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Effect of age on egg quality traits of Dahlem Red chicken under intensive system of management in Himachal Pradesh

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ABSTRACT

The present study was carried on Dahlem Red chicken breed to assess the effect of age on egg quality traits. Total 250 eggs were collected from birds at different age groups, i.e. 21, 28, 40, 52 and 64 weeks of age for studying the external and internal egg quality parameters. The external characters like egg weight, egg length and egg width were measured. Thereafter, the egg was broken and the internal traits like albumen length, height, width of albumen, yolk height, yolk width, shell thickness were recorded using standard procedure. The derived traits like shape index, albumen index, yolk index and Haugh unit, were estimated. Most of the egg quality traits differed significantly at different age of measurements. Egg weight increased as the age of bird advanced and egg weight varied from 39.35±0.69 at 21 week of age to 59.3±1.22 at 64 week of age. Analysis of variance revealed that shape index did not differ significantly with age. Length, width and height of albumen increased as the age of bird progressed. Albumin index was significantly higher at 21 and 40 weeks of age. Similarly, yolk height and width increased as the age of bird advanced. The differences for Haugh unit scores were non-significant among the different age groups and varied within a very narrow range (96.94–98.94) at different ages indicating uniform internal egg quality over the age. Significant differences in shell thickness were observed among different age groups. Correlation coefficient between egg weight with egg length, egg width, albumen length, albumen height and yolk width were positive. Albumen index and Haugh unit were negatively correlated with egg weight at 21, 52 and 64 week of age. The result indicate that the age of bird significantly affects the egg quality parameters.

Keywords: Dahlem Red, Egg quality, Egg weight, Haugh unit, Shape index

Poultry farming is one of the fastest growing segments of the agricultural sector in India. The poultry sector has shown a substantial improvement over the years. The total egg production reached 103.32 billion with per capita availability of 79 eggs per annum and the poultry meat production was estimated to be about 4.06 million tonnes in 2018–19 (BAHS 2019). Egg is accepted worldwide as a staple food and is recognised as an important ingredient in a balanced human diet. It is one of the finest foods, offering almost complete balance of essential nutrients with proteins, vitamins, minerals and fatty acids of great biological value (Brugalli *et al*. 1998). In addition to being one of the foods of lowest cost, it increases the consumption of food of high nutritional value for the low-income population (Menezes *et al*. 2009).

Egg quality is important for consumers by its characteristics (Stadelman 1977). The egg size and its quality are important attributes in poultry farming. The egg size and its component are influenced by a number of genetic and non-genetic factors (Washburn 1990). Genotype has direct influence on egg weight and eggshell characteristics. Among many quality characteristics, external factors including cleanliness, freshness, egg weight and shell weight are important in consumer's acceptability of eggs (Song *et al*. 2000, Adeogun and Amole 2004, Dudusola 2010). Internal quality of the egg begins to decline as soon as the egg is laid. The management and nutrition of the hen do play a role in internal egg quality, egg handling and storage practices do have a significant impact on the quality of the egg reaching the consumer (Gerber 2012).

The interior of hen´s egg consists of the yolk and white or albumen. Interior characteristics such as yolk index, Haugh Unit and chemical composition are also important in egg product industry as the demand for liquid egg, frozen egg, egg powder and yolk oil increases (Scott and Silversides 2000). The information on the egg quality traits of Dahlem Red birds was scanty. So the present study was carried out to see the effect of hen age on egg quality parameters and correlation of egg weight with different egg quality parameters at different ages.

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MATERIALS AND METHODS

The study was carried out on Dahlem Red breed maintained at CSK Himachal Pradesh Krishi Vishvavidyalaya Poultry Farm, Palampur, Himachal Pradesh, India. Himachal Pradesh is a western Himalayan state in northern part of India situated between 30°22 N and 33°12N latitude and 75°47 E and 79°04 E longitude. Dahlem Red is a dual-purpose breed of chickens, imported from Germany to India. It is a red-feathered breed which lays brown tinted eggs with good egg weight and known for its high disease tolerance and immune competence (Kundu *et al.* 1999). During the study, all chicks were brooded up to six weeks of age and then reared under deep litter system for a period of 72 weeks. The birds were provided starter feed up to 0–6 week, grower feed 7–18 week and layer feed 18 week onwards. Total 250 eggs were collected from birds at different age groups (21, 28, 40, 52 and 64 weeks) for studying the external and internal egg quality parameters. The eggs were weighed using electronic balance to an accuracy of 0.01 g. The length and width of the eggs were measured using digital vernier calipers. Shape index was calculated as the ratio of width to length × 100. Subsequently, the eggs were broken and internal quality traits, viz. albumen length, albumen width, yolk length and yolk height were recorded using the vernier caliper. The height of the albumen was measured at 3 or 4 locations with the help of spherometer and averaged. Shell thickness was measured from four pieces of shells, one each from the two ends (broad and narrow end) and two from the body of the eggs with the help of screw gauze and averaged. Haugh unit (HU) was calculated by using the formula $HU = 100 \log (H + 7.57 - 1.7W^{37})$ where H is albumen height in millimeters, measured by spherometer and W is observed weight of the egg in g. The data were analysed using SPSS 20.0 software. Significant differences between various age groups were tested by one way analysis of variance (ANOVA) (Sendecor and Cochran 1994).

RESULTS AND DISCUSSION

Egg weight: Egg weight showed significant (P<0.05) variation in different age group and egg weight increased as the age of bird advanced. However, egg weight did not show any significant variation at 52 and 64 weeks of age. The egg weight increased from 39.35±0.69 g at 21 week of age to 59.3±1.22 g at 64 week of age with overall mean of 51.04±0.86 g (Table 1). The result of present study are consistent with earlier report of Padhi *et al.* (2013) who observed that egg weight increases as the age of bird advances. However, he reported higher egg weight at 28, 40, 52 and 64 weeks of age in Vanraja male line (PD1). Similarly, Kalita *et al.* (2017) reported lower egg weight of 48.60±3.55 g and 54.62±2.73 g in Dahlem Red birds at 40 and 52 weeks of age under intensive system of rearing. In another study, Kalita *et al.* (2018) observed higher body weight of 42.33±2.59 g and 54.93±2.68 g at 32 and 40 weeks of age in PB-2 × Indigenous × Dahlem Red crossbred chicken under extensive system of rearing. Rajkumar *et al.* (2009) reported higher egg weight in broiler-based naked neck chicken, ranged from 56.29 g to 59.96 g at 32 and 40 weeks, respectively. Rajkumar *et al.* (2014) reported egg weight in Aseel chicken at 32, 40 and 72 weeks of age which is significantly lesser than the present study. Higher egg weight than the present finding were revealed by Hanusova *et al.* (2015) in Oravka and Rhode Island Red laying hens maintained at Slovak University of Agriculture in Nitra. Rajaravindra *et al.* (2015) reported higher egg weight of 51.97±0.32 g, 54.59±0.32 g and 55.93±0.32 g at 32, 36 and 40 weeks of age respectively in PB-2, a synthetic coloured broiler female line.

Egg length: Egg length at 21 week of age showed significant variation (P<0.05) with egg length at different ages. However, egg length at 28 and 52 week of age did not show significant variation with egg length at 40 and 64 weeks of age respectively. Average egg length was measured as 54.23±0.34 mm and varied from 49.42±0.32 mm at 21 week of age to 57.10±0.61 mm at 52 weeks of age (Table 1). The present findings are in agreement with earlier report of Sharma *et al.* (2021) who observed egg length of 56.42±0.44 mm in Dahlem Red Chicken. Similarly, Rajaravindra *et al.* (2015) reported egg length of 52.39±0.26 mm, 54.32±0.21 mm and 55.71±0.21 mm in PB2 birds at 32, 36 and 40 week of age respectively. Rath *et al.* (2015) obtained egg length of 54.39 mm in White Leghorn breed at 40 weeks of age.

Egg width: The width of the eggs also showed similar trend as that of the egg length. Egg width ranged from 36.57±0.26 mm (21 weeks) to 41.95±0.34 mm at 52 weeks of age with mean value of 40.07±0.24 mm (Table 1). The present results are consistent with report of Rajaravindra *et al.* (2015) in PB 2 birds and Sharma *et al.* (2021) in Dahlem Red. On the contrary, Rath *et al.* (2015) observed lower egg width (39.92 mm) in White Leghorn breed at 40 weeks of age. Sapkota *et al.* (2020) observed egg width of 40.35±1.48 mm in Sakini chicken breed in Nepal comparable to the present study.

Table 1. External egg quality traits of Dahlem red chicken at different ages

Trait	21 weeks	28 weeks	40 weeks	52 weeks	64 weeks	Overall
Egg weight (g)	39.35±0.69^{a}	46.55±0.99^{b}	52.33±1.21^{c}	56.98±1.34^{d}	59.3±1.22^{d}	51.04±0.86
Egg length (mm)	49.42±0.32^{a}	53.70±0.49^{b}	54.37±0.52^{b}	57.10±0.61^{c}	56.33±0.46^{c}	54.23±0.34
Egg width (mm)	36.57±0.26^{a}	40.16±0.40^{b}	40.42±0.40^{b}	41.95±0.34^{c}	41.09±0.37^{bc}	40.07±0.24
Shape index	74.54±0.71^{a}	74.82±0.64^{a}	74.09±0.55^{a}	73.59±0.69^{a}	73.0±0.71^{a}	74.02±0.30
Shell thickness (mm)	0.33±0.01^{a}	0.33±0.01^{a}	0.36±0.005^{b}	0.38±0.003^{b}	0.40±0.01^{c}	0.35±0.00

Table 2. Internal egg quality traits of Dahlem Red chicken at different ages

Trait	21 weeks	28 weeks	40 weeks	52 weeks	64 weeks	Overall
Albumen length (mm)	71.64±1.61[a]	72.12±1.31[a]	72.50±0.74[a]	76.35±0.86[b]	77.22±1.12[b]	74.02±0.57
Albumen width (mm)	58.29±1.22[a]	59.75±0.82[a]	60.85±1.04[a]	65.97±1.45[b]	63.91±0.91[b]	61.80±0.56
Albumen height (mm)	6.84±0.17[a]	6.87±0.13[ac]	7.22±0.06[b]	7.38±0.06[bc]	7.31±0.05[ac]	7.44±0.07
Albumen index	0.12±0.003[a]	0.11±0.002[b]	0.12±0.002[a]	0.11±0.002[b]	0.11±0.002[b]	0.12±0.00
Yolk height (mm)	16.25±0.16[a]	18.01±0.31[b]	18.97±0.19[c]	18.78±0.25[c]	18.70±0.25[c]	18.16±0.14
Yolk width (mm)	36.74±0.36[a]	38.75±0.39[b]	40.33±0.24[c]	40.29±0.54[c]	41.68±0.38[d]	39.58±0.24
Yolk index	0.44±0.005[a]	0.46±0.006[b]	0.47±0.005[b]	0.46±0.005[b]	0.44±0.006[ab]	0.45±0.00
Haugh Unit index	98.44±0.85[a]	96.94±0.78[a]	97.93±0.28[a]	97.89±0.33[ac]	97.1±0.32[ab]	97.71±0.18

Shape index: Shape index is the ratio between width and length of egg, which is a very good indicator of uniformity in size of the eggs. The higher the shape index, the more uniform the eggs are. In the present study, average shape index was 74.01±0.30 and did not vary significantly. Chatterjee *et al.* (2006) observed almost similar shape index for IWI (73.77±3.08) and IWH (72.62±7.56) strains of White Leghorn. The results of present study are consistent with earlier report of Kalita *et al*. (2017) in Dahlem Red, Kalita *et al*. (2018) in PB-2 × Indigenous × Dahlem Red crossbred chicken and Sharma *et al*. (2021) in Dahlem Red. Padhi *et al*. (2013) observed shape index value of 76.49±0.49, 75.29±0.41, 75.57±0.96 and 76.00±0.93 at 28, 40, 52 and 64 weeks of age in Vanraja male line (PD1). The shape index values reported by Rajkumar *et al*. (2014) in Aseel native chicken at 32 week (75.74), 40 week (76.49) and 72 week (78.40) are higher than the present estimate. Similarly, Rajaravindra *et al*. (2015) reported shape index value of 0.77±0.004, 0.77±0.003 and 0.76±0.004 at 32, 36 and 40 weeks of age in PB-2, a synthetic colored broiler female line, higher than the present study. Rath *et al*. (2015) estimated shape index value as 73.53±0.18 at 40 weeks of age in White leghorn breed at Central Poultry Development Organization, Eastern Region, Bhubaneswar. The higher shape index value indicates better uniformity in the eggs which is essential for good hatchability and healthy chick production. The shape index reported under the study (74.01±0.30) falls within the normal range of 72–76.

Shell thickness: Significant differences (P<0.05) in shell thickness were observed among different age groups. Average shell thickness was 0.35±0.004 mm and ranged from 0.33 mm at 21 weeks of age to 0.40 mm at 64 week of age (Table 1). The higher shell thickness helps in preventing the damage during handling and also improves the keeping quality of the eggs. The mean shell thickness of 0.34–0.38 mm (Padhi *et al*. 2013) in Vanraja male line (PD1), 0.34–0.36 mm in PB-2 (Rajaravindra *et al*. 2015) and 0.40 mm in Vanraja female line (Rajkumar *et al*. 2020) were comparable to shell thickness observed in present study for Dahlem Red eggs. Various study reported lower shell thickness of 0.32–0.34 mm in Aseel chicken (Rajkumar *et al*. 2014), 0.32 mm in White Leghorn (Rath *et al*. 2015), 0.301 and 0.289 mm in Dahlem Red and PB-2 × Indigenous cross respectively (Kalita *et al*. 2017), 0.291 mm in PB-2 × Indigenous × Dahlem Red crossbred chicken (Kalita *et al*. 2018) and 0.31 mm in Dahlem Red (Kumar *et al*. 2020), compared to present study.

Albumen quality: Albumen contributes around 54% towards the total egg weight and thus has a major influence on the internal quality of the egg. Different parameters of albumen like length, height, width and index are presented in Table 2.

Albumen height: There was significant (P<0.05) variation in albumen height at different ages (Table 2). However, albumen height at 21 weeks of age did not show any significant variation with albumen height at 28 and 64 weeks. Albumen height ranged from 6.84±0.17 mm at 21 weeks to 7.38±0.06 mm at 52 weeks of age with overall mean of 7.44±0.07 mm. In contrast to present findings, Rajaravindra *et al*. (2015) reported lower value of albumen height as 5.97±0.12 mm in coloured broiler female line at 40 weeks of age. Likewise, Sapkota *et al*. (2020) observed lower value of albumen height (5.06±0.67 mm) in Sakini chicken, Chatterjee *et al*. (2006) in WLH (5.59 mm) and Singh *et al*. (2009) in hill fowl (5.34 mm). Hanusova *et al*. (2015) also obtained the lower values of albumen height in Oravka and Rhode Island Red chicken as 5.47 and 5.67 mm, respectively. However Rath *et al*. (2015) reported higher value of albumen height as 8.41±0.04 mm in White leghorn breed.

Albumen length: The average albumen length was 74.02±0.57 mm and ranged from71.64±1.61 mm at 21 weeks of age to 77.22±1.12 mm at 64 weeks of age (Table 2). Albumen length at 21, 28, and 40 weeks differ significantly from albumen length at 52 and 64 weeks of age. However, there was no significant variation in albumen length at 52 and 64 weeks of age. In contrast to present study, Rath *et al*. (2015) reported higher value of albumen length as 92.97±0.26 mm in White leghorn breed. Albumen width also showed the similar trend as that of albumen length. Albumen length and albumen width increased with increase in hen age. Similar finding for albumen width (61.61±0.38 mm) was observed by Sapkota *et al*. (2020) in Sakini chicken. Whereas, higher albumen width was observed by Rajaravindra *et al*. (2015) in PB2, a synthetic coloured broiler female line and Rath *et al*. (2015) in White Leghorn breed.

Albumen index: Albumen index is an indicator of the firmness and viscosity of the egg white which is considered as most important factor for quality of eggs (Rajaravindra

et al. 2015). The mean value of albumen index was observed as 0.12 and did not vary significantly at different age of measurements. Albumen index was significantly (P<0.05) higher at 21 and 40 weeks of age. Higher indices at younger age describes the intact albumen leading to better albumen and egg quality. Contrary to present findings, Kalita *et al*. (2017) obtained lower value of albumen index (0.076±0.002) in Dahlem Red birds. Lower value of albumen index was observed by Rajkumar *et al*. (2014) in Aseel chicken, Rajaravindra *et al*. (2015) in PB2 (a synthetic coloured broiler female line), Rath *et al*. (2015) in White leghorn, Hunusova *et al*. (2016) in Oravka and Rhode Island red breed, Kalita *et al*. (2018) in PB-2 × Indigenous × Dahlem Red crossbred chicken and Jayanaik *et al*. (2021) in indigenous chicken.

Yolk height: Yolk height at 21 weeks of age showed significant variation with yolk height at different ages (Table 2). However, yolk height at 42, 52 and 64 weeks of age did not show any significant variation. Yolk height in the present study (18.16±0.14 mm) was higher than reported by Rajkumar *et al*. (2014) in Aseel chicken (14.57 mm) at different ages and Sapkota *et al*. (2020) in Sakini chicken as 14.49±0.44 mm.

Yolk width: Significant variation was observed for yolk width at different ages. Yolk width ranged from 36.74±0.36 mm at 21 weeks of age to 41.68±0.38 mm at 64 weeks of age with mean value of 39.58±0.24 mm (Table 2). The result of present study are in agreement with the earlier report of Rajkumar *et al*. (2014) who observed yolk width of 39.55 mm in Aseel chicken. Sapkota *et al*. (2020) estimated yolk width in Sakini chicken as 36.26±0.12 mm which is lower than that obtained in present study.

Yolk index: Yolk index at 21 weeks of age significantly varied from yolk index at different ages. No variation was observed in yolk index at 28, 40, 52 and 64 weeks of age. The average yolk index was 0.45 and ranged from 0.44 to 0.47 (Table 2). In a similar study, Padhi *et al*. (2013) reported yolk index value of 0.41, 0.37, 0.43, 0.39 and 0.35 at 28, 40, 52, 64 and 72 weeks of age respectively in Vanraja male line (PD 1). In contrast to present study, Kalita *et al*. (2017) obtained lower value of yolk index as 0.372±0.009 in Dahlem Red and 0.374±0.009 in PB-2 × Indigenous cross. In another study, Kalita *et al*. (2018) observed yolk index value 0.401±0.009 in PB-2 × Indigenous × Dahlem Red crossbred chicken under intensive system of rearing. The lower value of yolk index than the present study was reported by Rajkumar *et al*. (2014) in Aseel chicken, Hanusova *et al*. (2015) in Oravka and Rhode Island Red, Rajaravindra *et al*. (2015) in PB2 (a synthetic coloured broiler female line), Rath *et al*. (2015) in White leghorn breed of chicken and Jayanaik *et al*. (2021) in indigenous chicken of Gulbarga division of Karnataka.

Haugh Unit index: HU is one of the important criterion for determining the internal quality of the egg. It is the most accepted and widely used measure to evaluate the albumen quality. Thus better the albumen quality, better the Haugh unit and better the internal egg quality. The differences for Haugh unit scores were not significant among the different age groups. The average Haugh unit score was 97.71±0.18 and varied within a very narrow range (96.94–98.94) at different ages indicating uniform internal egg quality. The result of present study are consistent with earlier report of Kumar *et al*. (2020) who observed Haugh unit value of 98.92 in Dahlem Red chicken. Contrary to present study, Kalita *et al*. (2017) obtained lower value of Haugh unit as 79.23 and 75.02 in Dahlem red and PB-2 × Indigenous cross respectively. In another study, Kalita *et al*. (2018) observed Haugh unit value as 78.44 in PB-2 × Indigenous × Dahlem Red crossbred chicken. Lower value of Haugh unit than the present study was reported by Padhi *et al*. (2013) in Vanraja male line (PD 1), Sreenivas *et al*. (2013) in White leghorn chicken, Rajkumar *et al*. (2014) in Aseel chicken, Hanusova *et al*. (2015) in Oravka and Rhode Island Red, Rajaavindra *et al*. (2015) in PB-2 (a synthetic coloured broiler female line), Rath *et al*. (2015) in White Leghorn breed and Jayanaik *et al*. (2021) in indigenous chicken. However, Nwachukwu *et al*. (2006) reported a very high value of Haugh unit index (100.3–106.3) in crosses of normal chicken, naked neck and frizzle.

Correlation coefficient between egg weight and different egg quality traits: The correlation coefficient of egg weight with egg length and egg width was highly positive at 40 weeks of age (Table 3). The strong association of egg weight with egg length and egg width indicates that improvement in any one of these traits could result in concomitant improvement of other traits. Whereas, the shape index showed negative correlation with egg weight at 28 and 52 weeks of age and positive correlation at 21, 40 and 64 weeks of age, however the correlation coefficient were low in magnitude. Albumen length and albumen height were moderately and highly correlated with egg weight, whereas albumen width also showed high positive correlation with egg weight except at 21 week of age (–0.22). Correlation coefficient between albumen index and egg weight was negative except at 28 weeks of age. Yolk width was low to moderately correlated with egg weight

Table 3. Correlation coefficient (r) between egg weight and egg quality traits at different ages

Trait	21 weeks	28 weeks	40 weeks	52 weeks	64 weeks
Egg length	0.46	0.43	0.86	0.78	0.77
Egg width	0.87	0.36	0.91	0.75	0.75
Shape index	0.09	–0.04	0.14	–0.06	0.06
Albumen length	0.52	0.038	0.52	0.35	0.53
Albumen width	0.58	–0.22	0.54	0.44	0.49
Albumen height	0.014	0.45	0.41	0.35	0.45
Albumen index	–0.27	0.59	–0.10	–0.20	–0.09
Yolk height	0.26	0.05	–0.35	0.39	0.54
Yolk width	0.48	0.21	0.03	0.53	0.48
Yolk index	–0.15	–0.057	–0.36	–0.09	0.19
Haugh unit score	–0.16	0.55	0.08	–0.19	–0.33
Shell thickness	–0.035	0.25	0.17	–0.47	0.24

whereas yolk height showed positive correlation with egg weight except at 40 weeks of age. Correlation coefficient of egg weight with yolk index was negative except at 64 weeks of age. Similarly, Haugh unit also showed negative correlation with egg weight except at 28 and 40 weeks of age. Correlation coefficient of egg weight with shell thickness was positive at 28, 40 and 64 weeks of age and negative correlation was observed at 21 and 52 weeks of age. In a similar study, Padhi *et al*. (2013) revealed that the correlation coefficients between egg weight and shape index was negative up to 52 weeks of age and positive at 64 and 72 weeks of age. Further he reported that yolk index showed positive correlation with egg weight whereas albumen index showed positive correlation with egg weight up to 52 weeks of age. Similar trend was observed for Haugh unit but the magnitude was low compared to albumen index. Yakabu *et al*. (2008) observed positive correlation of egg weight with egg length, egg width, shape index, shell thickness, yolk height, albumen height and Haugh unit in free range naked neck and normal feathered Nigerian indigenous chickens. Sreenivas *et al*. (2013) reported that the genetic and phenotypic correlations of egg weight with egg quality traits were mostly positive and moderate to high in magnitude in White leghorn chickens.

The results revealed that most of the external and internal egg quality traits differed significantly at different ages in Dahlem Red. Age had significant effect on egg weight, egg length, egg width, albumen height, albumen index, yolk height, yolk width, yolk index and shell thickness. The correlation coefficient among various egg quality traits were positive in general. The result indicates that the age of bird significantly affect egg quality parameters. Egg quality characteristics are optimum in Dahlem Red chicken above 40 weeks of age to produce more number of good quality chicks.

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REFERENCES

Adeogun I O and Amole F O. 2004. Some quality parameters of exotic chicken eggs under different storage conditions. *Bulletin of Animal Health and Production in Africa* **52**: 43–47.

BAHS. 2019. Ministry of Fisheries, Animal Husbandry and Dairying, Government of India, New Delhi.

Brugalli I, Rutz F and Zonta E P. 1998. Effect of dietary oil and protein levels on internal egg quality under different conditions and storage time. *Revista Brasileira de Agrociencia* **4**(3): 187–90.

Chatterjee R N, Sharma R P, Niranjan M, Reddy B L N and Mishra A. 2006. Genetic studies on egg quality traits in different White Leghorn populations. *Indian Journal of Animal Genetics and Breeding* **27**: 51–54.

Dudusola I O. 2010. Comparative evaluation of internal and external qualities of eggs from quail and guinea fowl. *International Research Journal of Plant Science* **1**(5): 112–15.

Gerber N. 2012. Factors affecting egg quality in the commercial laying hen. A review. Available from: http://eggfarmers.org.nz/eggfarmers/wp-content/uploads/2012/04/ factors_affecting_egg_quality.pdf.

Hanusova E, Hrncar C, Hanus A and Oravcova M. 2015. Effect of breed on some parameters of egg quality in laying hens. *Actafytotechn Zootechn* **18**: 20–24.

Jayanaik S N, Nagaraj C S, Malathi V and Gopinath C R. 2021. External and internal egg quality traits of indigenous chicken of Gulbarga division reared under field conditions. *Pharma Innovation Journal* **10**(4): 227–30.

Kalita N, Gawande S S and Barua N. 2018. Production and reproduction performance of indigenous chicken of Assam under rural condition. *Indian Journal of Poultry Science* **44**(2): 253–55.

Kalita N, Pathak N and Ahmed M. 2017. Comparative evaluation of various traits of PB-2 × indigenous and Dahlem Red chicken under intensive system of rearing. *Journal of Entomology Zoological Studies* **5**(6): 156–59.

Kumar B, Kumar H and Singh S K. 2020. Comparative study of egg quality traits in chicken varieties for backyard farming in Jharkhand. *Journal of Entomology and Zoology Studies* **8**(4): 1565–69.

Kundu A, Singh D P, Mohapatra S C, Dash B B, Moudgal R P and Bisht G S. 1999. Antibody response to sheep erythrocytes in Indian native vis-à-vis imported breeds of chickens. *British Journal of Poultry Science* **40**: 40–43.

Menezes P C, Cavalcanti V F T and Lima E R. 2009. Productive and economic aspects of commercial laying hens subjected to different housing densities. *Brazilian Journal of Animal Science* **38** (11): 2224–29.

Nwachukwu E N, Ibe S N and Ejekwu K. 2006. Short term egg production and egg quality characteristics of main and reciprocal crossbred normal local, Naked neck and Frizzle chicken × exotic broiler breeder stock in a humid tropical environment. *Journal of Animal and Veterinary Advances* **5**: 547–51.

Padhi M K, Chatterjee R N, Haunshi S and Rajkumar U. 2013. Effect of age on egg quality in chicken. *Indian Journal of Poultry Science* **48**(1): 122–25.

Rajkumar U, Sharma R P, Rajaravindra K S, Niranjan M, Reddy B L N, Bhattacharya T K and Chatterjee R N. 2009. Effect of genotype and age on egg quality traits in Naked Neck chicken under tropical climate from India. *Indian Journal of Poultry Science* **8**: 1151–55.

Rajkumar U, Raju M V L N, Niranjan M, Haunshi S, Padhi M K and Rama Rao S V. 2014. Evaluation of egg quality traits in native *Aseel* chicken. *Indian Journal of Poultry Science* **49**(3): 324–27.

Rajkumar U, Prince L L L, Haunshi S, Paswan C and Reddy B L N. 2020. Evaluation of Vanaraja female line chicken for growth, production, carcass and egg quality traits. *Indian Journal of Animal Sciences* **90**(4): 603–09.

Rajaravindra K S, Rajkumar U, Rekha K, Niranjan M, Reddy B L N and Chatterjee R N. 2015. Evaluation of egg quality traits in a synthetic coloured broiler female line. *Journal of Applied Animal Research* **43**(1): 10–14.

Rath P K, Mishra P K, Mallick B K and Behura N C. 2015. Evaluation of different egg quality traits and interpretation of their mode of inheritance in White Leghorns. *Veterinary World* **8**(4): 449–52.

Sapkota S, Kolakshyapati M R, Deckota N R, Gorkhali N A and Bhatarai N. 2020. Evaluation of external and internal egg

quality traits of indigenous Sakini chicken in different generations of selection. *International Journal of Agriculture and Forestry* **10**(2): 41–48.

Scott T A and Silversides F G. 2000. The effect of storage and strain of hen on egg quality. *Poultry Science* **79**(12): 1725–29.

Sharma S, Singh G, Vij R, Sankhyan V and Dinesh K. 2021. Physical and biochemical characterization of eggs of chicken crossbreed and its comparison with Dahlem Red for rural poultry development. *Asian Journal of Dairy and Food Research*. doi:10.18805/ajdfr.dr-1656.

Singh B, Kumar S, Kuar N and Yadav S N. 2009. Evaluation of external and internal egg quality traits of hill fowl reared under backyard system. *Indian Journal of Poultry Science* **44**: 25–29.

Snedecor G W and Cochran W G. 1994. *Statistical Methods*, *8th edition.* Affiliated East-West Press and Iowa State University Press.

Song K T, Choi S H and Oh H R. 2000. A comparison of egg quality of Pheasant, Chukar, Quail and Guinea fowl. *Australasian Journal of Animal Sciences* **13**(7): 986–90.

Sreenivas D P, Manthani G, Mahender M and Chaterjee R N. 2013. Genetic analysis of egg quality traits in White Leghorn chicken. *Veterinary World* **6**(5): 263–66.

Stadelman W J. 1977. *Egg Science and Technology*. 2nd ed. Westport: AVI Pub. Co. Inc.

Washburn K W. 1990. Genetic variation in egg composition. (Ed.) R. D. Crawford. *Poultry Breeding and Genetics.* pp. 781–98.

Yakubu A, Ogah D M and Barde R E. 2008. Productivity and egg quality characteristics of free range naked neck and normal feathered Nigerian Indigenous chickens. *International Journal of Poultry Science* **7**: 579–85.