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Evaluation of External and Internal Egg Quality Traits of Indigenous Sakini Chicken in Different Generations of Selection

Saroj Sapkota[1,2], Mana Raj Kolakshyapati[3], Naba Raj Devkota[4], Neena Amatya Gorkhali[1], Nirajan Bhattarai[2,*]

[1]Animal Breeding Division, Nepal Agricultural Research Council, Khumaltar, Lalitpur, Nepal
[2]Department of Animal Breeding and Biotechnology, Faculty of Animal Science Veterinary Science and Fisheries Agriculture and Forestry University, Rampur, Chitwan, Nepal
[3]Department of Animal Breeding and Biotechnology, Institute of Agriculture and Animal Science, Tribhuvan University, Kathmandu, Nepal
[4]Directorate of Research and Extension, Agriculture and Forestry University, Rampur, Chitwan, Nepal

Abstract Indigenous Sakini chicken is the principal breed in Nepal. Present study was conducted mainly aiming at comparing external and internal egg quality traits in four different generations (G0, G1, G2 and G3) of Sakini chicken and determining relationships among these traits. Total of 154 eggs (G0: 30, G1: 44, G2: 40, G3: 40) were evaluated for external egg traits like egg weight, egg length, egg breadth, shell thickness, shell weight and internal egg traits like yolk weight, yolk height, yolk diameter, albumen weight, albumen height, albumen diameter. The data were recorded and analysed using GenStat 19 edition software. There was significant difference in almost all traits of external and internal traits of egg except egg shell quality, yolk to albumin ratio and yolk percentage. Encouragingly, we had observed an increasing trend for each trait specially Haugh unit, a measure for better quality of egg protein in every generation indicating that selection to be continued unless the uniform performance is demonstrated in the population. Positive and significant ($p<0.01$) correlations ($r = 0.44-0.92$) were observed between egg quality traits under study. Findings suggested that selection brings genetic improvement in most of the egg quality traits of indigenous Sakini chicken. However, continuous selection practices to be employed in successive generations to exploit the maximum genetic potential in Sakini chicken.

Keywords Sakini, Indigenous, Chicken, Egg quality traits

1. Introduction

Chicken farming is one among the fastest growing livestock commodity in Nepal. It occupies a fundamental position in current Nepalese economy with the share of 9% in Agriculture GDP and contribution of 17.4% of total meat production (DLS, 2018) and has evolved from subsistence farming to an extremely sophisticated business oriented enterprise. This transformation was indebted to huge investment in overall management practices by both government and private organizations. The share of backyard chicken (indigenous) in total poultry production is about 50% and the trend is increasing (DLS, 2018). Indigenous chicken has very important socio-economic role in rural communities providing them animal protein, generation of extra cash incomes and religious considerations. Sakini chicken is the principal indigenous breed of Nepal. This is found in all agro-ecological zones and distributed across the country. Sakini chicken is well-known as the appropriate backyard poultry breed in resource poor environment and raised under traditional scavenging management system. They have adaptive potential to the prevailing environment, disease and other stresses (Chebo and Nigussie, 2016). Consumers usually prefer products (meat and eggs) of indigenous chicken to exotic ones because of their taste, flavor and nutrition. In spite of their significant roles, their low performance in their egg and meat production masked their contribution to uplift the living standards of their owners and contribute to rural development (Markoset al., 2017). Beside about traits, the storage and hatchability traits of egg could play an important role for the acceptability to the consumer preference,. Hence, the present study was designed to improve the external and internal egg quality traits through selection over four generations (G0-G3). In this study, we compared the egg

* Corresponding author:
nbhattarai@afu.edu.np (Nirajan Bhattarai)
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quality traits of Nepalese Sakini chicken improved over the generations and determined relationships among these traits.

This study aids to ensure improvement of chicken productivity, sustainable utilization and conservation of indigenous chicken genetic resources to respond the demand of chicken products. However, no research or very limited work has been done regarding the evaluation of egg quality traits of indigenous chicken.

2. Methodology

Description of experimental location

The study was carried out under Animal Breeding Division, NARC in poultry unit of Swine and Avian Research Program, NARC, Khumaltar from March 2015 to December 2018 for four consecutive generations (G0, G1, G2 and G3). The poultry unit at SARP lies at a mean elevation of about 1350 masl. Yearly average temperature in the Khumaltar is 15-20℃ and receives yearly average rainfall of 2000-2400 mm.

Experimental birds and their management

All four generations of indigenous Sakini chicken were reared in deep litter pens and fed conventional starter, grower and layer rations. Altogether 269 birds were evaluated from parent to third generations where 180 hens were sired by 89 cocks. A lighting schedule of 16 h/day was applied during laying period. Standard procedure with respect to preventive vaccination and medication were followed during the study period. The eggs were collected at 40 weeks of age and data for egg quality were recorded on the same day of collection. Total of 30, 44, 40 and 40 eggs were evaluated from parent base population (G0) and three consequent generations (G1, G2 and G3), respectively.

Measurement of external egg characters

The individual egg for each generation were weighed using digital balance to the nearest of 0.01 gm accuracy. The length (L) and breadth (B) of egg were measured with the help of digital Vernier calipers and shape index was calculated as the ratio of breadth to length times 100 as suggested by Anderson et al. (2004). Surface area (cm^2) of the egg was calculated from L and B using formula (3.115-0.0136*L+ 0.0115*B) L*B as suggested by Narushin (2005).

The egg shell Breaking Strength (BS, g) of each egg was computed from its Egg Weight (EW) using the formula (**50.86*EW^0.915) as** suggested by Arad and Marder (1982). Similarly, the values of the egg length (L) and egg breadth (B) were used to determine the egg volume (V, cm^3) using Hoyt (1979) equation ($V=Kv*LB^2$) where the estimated volume coefficient (Kv=0.507) is applicable to all eggs which are not very pointed.. The shells were kept in the open air for 24 hours for drying. All the dried shells were weighed with the help of a digital balance. The shell weight was divided by the egg weight to get the shell ratio. The thickness of four pieces of egg shells, one each from the two ends (broad and narrow end) and two from the middle of the eggs, were measured to the nearest of 0.01 mm with the help of screw gauze micrometer and averaged.

Measurement of internal egg characters

The length and width of the albumen and yolk were measured in mm with the help of a vernier caliper (least count 0.01 mm). The height of the albumen and yolk were measured at the top by spherometer on a flat table (level for the table is maintained using standard procedure). The height of the albumen was measured at 3 or 4 locations and averaged. Haugh unit (H.U.), a measure of egg protein quality was calculated by using the formula 100 log ($H+7.57-1.7EW^{0.37}$) given by Haugh (1937) where, H is albumen height in millimeters and EW is observed weight of the egg in grams. Albumen and yolk indices were estimated in percentage, taking the ratio of their respective heights to the average of breadth and length as suggested by previous workers (Kul and Seker, 2004). Albumen weight (g) was calculated as Egg Weight - (Yolk Weight + Shell Weight). Albumen and yolk ratio was calculated taking the individual weight as the percentage of total egg weight. Yolk diameter was estimated as the average of yolk length and breadth. Yolk to albumen ratio was calculated as weight of yolk to the weight of albumen. Yolk index (%) was calculated as the ratio of yolk height to yolk diameter times 100.

Statistical Analysis

All the egg quality data were managed using Ms-Excel spreadsheet. Least square means with standard errors of mean (LS±SEM) were calculated for all the egg quality traits using GenStat 19th edition software (VSN International, 2018).

3. Results and Discussion

The results on comparative internal and external traits of egg quality of Sakini base population (G0) and their subsequent generations (G1, G2, G3) after selective breeding is presented in Table 1.

External quality traits

Egg weight

The overall least square mean of egg weight of Sakini chicken was 49.02±0.87g. Egg weight differ significantly ($p<0.001$) with generations. It has been revealed that the egg weight was increased in each generation of selection by 8.3% in G1, 11.8% in G2 and 17.2% in G3 with respect to G0. The egg weight of free range normal feathered Nigerian indigenous chicken was 40.83 g (Yakubu et al., 2008) and Sudanese indigenous chicken eco-types was 38.46 g (Mohammed et al., 2005) which were lower values with respect to present study. Similarly, Assefa et al. (2019) reported significantly lower value of egg weight of local chicken in lowland (41.2±4.5 g) and midland (39.5±4.8 g) of Ethiopia. Similarly, Bhurtel (1998) reported lower range of egg weight of Nepalese indigenous Sakini chicken as 40-45 g. Egg weight is largely affected by environmental factors, feed restriction (Cary et al., 1993) and parental average body weight.

Egg length

Findings of this study indicated that overall mean egg length of Sakini chicken was 53.76±0.51 mm (Table 1). Results also suggested that significant increment ($p<0.001$) could be achieved in the egg length by applying selection at subsequent generations. Accordingly, highest value of egg length was found in G3 (55.59±0.25 mm) followed by G2 (54.27±0.32 mm) and G1 (53.93±0.30 mm). Based on the average egg length of base population (G0) of Sakini chicken under study, 4.41 percent longer eggs were achieved in first generation of selection and that of 5.11 and 7.77 percent in second and third generation of selection, respectively. In contrast to the findings of this study, Yakubu, et al. (2008) found the lower value of egg length of Nigerian normal feathered chicken as 48.7 mm. On the other hand, Assefa et al. (2019) reported the egg length of chicken in the range 43.3 mm to 55.6 mm. The value of egg length was comparable with the values recorded for commercial layers by Abanikannda and Leigh (2007) whereas Fayeye et al. (2005) reported the lower value of egg length in Fulani-ecotype chicken as compared to the findings of this study.

Egg width

Overall average egg width of Sakini chicken in this study was observed as 40.35±1.48 mm. There was no significant difference in egg width of chicken for different generation due to selection. However, egg width was increased by 9.14 percent in third generation of selection as compared to the average egg width of base population (39.15±1.06 mm) in this study. Yakubu et al. (2008) reported the lower egg width of Nigerian normal feathered chicken as 35.4 mm. However, Abanikannda and Leigh (2007) reported similar value of average egg width which was comparable to the finding of this study. The variations in the egg length and width can be associated with the genetics of the birds (Melesse et al., 2010). Whereas, Monira et al. (2003) explained and emphasized the genetic difference in egg length and egg width.

Egg volume

Overall mean egg volume of Sakini chicken in this study was found 48.38±4.42 cm^3. Results indicated that selection over the generations has no significant effect in egg volume. However, higher value of egg volume was observed in G2 (53.84±2.74 cm^3) and G3 (50.45±2.88 cm^3) as compared to G0 and G1. In contrast to the findings of this study, Narushin (2005) reported the higher value of mean egg volume of as 60.19 cm^3 with the minimum of 52.0 cm^3 and maximum of 70.4 cm^3.

Shape index

Results of present study reflected that the overall mean shape index of Sakini chicken eggs was 75.06±1.42 percent. Shape index was significantly differed with respect to the generation of selection. Accordingly, highest shape index was obtained for the hens at G3 (76.87±0.54) followed by G2 (77.66±0.88) and G1 (72.96±0.84) as compared to the base population. In contrast to the findings of present study, Rath et al. (2015) reported lower shape index of White Leghorn chickens as 73.53 percent. Similarly, shape index for Bovans Brown, Koekoek, Sasso and local breeds were observed as 74.5, 73.4, 72.7 and 69.8 percent, respectively by Assefa et al. (2019) which was found lower than the value of shape index in this study. Higher value of shape index can be related with high egg quality and consumer preference.

Surface area

Overall mean surface area of Sakini chicken eggs in present study was 61.22±0.47 cm^2. Findings suggested that surface area could be significantly increased ($p<0.001$) by selection approach. Accordingly, surface area of Sakini chicken eggs was increased by 4.02 for G1, 8.43 for G2 and 10.61 percent for G3 as compared to that of base population. In contrast to the findings of this study, Rath et al. (2015) and Rasali et al. (1993) reported higher value of egg surface area of 69.9 cm^2 in White Leghorn and 69.17 cm^2 in Philippine Native chicken, respectively.

Shell weight

Average dry shell weight of Sakini chicken eggs in this study was found 4.51±0.21 g. According to the results, dry shell significantly differ ($p<0.001$) with generations (G1 to G3). The mean shell weight obtained in this study was at par to the findings of El-Safty et al. (2006). Whereas, Yakubu et al. (2008) working in normal feathered chickens in Nigeria reported the slightly higher values of average dry shell weight as 4.65g. However, Ershad (2005) reported the lower value of shell weight for native hen eggs in Bangladesh. Higher value of dry shell weight in this study suggests the significance for adaptability and suitability of Sakini chicken to the sub-humid tropical environment.

Shell thickness

The overall mean of egg shell thickness of Sakini chicken in this study was 0.39±0.03 mm. There was significant influence of generation ($p<0.001$) on the egg shell thickness of the chicken in this study.. The value of egg shell thickness in this study was in the range. as reported in Nigerian indigenous chicken as 0.34 mm (Yakubu et al., 2008). The shell quality, particularly shell thickness, is an important bioeconomic trait that primarily breeder of egg laying flock incorporate in their breeding programs. The hatchability of turkey eggs to be higher for eggs with thinner shells (Andrews, 1972). Despite their differences in the findings, all of these studies reported eggshell thickness to have an effect on egg hatchability. The shell thickness is closely correlated with the deposition of calcium, which is metabolized from the skeleton of the birds and the dietary sources (Melesse et al., 2010).

Shell percent

Results showed that the overall mean shell percent of Sakini chicken eggs in this study was 9.18±0.33 percent.

Shell percent was found significantly influenced (p<0.001) by the effect of selection on subsequent generations. Accordingly, higher shell percent was observed in G1 (9.91±0.19) which was not significantly differed with the shell percent of G3 (9.47±0.19).. However, higher egg shell percent of indigenous chicken of Pakistan was 10.80 percent (Hussain et al., 2013) The structure and composition of the avian eggshell serves to protect the egg against damage and microbial contamination, prevention of desiccation, regulation of gas and water exchange for the growing embryo, and provides calcium for embryogenesis (Layelin et al. 2000; Burley and Vadehra, 1989).

Breaking strength

Overall mean breaking strength of eggs in this study was observed as 1790.21±34.1 g. Results of this study indicated that breaking strength was significantly affected by the generation of selection (p<0.001). According to the findings, breaking strength was increased by 7.6, 12.1 and 15.7 percent in G1, G2 and G3 as compared to the base population of Sakini chicken under the experimentation. In agreement to the findings of this study, Rasali et al. (1993) also reported the similar breaking strength of the eggs in Philippine native chickens (PN) and their upgrades (NH-N and WL-N) as 1610.66, 1719.30 and 1914.99 g, respectively. In a separate study by Sapkota et al. (2017), breaking strength of Sakini chicken from different agro-ecological zones (Terai, mid-hills and high hills) was reported to be 1575.02, 1663.43 and 1718.74 g, respectively with the overall mean value of 1641.34 g. Higher breaking strength can be related with handling and transportation of eggs.

Internal quality traits

Albumen percent

Results of this study indicated that overall mean albumen percent of Sakini chicken was 59.84±0.74 percent as presented in Table 1. There was no any significant change observed in the albumen percent of the eggs with respect to the generations from G0 to G3. However, highest albumen percent was observed in G2 (60.77±0.64 percent). Dudusola (2010) reported higher albumen content (61.2%) in quail and lower in Guinea fowl (55.9%) as compared to the albumen content of Sakini chicken in present study. Similarly, Hanusovaet al. (2015) reported lower albumen percent of Oravka and Rhode Island Red chicken as 57.26±0.52 and 56.74±0.59 percent, respectively.

Albumen height

Albumen height of Sakini chicken eggs in this study was 5.06±0.67 mm. As indicated in Table 1, s Generation has highly significant influence (p<0.001) on albumen height of the eggs. Accordingly, highest value of albumen height was observed in third generation of selection (5.84±0.15 mm) followed by second (4.75±0.10), and first (4.61±0.12) as compared to that of foundation population. The albumen height of Sakini chicken in this study was lower with that of Nigerian normal feathered chicken as 4.29 mm (Yakubu et al., 2008). Likewise, similar albumen height was observed for Fulani ecotype chicken as reported by Fayeye et al. (2005). On the other hand, Olawumi et al (2006) obtained lower value of albumen height of eggs in layer breeders. Similarly, Dudusola (2010) obtained higher albumen height (5.74 mm) in quail and lower in Guinea fowl (3.50 mm) as compared to the albumen height of Sakini chicken in present study. Moreover, Hussain et al. (2013) found the albumen height of indigenous chicken eggs in Pakistan as 4.4 mm which was lower than the findings of this study. Hanusova et al. (2015) also obtained the similar values of albumen height of Oravka and Rhode Island Red chicken as 5.47 and 5.67 mm, respectively.

Albumen width

The overall mean albumen width of Sakini chicken eggs in this study was obtained 61.61±0.38 mm. Albumen width was significantly varied (p<0.001) with respect to generation. Albumen width was observed to be decreased with the advancement in the generation (G0 to G3). Accordingly, albumen width decreased by 6.29, 10.09 and 11.67 percent in G1, G2 and G3 as compared to G0. In contrary to the findings of present study, Hanusova et al. (2015) obtained higher values of albumen height in Oravka and Rhode Island Red chicken i.e. 79.81±0.73 and 79.15±1.16 mm, respectively. On the other hand, Monira et al. (2003) explored significantly lower value of egg width of Barred Plymouth Rock, White Leghorn, Rhode Island Red and White Rock chicken breeds as 41.6, 42.1, 41.3 and 41.6 mm, respectively. As, albumen width has negative correlation with albumen height, the increment in albumen height reflects the egg protein quality and decrease in albumen width reflects the egg freshness.

Albumen weight

The overall mean albumen weight of Sakini chicken was 29.38±0.80 g. Albumen weight was significantly increased (p<0.001) with advancement in generation. According to the results, highest albumen weight was obtained in G3 (31.27±0.40 g) followed by G2 (30.53±0.49 g) and G1 (29.08±0.47 g) as compared to G0. Yakubu et al. (2008) reported lower value of albumen weight of Nigerian normal featherd chickens (17.61 g). However, Hanusova et al. (2015) found higher albumen weight of Oravka (34.96±0.58) and Rhode Island Red (32.78±0.73) chicken breeds.

Haugh Unit

The Haugh Unit (HU) is mainly influenced by the albumen height and egg weight (Assefa et al., 2019). The overall mean Haugh Unit of indigenous Sakini chicken eggs was 64.46±1.52. Generations had significant influence on Haugh Unit of the eggs (p<0.001). However, HU had non significant effect in the G0 and G1 however significant difference was observed in G2 (76.37±0.94) and G3 (79.47±0.74). The Haugh unit of eggs from the local chickens of Ethiopia and Nigerian normal feathered chicken was comparable (Moges et al., 2010 and Yakubu et al., 2008). HU improvement with generations might be due to the increase in egg weight and albumen height as it is the major indicator for egg protein quality.

Yolk percent

The overall mean yolk percent of Sakini chicken in this study was observed 30.89±0.84 percent. There was no any significant effect of generations on yolk percent. However, it was found to be higher in G2 (31.07±0.52 percent) and G3 (31.39±0.43 percent) as compared to G1 and G0. Findings of this study were in agreement with the yolk percent (30.38 percent) suggested by Hrncar et al. (2016) in New Hampshire chicken. However, Hanusova et al. (2015) reported slightly higher yolk percent of Oravka (32.76±0.48) and Rhode Island Red (32.43±0.48) chicken breeds.

Yolk weight

The overall mean yolk weight of Sakini chicken was 15.13±0.49 g. Generation had significant effect on the yolk weight of Sakini chicken eggs (p<0.001). Accordingly, highest egg yolk was obtained in the eggs of chicken in G3 (16.52 g) followed by G2 and G1 (14.86±0.29 g). Hrncar et al. (2016) observed slightly higher yolk weight of New Hampshire, Oravka, Plymouth Rock Buff, Rhode Island Red and Sussex Light chicken breeds as 17.83, 17.93, 18.07, 18.23, and 17.58 g, respectively. Whereas, Dudusola (2010) reported lower value of yolk weight of Gunea Fowl (14.26 g).

Yolk: Albumen ratio

Present findings suggested that yolk albumen ratio of Sakini chicken eggs was 0.52±0.02. There was no significant effect (p>0.05) of generation of selection on the yolk albumen ratio with respect to generation of selection. However, yolk albumen ratio was observed higher for the eggs laid by the hens in (0.54±0.02) G3 of selection as compared to first, second and base population. In contrary to the findings of this study, Rath et al. (2015) reported lower value of yolk albumen ratio (0.45). Yolk albumen ratio increases as egg size increases.

Yolk height

Overall mean yolk height of Sakini chicken eggs in this study was obtained 14.49±0.44 mm. The yolk height was significantly increased (p<0.001) with the advancement in the generation from G0 to G3. Accordingly, the results suggested that significant increment could be brought on the yolk height in lateral generation as compared to the base population. The similar values of yolk height of eggs from market, commercial farms and backyard farms was 15.40, 16.27 and 13.60 mm respectively (Hussain et al., 2013). However, in contrast, the findings of the present study have higher values in comparison to the Nigerian indigenous chicken (10.5 cm) (Yakubu et al., 2008).

Table 1. Effect of selection on egg quality traits in different successive generations in Indigenous Sakini chicken (LS mean ± SE)

Generations	Overall mean	G-0	G-1	G-2	G-3	Level of significance
N	134	30	44	40	40	
External traits						
Egg weight (g)	49.02±0.87	45.05±0.73^{c}	48.78±0.60^{b}	50.37±0.63^{b}	52.80±0.49^{a}	*** (p<0.001)
Length (mm)	53.76±0.51	51.63±0.37^{d}	53.93±0.30^{c}	54.27±0.32^{b}	55.59±0.25^{a}	*** (p<0.001)
Width (mm)	40.35±1.48	39.15±1.06	39.35±0.87	42.15±0.92	42.73±0.69	NS
Egg volume (cm^3)	48.38±4.42	43.04±3.17	46.13±2.62	53.84±2.74	50.45±2.88	NS
Shape index (%)	75.06±1.42	75.82±1.02^{b}	72.96±0.84^{c}	77.66±0.88^{a}	76.87±0.54^{a}	*** (p<0.001)
Surface area (cm^2)	61.22±0.47	57.88±0.52^{d}	60.21±0.38^{c}	62.76±0.46^{b}	64.02±0.51^{a}	*** (p<0.001)
Shell weight (g)	4.51±0.21	4.16±0.15^{c}	4.15±0.13^{c}	4.84±0.12^{b}	5.00±0.18^{a}	*** (p<0.001)
Shell thickness (mm)	0.39±0.03	0.43±0.02^{a}	0.37±0.02^{b}	0.33±0.02^{bc}	0.29±0.02^{c}	*** (p<0.001)
Shell %	9.18±0.33	9.27±0.24^{b}	9.91±0.19^{a}	8.16±0.21^{c}	9.47±0.19^{ab}	*** (p<0.001)
Breaking strength	1790.21±34.1	1657.11±24.43^{c}	1782.24±20.18^{b}	1835.69±21.16^{b}	1916.45±23.93^{a}	*** (p<0.001)
Internal traits						
Albumen %	59.84±0.74	59.89±0.73	59.55±0.61	60.77±0.64	59.14±0.50	NS
Albumen height (mm)	5.06±0.67	4.61±0.12^{c}	4.75±0.10^{c}	5.36±0.11^{b}	5.84±0.15^{a}	*** (p<0.001)
Albumen width (mm)	61.61±0.38	67.32±0.57^{a}	63.08±0.47^{b}	60.53±0.49^{c}	59.47±0.30^{c}	*** (p<0.001)
Albumen weight (g)	29.38±0.80	27.03±0.57^{c}	29.08±0.47^{b}	30.53±0.49^{a}	31.27±0.40^{a}	*** (p<0.001)
Haugh unit	74.46±1.52	72.52±1.09^{b}	71.79±0.90^{b}	76.37±0.94^{a}	79.47±0.74^{a}	*** (p<0.001)
Yolk weight (g)	15.13±0.49	13.85±0.35^{c}	14.86±0.29^{b}	15.69±0.31^{a}	16.52±0.33^{a}	*** (p<0.001)
Yolk height (mm)	14.49±0.44	12.31±0.29^{c}	13.54±0.30^{c}	15.12±0.41^{b}	16.97±0.36^{a}	*** (p<0.001)
Yolk width (mm)	36.26±0.12	35.07±0.60^{c}	35.82±0.45^{bc}	36.55±0.52^{b}	37.77±0.48^{a}	** (p<0.01)
Yolk %	30.89±0.84	30.84±0.59	30.54±0.49	31.07±0.52	31.39±0.43	NS
Yolk : Albumen	0.52±0.02	0.52±0.02	0.52±0.01	0.52±0.01	0.54±0.02	NS

Note: NS= Not Significant, **significance at 1% level, *Significant at 5% level, means with the different superscripts differed significantly within the column (P<0.05), N= Number of Observations

Yolk width

Results of this study reflected that overall mean yolk width of Sakini chicken was 36.26±0.12 mm. Generation significantly differ ($p<0.01$) in the yolk width subsequently as compared to G0 of indigenous chicken in this study. Accordingly, highest value of yolk width was determined G3followed by G2 and G1 as compared to G0. In contrast to this finding, Rath et al. (2015) and Rajkumar et al. (2009) obtained higher yolk width of 44.72±0.11 mm in White Leghorn and 38.83-39.39 mm in naked neck chicken, respectively.

Correlation between the external and internal egg quality traits of Sakini chicken

Positive and significant ($p<0.01$ and $p<0.05$) correlations (r = 0.44-0.92) were observed between egg weight and other egg quality traits such as egg length, breadth, shell weight, yolk weight, albumen weight, albumen height, albumen weight, shape index, Haugh unit, and surface area (Table 2). Results indicated that there was perfect association (r = 1.0) between egg weight and breaking strength suggesting the need of high breaking strength for the eggs with higher weight. However, significantly ($p<0.01$) negative relationship between egg weight and egg shell thickness (r = -.23) was observed.

Similarly, egg length had significantly ($p<0.01$) positive association (r = 0.36-0.79) with shell weight, yolk weight, albumen height, albumen weight, shape index, breaking strength and surface area. Whereas, there was inverse relationship of egg length with egg breadth and shell thickness. Similarly, egg breadth had low correlation (r = 0.01-0.25) with shell thickness, shell weight, yolk weight, albumen height, albumen weight, shape index, breaking strength and Haugh unit.

Moreover, Shape index had significantly ($p<0.01$) positive association (r = 0.39-0.58) with shell weight, yolk weight, albumen height, and albumen weight. Positive but not significant relationship was found between shape index and breadth of eggs. However, significantly ($p<0.05$) negative association (r = -0.21) was observed between shape index and shell thickness. Likewise, there was positive and significant correlation (r = 0.44-0.92) between breaking strength and shell weight, yolk weight, albumen height, albumen weight, and shape index ($p<0.01$). On the other hand, egg breadth and shell thickness were weakly associated with breaking strength (r = 0.09 and 0.23, respectively).

At the meantime, Haugh unit was found strongly and significantly ($p<0.01$) associated to albumen height (r = 0.93) whereas it had moderately significant ($p<0.01$) association with egg wight (r = 0.44), egg length (r = 0.49) and albumen weight (r = 0.43). However, there was low positive correlation between Haugh unit and egg breadth, shell weight, yolk weight and breaking strength. Besides, Haugh unit had significantly ($p<0.05$) reverse relationship (r = -0.21) with shell thickness.

As in case of Haugh unit, surface area had significantly ($p<0.01$) positive association (r = 0.39-0.83) with other biometric traits including egg breadth, shell weight, yolk weight, albumen weight, albumen height, shape index, and breaking strength (Table 2). However, the association of egg surface area was weak with Haugh unit (r = 0.09) and negative with shell thickness (r = -0.17).

Similar results were observed by Rasaili et al. (1993) while studying with Philippine native chicken and their upgrades. As in this study, Tatara et al. (2016) revealed a weak correlation between eggshell thickness and breaking strength, indicating that mechanical endurance of the eggshell is not simply affected by its thickness but other factors such as mineral density and mineral content contribute to this characteristic.

Table 2. Correlation among the external and internal egg quality traits of Indigenous Sakini chicken under intensive management

Traits	Eg_wt	Eg_ln	Eg_br	Sh_thk	Sh_wt	Y_wt	Y_ht	Y_wd	Al_ht	Al_wt	Shape_I	BS	HU	SA
Eg_wt	1	.79**	.49**	-.23**	.59**	.64**	0.74**	0.61	.44**	.82**	.92**	1.00**	.44**	.83**
Eg_ln		1	-.06	-.18*	.51**	.53**	.56**	.38	.36**	.62**	.49**	.79**	.49**	.63**
Eg_br			1	.01	.04	.08	.44**	.35	.07	.08	.17	.09	.25	.58**
Sh_thk				1	.45**	-.31**	.21	.52	-.27**	-.01	-.21*	.23	-.21*	-.17
Sh_wt					1	.61**	.48**	.08	.29**	.17*	.51**	.59**	.09	.45**
Y_wt						1	.65**	.47**	.36**	.11	.58**	.64**	.13	.56**
Y_ht							1	.59**	.62**	.51	.11	.23	.37	.48**
Y_wd								1	.49**	.43	.09	.15	.31	.57**
Al_ht									1	.30**	.39**	.44**	.93**	.39**
Al_wt										1	.77**	.82**	.43**	.67**
Shape_I											1	.92**	.07	.78**
BS												1	.09	.83**
HU													1	.11
SA														1

Note: Eg_wt= egg weight, Eg_ln= egg length, Eg_br= egg breadth, Sh_thk= shell thickness, Sh_wt= shell weight, Y_wt= yolk weight, Y_ht= yolk height, Y_wd= yolk width, Al_ht= albumen height, Al_wt= albumen weight, Shape_I= shape index, BS= breaking strength, HU= Haugh unit, SA= surface area.

4. Conclusions

The results of this study provide support to suggest that genetic improvement in most of the egg quality traits of indigenous Sakini chickens could be achieved through selection practice in subsequent generations. Egg external and internal quality traits like egg weight, length, shape index, surface area, shell thickness, shell percent, shell ratio, breaking strength, albumen and yolk related traits and most importantly Haugh Unit mainly related to egg protein quality plays significant roles. Similarly, egg weight has medium to high correlation with all egg quality traits except shell thickness.

Ethical Statement

I testify that my article submitted to International Journal of Agriculture and Forestry entitled "Evaluation of external and internal egg quality traits of indigenous Sakini chicken in different generations of selection" Authors:

1) this material has not been published in the whole or in part elsewhere;
2) the manuscript is not currently being considered for publication in another journal;
3) We have been actively involved in substantive work leading to the manuscript and will hold ourselves responsible for content.

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