable, and large HD's such as 60 cm not advisable.

Keywords. *Laying hens, Perch, Horizontal distance, Animal welfare, Alternative hen housing*

Introduction

Perching is a natural behavior of laying hens (Cooper & Albentosa, 2003; Weeks & Nicol, 2006). Thus provision of perches in hen housing systems can accommodate hen's natural behavior, hence enhancing animal welfare. In the past decades, perching behaviors have drawn increasing attention of researchers and egg producers. A number of perch-related studies have been conducted, focusing on effects of provision of perches on hen health, production performance, and specific perching behaviors of laying hens.

Currently, perches are commonly used in furnished or enriched cages and non-cage systems. Studies have shown some benefits as well as detriments of providing perches to laying hens. For example, perches can increase bone strength, relieve physiological stress of hens; however, using perch may lead to keel-bone deformities, bone fractures, and bumble foot (Struelens & Tuyttens, 2009). There are controversies on proper perch design, e.g., perch type, size, and arrangement, which may enhance the hen welfare in terms of feather conditions, mortality and foot hyperkeratosis (Tauson, 1984; Appleby et al., 1992; Tauson & Abrahamsson, 1994; Glatz & Barnett, 1996; Moinard et al., 1998; Hester et al., 2012). To date, neither the egg industry nor the scientific community has designed a perfect perch system.

EU Directive 99/74/EC first set forth the minimum standards for protection of laying hens, which states that perch must have no sharp edges and perch space must be at least 15 cm per hen in alternative laying-hen systems. In addition to this, the horizontal distance (HD) between perches should be at least 30 cm. However, ambiguities and debates were aroused due to the unclear statements in perch arrangements and lack of substantive scientific information. Some researchers (Savory, 2004) criticized that this directive was more about satisfying public opinion than to meet actual laying hen's need. In order to meet the recommended minimum lineal space requirement of 15 cm, multiple parallel perches are typically used in both US and EU alternative laying-hen facilities. However, research does not exist in the literature that investigates HD between the parallel perches to meet the hen's actual needs.

Therefore, the objective of this study was to investigate the effect of different HD's between parallel perches on hen perching behaviors, including the number of perching hens, perching duration, perching trips, heading direction of perching hens, and the pattern of perch occupancy. The results will provide scientific evidence for setting and implementing the guidelines on HD of perches for laying hens in alternative hen-housing systems.

Materials and Methods

Animal and Experiment Management

A total of 48 hens (Hy-Line W-36) provided by a cooperative egg producer were used in the study. The hens were from a commercial aviary house with similar physiological conditions (body weight, feather coverage, feet health) and then randomly assigned to three groups, 16 hens per group. The hens were 68 weeks old at the onset of the experiment, and had previous perching experience in the aviary house.

Three identical experimental pens (L x W x H: 1.2 m x 1.2 m x 1.2 m, fig. 1) with wire-mesh floor were constructed for the study. Each pen was furnished with a nest box (L x W x H: 1.2 m x 0.3 m x 0.4 m) that allowed hens to access during light period. Two 1.0 m-long feeders were installed outside the sidewalls. Two nipple drinkers were installed on the rear wall at a height of 0.4 m above the floor. Two round galvanized tubing perches with an outer diameter of 32 mm were provided in each pen and paralleled to the sidewalls. The perches were designed to be easily dismantled and adjusted. Both perches were installed at 30 cm above the floor which is within the height range in commercial aviary systems (19-32 cm above the floor). The resource allowance provided in this study is listed in table 1.

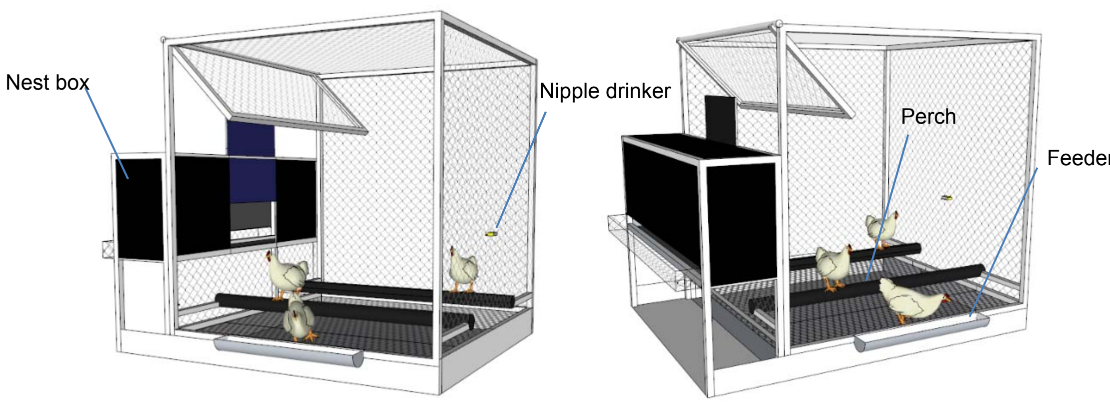
Table 1. Resource allowance in the experimental pens

Resource	This study	U.S. Recommendation[1]	E.U. Recommendation[2]
Perch Space	15 cm/bird	15 cm/bird	15 cm/bird
Floor Space	900 cm^2/bird	929 cm^2/bird	750 cm^2/bird
Feeder	12.5 cm/bird	7.6 cm/bird	12 cm/bird
Nesting space	225 cm^2/bird	83.6 cm^2/bird	a nest
Nipple drinker	2 per 16 birds	1 per 10 birds	2 within reach of each bird

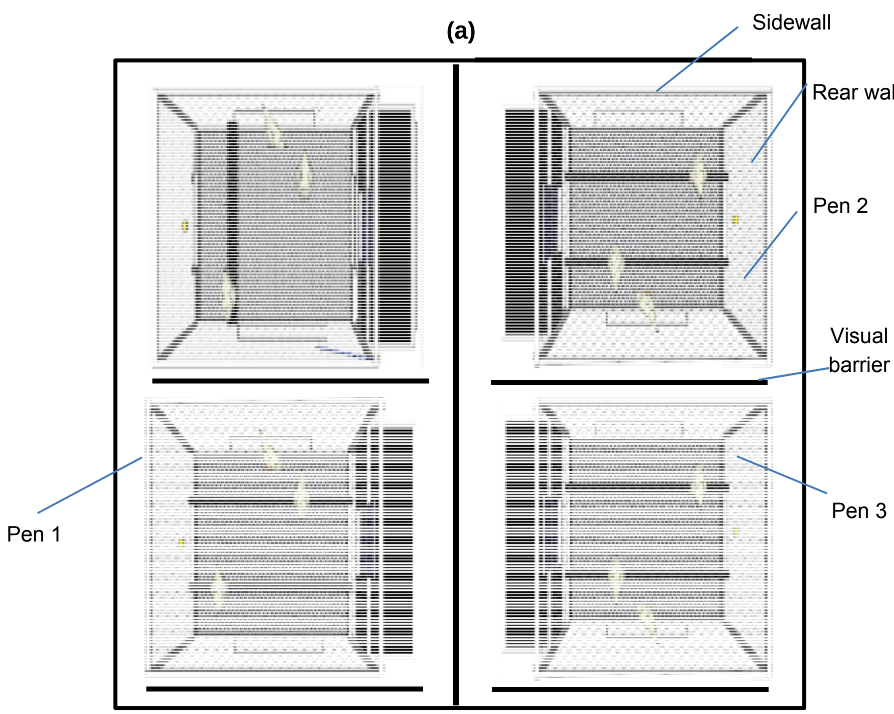
1: United Egg Producers (UEP) recommendations for cage-free systems.
2: Directive 99/74/EC legislation for alternative systems.

Light was provided by compact fluorescent lamps (CFL). Light scheme of the study was set according to the commercial management guidelines. Consistent photoperiod (16-h light, 20 lux, 06:00-22:00 h; 7.5-h dark, 0 lux, 22:15-05:45 h; 0.5-h dim, 1-2 lux, 05:45-06:00 h and 22:00-22:15 h) was used. Light intensity at perch level was measured using a light meter (0 to 20,000 lux, model EA31, FLIR Systems Inc., Wilsonville, OR, USA[1]) and was maintained at about 20 lux. The experimental rooms were ventilated and room temperatures were maintained relatively constant at 21ºC. Feeders were replenished once a day at 18:00 h and water was provided *ad lib*. Eggs were collected at 18:00 h each day. The experiment facilities were cleaned twice a week.

The three groups of hens were randomly assigned to three experimental pens. Before the test, hens were allowed to acclimate in their respective pen for one week. During the test, HD of the perches was decreased from 60 cm to 15 cm (O.C.) and then increased in a reversed order (table 2) in order to determine the minimal HD. The experimental protocol was approved by the Iowa State University Institutional Animal Care and Use Committee (IACUC).



(a)



(b)

Figure 1: Schematic drawing of the experimental pens: (a) side views, (b) top view (The fourth pen was used for housing hens that might need special care).

1: Mention of product or company name in the paper is for presentation completeness and does not imply endorsement by the authors or their affiliations, nor exclusion of other suitable products.

Table 2. Horizontal distance (HD) between perches and the associated test days

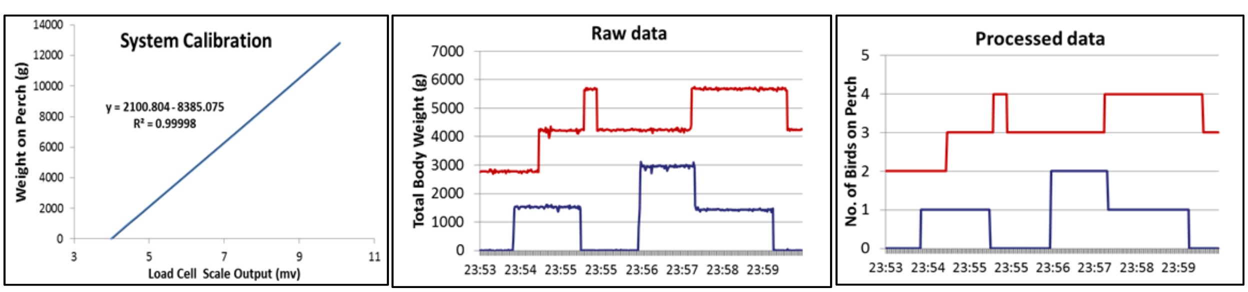
Order	HD, cm	Number of test days
1	60	5
2	40	2
3	30	2
4	25	2
5	20	2
6	15	6
7	20	3
8	25	6
9	30	3
10	40	4
11	60	5

Measurement Instruments and Data Acquisition

Perch use by the hens was recorded using a pair of load cells (5 to 100 kg ± 30 g, model 642C, Revere Transducers Inc., Tustin, CA, USA[1]; 7 to 100 kg ± 20 g, model RL1040, Central Caralona Scale, Inc., Andover, MA, USA[1]) that were installed underneath each perch. The paired load cells (fig. 3a) and the perch made up a weighing system that could measure the weight load on the perch (fig.2a). Analog signals produced by the load cells were read by two 8-chanel input modules (model FP-TC-120, National Instruments Inc., Austin, TX, USA[1]). Ethernet control module (model FieldPoint FP2000, National Instruments Inc., Austin, TX, USA[1]) was used to interact with a user interface (fig.3c) programed using LabVIEW (version 7.1, National Instruments Inc., Austin, TX, USA[1]). Analog voltage outputs of the load cells were collected every second, converted to weight using pre-defined calibration curves and saved into text files for further analysis (quantitative analysis: number of perching hens, perching duration, and perching trip). A real-time video system (MSH-Video surveillance system, S-VIDIA Inc., Santa Clara, CA, USA[1], fig.3d) was used to record hens behaviors to determine the heading direction and pattern of perching occupancy (qualitative analysis).

Data Processing and Statistical Analysis

A VBA program was developed to process the raw data. First, the total weight of hens on each perch (fig. 2b) was converted to the number of perching hens (fig.2c) by using a series of body weight thresholds. Then perching duration and perching trips (times of jumping on and off the perch) during light (6:00 – 22:00 h), dark (22:15-05:45 h) and dim (5:45-6:00 h, and 22:00-22:15 h) periods of the day were calculated. As a result, 11 variables as listed in table 3 were summarized and used for further analysis. Heading direction of each perching hen during dark period was also monitored to determine the proportion of hens that perched outward from the opposite perch or hens (PHPO).



(a) (b) (c)

Figure 2. Calibration of load-cell scale. (a) Relationship between analog voltage output of load-cell scale and loaded weight, (b) raw data—total body weight of perching hens on each perch, (c) processed data—number of perching hens on each perch.

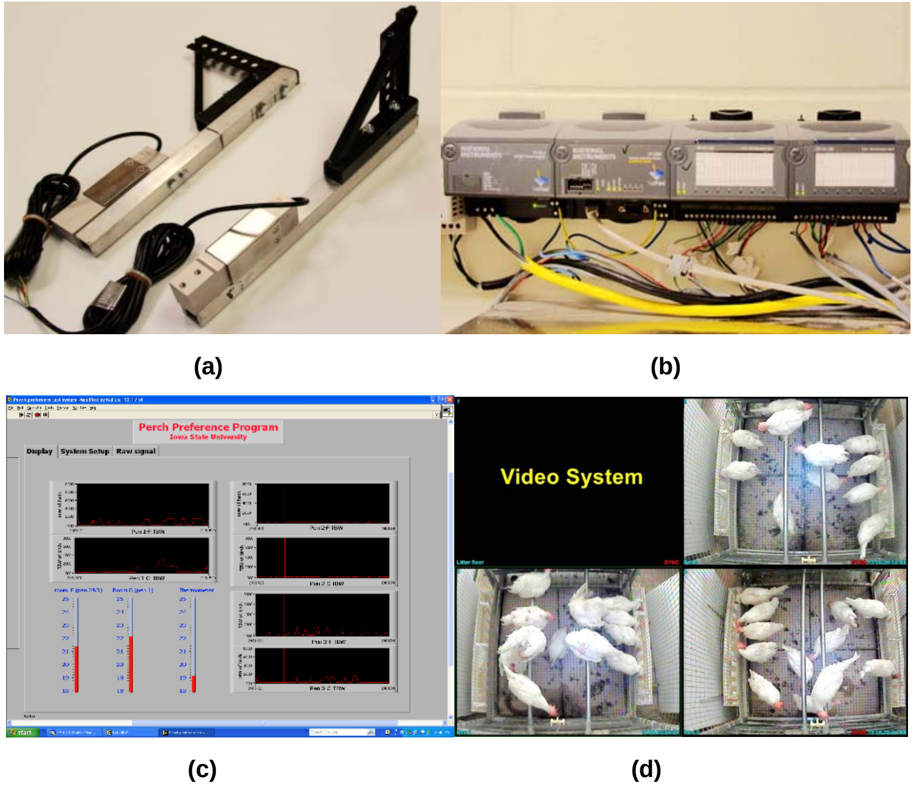


Figure 3. Data acquisition system for hen behavior monitoring. (a) Load cells with support, (b) FieldPoint, (c) LabVIEW based user Interface, (d) Video System.

Table 3. Nomenclature

Abbreviation	Description
OAPD	Overall perching duration (min/hen-hr)
OAPT	Overall perching trips (times/hen-hr)
LPPD	Light-period perching duration (min/hen-hr)
LPPT	Light-period perching trips (times/hen-hr)
DPPD	Dark-period perching duration (min/hen-hr)
DPPT	Dark-period perching trips (times/hen-hr)
DIPD	Dim-period perching duration (min/hen-hr)
DIPT	Dim-period perching trips (time/hen-hr)
DPPP	Dark-period perching proportion (%)
PDPD	Perching duration during 45 min prior to dark period (min/hen-hr)
PTPD	Perching trips during 45 min prior dark period (times/hen-hr)
PHPO	Proportion of hens perching outward during dark period (%)

Pearson correlation test was performed using SAS (version 9.3) among the afore-mentioned variables with the ‘Proc Corr’ procedure. If any two variables were significantly correlated ($p<0.05$) and their absolute Pearson correlation coefficient was greater than 0.60 (high correlation), only one of the two variables was used in examining the effect of horizontal distance. Effects of HD, group, and their interaction were tested using a general linear model (GLM) (eq. 1). Potential carry-over effect was not considered for this study (Struelens, et al, 2008). Tukey's Studentized Range tests were used for the pairwise comparisons of HD effect on different behavioral variables. The model is of the following form,

$$Y_{ijk} = \mu + \alpha_i + \gamma_j + (\alpha\gamma)_{ij} + \xi_{ijk} \qquad (1)$$

Where:

α_i: horizontal distance (HD) between parallel perches (15, 20, 25, 30, 40, and 60 cm)

γ_j: group (group 1, group 2, group 3)

$\xi_{ijr:}$ error

Results and Discussion

Qualitative Analysis of Hens Perching Behavior

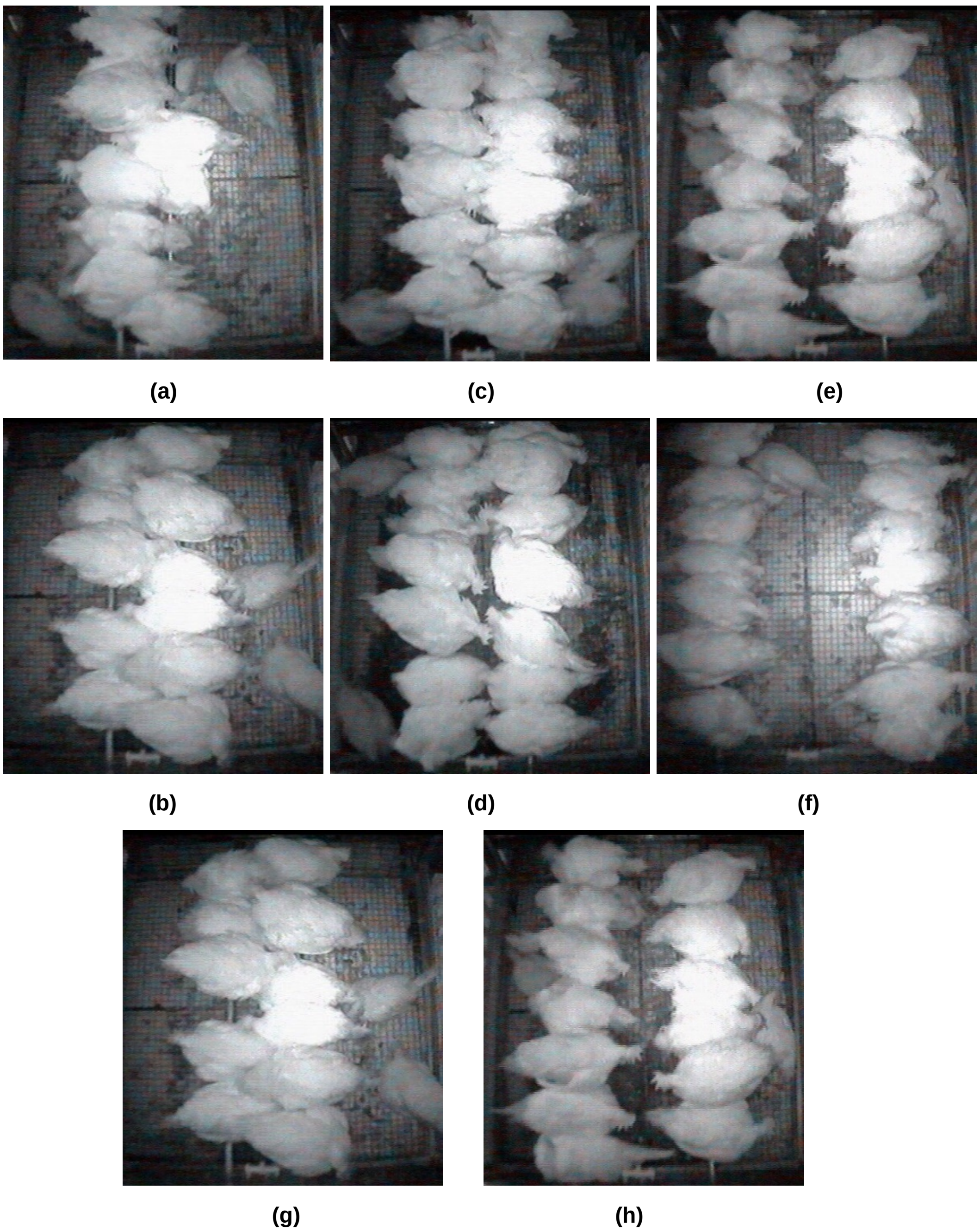


Figure 4. Representative patterns of perch occupancy by perching hens during dark period at horizontal distance of 15, 20, 25, 40, and 60 cm bewteen perches. (a) 15 cm, (b) 20 cm, (c) 25 cm, (d) 30 cm, (e) 40 cm, and (f) 60 cm. (g) interlaced pattern, (h) random pattern.

Representative patterns of perch occupancy by perching hens during dark period at HD of 15, 20, 25, 30, 40, and 60 cm bewteen perches are shown in figure.4. There were 10, 11, 13, 14, 13, and 14 hens out of 16 perching during dark period, respectively. Two obvious patterns of perch occupancy (interlaced, fig. 4g and random, fig. 4h) could be sorted based on the relative positions of perching hens on two perches (fig. 4 a, b, c vs. fig. 4d, e, f). For interlaced pattern, perching hens slightly interfered with one another at the HD of 25 cm when roosting on both perches. At HD of 20 cm or 15 cm, only one of the perches could be used at the same location (relative to the length) because the horizontal space between perches was unable to accommodate two parallel hens. In other words, the perch availability was reduced even though the overall perch length remained the same, indicating insufficient HD. For parallel pattern, HD was sufficient and using one perch did not interfere with the other. However, there were still several hens unable to perch despite the provision of the recommended 15 cm perch length per hen. This outcome may be explained by the fact that hens usually did not perch exactly every 15 cm on the perch, e.g., gaps existed between hens and the wall, but no more evidence can be provided here since perch length requirement was not the objective of this study. Therefore, In terms of perching pattern, HD < 30 cm (fig. 4d) might be not sufficient to accommodate hens roosting at night.

Quantitative Analysis of Hens Perching Behavior

As shown in table 4, LPPD, LPPT, DPPP, PTPD and PHPO were selected for further analysis. Non-selected variables (OAPD, OAPT, DPPD, DIPD, DIPT, and PDPD) had Pearson correlation coefficients of >0.60 with at least one of selected variables. Although DPPT had weak correlation with any of the five selected variables (0.131, -0.034, -0.230, 0.430, and -0.049, respectively), it was not analyzed due to the constant perching trips (about 0.01 times/hen-hr) during dark period.

Table 4. Pearson correlation coefficients between variables.

	LPPD	LPPT	DPPP	PTPD	PHPO
OAPD	0.613 (***)	-0.417 (***)	0.894 (***)	-0.181 (NS)	0.215 (NS)
OAPT	-0.057 (NS)	0.994 (***)	-0.513 (***)	0.358 (***)	-0.254 (*)
DPPD	0.242 (NS)	-0.475 (***)	0.985 (***)	-0.252 (*)	0.381 (***)
DPPT	0.131 (NS)	-0.034 (NS)	-0.230 (NS)	0.430 (***)	-0.049 (NS)
DIPD	0.390 (***)	-0.418 (***)	0.611 (***)	-0.131 (NS)	0.311 (**)
DIPT	0.065 (NS)	-0.340 (**)	-0.364 (***)	0.726 (***)	-0.347 (**)
PDPD	0.453 (***)	-0.559 (***)	0.639 (***)	-0.153 (NS)	0.369 (**)
LPPD	1.000	-0.060 (NS)	0.220 (*)	0.057 (NS)	-0.300 (*)
LPPT		1.000	-0.497 (***)	0.280 (**)	-0.233 (*)
DPPP			1.000	-0.259 (*)	0.385 (***)
PTPD				1.000	-0.253 (*)
PHPO					1.000

Single, double and triple asterisks (*, **, ***) stand for significance at p<0.05, p<0.01 and p<0.001, respectively. NS means not significant. Refer to table 3 for the meaning of nomenclatures.

Table 5. Horizontal distance (HD), group and their Interaction effects on LPPD, LPPT, DPPP, PTPD, and PHPO (Refer to table 3 for the meaning of nomenclatures).

Variables	HD		Group (G)		HD x G	
	F-value	P-value	F-value	P-value	F-value	P-value
LPPD	$F_{5, 69}$=10.95	<0.0001	$F_{2, 69}$=0.10	0.904	$F_{10, 69}$=1.87	0.065
LPPT	$F_{5, 69}$=7.54	<0.0001	$F_{2, 69}$=108.69	<0.0001	$F_{10, 69}$=4.63	<0.0001
DPPP	$F_{5, 102}$=14.27	<0.0001	$F_{2, 102}$=45.24	<0.0001	$F_{10, 102}$=1.47	0.161
PTPD	$F_{5, 102}$=4.22	0.0016	$F_{2, 102}$=17.22	<0.0001	$F_{10, 102}$=0.28	0.984
PHPO	$F_{5, 102}$=6.51	<0.0001	$F_{2, 102}$=21.05	<0.0001	$F_{10, 102}$=1.07	0.392

According to the results of statistical tests (table 5), HD had significant effects on all selected variables (LPPD, LPPT, DPPP, PTPD, and PHPO). Group also had significant effects on LPPT, DPPP, PTPD and PHPO, but not on LPPD. In addition, only interaction between distance and group on LPPT was significant ($F_{10, 69}$=4.63, p<0.0001). These results indicate that HD would greatly affect perching behaviors of hens although there were significant differences in perching behaviors among groups of hens. Besides, particular attention should be paid on analyzing LPPT due to the significant interaction effect.

DPPP is one of the most important criteria to assess HD threshold. Previous studies had reported that laying hens were highly motivated to perch (Olsson & Keeling, 2002) and approximately 85 to 100% of the hens in furnished cages used perches during the night (Tauson, 1984; Tauson & Abrahamsson, 1994; Wall & Tauson, 2007). Our result shows that proportion of perching hens was affected by HD between parallel perches (table 6). Fewer hens were able to perch simultaneously as HD decreased even though the overall perch length allowance was kept the same. As we can see in figure 5, when HD was 15 cm, only 56.97 ± 1.77% of the hens perched, which was significantly lower than the values for 20, 25, 30, 40, and 60 cm. The proportion of perching hens at 20 cm HD (66.61 ± 3.41%) was significantly lower than those at 40 or 60 cm, meaning HD of 20 cm is not wide enough. However, no difference in proportion of perching hens was noticed when HD was equal to or larger than 25 cm. Previous analysis (fig. 4) found that perching hens at HD of 25 cm slightly interfered with one another. DPPP indicated that slightly interfering with one another may not reduce availability of perches.

Horizontal distance also had some influence on heading direction of the perching hens (fig.6). We expected that PHPO would decrease as HD between perches decreased since the hens were more likely to jump on the perch from the space outside the paired perches. This assumption was validated by our result that PHPO tended to decrease as HD decreased from 60 cm to 25 cm. A previous study also showed that hens (group of 3 hens with space of 1408 cm^2/hen) tended to orientate away from each other at HD >25 cm and towards each other at HD less than this when hens were on the floor (Keeling & Duncan, 1989). However, further decrease of HD to 15 cm led to fewer hens perching with their heads towards each other. Judging from observations of the hens, a possible explanation is that the hens tried to avoid or reduce physical contact with others when HD was too narrow such as 15 cm since interlaced perching pattern (fig.4) was also associated with insufficient HD. Perching outward might be a strategy for hens to use the perch more efficiently.

Table 6. LPPD, LPPT, DPPP, PTPD, and PHPO (Mean ± SEM) at different horizontal distances (HD's) (Refer to table 3 for the meaning of nomenclatures).

HD, cm	LPPD min/hen-hr	LPPT times/hen-hr	DPPP %	PTPD Times/hen-hr	PHPO %
60	13.97 ± 0.41^{a}	1.47 ± 0.06^{b}	76.58 ± 2.41^{a}	5.81 ± 0.37^{ab}	57.21 ± 3.65^{a}
40	12.30 ± 0.49^{b}	1.90 ± 0.22^{a}	77.52 ± 2.83^{a}	5.34 ± 0.35^{ab}	47.35 ± 4.57^{ab}
30	11.21 ± 0.56^{b}	1.95 ± 0.22^{a}	74.00 ± 3.15^{ab}	4.76 ± 0.29^{b}	43.08 ± 5.37^{ab}
25	11.27 ± 0.27^{b}	1.70 ± 0.12^{ab}	75.05 ± 2.94^{ab}	5.07 ± 0.27^{b}	32.40 ± 4.02^{c}
20	10.85 ± 0.36^{b}	1.67 ± 0.17^{ab}	66.61 ± 3.41^{b}	5.00 ± 0.31^{b}	37.58 ± 3.96^{bc}
15	11.14 ± 0.41^{b}	1.86 ± 0.19^{a}	56.97 ± 1.77^{c}	6.58 ± 0.32^{a}	45.86 ± 3.46^{ab}

Within each column, means sharing the same letter do not differ significantly at 5% significance level.

As previously reported, hens in furnished cages only spent approximately 20 to 25% of their time on the perch during the day (Tauson, 1984; Tauson & Abrahamsson, 1994; Appleby et al., 1993); therefore, perch space may be not as critical as for dark period. The LPPD at HD of 60 cm (13.97 ± 0.41 min/hen-hr) was significantly higher than those at other HD's, while LPPD was similar at HD of 15 to 40 cm (table 6). A distance of 20 cm or even 15 cm, which proved to be not wide enough from the standpoint of DPPP, did not affect LPPD. The LPPT tended to be lowest at HD of 60 cm as compared to others. But none of the differences among 15, 20, 25, 30, and 40 cm was significant (table 6). Perch has been shown to improve bone strength of laying hens by providing the opportunities of weight loaded exercise, e.g., hens jump on and off to the perches, but long time roosting on the perch is more likely to cause keel bone deformity (Hughes & Wilson,1993; Cooper & Albentosa, 2003). Thus a proper perch design might encourage more perching trips but less time perching during the day. Therefore a large HD such as 60 cm might not be in the best interest of the hens' well-being.

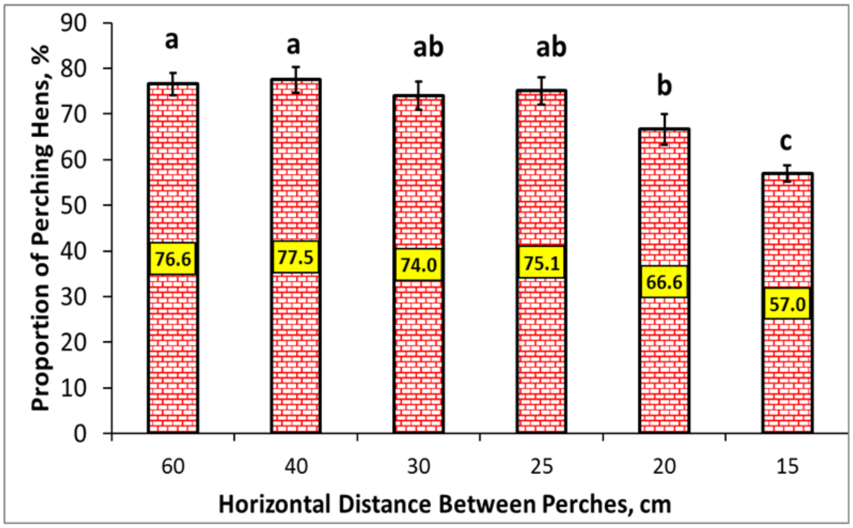


Figure 5. Proportion of hens perching during dark period (Mean ± SE) at different horizontal distances between parallel perches. Means sharing the same letter do not differ significantly at 5% significance level.

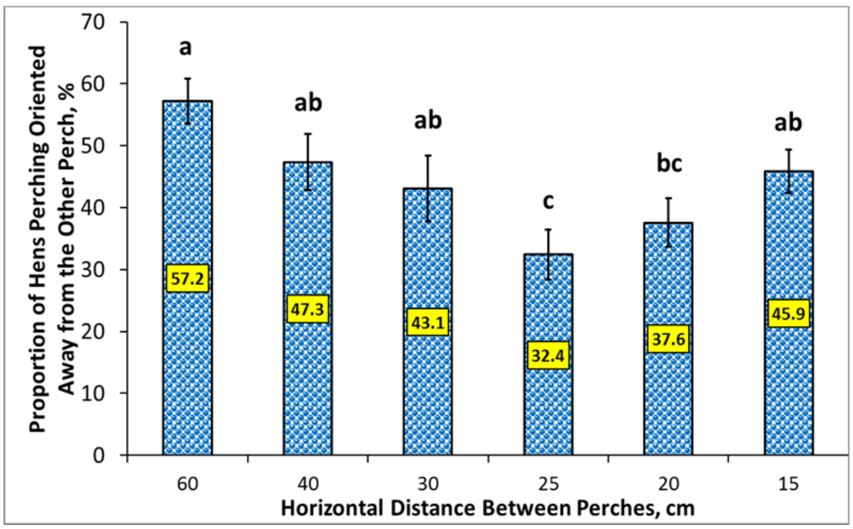


Figure 6. Proportion of birds perching outwards during dark period (Mean ± SE) at different horizontal distances. Means sharing the same letter do not differ significantly at 5% significance level.

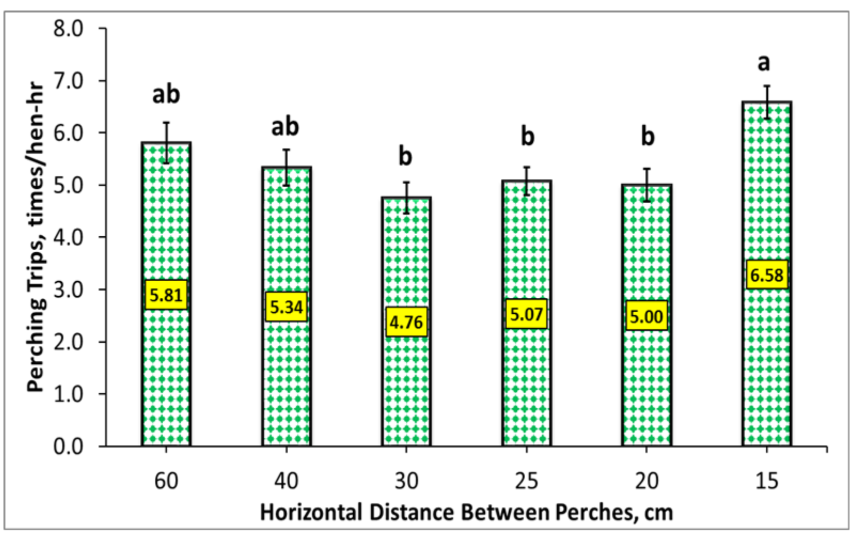


Figure 7. Perching trips during 45-min prior to dark period (Mean ± SE) at different horizontal distances. Means sharing the same letter do not differ significantly at 5% significance level.

It was also observed that perching trips were much more extensive during 45 min prior to dark period than any other periods. During this period, hens tried hard to search and compete suitable roosting positions. Especially when perch space is limited, hens struggle vigorously to secure a perching place for the night (Appleby et al., 1992). Figure 7 shows the PTPD when different HD's were provided. A trend of decrease in PTPD from large to small HD existed except for the smallest HD (15 cm). PTPD for 15 cm HD (6.58 ± 0.32 times/hen-hr) was significanlty larger than PTPD values for HD of 20, 25, and 30 cm. This result is within expectation because perching competition intensified due to reduced perch availablity (57% hens perch at 15 cm HD vs. 75% hens perch at 25 cm HD) when HD was narrowed to 15 cm. A similar finding had also been reported in an earlier study of cross-wise perches (Struelens et al., 2008).

Conclusions

With a group size of 16 hens and provided an average of 15 cm perch length per hen, horizontal distance (HD) of 25 cm did not restrain hen's perching behavior though hens interfered slightly with each other; however, HD <25 cm significantly reduced the proportion of perching hens. Insufficient HD led to more perching trips during 45 min prior to dark period, indicating increased competition due to reduced perch availablity. Under such conditions, hens perched interlacing with each other and tended to perch outward from the opposite perch during dark period, which might be a strategy adopted by hens to make full use of perches. Horizontal distance of 60 cm increased the perching duration and reduced the perching trips during light period; however HD less than 60 cm had similar light-period perching duration and trips. The results suggest 25 cm as the minimum HD between laying-hen perches, 30 cm being preferable to alleviate mutual interference of the hens, and large HD such as 60 cm not advisable.

Acknowledgements

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