International Journal of Modern Agriculture, Volume 9, No.4, 2020
ISSN: 2305 - 7246

EFFECT OF REARING SYSTEM IN PRODUCTION PERFORMANCE AND EGG QUALITY CHARACTERISTICS OF VANARAJA LAYERS (*GALLUS GALLUS DOMESTICUS*)

Yashaswi Nayak[1], Banaja Prakashini Samantaray[2], Lipsa Biswal[3]

[1,2,3] Department of Zoology, School of Applied Sciences, Centurion University of Technology and Management, Odisha, India

Corresponding Author

Yashaswi Nayak
Department of Zoology, School of Applied Sciences, Centurion University of Technology and Management, Odisha, India
Email: yashaswi.nayak@cutm.ac.in

Abstract

This paper presents investigation on the production performance and egg quality characteristics of Vanaraja layers in three different rearing system i.e. conventional cage rearing, free range or backyard system of rearing and semi intensive system of rearing. A total of 60 laying hens of Vanaraja were taken of same age between 18 to 20 weeks and maintained in 3 different rearing systems for 120 days. All the birds were divided equally among three rearing system. Analysis of data on 60 eggs revealed significant differences in egg quality and production performance and proximate chemical composition. The production performance of Vanaraja was recorded to be highest (89.27%) in caged system as compared to free range and semi intensive. Detailed analysis of the physical characteristics of eggs of Vanaraja layers showed significant differences ($P \leq 0.05$) in different housing system .The research work revealed that birds reared in semi intensive system produced heaviest eggs of (54.50g), higher egg volume of (51.29ml), highest Haugh unit i.e. (79.791), heaviest shell weight of (4.12g), thickest shell of (0.395cm) and with heaviest albumin and yolk weight of (32.09g) and (21.03g) respectively. However the birds reared in caged system showed the highest shape index of (74.90%) and lightest shell of (3.65g), whereas the birds reared in backyard or free range produced eggs of comparatively lower egg quality characteristics. Proximate chemical composition of eggs of Vanaraja birds also differed significantly ($P \leq 0.01$) at different housing system. Higher values of moisture content, fat and energetic value was observed in caged hens as compared to free range and semi intensive. The research was carried out in poultry unit of Centurion University of Technology and Management, Odisha, India.

Key words: Vanaraja hen, Egg quality traits, Free range, Semi intensive and Conventional cages

Introduction

Vanaraja is a dual purpose multi coloured bird, grows faster with a high degree of immune power and can easily scavenge its food from the backyard or pasture area developed by Project Directorate on Poultry, ICAR Hyderabad for backyard farming in rural and tribal areas of India which has contributed significantly to the overall economy of rural people in terms of egg and meat, M. Bhattacharya at al., (2005).

Different housing systems of egg laying, directly and indirectly influenced, the health of the birds, their behavior and productivity, along with the quality of the eggs they produced , Abrahamsson, and Tauson (1995); Krawczyk (2009).

Considering the fact that people in different societies are now growing increasingly health conscious, so the quality of food products have become the area of interest among consumers and producers. For this reason, in this competitive and challenging age efforts are taken to produce products whose quality and safety can be guaranteed.

In order to achieve this, we need to provide the animals with conditions that are optimum for husbandry and provide them feed which are enriched with all essential nutrients. This will guarantee high productivity and good quality of eggs Krawczyk. And Calik (2006).

In order to meet consumer demand, efforts have been made by producers to begin marketing eggs that are laid by hens that are provided with enhanced nutrient and are reared in alternative production system. Among the available rearing system for birds the semi intensive system involves keeping the birds in an area with shed and pasture in which the birds are housed in the evening and in the morning they are allowed to have free access to pasture area. The system has been increasingly used in the last years, mainly due to the aspects related to the greater concern with food quality by consumers, besides it is also believed that since birds will have access to a pasture area so costs to diet might be reduced, Silva (2001); Silva and M Nakan (1998). According to Sundrum, animal health and well-being may be affected by increasing the area in which animal is able to move freely, Sundrum (2001). Once the birds stay longer in pasture area, they have greater mobility, which adds up to the welfare of the birds.

The knowledge of performance of a breed with respect to various economic traits in the chicken is important in carrying out the breeding plans for further improvement in production and egg quality traits. Though many research works have been carried out on egg quality traits, but the information on comparison of productive performance and egg quality traits and varieties developed and being popularized for backyard farming, rearing in rural areas are limited.

So the present study is carried out to assess the effects of three different housing system (caged ,free range or backyard and semi intensive) on laying performance and egg quality traits of Vanaraja layers under agro-climatic conditions of Jatani (a village near Bhubaneswar).

The objective of the current study was to compare a number of nutritional and physical characteristics, of eggs from different housing system which are of interest to the consumers.

Material and Methods

The study was conducted in the experimental Poultry section located at Centurion University of Technology and Management in Jatani (Bhubaneswar campus),Odisha, India to evaluate the production performance and egg quality characteristics of Vanaraja layers reared under three different housing system i.e. conventional cage, free range or backyard and semi intensive system.

A total of 60 Vanaraja laying hens of 18 to 20 weeks of age with an average body weight of 2.150kg± 10 g were used in the experiment. All the hens were individually weighed and after weighing all the hens were maintained for one month on similar feeding and management conditions. After 4 weeks of brooding birds were divided randomly into three groups of 20 hens in each group.

Twenty number of birds were supplied to the farmers in Jatani area for their evaluation under free range, condition and were housed only at night. Another twenty number were allowed for free access to the pasture area during the day time and during evening they were fed with ration (experimental diet) prepared with different cereal grains and oilseeds like corn, wheat, Soyabean meal, green sprouts, Sun flower meal and groundnut seeds during the rearing period.

Remaining 20 number of Vanaraja hens were kept in conventional cage with 4 replicates of 5 birds in each group equipped with linear feeders and nipple drinkers and the area of each house measured about 10 ft. X10 ft. . Birds were exposed to 13 to 14 hours of light per day.

The birds kept in cages were fed with 200g of the experimental diet twice a day i.e. in the morning and afternoon , whereas birds reared under semi intensive system were fed with the experimental diet only once in a day for the experimental period of 42 days .

The proximate composition of feed ingredients were analysed as per AOAC and the same is furnished in Table 1, AOAC (1990).

Table 1. Proximate Composition of Different Feed Ingredients

	Soyabean Meal(Sbm)	**Cereal Grain**		**Green Gram Sprouts**	**Ground Nut**	**Flax Seed**	**Sunflower**
		Wheat	Maize				
Crude Protein (%)	46.22	11.75	9.10	23.96	42.10	16.40	18.00
Ether Extract (%)	19.19	1.29	4.10	1.2	5.03	5.05	6.10
Crude Fibre (%)	5.89	3.33	2.5	3.5	6.69	4.00	3.41
Total Ash (%)	6.89	1.51	3.01	3.88	4.91	4.80	3.18
Energy/Kcal/Kg	2400	2753	3350	2782	2600	2869	2050

The laying diets used in the study were calculated to be isocaloric and isonitrogenous with an average metabolizable energy of 2400 Kcal in Soyabean meal, 3051 Kcal in Wheat and maize, green sprouts and groundnut, 2050 Kcal in Sunflower and 2859 Kcal present in Flaxseed having 23.93% of crude protein, 5.9% of crude fat, 4.1% of crude fibre and 4.2% of total ash.

Feed consumption and egg production were recorded daily and eggs were collected from each group during the experimental period and stored in the refrigerator at 4^0 C. The hen daily egg production, number of damaged eggs and number of dirty eggs were recorded daily.

Feed intake and egg weight were recorded weekly. Egg production was calculated by dividing the number of daily laid eggs by the number of hens on the same day. The eggs were analysed within 2 days of its lay for external and internal quality characteristics.

At the end of the experimental period of 6 weeks a total of 60 eggs were used to evaluate the external and internal quality characteristics and proximate chemical composition.

The external egg quality parameters like egg weight was measured in analytical balance of Dhona- 200 (AB – 204), egg length and egg width were measured with a Vernier calliper in centimetres, and egg shape index was obtained by the following formula

$$\text{Shape Index} = \frac{\text{Width of egg}}{\text{Length of egg}} \times 100$$

For internal egg quality traits each and every egg sample was broken out on a flat white tile being cautious not to break the vitelline membrane that encloses the yolk. The parameters measured were as follows.

a) Yolk width was measured as the widest horizontal circumferences with a Vernier calliper in centimetres.

b) Yolk height was measured as the height of yolk at the midpoint with a tripod micrometre.

c) Yolk index = $\frac{\text{Height of yolk}}{\text{Width of yolk}}$.

d) Albumin heights were measured from at least three places each with tripod micrometre, Froning and DEM Fank et al., (1958).

e) Albumin width was measured as the widest horizontal circumference of the thick albumin with a Vernier calliper in centimetre.

f) Albumin index = $\frac{\text{Height of albumin}}{\text{Width of albumin}}$.

g) Shell thickness of dry egg shell was measured with a micrometre screw gauge. The mean of three points (the narrow, broad and middle) were taken as shell thickness.

h) Haugh unit was determined using the following formula.

$$HU = H + 7.57 - 1.7\,W^{0.37}$$

Where, HU = Haugh Unit
H = height of albumin (mm)
W = weight of egg (g)

Individual Haugh Unit score was calculated using egg weight and albumin height, Haugh (1937); Doyon et al., (1986). The mean values were calculates for each trait, according the, Snedechor et al., (1994).

i) Subsequently, the yolk was separated from albumin and weighed. Shell weight was measured after the removal of remaining albumin with water and rapid sun drying for six hours.

j) The weight of albumin was calculated by subtracting the weight of yolk and shell from the weight of whole egg.

Analytical determination

A total of 12 eggs were analysed from all the three rearing system for whole egg protein content, crude fat, total ash, moisture content computational energetic and carbohydrate value. Egg protein content was determined by Lowry's method.

Crude fat content was estimated by ether extract (Soxhlet extraction) method according, AOAC (1990).

Total ash in the egg sample was determined by incineration in Muffle furnace (made by Sunbeam India) at 600°C.

The moisture content was determined by drying the egg sample at 100-102°C for 16 to 18 hours in a hot air oven as described by Association of Official Analytical chemists (AOAC), AOAC (1990).

Energy value and carbohydrate content were calculated computationally using the following formula Matt et al., (2009).

Energy per kcal 100g of edible portion of egg = (g protein x 4.63) + (g lipids x 9.02) + (g carbohydrate x 3.87).

Carbohydrate = 100% - (protein % + fat % + humidity % + ash %)

Statistical Analysis

In order to find out the significant difference in egg quality characteristics of Vanaraja hens reared under different housing systems, analysis of variance (ANOVA) was conducted and mean values were compared by Duncan's Multiple Range Test, Duncan et al., (1955). Statistical analyses were conducted with Past3 software.

Result and Discussion

External and Internal Quality Traits

The housing system influenced the production performance characteristics of laying Vanaraja hens. The effect of rearing system on egg quality parameter are presented in Table 2.

Table 2: Mean values of egg quality traits in different housing system

	Egg Quality Parameters	Housing System		
		Caged	**Free Range (Backyard)**	Semi-Intensive
1	Production Performance (%)	89.27 ± 1.63^{b}	84.67 ± 1.75^{a}	83.12 ± 1.64^{a}
2	Egg Weight (g)	53.39 ± 1.18^{a}	52.80 ± 0.38^{a}	54.50 ± 0.69^{b}
3	Egg Volume (ml)	50.70 ± 0.31	50.12 ± 0.36	51.29 ± 0.33
4	Shape Index (%)	74.90 ± 0.92^{a}	72.17 ± 0.42^{a}	73.87 ± 0.28^{a}
5	Shell Weight (g)	3.65 ± 0.069^{a}	4.11 ± 0.128^{b}	4.12 ± 0.04^{b}
6	Shell Thickness (mm)	0.372 ± 0.003	0.365 ± 0.006	0.395 ± 0.004
7	Albumen Weight (g)	31.090 ± 0.268^{a}	30.098 ± 0.224^{a}	32.098 ± 0.271^{b}
8	Yolk Weight (g)	19.343 ± 0.172^{a}	18.141 ± 0.091^{a}	21.032 ± 0.191^{b}
9	Albumen Index (%)	0.108 ± 0.008^{b}	0.098 ± 0.003^{a}	0.103 ± 0.004^{b}
10	Yolk Index (%)	0.453 ± 0.004^{a}	0.440 ± 0.005^{a}	0.427 ± 0.004^{b}
11	Haugh Unit	79.491 ± 1.183^{b}	75.421 ± 0.54^{a}	79.791 ± 0.35^{b}

Means bearing different superscripts with in rows differ significantly at $P \leq 0.05$.

The overall **egg production** was found to be significantly higher in Vanaraja hens reared in conventional cages as compared to the alternative systems i.e. free range and semi intensive. These performance results are in agreement with studies by Leyendecker et al. and Tumova and Ebeid, Leyendecker et al., (2001); Tumova et al., (2003). Hulzebosch reports that hens housed in cages had higher egg production than hens housed in litter housings and aviaries Hulzebosch (2006). Michel and Huonnic notes lower egg production in aviaries than in cages, but the difference was smaller than observed in the present study Michel et al., (2003).

Lower egg production in aviaries may have been caused, as a result of some eggs being laid on the floor, perhaps eaten, or left not counted. Conversely, Tactacan et al. compared conventional battery cages and enriched cages and found that the cage design did not affect the hen-day egg production, feed consumption or egg weight in fact the egg production also depends on size of the group of hens Tactacan et al., (2009) .

In the present study, heavier eggs were laid by hens reared in semi-intensive system. The heavier eggs produced under semi intensive system than those under backyard system and caged might be due to better nutrition and improved care and management. This is in agreement with Khan and Krishna Khan et al., (1998).

The mean ± SE average **egg weight** values in the caged , free range, semi intensive were found to be 53.39±1.18, 52.80± 0.38 and 54.50± 0.69 respectively.

Egg weight is the essential selection trait in layer breeding and one of the most important traits preferred in breeding programme by the producers. Egg weight is also considered to be the basic quality included in egg marketing regulation, which classify egg into four categories.

The results of present study on egg weight are not consistent. According to the findings of Clerici et al., an organic rearing system results in producing eggs with heavier egg weight as compared to the conventional system , which does not agree with the results of present study Clerici et al., (2006). In contrast to our findings, Mugnai et al. showed that the rearing system did not affect egg weight Mugnai et al., (2009).

The average egg weight between each rearing system differ significantly at ($P \leq 0.05$) between them. Heaviest egg weight was observed in semi intensive system i.e. (54.50±0.69) as compared to caged (53.39± 1.18) and free range (52.80± 0.38).

Dukic-Stojcic et al. found that heavier eggs were laid by caged hens Dukic-Stojcic et al., (2009). Meanwhile Van Den Brand et al reports the free range layers producing heavier eggs Brand et al., (2004) .Voslarova et al. while comparing egg quality traits of Isa Brown layers, which were raised in caged and litter system observed heavier eggs in caged layers Voslarova et al., (2006). Stanley et al. did not find significant differences between cage and barn eggs in average egg weight or egg components weight Stanley et al., (2013). However, Jones et al. found that eggs from aviary and furnished cages were significantly heavier than those produced in conventional cages Jones et al., (2014). LayWel, a trend towards heaviest eggs appears in conventional cages and small furnished cages, while lighter eggs correspond to the other systems Laywel (2006). The differences in egg weight, in particular between free-range and cage production, could also be due to differences in feeding levels, and/or in environmental temperature.

Depending on the housing system no significant differences were observed in egg **volume**. In the present experiment, eggs with a higher yolk index were laid by birds in cages. Accordingly, Anderson and Adams and Tumova and Ebeid reported higher values of albumen indices, as well as yolk indices in eggs from cage systems Anderson et al., (1994); Tumova et al., (2003).

Albumin and yolk weight differed significantly at ($P \leq 0.05$). Eggs laid by birds reared in semi intensive system exhibited a little higher values of albumin and yolk weight with 32.098±0.271g and 21.032±0.191g respectively as compared to the other housing system.

Meanwhile Van Den Brand et al reported that free range layers produces eggs, high shape index and greater albumin and yolk content as compared to caged hens Doley recorded significantly ($P \leq 0.05$) higher overall egg **yolk index** under caged system than that of backyard system of rearing, which agrees with the present findings Brand et al., (2004); Doley et al., (2006).

In the present study the overall **albumen index** and **yolk index** of eggs of Vanaraja layers differed significantly among the rearing systems with highest value recorded in caged system as (0.108±0.008) and (0.453± 0.004) respectively whereas the lowest albumin index was recorded in the eggs of free range hens as (0.098±0.003) and lowest yolk index was recorded in eggs of birds in semi-intensive system as (0.427±0.004). The impact of rearing system on egg **shell parameters** was clearly visible and statistically confirmed. Comprehensive quality analysis of shells revealed that the eggs of birds reared in semi intensive had the highest shell weight of (4.12±0.04g)) whereas highest shell thickness of (0.395±0.004mm) was observed in the eggs of birds reared in semi intensive system and the lightest shells came from caged layers (3.65±0.06g).

In agreement with the present study Lewko and Gornowicz also confirmed that free range eggs contains comparatively heavier shell than caged and deep litter system Lewko et al., (2011). These authors pointed out that rearing system influences the shell quality traits. In contrast comparing, the parameters of egg shell in eggs of free range vs caged hens, Van Den Brandt et al. and Dukic-Stojcic et al. found no differences in housing systems in weight and thickness of shells Dukic-Stojcic et al., (2019); Brand et al., (2014).

Measurement of **Haugh unit** is a way of determining the egg quality, a higher Haugh unit indicates a better internal egg quality Haugh (1937). In this study it was found that hens from both caged and semi intensive

rearing system produced eggs with significantly higher Haugh unit values of 79.491± 1.183 and 79.791±0.35 respectively, as compared to eggs produced by free range hens.

However authors who have studied Haugh unit in different rearing system gave contradictory result. Present Haugh unit values agrees with the result of Patterson et al., Hidalgo et al., but Castellini et al. and Dukic-Stojcic et al. reported higher Haugh unit value in free range system, Dukic-Stojcic et al., (2019); Patterson et al., (2001); Hidalgo et al., (2008); Castellini et al., (2006). Anderson and Adams and Tumova and Ebeid reported higher values of Haugh units in eggs from cage systems, which agrees with the present study Anderson et al., (1994); Tumova et al., (2003).

Proximate chemical composition

Our study showed that differences in eggs chemical composition between different rearing systems was significant with (P≤0.01) as seen in Table-3.

Table.3 Mean values of proximate chemical composition in different housing system

Sl. No.	Proximate Chemical Composition	Free Range	Caged	Semi-Intensive
1	Computational Energetic Value (kcal/100 g-1)	121.031 ± 2.57^{a}	134 ± 8.82^{a}	120.109 ± 1.63^{a}
2	Computational Carbohydrate (%)	1.9 ± 0.48^{a}	2.521 ± 0.268^{b}	2.47 ± 0.104^{b}
3	Crude Protein (%)	11.9 ± 0.48	12.42 ± 0.49^{b}	12.35 ± 0.49^{b}
4	Crude Fat (%)	8.84 ± 0.4^{a}	11.63 ± 0.39^{b}	8.42 ± 0.44^{a}
5	Total Ash (%)	1.06 ± 0.55^{a}	1.95 ± 0.02^{b}	0.95 ± 0.03^{a}
6	Moisture Content (%)	68.081 ± 0.44^{a}	72.13 ± 0.248^{b}	66.131 ± 0.24^{a}

Means bearing different superscripts with in rows differ significantly at P≤ 0.01.

A high **protein** content was found in the eggs of caged hens as 12.42±0.49, and in semi intensive as 12.35±0.43 in contrast to free range as 11.9±0.48. It is well established that the protein content of the egg is highly influenced by the diet of the hen Csonka et al., (1952). It is entirely possible that caged hens have continuous access to a more balanced diet that meet the requirement and so therefore produce a more nutritious egg.

Regarding **carbohydrates** our study showed that the carbohydrate content and energetic value was significantly higher in eggs of conventional caged hens and also caged hens showed more **moisture content and fat.**

Same findings were also reported by Minelli et al. who also reported high moisture content and protein in eggs produced by caged hens Minelli et al., (2007).

Conclusion

In conclusion, all the three rearing system had considerable effects on some of the performance parameters and egg quality characteristics examined in this study.

In caged condition Vanaraja hens had a higher egg production rate and produced eggs with better albumin quality than the free range condition and semi intensive condition.

Caged hens had better overall egg production and some of the quality characteristics like egg volume, shape index, albumin and yolk index compared with free range hens and semi intensive.

Whereas, Haugh unit is found to be highest in case of semi intensive system of rearing. The consumption of a fortified, balanced diet may largely be the reason behind the improvement in the overall production performance of hens reared in the caged system. The production performance of birds reared in the cage environment, also depends upon their ability to consume more quantity of nutrients.

The hens in free range experienced a decline in the nutrients in their diet due to which their production performance was low, as nutrients are essential in order to support foraging and other associated behaviours specific to free range environment.

The hens reared in caged system showed better proximate chemical composition as compared to free range and semi intensive.

This comparable analysis of literature on the usage of various kinds of rearing system for the production of table eggs, can be used as a tool in order to determine the future prospects of research as well as an indicator of its practical application.

The backyard poultry system with improved management practices and better germplasm can provide a solution to food security to the rural masses and provides new ways for sustainable poultry production in India.

Acknowledgements

The authors are obliged to the Head of the Zoology Department of Centurion University Of Technology and Management for his cooperation and support in completing the study. The authors are also indebted to the farmers who extended their complete cooperation during the experiment and also the Head of poultry unit of Centurion University of Technology and Management for managing the birds in different housing system very systematically throughout the experimental period.

Conflict Of Interest

There is no conflict of interest.

References

1. Bhattacharya M, Buragohain R, Ahmed FA, Pathak PK and Ghosh MK. 2005. Laying performance of Vanaraja birds in high altitude areas of Arunachal Pradesh under backyard system of rearing. Proceedings of XXIII IPSACON on Indian Poultry Production in changed global scenario: Challenges and opportunities. Hyderabad. Pp 198.
2. Abrahamsson P and Tauson R. 1995. Aviary systems and conventional cages for laying hens.Effects on production, egg quality, health and bird location in three hybrids. Acta Agric.Scand.A Anim. Sci. 45: 191–203.
3. Tauson R. 2005. Management and housing systems for layers – effects on welfare and production. World Poultry Sci.; 61, 477–490.
4. Krawczyk J. Quality of eggs from Polish native greenleg partridge chicken-hens maintained in organic vs. backyard production systems. Anim Sci P, 2009; 27, 227–235.
5. Krawczyk J. And Calik J. Quality of table eggs from hens of conservation breeds kept in confinement or on free range. Pol. J. Nat. Sci., 2006; 3(1), 433–438.
6. Silva IJO. Ambiencia na producao de aves em clima tropical. Piracicaba (SP): Degaspari. 2001.
7. Silva RDM and Nakan M. Sistema caipira de criação de galinhas. Piracicaba (SP): O Editor 1998.
8. Sundrum A. Organic livestock farming - a critical review. Livestock Production Science, 2001; 67(3), 207-215.
9. AOAC.Official Method of Analysis, 15th edition. Association of Official Analytical Chemist Washington, DC, 1990, 20044.

10. Froning GW and Fank DEM. Seasonal variation in quality of egg laid by caged layers and their sisters on the floor. Poultry Science, 1958; **37**, 215-223.
11. Haugh R. The Haugh unit for measuring egg quality United States Egg Poultry Magazine, 1937; 43,552-555, 572–573.
12. Doyon G, Bernier-Cardon M, Hamilton RM and Ramdald CT. Egg quality and Albumin quality of egg from five commercial strains of White Leghorn hens during one period of lay. Poultry Science, 1986; 42, 74 – 83.
13. Snedechor GW, and Cochran WG. Statistical methods, 8th edn. Oxford and IBH Publishing Co., Calcutta. 1994
14. Matt D, Veromann E, and Luik A. Institute of Agricultural and Environmental Sciences. Estonian University of Life Sciences, Agronomy Research, 2009; 7(2), 662–667.
15. Duncan DB. Multiple range and Multiple F- Test. Biometrics, 1955; 11, 1-42.
16. Leyendecker M, Hamann H, Hartung J, Kamphues J, Ring C, Glunder G, Ahlers C, Sander I, Neumann U and Distl O. Analysis of genotype–environment interactions between layer lines and housing systems for performance trails, egg quality and bone strength. 1st Communication: Performance traits. Zuchtungskunde, 2001;73, 290–307
17. Tumova E, and Ebeid T. Effect of housing system on performance and egg quality characteristics in laying hens. Scientia Agriculturae Bohemica, 2003; 34, 73–80.
18. Hulzebosch J. Wide range of housing options for layers. World's Poultry, 2006; 22, 20–22.
19. Michel V, and Huonnic D. A comparison of welfare, health and production performance of laying hens reared in cages or in aviaries. British Poultry Science, 2003; 44, 775–776.
20. Tactacan GB, Guenter W, Lewis NJ, Rodriguez-Lecompte JC, and House JD. Performance and welfare of laying hens in conventional and enriched cages. Poultry Science, 2009; 88, 698–707.
21. Khan AG and Krishna J. A coloured dwarf layer for rural and tribal poultry production in India. Proceedings of 10th European Poultry Conference, 21-26 June, Jerusalem, Israel, 1998; 2, 604-606.
22. Clerici F, Casiraghi E, Hidalgo A and Rossi M. Evaluation of eggshell quality characteristics in relation to the housing system of laying hens. In : XII Eur Poult Conf; 10–14 September, Verona-Italy, 2006.
23. Mugnai C, Bosco A D, and Castellini C. Effects of rearing system and season on the performance and egg characteristics of Ancona laying hens. Italian Journal of Animal Science 2009; 8, 175–188.
24. Dukic-Stojcic M, Peridk L, Bjedov S. And N Milošević. The quality of table eggs produced in different housing systems. Biotech. Anim. Husb. 2009; 25, 1103-1108.
25. Brand H V D, Parmentier HK and Kemp B. Effects of housing system (outdoor vs cages) and age of laying hens on egg characteristics. British poultry Science Journal, 2004; 45(6), 745-752.
26. Voslarova E, Hanzalek Z, Vecerek V, Strakova E and Suchy P. Comparison between laying hen performance in the cage system and the deep litter system on a diet free from animal protein. Acta Vet. Brno. 2006; 75, 219–225.
27. Stanley VG, Nelson D and Daley MB. Evaluation of two laying systems (floor vs. cage) on egg production, quality, and safety. Iranian Journal of Applied Animal Science 2013; 4(3), 597-601.
28. Jones DR, Karcher DM, and Abdo Z. Effect of a commercial housing system on egg quality during extended storage. Poultry Sci., 2014; 93, 1282-1288.
29. Laywel. Welfare implications of changes in production systems for laying hens. Deliverable 6.2: Report on production and egg quality. http://www.laywel.eu/web 2006
30. Anderson KE, Adams AW. Effects of cage versus floor environments and cage floor mesh size on bone strength, fearfulness and production of single comb White Leghorn hens.Poultry Science, 1994;73, 1233–1240.
31. Doley S. Ph.D Thesis. Assam Agricultural University, Khanapara, 2006.
32. Lewko LK and Gornowicz EG. Effect of housing system on egg quality in laying hens. Ann. Anim. Sci. 2011; 11, 607-616.
33. Patterson PH, Koelkebeck KW, Bell DD, Carey JB, Anderson KE and Darre MJ. Egg marketing in national supermarkets: Specialty eggs-part 2. *Poult. Sci.* 2001; 80, 390–395.

34. Hidalgo A, Rossi M, Clerici F and Ratti S. A market study on the quality characteristics of eggs from different housing system. Food Chem. 2008; 106, 1031–1038.
35. Castellini C, Ceclia M and Martina P. Comparison of two genotypes organically reared: oxidative stability and other qualitative traits of the meat. Italian Journal of Poultry Science, 2006; 5(1), 29-42.
36. Csonka FA, and Jones MA. Factors affecting the percentage of certain proteins in egg white. Journal of Nutr. 1952; 46,531–537.
37. Minelli G, Sirri F, Folegatti E, Meluzzi A, and Franchini A. Egg quality traits of laying hens reared in organic and conventional systems. Ital. J. Anim. Sci., 2007; 6(1), 728–730.
38. Brandt H, Van den HK, Paramentier B and Kemp B. Effects of housing system (outdoor vs cages) and age of laying hens on egg characteristics. British Poultry Science, 2004; **45** (6), 745-752.
39. Deka P, Sarma M, Nath PJ, Borgohain R, Mahanta JD, Deka B and Phukon M. International Journal of Livestock Research, 2014; 81-85.
40. Englmaierova M, Tumova E, Charvatova V and Skrivan M. Effects of laying hens housing system on laying performance, egg quality characteristics, and egg microbial contamination. Czech J. Anim. Sci, 2014; 59, 345-352.
41. Giri SC and Sahoo SK. Performance of Gramapriya chicken under extensive and intensive system of management. Indian Veterinary Journal, 2012; 89, 75-76.
42. Jha DK, Prasad S, Patel N and Baskar K. Comparative evaluation of dahlem red and desi crosses chicken reared under intensive of poultry management. International journal of agricultural Technology 2013; 9(6), 1405-1410.
43. Patel N, Sundi B, Prasad S, Kumar R and Mandal B. Reproductive and egg quality traits of Vanaraja Birds under different systems of management. International Journal of Current Microbiology and Applied Sciences, 2018; 7, 696-699.
44. Preetam VC, Reddy VR, Gurram S and Qudratullah S. Quality traits in Rajasri birds reared under scavenging and other systems of management. The J.Res. PJTSAU Vol. XLVI. 2018; 39, 1-67.
45. Singh P, Kachroo D, Thakur NP, Khajuria V, Kumar P, Kumar M and Kour G. Comparative performance of Vanaraja, Gramapriya and indigenous Desi bird under backyard system of rearing in Jammu province. Int J Current Micro and Applied Sci. 2018; 7(2), 101-105.
46. Singh PP, Chauhan SVS and Singh YP. Evaluation of performance of improved dual purpose coloured birds under backyard system of rearing at morena district of Madhya Pradesh. Indian Res J. Ext. Edu. 2017; 17(3), 30-32.