



Comparative effect of stocking density and flock size on performance and egg quality of laying hens in conventional and furnished California cages

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ABSTRACT

Two experiments were carried out with an objective to test the comparative performance of laying hens reared in conventional California cages vs furnished California cages with regards to production performance, egg quality parameters and immune status. Experiments were conducted at Poultry Research and Training Centre, Department of Poultry Science, Nagpur Veterinary College during 2019-21. Commercial White Leghorn (BV300) hens ($n = 72$) in each experiment were assigned into two treatments with six replicates in conventional and furnished California cages, and reared for a 20 week period. The furnished cages (FC) are provided with perches, nesting area and scratch pad to meet the natural behaviour of the birds. There were two different treatments viz. 548 cm²/b×6 birds and 645cm²/b×6 birds to see the effect of different stocking density in cages. The performance of the laying hens reared in furnished cages were recorded and compared with findings of birds reared in conventional California cages (CC). The results showed that body weight, weight gain, hen day egg production percentages, feed : egg ratio, egg weight and proportion of broken eggs and dirty eggs were not significantly affected by cage types. However, Haugh unit and albumen height of the eggs from furnished cages hens were significantly higher than those from the conventional California cage hens. While H/L ratio and corticosterone values were significantly lowest in furnished cage system birds. It can be concluded from study that the layer birds can be reared in stress free condition in furnished cage system.

Keywords: Conventional cage, Egg quality, Furnished cage, Laying hens, Performance, Stocking density

With the development of modern intensive animal husbandry, stocking density became one of the most important environmental and management factors. To obtain maximum benefits, the stocking density is often set very high in poultry farms. High stocking density has been reported to bring a number of negative effects, such as decreasing body weight and average weight gain, lowering the performance and egg mass per hen per day, resulting in worse feed egg conversion and higher mortality rate, affecting the egg quality (Kang *et al.* 2018) and having adverse effects on the health and welfare of chicken (Feng *et al.* 2018). Apart from European Union who have advocated for cage free raising of layers in the recent years, only Australia and New Zealand have some commercial non-cage systems. In all other countries, farmers mainly keep layers in cage systems.

Housing is important for raising layer poultry commercially and in small scale. A good layer poultry housing system keeps the bird safe, well growing and productive (Kogoor *et al.* 2021). Considerable debate on the use of battery cages pertaining to the relative effect of

the practice on hen well-being is going on. Furnished cage systems is an attempt to provide an enriched environment (i.e. facilities) to meet the needs of hens while maintaining small group size to minimize social stress. Furnished cages are equipped with perches, dust bath and nesting areas, to increase opportunities for the hens to exhibit natural behaviours (Appleby *et al.* 2002). So, the furnished cages are used as an alternative system to the conventional cage system. Furnished cages with larger flock are beneficial for the layers as by providing a larger total cage area, the layers would have more space for exercise and also reducing the egg production cost per hen. Bird preferences for space are complex and confounded by interactions between group sizes and stocking density. The aim of the current study was to examine the differential effects of stocking density flock size with and without furnished cages on the performance, egg quality and immune status of laying hens under commercial conditions.

MATERIALS AND METHODS

The present research study was carried out at Poultry Research and Training Centre, Department of Poultry Science, Nagpur Veterinary College, Maharashtra Animal and Fishery Sciences University, Nagpur.

Study birds and housing systems: A total of 72 hens with similar body weight, aged 20 weeks were selected for each

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Table 1. Experiment I-Rearing of laying hens at two different stocking densities and flock sizes in conventional California cages

Treatment	Space per bird	Flock size	Bird × cage box	Flock size each box	Replicate	No. of birds
A	85 sq. inch/bird (548 cm ² /bird)	Double	3×2	6 birds	6	36
B	100 sq. inch/bird (645 cm ² /bird)	Double	3×2	6 birds	6	36

*Restructured cage box specification of group A-34''×15''×16'' (width × depth × height); Cage box specification of group B-40''×15''×16'' (width × depth × height).

experiment. Two experiments were conducted for 20 weeks period (Tables 1, 2). The hens were randomly assigned to conventional and furnished California cages. Each cage box represented one replicate to form six replicate per treatment to achieve specific flock size and stocking density. The existing conventional California cages were furnished with additional facility of perch, scratch pad and nesting area for laying birds. At one corner of the furnished California cage, nesting area was provided with the help of hanging curtains flaps so as to provide privacy for the birds during the oviposition/ laying time. The nesting area was covered from three sides and the front was kept open for the access of feed. The nesting area of 265 cm² per hen was provided in each cage as experimented and suggested by Guo *et al.* (2012). A perch was provided across the width of the cage at middle portion. The provided perch space was 14.39 cm and 16.93 cm per bird for 548 cm²/b and 645 cm²/b stocking densities. A scratch pad of astro-turf (5×15'') was tied to floor wire of furnished cages so that layer birds had the facility of scratch. Before the initiation of an experiment, the birds were dewormed and vaccinated against New Castle Disease. As per experimental design, the birds were shifted three weeks before into the assigned cages so that the birds get acclimatize with change in housing environment. The birds were maintained on standard commercial layer feed. A commercial layer feed was procured from M/s Megataj Agrovet Pvt Ltd, MIDC, Nagpur. As per recommendation (BV 300 manual) for commercial laying hen, the birds were offered with 110 g feed/bird/day. At the end of each week, the feed refusals were collected to measure the feed intake of the experimental birds. The feed was offered twice a day in the proportion of 40 g (Morning): 60 g (Evening) for optimum production performance. Throughout the experimental period, 16 h of light was provided with ideal management conditions. The birds were given free access to fresh, clean and wholesome drinking water. The specifications of BV-300 manual were followed for all management practices including for medication and vaccination. The furnished

cage treatments were divided into two treatment groups X and Y. All the furnitures were provided in allotted (548 and 645 cm²/b) area only.

Performance: Body weight was recorded before start of the experiment and at the end of experimental trial. Egg production was recorded daily. Feed intake (FI) was recorded weekly and feed efficiency was calculated.

Egg quality: Cracked and dirty Eggs (%), shell weight, albumen index, yolk index, haugh unit, yolk colour were measured. Egg shell thickness without membranes (mean of three pieces of eggshell from equator and two ends) and shape index (length to width ratio) were measured.

Immune status (Heterophil : Lymphocyte ratio and corticosterone): For estimation of heterophil to lymphocyte ratio and corticosterone, six to eight birds from each treatment were randomly selected for the blood collection at 28 (start of experiment), 37 (mid of experiment) and 47th (end of experiment) weeks of age. Heterophil to lymphocyte ratio was calculated as the method described by Gonzales *et al.* 2003. In this study, corticosterone has been analyzed by ELISA kit (Eiahcort 96-Invitrogen-Thermo Fisher Scientific).

Statistical analysis: Data were analyzed for statistical significance using completely randomized factorial designs (Snedecor and Cochran 1989). All data were statistically analyzed using SPSS software package version 20.0. Variables having unequal observations were analyzed following least square design method and the Duncan's multiple range test (Duncan 1955). Each replicate served as an experimental unit for statistical analysis of growth, production and economics while each representative bird from respective replicate served as an experimental unit for statistical analysis of immunity.

RESULTS AND DISCUSSION

Better stocking density, optimum flock size and raising birds in furnished cages are some of the attempts brought about in a response to the criticism of raising commercial laying hens in conventional battery cages for

Table 2. Experiment II-Rearing of laying hens at two different stocking densities and flock sizes with Modified/Furnished California cage

Treatment	Space per bird	Flock size	Bird × cage box	Flock size	Nesting area /bird	Perch space/bird	Scratch-pad space/cage box	No. Of replicates	No of birds
X	85 sq. inch/bird (548 cm ² /bird)	Double	3 × 2	6 birds	265 cm ²	14.39 cm	483.87 cm ²	6	36
Y	100 sq. inch/bird (645 cm ² /bird)	Double	3 × 2	6 birds	265 cm ²	16.93 cm	483.87 cm ²	6	36

Restructured cage box specification of group X is 34''× 15''× 16 with furnished facility of perch, nest and scratch pad. Cage box specification of group Y is 40''× 15''× 16'' with furnished facility of perch, nest and scratch pad.

Table 3. Comparison of hen day egg production % in furnished cages vs conventional California cages

Treatment	Experimental duration/birds age					
	28- 31 wk	32-35 wk	36-39 wk	40-43 wk	44-47 wk	28-47 wk
FC-548cm ² /b × 6B	84.64±2.85	90.04±2.02	90.91±1.38	91.72±0.35	90.13±1.17	89.49±1.02
FC-645cm ² /b × 6B	86.73±2.11	89.98±1.35	86.51±3.03	93.45±1.37	89.48±2.31	89.23±1.46
CC-548cm ² /b × 6B	91.89±1.80	92.39±1.30	92.49±1.24	91.59±1.78	93.22±1.40	92.31±0.82
CC-645cm ² /b × 6B	89.11±1.46	93.28±1.71	93.77±1.76	94.57±1.73	92.19±1.82	92.58±1.50
SEM	1.137	0.814	1.087	0.713	0.866	0.659
P value	NS	NS	NS	NS	NS	NS

Means bearing superscript within a column differ significantly. NS- Non-significant, *P<0.05, **P< 0.01.

egg production. Optimum space along with comfortable flock size and furnished cage systems provide an enriched environment (i.e., facilities) to meet the welfare needs of laying hens.

The below mentioned results are of comparison in between CC×6B and FC×6B.

Live body weight and weight gain: A comparison of the live body weight and weight gain for laying birds raised in modified furnished cages and conventional California cages is presented in Supplementary Table 1. On comparison of body weight of birds in furnished cages with that of conventional cages maintained in same stocking density (548 cm²/hen and 645 cm²/hen), no significant difference was noticed.

Non-significant difference in body weight of birds maintained in conventional vs furnished cages and non-significant effect of flock size (5 to 8) maintained in furnished cages was reported by Abrahamsson and Tauson (1997), similar to the present experiment. Heckert *et al.* (2002) also reported a non-significant difference in body weight for birds reared in furnished cages with and without perches maintained at different stocking density (10, 15 and 20 birds/m²).

Significant body weight differences in birds provided with perches (1.82 kg) as compared to non-perch birds (1.89 kg) in conventional cages was reported by Tauson (1998) which was thought to be because more energy was directed for perching rather than production. Similarly, Hester *et al.* (2013) observed differences in body weight when cages were furnished with perches at different stages of growing and laying as compared to control with no perches. Further they observed that chickens with access to perches during the pullet phase had heavier body weight, consumed more feed, and had poorer feed efficiency during egg laying than control chickens without access of perches as pullets.

In the present study, non-significant differences in body weight for conventional cages and furnished cages may be because of non-significant difference in feed consumption and the entire energy being directed towards egg production and egg mass.

Hen day egg production (HDEP%): The data concerning to comparison of HDEP% between conventional cage (CC) and furnished cages (FC) during the entire experimental (20-week) period from all the treatment groups is presented in Table 3. The total twenty week trial were comprised of

28 to 31st, 32 to 35th, 36 to 39th, 40 to 43rd and 44 to 47th week periods. The effect of stocking density on HDEP% in furnished cages and conventional cages was non-significant for all the periods viz. 28-31st, 32-35th, 36-39th, 40-43rd, 44-47th and entire 28-47th week of age. Similar to present results, Appleby *et al.* (2002) reported egg production was not significantly affected by cage design and flock size for the different conventional and furnished cage. Non-significant difference in egg production between conventional cages of 5 birds at stocking density of 550 cm² per hen and in enriched cages with 22 hens equipped with perch, nest box and litter areas as per EU directives was demonstrated by Karkulin (2006). Wall and Tauson (2007) compared performance of hens in furnished cages having eight hens with conventional cages of four hens and production was recorded from 20th week to 80th week of age and found no significant difference. Tactacan *et al.* (2009) reported non-significant effect on hen-day egg production between conventional battery cages and in enriched cages. Shimmura *et al.* (2010) also reported non-significant effect of egg production in birds reared in conventional and furnished cages. Guo *et al.* (2012) also reported non-significant difference in laying rate of birds housed in conventional and in small furnished (586 cm²/hen) and large furnished (543 cm²/hen) cages. Windowski *et al.* (2017) demonstrated that by providing two space allowance (520 cm² and 748 cm²) and 2 cage size (Smaller furnished cages and Larger Furnished cages) could not bring any significant effect on hen day egg production. Meng *et al.* (2014) had reported a significant improvement in egg production which is contradictory to the present experimental result on egg production. There was a significant reduction in egg production in birds maintained in Large Furnished cages (stocking density of 750 cm²/bird with 40 birds as group size) as compared to Small Furnished cage (stocking density of 750 cm²/bird with 8 birds as group size) and Conventional cages (stocking density of 528 cm²/hen with 12 birds as group size) as possibly the large furnished cages provided the hens more space, allowing them more activity and higher utilization of energy to activities other than egg production.

Most of the reports are from European countries, hens in furnished cage systems have productivity equal to those in conventional cage systems which is consistent with our results. However many studies have also shown that the productivity in conventional cage systems is better than

Table 4. Comparison of external and internal egg quality in furnished cages vs conventional California cages

Treatment	Egg weight	Shape index	Dirty eggs	Broken eggs	Albumen index	Yolk index	Shell thickness	Haugh unit	Shell weight	Yolk score
FC-548cm ² /b × 6B	55.00±0.54	77.13±0.38	0.73±0.52	0.13±0.07	0.14±0.00	0.41±0.00	0.35±0.00	94.66±0.32	5.41±0.06	5.38±0.07
FC-645cm ² /b × 6B	53.91±0.36	77.70±0.24	0.44±0.26	0.01±0.00	0.14±0.00	0.41±0.01	0.34±0.00	95.34±0.34	5.51±0.06	5.35±0.08
CC-548cm ² /b × 6B	54.13±0.56	77.44±0.21	2.03±1.09	0.07±0.04	0.14±0.00	0.41±0.00	0.34±0.00	95.18±0.75	5.40±0.04	5.25±0.08
CC-645cm ² /b × 6B	54.57±0.52	76.93±0.26	0.31±0.07	0.18±0.14	0.13±0.00	0.41±0.00	0.35±0.01	93.79±0.60	5.49±0.08	5.28±0.05
SEM	0.251	0.143	0.322	0.040	0.001	0.002	0.002	0.280	0.031	0.034
P value	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means bearing superscript within a column differ significantly. NS-Non-significant, *P<0.05, **P<0.01.

alternative systems such as free-range, outdoor-run, non-caged indoor, or furnished cage systems (Abrahamsson *et al.* 1996). It can be concluded that furnishing the cages did not bring any significant change in HDEP% compared to conventional California cages as the space provided was similar in this study, however the numerical higher egg production was recorded in CC reared birds. This could possibly due to the layer birds was reared in cage system since the chick stage to liquidation stage (0-80 week). Hence birds did not have any exposure of the perch, nesting and dust bath from their early stage of life and adopted for conventional cage system that could be the reason there was non significant difference in production performance in conventional and furnished cages.

Feed conversion ratio: A weighed quantity of feed (110 g) was offered to all the treatment groups as per standard specification. At the end of each week, the residual feed from the feeding trough of each cage box was collected, quantitatively weighed and divided by the number of birds in that cage which was merely 0.5 g/b. Therefore, the actual feed intake of birds was considered to be 110 g/bird for all the experimental birds. The data pertaining to comparison of the FCR per dozen eggs and per kg egg mass for birds raised in furnished and conventional cages is presented in Supplementary Table 2 and Table 3. FCR per dozen eggs and per kg egg mass when compared between conventional and furnished cages at different stocking density were non-significant for the entire 20 week period.

Appleby *et al.* (2002) observed no significant difference in feed consumption when kept various group size birds of 4 to 8 birds in conventional and furnished cages, though there was a trend for higher feed consumption in groups with fewer birds. More eggs per bird were collected when there were fewer birds per cage but food consumption also then tended to be higher, therefore the reason for non-significant effect on food conversion efficiency. Non-significant results were observed for feed consumption and feed efficiency by Karkulin (2006) for hens maintained at enriched and conventional cages. Also, non-significant effect in feed efficiency between furnished and battery cages was reported by Pohle and Chang (2009). Though, Tactacan *et al.* (2009) observed in certain ages 21-24 week

and 33-36 week, feed consumption was significantly more in conventional cages than in enriched cages and less in 49-52 week and 52-56 week.

In contrast with the current study, significant differences in feed efficiency was noticed by Guo *et al.* (2012) and Meng *et al.* (2014) for hens housed in large furnished cages and small furnished cages had a poorer feed efficiency (P<0.01) than that of conventional battery cages. Feed conversion can be influenced by the housing system and in alternative housing systems, hens have to use some of their energy for heat production and movement, because of lower stocking densities and sometimes lower temperatures in these systems. This leads to higher feed consumption and unfavourable feed conversion. In the present investigation, due to similar stocking density, there could be non-significant difference in feed conversion ratio in the laying hens reared at FC and CC housing systems.

External and internal egg quality parameters: A comparison of the external and internal egg quality parameter for birds raised in modified furnished and conventional California cages is presented in Table 4. There was no significant differences for the egg quality parameters for birds raised in modified furnished and conventional California cages.

Appleby *et al.* (2002) observed no significant differences on cage type that is conventional and various design of furnished cages on egg weight measured at 50 and 72 weeks of age, though at 60 weeks one of the furnished cages had significantly better egg weight (P<0.01). There were no significant effects of stocking density on any of the egg quality characteristics. Karkulin (2006) also reported non-significant effects of cage system (conventional and furnished) on various egg quality except for egg weight. Hens housed in enriched cages laid significantly (P<0.05) heavier eggs compared to hens housed in conventional cages in contrast to present experiment. Wall and Tauson (2007), Tactacan *et al.* (2009), Pohle and Chang (2009) and Meng *et al.* (2014) reported non-significant difference on egg weight when birds were kept in conventional and enriched cages. Also, Meng *et al.* (2014) observed non-significant differences in egg weight due to different flock size in furnished cages. Albumen index and Haugh unit were

Table 5. Comparison on heterophil: lymphocyte ratio and corticosterone in furnished cages vs conventional California cages

Treatment	H/L Ratio			Corticosterone (ng/ml) at 47 th week		
	28 th wk	37 th wk	47 th wk	28 th wk	37 th wk	47 th wk
FC-548cm ² /b × 6B	0.36±0.03	0.24±0.03	0.23 ^b ±0.02	1.73 ^a ±0.14	0.87±0.08	0.86 ^{ab} ±0.10
FC-645cm ² /b × 6B	0.30±0.05	0.31±0.02	0.35 ^a ±0.02	1.76 ^a ±0.11	1.09±0.02	0.67 ^b ±0.10
CC-548cm ² /b × 6B	0.26±0.02	0.23±0.01	0.31 ^a ±0.03	1.20 ^b ±0.01	0.93±0.09	1.02 ^a ±0.06
CC-645cm ² /b × 6B	0.31±0.04	0.25±0.02	0.29 ^{ab} ±0.02	1.08 ^b ±0.07	1.01±0.04	1.01 ^a ±0.06
SEM	0.018	0.011	0.015	0.078	0.034	0.048
P value	NS	NS	*	**	NS	*

Means bearing superscript within a column differ significantly. ^{NS}Non-significant, *P<0.05, **P<0.01.

reported to be better in furnished cages than in conventional cages which were in contrast to present experiment. The better egg shell thickness in furnished cages by Meng *et al.* (2014) was thought to be due to lower egg production in furnished cages as compared to conventional while the feed consumption remained the same. The similar calcium intake with lower egg production would convert more blood calcium into eggshell, making the egg shell thicker. Widowski *et al.* (2017) observed no changes in egg weight between conventional cages and furnished cages, though a significant (P<0.01) increase in egg weight was noticed with age. Hester *et al.* (2013) found no significant differences on the various egg quality parameter for the furnished cages with availability of perches either in pullet or laying phase. Karkulin (2006) also reported non-significant effect of furnished and conventional cages on percentage of dirty and cracked eggs, though downgraded eggs were low in enriched cages. It was reported that low amount of downgraded eggs in enriched cages were reached because of the plastic curtain fixed round the nest which effectively reduce the rolling out speed of egg from the nest and so the risk of its breakage was lower. Non-significant effect of cage type that is between conventional and enriched cages on cracked eggs was reported by Tactacan *et al.* (2009) probably because of the egg saviour employed, however there was significant more dirty eggs in enriched cages as more eggs were laid at the scratch pad region of the cage. Non-significant difference on cracked and dirty eggs was also reported by Widowski *et al.* (2017) for different floor space (516, 522, 750 and 746 cm²/hen) and group size (80, 40, 55 and 28). In contrast, Appleby *et al.* (2002) reported significant effect of cage type (conventional vs different designs of furnished cages) on the percentage of cracked and dirty eggs. Also, Wall and Tauson (2007) reported significantly (P<0.001) low proportion of cracked eggs in conventional cages as compared to furnished cages, but dirty eggs were non-significant on cage type but numerically higher in conventional cages. Wall (2011) found significant difference in flock size in furnished cages for percentage dirty and cracked eggs with a better result in smaller flock size of 8 to 10 birds as compared to bigger group of 20 and 40 birds in the furnished cages. The group size of 8 and 10 birds were non-significant, which was similar to present experiment of smaller flock size of 6 and 9 birds. Li *et al.* (2017) reported no significant differences in the nesting behaviour for birds kept in various types of

modified cages.

Immune status (heterophil/lymphocyte ratio and corticosterone): The heterophil/lymphocyte ratio observed for the three different periods start, mid and end, shown significant differences among the furnished (FC) and conventional (CC) cages only at the end of the experiment with significantly lowest (P<0.05) value in FC-548cm²/b×6B as compared to other furnished and conventional cage though it remained non-significant with CC-645cm²/b×6B, having a better stocking density. At stocking density of 548 cm²/b, the difference in H/L ratio between furnished and conventional cage indicated that furnished cages were in lower level of stress than conventional California cages. Significantly different corticosterone value between furnished and conventional California cages was observed only during the start or 28th week and at the end of the experiment i.e. 47th week of bird's age. At the end of the experiment, significant differences (P<0.05) were observed for birds maintained in furnished cages had lower corticosterone (ng/ml) value indicating lower level of stress as compared to conventional California cages (Table 5).

Tactacan *et al.* (2009) reported non-significant difference in H/L ratio for birds in furnished and conventional cages. In contrast, Shimmura *et al.* (2010) reported highly significant difference in H/L ratio between furnished cages and conventional cages with different flock size. In the present experiment, H/L ratio and plasma corticosterone (ng/ml) value comparison of conventional cage with furnished cages varied differently for various age or periods; but towards the end of the experimental period, bird's in furnished cages had lower values of H/L ratio and corticosterone (ng/ml) indicating a less stressful condition in furnished cages. In poultry, population differences exist in response to various stressors and social interaction among chickens can be a serious source of stress. Findings of Cheng and Muir (2004) support the hypothesis that chickens need social attachments within a group but prefer a low-density social environment and within a low density and stable group, chickens are less stressed by following the established social rank order. In the present experiment, non-significant differences for few periods of the experiment between furnished and conventional cages could be related to low density of birds and stable group. Pohle and Chang (2009) reported non-significant difference in battery and furnished cages on the plasma corticosterone value with flock size of 6 and 10 hens and floor space per

hens was 645 and 610 cm²/hen respectively, apart from the dust-bath and nest box area. Tactacan *et al.* (2009) also reported non-significant differences in corticosterone value in the birds reared at conventional and furnished cages.

While comparing conventional and furnished cages, the production and egg quality parameters were non-significantly different. However, considering the immune status, furnished cage birds were stress free.

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