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Research Article

Hyline-White Behaviour, Laying Performance and Egg Quality in Two Conventional Caging Systems with Different Densities

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Abstract

Improving layer performance is considered as the main objective of the breeders. This can be achieved by managerial conditions of such birds, the housing system is considered as one of the important factors which affect the layer performance. The aim of this study was to compare between two cage housing systems with different stocking densities for laying hens (Hyline-white) with their laying performance, egg quality and behaviour. This work was carried out in two pens from the two conventional caging systems in Sadat project (one of Beni-Seuf governorate projects). Each pen holds about 22850 laying hens with an average 385.7 cm^2 per hen in system (I) and with an average 320 cm^2 per hen in system (II), feed intake and daily egg production were calculated for each pen. Freshly laid eggs were collected and examined for their external and internal quality. In addition to three replicate from each pen was utilized for behaviour observation. The results showed a non significant difference in external and internal egg quality measurements except for egg volume, specific gravity and albumin ratio which were significantly ($p<0.05$) increased in the system (I) than the system (II). There was significant ($p<0.05$) difference in eating, drinking and walking. Also abnormal behaviour like eating dropping was recorded in system (II). In conclusion, housing system and cage design beside the number of hens per cage were found to have a significant effect on hen behaviour, performance and egg quality.

Key words: Hyline-white, behaviour, egg quality, caging system, egg production

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In poultry management, housing system may be associated with certain problems such as social stress, inability to express natural behaviours, which determine productivity and welfare (Sosnowka-Czajka *et al.*, 2010). Stocking density is also an important consideration because of its effect on bird's performance. Egg producers have increased their net income by utilizing available housing facilities at maximum capacity (Jalal *et al.*, 2006). Currently, commercial layer farms tend to overcrowd the hens by increasing the number of birds per cage (Nahashon *et al.*, 2006) or increasing the number of cages per house and reducing their sizes. These intensive systems may cause stress and behavioural and physiological abnormalities, which adversely affect productivity and health (Hall, 2001; McLean and Savory, 2002; Bessei, 2005).

Layer production system has an effect on the quality of eggs as documented by many studies (Giannenas *et al.*, 2009; Matt *et al.*, 2009). Also there are numerous studies regarding the effect of cage stocking density on behaviour (Anderson *et al.*, 2004), welfare (Tauson, 2005; Nicol *et al.*, 2006; Guo *et al.*, 2012), production (Jalal *et al.*, 2006; Nahashon *et al.*, 2006), egg quality (Sarica *et al.*, 2008) and mortality (Onbasilar and Aksoy, 2005) of commercial layers.

Many studies were done to investigate the effect of different poultry housing systems (outdoor, conventional caging system, enriched cages, etc) on laying performance and egg quality (Vits *et al.*, 2005; Benyi *et al.*, 2006). However, within the same type of system, there may be some differences in the design or dimensions which may affect the layer behaviour and performance. The aim of this study was to compare between the effects of two cage housing systems for laying hens (Hyline-white) on their laying performance, egg quality and behaviour.

MATERIALS AND METHODS

Bird management: This work was carried on 45 weeks old Hy-line white laying hens with the average weight of (1.518 g). The hens were reared in wire cages provided with metal food managers and automatic nipples for drinking water supply. Their management procedures (temperature, light intensity and duration) were in accordance with the recommendations of Hyline management guide (registered trademark of Hy-line international, West Des Moines, Iowa USA). All birds were provided lighting for 16 h a day, 20 lux light intensity. A commercial layer diet containing (17.5% crude protein, 2799.99 kcal kg^{-1} net energy, 0.87% lysine, 0.45% methionine, 4% calcium, 0.444% phosphorus, 0.19% sodium) was provided to layers (95 g per hen daily) and fresh clean drinking water was constantly available.

Housing systems: There were two conventional housing systems in the Sadat project, Beni-Suef governorate. The construction of both systems was differing in some aspects.

The first system (I) pen dimensions were 100×12 m that contains 4 double batteries each one consisted of 3 rows. There were exhausted fans in one side of the pen and cooling cells on the top and bottom of the other side. Cage dimensions were (60×45×45) cm, length×width×height with vertical head gate (5 cm). The average stocking density per cage was 7 hens, with an average 385.7 cm^2 per hen.

The second system (II) pen dimensions were 100×12 m that contains 5 double batteries each one consisted of 3 rows. The exhausted fans were found in both sides of the pen, with the cooling cells were at the top of both sides. Cage dimensions were (40×48×48) cm, length×width×height, with horizontal head gate (10 cm). The average stocking density per cage was 6 hens, with an average 320 cm^2 per hen (Fig. 1).

Behavioural observation: Behavioural observations were performed for four weeks using scanning techniques. In each system, three replicates, composed of two cages were observed personally. The observation was conducted at a 1 min interval for 15 min in the morning (9-12 AM). A scan consisted of scoring the number of hen eating, drinking, standing, walking, sitting, pecking and others (Bubier, 1996; Marıa *et al.*, 2004). Hens were accustomed to the presence of the observer in the first day and the other data were used for the analysis (Table 1).

Performance and egg quality: The daily egg production for each housing system was recorded, where egg production was expressed as hen-day egg production (no. eggs/no. live hens/day). Feed Intake (FI) in the study period was recorded (95 g per hen/day) and feed conversion ratio was calculated. At the forth week of the experiment, 30 eggs were collected from each system and used for the measurement of egg quality. Time interval between the eggs being laid and measured was less than 24 h. The length and breadth of the eggs were measured and Egg Shape Index (ESI) was calculated (breadth/length×100) according to Wang *et al.* (2009). The Egg Weighed (EW) and the Egg Volume (EV) was estimated by water displacement in a graduated cylinder and the egg specific gravity (SPG) was calculated (egg weight/volume) (Romanoff and Romanoff, 1949). Then eggs were carefully

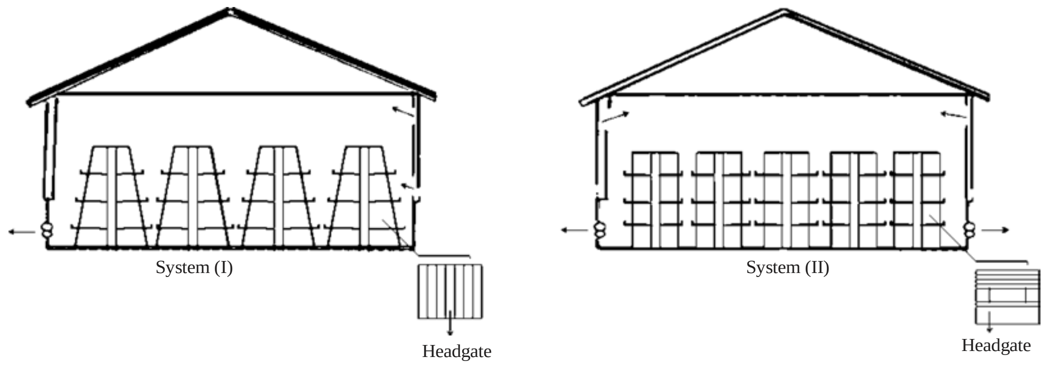

Fig. 1(a-b): Housing systems designs (a) System I and (b) System II

Table 1: Behavioural ethogram of layers according to Guo *et al.* (2012)

Behaviour	Description
Eating	Pecking the feed from the food trough continuously
Drinking	Ingestion of water from drinking nipples continuously
Walking	Taking at least one step in any direction
Body care	Preening and behaviour of dust bathing at the cage floor
Rest and sleep	Standing idle posture, sitting with open eyes and sleeping
Pecking	Pecking at feathers, neck, head, tail, claw of another bird, gentle pecks aimed at beak, at particles in the body of another bird, pecking at the cages, trough and perches
Aggression	Aggressive pecking towards other birds
Brooding	Hen lie down and bring an egg and put it under its breast
Other activities	Flapping, pandiculation, ruffling, beak cleaning and defecation
Abnormal behaviour	Feather pecking and eating dropping from the tray above the cage

broken by using sharp scissors in a clean weighed dish keeping the internal components of the egg undisturbed. The albumin sac which envelops the yolk was dissected away using a fine pair of scissors. The albumin and yolk were weighed separately in a dry previously weighed dish. Eggshell was weighed with eggshell membranes giving eggshell weight. The Yolk Ratio (YR), Albumen Ratio (AR) and Egg Shell Ratio (ESR) were expressed as yolk weight/egg weight$\times$100, albumin weight/egg weight$\times$100 and egg shell weight/egg weight$\times$100, respectively. Egg Mass (EM) was calculated by multiplying the percentage of hen day egg production by the average egg weight for each hen. Mean Feed Conversion Ratio (FCR) was calculated as the ratio between the daily feed consumption and the daily egg mass. Mortality rate was recorded daily.

Statistical analysis: Results were statistically analyzed by the use of independent t-test and wilcoxon signed ranks (a non parametric) test for behavioural data, using Statistical Package for Social Sciences (SPSS) 20 together with least square analysis procedure.

RESULTS

The behavioural patterns of laying hens were summarized in Table 2, where the mean values of the behaviour frequency and standard error are shown for each housing system. A p-value of 0.05 or less would indicate a significant difference between housing systems for each pattern, the table showed a significant ($p<0.05$) increase in eating, drinking and walking frequencies in system (I) than in system (II). However, the other behavioural patterns studied were not significantly differing.

The same table revealed occurrence of some abnormal behaviours such as eating droppings in the system (II) which was not observed in system (I), also the feather pecking abnormal behaviour (feather pecking frequency) was more in system (II) but in a non-significant manner.

Figure 2 showed the maintenance behaviour of layer hens under the two housing systems, which revealed significant increase in eating and drinking frequency in system (I) higher than system (II), however the body care and rest and sleep behavioural patterns were increased in system (I) more than system (II) in a non significant manner.

Table 3 demonstrated the laying performance, internal and external quality of eggs, the results showed no significant difference in daily egg production, egg mass or feed conversion ratio between the two systems. With respect to the external egg quality, egg volume was significantly ($p<0.05$) increased in system (I) in comparison with system (II). In addition, the specific gravity was significantly ($p<0.01$) affected by housing system. However egg weight, egg shape index and egg shell ratio were not significantly different.

Table 2: Behavioural ethogram of layers under two housing systems with different densities

	Behavioural patterns							
				Body care		Rest and sleep		
Housing system	Eating	Drinking	Walking	Preening	Sham dust bathing	Standing idle	Sitting	Sleeping
I	37.8±2.45*	14.1±1.24*	57.6±2.00*	13.9±1.22	0.3±0.00	8.4±0.23	4.4±0.62	1.2±0.00
II	6.2±0.92	39.3±3.44	13.3±1.32	0.0±0.00	6.6±0.58	4.6±0.62	2.0±0.51	7.2±0.00

	Behavioural patterns					
					Abnormal behaviour	
Housing system	Pecking	Aggression	Brooding	Other activities	Feather pecking	Eating dropping
I	6.8±1.11	3.5±0.54	0.2±0.00	2.8±0.32	0.6±0.02	No
II	29.0±0.79	3.4±0.31	0.4±0.16	2.6±0.61	1.5±0.44	1.6±0.6

*Superscript means significance between columns at p<0.05, NO: Not observed

Table 3: Laying hen performance and egg quality traits under two housing systems with different densities

				Egg quality						
				External					Internal	
Housing system	Daily egg production (%)	EM (g)	FCR	EW (g)	EV (cm3)	ESI	SPG	ESR (%)	YR (%)	AR (%)
I	78.5±0.91	51.3±0.59	1.85±0.02	65.4±0.66	62.1±0.73*	92.6±1.15	1.05±0.03	14.9±0.28	26.5±0.58	59.4±0.59*
II	79.3±0.78	50.6±0.49	1.88±0.02	63.8±0.94	59.3±1.06	92.5±1.29	1.07±0.03**	15.2±0.42	27.6±0.40	57.8±0.52

*Significance between columns at p<0.05, **Significance between columns at p<0.05, EM: Egg mass, FCR: Feed conversion ratio, EW: Egg weight, EV: Egg volume, ESI: Egg shape index, SPG: Specific gravity, ESR: Egg shell ratio, YR: Yolk ratio, AR: Albumin ratio

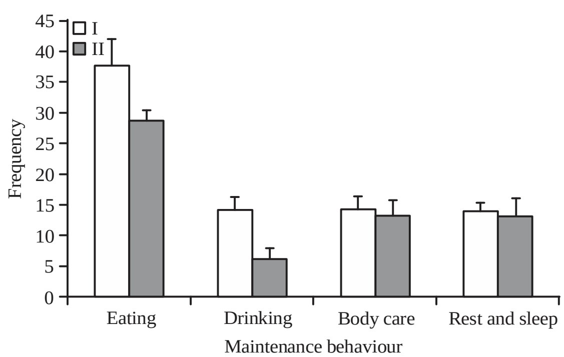

Fig. 2: Maintenance behaviour under two housing systems with different densities

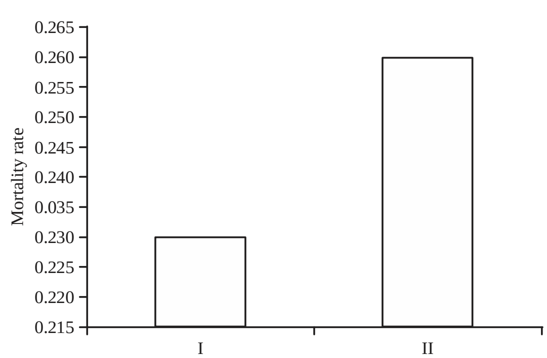

Fig. 3: Effect of different systems with different densities on hen mortality rate

Concerning the internal egg quality, albumin ratio was significantly (p<0.05) increased in system (I) more than system (II), while there was no significant difference between the two housing systems regarding to yolk ratio.

Results of mortality rate for both housing systems are shown in Fig. 3. The mortality rate was significantly higher (p<0.05) in system (II) than system (I).

DISCUSSION

To save costs, cage sizes have decreased and number of hens per cage increased and for the floor allowance to be so restricted that not all birds can sit down at any one time (Mills *et al.*, 2010). In the present study, a comparison was done between two cage housing systems for laying hens (Hyline-white) with different stocking densities regarding their behaviour, laying performance, egg quality and mortality rate.

Some laying hen behavioural patterns were significantly differing between the two housing systems, where eating and drinking were with higher frequency in system (I) than system (II). This was not the case with Guo *et al.* (2012) who found no significant difference between group sizes in feeding and drinking behaviours. However they agree with us in finding a non-significant effect in pecking or resting behaviours. Also Cook and Xin (2005) found no significant differences between the stocking densities for any of the feeding behaviour parameters recorded during their trials. These results may be explained in light of published project report (DEFRA., 2004) which reported that the mean feeding bout length was affected by cage width or feed trough length/hen. They observed that the shortest mean bout length occurring in wide cages containing seven hens that had an overall feed trough length of 17.1 cm per hen. They also reported that mean feeding bout length was influenced by hen number in the cage and drinking was most frequent in cages of 6 hens.

Concerning the locomotion behaviour, there was significant increase in system (I) compared with system (II) and this result in consistence with that of project report (DEFRA., 2004) as they found that locomotion was highest in cages containing eight hens and lowest in cages containing 10 hens. Which may also attributed to the space allowed for each hen to perform specific behaviour. Wing flapping and other body activities in two systems were not significantly different. This result was in agreement with Appleby *et al.* (2002) and Rodenburg *et al.* (2005). The eating droppings were only recorded in the system (II) which may be attributed to feeding space allowance per each hen. Moreover, feather pecking is more observed in high density cages than in low ones as recorded by Bilcik and Keeling (2000).

With respect to egg production, mass, FEU and quality, the present results were in consistent with that of Nagarajan *et al.* (1990) and Guo *et al.* (2012), who found no significant effect of housing system on laying rate, egg weight and egg shape index. Also Altan *et al.* (2002) demonstrated that egg shell quality and egg weight were not affected. However they reported that increasing cage density in white layers decreased egg production. On the other hand Padmakumar *et al.* (2000) found significant influence of housing density on egg weight. Also they demonstrated that the different floor space allowances provided significantly attacked the shape index of eggs, Bandyopadhyay and Ahuja (1990) also had similar findings. Regarding the FEU results, it could be supported by Turkyilmaz (2008) results who found no significant effect of stocking density on FCR. Specific gravity considered as an accurate predictor of shell thickness, much more reliable for this purpose than percentage shell (Tyler and Geake, 1961). The results showed higher specific gravity in system (II) than in system (I) that is meant that it had higher eggshell quality traits. Also the decreased albumin ratio in system (II) can reflect high egg quality as clarified by Englmaierova *et al.* (2014) and the low quality white may be attributed to high level of ammonia gas resulted from improper optimum ventilation system as reviewed by David *et al.* (2015).

Padmakumar *et al.* (2000) found that space allowance for birds did not significantly affect the yolk index and this was similar to the present result while Nagarajan *et al.* (1991) and Viswanathan (1992) observed highly significant ($p<0.01$) difference in yolk index value between the different floor space allowances studied. Differences in the species utilized for investigations by the workers might explain for these contrasting observations.

Increased mortality in this study could be explained by Perry (2004) who reported that cage design appears to play a major role in the mortality of hens in cages and Moinard *et al.* (1998), who found that hens in tall cages experienced more mortality than hens in low cages. But this was not the case with Anderson and Adams (1991) that showed that cage front type (vertical versus horizontal) did not affect mortality levels in hens. Also the increased mortality rate may be due to the hen's stocking density and this in agreement with Craig *et al.* (1986), who demonstrated that hen at high density in cages experienced greater mortality than that at moderate and low cage densities. However Abrahamsson and Tauson (1997, 1998) reported that hen density did not affect the mortality rate of hens.

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REFERENCES

Abrahamsson, P. and R. Tauson, 1997. Effects of group size on performance, health and birds' use of facilities in furnished cages for laying hens. Acta Agric. Scand. Section A-Anim. Sci., 47: 254-260.

Abrahamsson, P. and R. Tauson, 1998. Performance of egg quality of laying hens in an aviary system. J. Appl. Poult. Res., 7: 225-232.

Altan, A., O. Altan, S. Ozkan, K. Ozkan, Y. Akbas and V. Ayhan, 2002. Yuksek yaz sicaklarinda kafes yerlesim sikliginin yumurta tavuklarinin performansi uzerine etkileri. Turk. J. Vet. Anim. Sci., 26: 695-700.

Anderson, K.E. and A.W. Adams, 1991. Effects of type of cage front and feed trough partitions on productivity and ingestive, agonistic, and fearful behaviors of egg-type hens. Poult. Sci., 70: 770-775.

Anderson, K.E., G.S. Davis, P.K. Jenkins and A.S. Carroll, 2004. Effects of bird age, density, and molt on behavioral profiles of two commercial layer strains in cages. Poult. Sci., 83: 15-23.

Appleby, M.C., A.W. Walker, C.J. Nicol, A.C. Lindberg, R. Freire, B.O. Hughes and H.A. Elson, 2002. Development of furnished cages for laying hens. Br. Poult. Sci., 43: 489-500.

Bandyopadhyay, U.K. and S.D. Ajuja, 1990. Effect of cage density on some of the egg quality traits in Japanese quail. Indian J. Poult. Sci., 25: 159-162.

Benyi, K., D. Norris and P.M. Tsatsinyane, 2006. Effects of stocking density and group size on the performance of white and brown Hyline layers in semi-arid conditions. Trop. Anim. Health Prod., 38: 619-624.

Bessei, W., 2005. Welfare of meat producing poultry-an overview. Anim. Sci. Papers Rep., 23: 205-216.

Bilcik, B. and L.J. Keeling, 2000. Relationship between feather pecking and ground pecking in laying hens and the effect of group size. Applied Anim. Behav. Sci., 68: 55-66.

Bubier, N.E., 1996. The behavioural priorities of laying hens: the effects of two methods of environment enrichment on time budgets. Behav. Processes, 37: 239-249.

Cook, R.N. and H. Xin, 2005. Effects of cage stocking density on feeding behaviour of group housed laying hens. Animal Industry Report: AS 651, ASL R2018. http:// li.dr. astate. du/gi/ viewcontent.cgi?article=1910&context=ans_air.

Craig, J.V., J.A. Craig and J.V. Vargas, 1986. Corticosteroids and other indicators of hens' well-being in four laying-house environments. Poult. Sci., 65: 856-863.

DEFRA., 2004. The effect of stocking density and cage height on the health, behaviour, physiology and production of laying hens in furnished cages. Department for Environment, Food and Rural Affairs (DEFRA), London, UK. http:// randd. defra. ov.uk/Default. spx?enu= enu and ule=More and Location= None and Completed=0 and ProjectID=9859

David, B., C. Mejdell, V. Michel, V. Lund and R.O. Moe, 2015. Air quality in alternative housing systems may have an impact on laying hen welfare. Part II-Ammonia. Animals, 5: 886-896.

Englmaierova, M., E. Tumova, V. Charvatova and M. Skrivan, 2014. Effects of laying hens housing system on laying performance, egg quality characteristics and egg microbial contamination. Czech J. Anim. Sci., 59: 345-352.

Giannenas, I., P. Nisianakis, A. Gavriil, G. Kontopidis and I. Kyriazakis, 2009. Trace mineral content of conventional, organic and courtyard eggs analysed by inductively coupled plasma mass spectrometry (ICP-MS). Food Chem., 114: 706-711.

Guo, Y.Y., Z.G. Song, H.C. Jiao, Q.Q. Song and H. Lin, 2012. The effect of group size and stocking density on the welfare and performance of hens housed in furnished cages during summer. Anim. Welfare-UFAW J., 21: 41-49.

Hall, A.L., 2001. The effect of stocking density on the welfare and behaviour of broiler chickens reared commercially. Anim. Welfare, 10: 23-40.

Jalal, M.A., S.E. Scheideler and D. Marx, 2006. Effect of bird cage space and dietary metabolizable energy level on production parameters in laying hens. Poult. Sci., 85: 306-311.

Marıa, G.A., J. Escos and C.L. Alados, 2004. Complexity of behavioural sequences and their relation to stress conditions in chickens (Gallus gallus domesticus): A non-invasive technique to evaluate animal welfare. Applied Anim. Behav. Sci., 86: 93-104.

Matt, D., E. Veromann and A. Luik, 2009. Effect of housing systems on biochemical composition of chicken eggs. Agron. Res., 7: 662-667.

McLean, J.A. and C.J. Savory, 2002. Welfare of male and female broiler chickens in relation to stocking density, as indicated by performance, health and behaviour. Anim. Welfare, 11: 55-73.

Mills, D.S., J.N. Marchant-Forde and P.D. McGreevy, 2010. Laying Hen Housing. In: The Encyclopedia of Applied Animal Behaviour and Welfare, Mills, D.S. and J.N. Marchant-Forde (Eds.). CABI, USA., ISBN: 9780851997247, pp: 382.

Moinard, C., J.P. Morisse and J.M. Faure, 1998. Effect of cage area, cage height and perches on feather condition, bone breakage and mortality of laying hens. Br. Poult. Sci., 39: 198-202.

Nagarajan, S., D. Narahari, L.A. Jayaprasad and D. Thyagarajan, 1990. Laying performance of Japanese quail hens under different stocking densities. Indian J. Poult. Sci., 60: 1467-1470.

Nagarajan, S., D. Narahari, I.A. Jayaprasad and D. Thyagarajan, 1991. Influence of stocking density and layer age on production traits and egg quality in Japanese quail. Br. Poult. Sci., 32: 243-248.

Nahashon, S.N., N.A. Adefope, A. Amenyenu and D. Wright, 2006. Laying performance of pearl gray guinea fowl hens as affected by caging density. Poult. Sci., 85: 1682-1689.

Nicol, C.J., S.N. Brown, E. Glen, S.J. Pope and F.J. Short *et al*., 2006. Effects of stocking density, flock size and management on the welfare of laying hens in single-tier aviaries. Br. Poult. Sci., 47: 135-146.

Onbasilar, E.E. and F.T. Aksoy, 2005. Stress parameters and immune response of layers under different cage floor and density conditions. Livestock Prod. Sci., 95: 255-263.

Padmakumar, B., G.R. Nair and A. Ratnakrishnan, 2000. Effect of floor space on egg weight and egg quality traits of japanese quails reared in cages and deep litter. J. Vet. Anim. Sci., 31: 34-36.

Perry, G.C., 2004. Stress and Welfare in Laying Hens. In: Welfare of Laying Hens, Perry, G.C. (Ed.). CABI, USA., ISBN: 9780851990361, pp: 83.

Rodenburg, T.B., F.A.M. Tuyttens, B. Sonck, K. De Reu, L. Herman and J. Zoons, 2005. Welfare, health and hygiene of laying hens housed in furnished cages and in alternative housing systems. J. Applied Anim. Welfare Sci., 8: 211-226.

Romanoff, A.L. and A.J. Romanoff, 1949. The Avian Egg. John Wiley and Sons Inc., New York.

Sarica, M., S. Boga ans U.S. Yamak, 2008. The effects of space allowance on egg yield, egg quality and plumage condition of laying hens in battery cages. Czech J. Anim. Sci., 53: 345-353.

Sosnowka-Czajka, E., E. Herbut and I. Skomorucha, 2010. Effect of different housing systems on productivity and welfare of laying hens. Ann. Anim. Sci., 10: 349-360.

Tauson, R., 2005. Management and housing systems for layers-effects on welfare and production. World's Poult. Sci. J., 61: 477-490.

Turkyilmaz, M.K., 2008. The effect of stocking density on stress reaction in broiler chickens during summer. Turk. J. Vet. Anim. Sci., 32: 31-36.

Tyler, C. and F.H. Geake, 1961. Studies on egg shells. XV: Critical appraisal of various methods of assessing shell thickness. J. Sci. Food Agric., 12: 281-289.

Viswanathan, K., 1992. Productive efficiency of Japanese quails. Ph.D. Thesis, Tamil Nadu Veterinary and Animal Sciences University, Madras.

Vits, A., D. Weitzenburger and O. Distl, 2005. Comparison of different housing systems for laying hens in respect to economic, health and welfare parameters with special regard to organized cages (literature review). Deutsche Tierarztliche Wochenschrift, 112: 332-342.

Wang, X.L., J.X. Zheng, Z.H. Ning, L.J. Qu, G.Y. Xu and N. Yang, 2009. Laying performance and egg quality of blue-shelled layers as affected by different housing systems. Poult. Sci., 88: 1485-1492.