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REGULAR ARTICLES

Inheritance of growth traits and impact of selection on carcass and egg quality traits in *Vanashree*, an improved indigenous chicken

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Abstract
The present study was carried out to assess the inheritance of growth traits and to study the effect of selection on carcass characteristics and egg quality traits in *Vanashree*, an improved indigenous chicken. Estimates of heritability were high for body weights recorded at 4, 5 and 6 weeks of age and 8th week shank length, while it was moderate for 8th week body weight. Estimates of heritability on sire component of variance declined as age increased from 4 to 8 weeks of age. The genetic and phenotypic correlations among various growth traits were positive and high in magnitude. The body weight continued to increase up to 40 weeks of age particularly in male birds, while there was little increase in shank length from 20 to 40 weeks of age particularly in hens. There was no significant change in carcass characteristics and egg quality traits except that there was some improvement in dressing percentage over the generations. Sex effect was significant on relative weights of the breast, legs, gizzard, liver and heart and abdominal fat percentage. There was increase in Haugh unit and albumen index, yolk percentage, yolk to albumen ratio and yolk colour in the present generation. The results suggest that there is adequate additive genetic variation for growth traits in the population and that *Vanashree* chicken could continue to be improved so as to make it a promising dual purpose purebred indigenous chicken for increasing the productivity of free range or semi-intensive systems of production.

Keywords *Aseel-Peela* · Indigenous · Improvement · Heritability · Carcass · Egg quality

Introduction

In recent years, meat and eggs of indigenous chickens (IC) are witnessing higher demand due to their perceived health benefits over commercial fast-growing broilers and layer eggs. Furthermore, limited number of IC is fuelling the price rise for their meat and eggs. Indigenous chickens are mostly reared in free range or backyard systems in rural and tribal areas with low or no inputs (Kumar et al. 2013). However, higher demand for the meat and eggs of IC is compelling the farmers to rear them in semi-intensive and intensive systems in urban and semi-urban areas of the country. Rearing of IC in semi-intensive and intensive systems with higher inputs in the form of balanced ration increases the cost of production due to less efficient utilization of feed resources as they are slow growers and low producers of eggs. Therefore, it is imperative to increase the growth and production potential of IC through genetic improvement (Padhi 2016). The best way to improve the productivity of IC, without altering any morphological characteristics, is to select for production traits within a given population (Besbes 2009). Genetic improvement for economic traits such as growth and production traits can be made through within breed selection without affecting the unique characteristics of IC (Maki-Tanila 2007; Magothe et al. 2012). *Aseel* is one of the important indigenous chicken breeds of India. *Aseel-Peela* (yellow) and *Aseel-Kagar* (black) are two main varieties among seven standard varieties of Aseel breed reported in the literature (Panda and Mohapatra 1989). Efforts are being made to improve the growth and production performance of *Aseel-Peela* (PD-4) through within population selection while retaining all morphological characteristics. Thus, an improved IC evolved from Aseel which underwent selection for higher body weight at 8 weeks of age and egg production up to 40 weeks of age (Haunshi et al. 2019a) during

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last nine generations at ICAR-Directorate of Poultry Research, Hyderabad, was named as *Vanashree* (Haunshi et al. 2019b). However, it is important to assess the impact of selection on genetic variability in growth traits and genetic and phenotypic correlations at this juncture as it helps in deciding the future course of selection program. Furthermore, it is important to study the status of carcass and egg quality traits to see if there is any change in these two important parameters over the generations. Therefore, the present study was carried out with the objective of assessing the inheritance of growth traits by estimating heritabilities and genetic and phenotypic correlations and assessing the status of carcass and egg quality traits in *Vanashree* chicken population.

Materials and methods

Experimental population

A total of 861 good chicks (pedigreed) of *Vanashree* were produced in two hatches by mating 50 sires with 150 dams in 1:3 ratio through artificial insemination. Chicks were wing banded and reared on floor in deep litter system up to 20 weeks of age in open-sided poultry house. At 20 weeks of age, selected male and female birds were housed in individual cages for recording of growth and egg production traits in high-raised open-sided poultry house. The housing, management and healthcare practices followed were described previously (Haunshi et al. 2019a). Institute Animals Ethics Committee (IAEC) had approved the experiment.

Physical characteristics

Physical characteristics of male and female birds of *Vanashree* were recorded in adult birds as per the format of breed/variety/line descriptor of chicken (Guidelines for management of animal genetic resources of India, http://www.nbagr.res.in/guidelines_management_AnGR.pdf).

Traits studied

The data on body weight (to the nearest of 0.1 g accuracy) of all surviving birds at 0 day and 4, 5, 6, 8, 20 and 40 weeks of age were recorded. Similarly, the shank length of all survived birds at 8, 20 and 40 weeks of age was recorded to the nearest of 0.1-mm accuracy using Vernier callipers. Body weight at 12 weeks of age and shank length at 5, 6 and 12 weeks of age were recorded in 100 straight run birds randomly taken from the population. Age at first egg (AFE) was recorded by averaging the age at which first egg was laid by each hen in the population. Egg production up to 40 weeks of age was recorded for each hen and averaged over the population to determine the hen housed, hen day and survivors' egg production.

Carcass characteristics

Carcass characteristics were studied at 20 weeks of age in randomly selected 25 males and 25 females with body weight close to the average of the population. Feed was withdrawn 12 h before slaughter, while birds continued to have access to clean drinking water. Birds were then individually weighed, bled, de-skinned, eviscerated and cut up to determine the yield of carcass and cut-up parts. Carcass yield was calculated as carcass weight without the head, feet and skin relative to live weight. Breast, legs (thigh and drumstick), neck and back, wing, organ weights (liver, heart, gizzard, heart and testes) and abdominal fat percentage were calculated as their weight relative to live body weight.

Egg quality traits

External and internal egg quality traits were studied at 40 weeks of age using 120 eggs as per the standard procedures. Length and breadth of eggs were measured using digital Vernier callipers (least count 0.01 mm).

Statistical analysis

Least square means, estimates of heritability and genetic and phenotypic correlations among growth traits were determined using PC-2 version of the mixed model least squares and maximum likelihood computer program (Harvey 1990).

$$\text{Model}: Y_{\text{ijkl}} = \mu + S_{\text{i}} + D_{\text{j}} + H_{\text{k}} + e_{\text{ijkl}}$$

where,

Y_{ijkl} = observation on k$^{\text{th}}$ bird of i$^{\text{th}}$ sire in j$^{\text{th}}$ dam and k$^{\text{th}}$ hatch

μ overall population mean

S_i random effect due to i$^{\text{th}}$ sire

D_j random effect due to j$^{\text{th}}$ dam within i$^{\text{th}}$ sire

H_k fixed effect due to k$^{\text{th}}$ hatch (k = 1–2)

e_{ijkl} random error associated with each observation

Variance component analysis (King and Henderson 1954; Becker 1992) was used to partition the variance due to sire, dam and sire + dam. Pearson product moment correlation was used to see the relationship between growth and production traits. The means and standard errors were calculated using descriptive statistics (MS Excel). Comparison of means of egg quality traits of two different generations and carcass characteristics between two generations and also between male and female birds was carried out using 't' test (MS Excel). Differences among means were considered significant, if $P < 0.05$.

Results

Physical characteristics

Rapid (fast) feathering, normal feather morphology and feather distribution are seen in *Vanashree* birds. Plumage colour in hens is uniform yellow, while in males, it is characterized by reddish golden yellow-coloured hackle and saddle feathers with black-coloured sickle feathers. The tail is small and drooping. Face is long and slender. The beak is short. Comb is small but firmly set. Red-coloured pea comb is observed in both male and females. Small but bright red wattles are seen in males. Skin colour is white, and shank colour is yellow. Colour of the ear lobe is red. The eyes are compact and well set. Eye ring colour is mostly brown (Fig. 1).

Growth traits

The least square means of body weight and shank length recorded during juvenile stage are presented in Table 1. Heritability estimates were high for body weights recorded at 4, 5 and 6 weeks of age and shank length at 8 weeks of age, while it was moderate for body weight at 8 weeks of age and low for 0 day body weight. There was a declining trend in heritability estimates on sire component of variance (additive genetic variance) as age increased from 4 to 8 weeks of age. The genetic and phenotypic correlations among various growth traits were positive and high in magnitude (Table 2). There was significant increase in body weight (pooled sex) from 20 to 40 weeks of age (Fig. 2), while there was little increase in shank length (Fig. 3) suggesting that muscular growth in IC continues beyond 20 weeks of age, while there was negligible skeletal growth after 20 weeks of age. However, this was not the case when the trend of these two traits was studied sex wise (Table 3). It was apparent that both body weight (weight gain of 1159 g) and shank length (gain in shank length of 5.7 mm) improved considerably in male birds.

Fig. 1 A pair of male and female *Vanashree* birds

Table 1 Least square means and estimates of heritability of growth traits of straight run *Vanashree* birds

Traits	Mean ± S.E.	$h^2_{(Sire)}$	$h^2_{(Dam)}$	$h^2_{(Sire+Dam)}$
Body weight, g				
0 day	34.22 ± 0.11	0.15 ± 0.25	–	–
4 wks	197.8 ± 1.95	0.70 ± 0.24	0.21±0.24	0.46±0.15
5 wks	279.7 ± 1.93	0.56 ± 0.20	0.03±0.23	0.29±0.13
6 wks	371.6 ± 2.39	0.49 ± 0.21	0.42±0.27	0.46±0.14
8 wks	570.6 ± 0.21	0.29 ± 0.18	0.59±0.30	0.43±0.14
Shank length, mm				
8 wks	77.08 ± 0.21	0.75 ± 0.24	0.04±0.21	0.39±0.14

In females, there was improvement in body weight (weight gain of 573 g) with little improvement in shank length (1.8 mm). These results suggest that musculoskeletal growth continues to take place up to 40 weeks of age in males. This finding has implications in deciding the marketing age of male birds.

Production traits

Survivors, hen housed and hen day egg production recorded up to 40 weeks of age were 74.45 ± 2.1, 73.74 ± 1.4 and 74.52, respectively, with average egg weight of 48.84 ± 0.24 g at 40 weeks of age. AFE recorded was 164.1 ± 0.91 days. Pearson correlation coefficients determined among various growth and production traits are presented in Table 4. Small but significant ($P < 0.05$) positive correlation was observed between body weights at 4, 6, 20 weeks of age and shank length at 8 weeks of age with egg production up to 40 weeks of age (EP40w). The correlation between body weight at 40 weeks of age and EP40w was also small but negative in direction ($P < 0.05$). Similarly, the correlation between body weights at 4 ($P < 0.05$), 6 and 20 weeks of age ($P < 0.01$) with AFE was small and negative in direction. The correlations among growth traits recorded up to 20 weeks of age were positive in direction and ranged from small to large ($P < 0.01$). The association between AFE with EP40w was high and negative in direction ($P < 0.01$).

Liveability

Liveability of straight run birds during 0–8, 9–20 and 0–20 weeks of age was 95.35, 98.05 and 93.50%, respectively. Liveability of males and females during 21 to 40 weeks of age was 92.22 and 92.89%, respectively.

Carcass characteristics

Carcass characteristic study was carried out in twenty-five male and twenty-five female birds at 20 weeks of age

Table 2 Genetic (above diagonal) and phenotypic (below diagonal) correlations in straight run *Vanashree* birds

Traits	4 wks bwt	5 wks bwt	6 wks bwt	8 wks bwt	8 wks SL	20 wks SL
4 wks bwt		0.98±0.08	1.00±0.06	1.00±0.16	0.96±0.08	–
5 wks bwt	0.63		0.89±0.09	0.86±0.17	0.80±0.11	–
6 wks bwt	0.77	0.66		1.00±0.08	0.83±0.27	0.50±0.41
8 wks bwt	0.60	0.54	0.83		1.00±0.11	0.76±0.39
8 wks SL	0.56	0.52	0.70	0.79		0.79±0.30
20 wks bwt	0.26	0.21	0.45	0.53	0.47	1.00±0.99
20 wks SL	0.12	0.15	0.36	0.50	0.52	

bwt body weight, *SL* shank length, *wks* weeks

(Table 5). Significantly higher relative weight of the legs, liver and heart was observed in males, while higher relative weight of the breast, gizzard and abdominal fat percentage was observed in females. There was no significant difference in dressing percentage, proportion of giblets and other body parts between male and female birds. Dressing percentage observed in the present generation was somewhat higher than that observed during S-1 (66.96%) and S-2 generation (66.47%). Proportions of cut up parts were almost similar to those observed in the earlier generation except that breast percentage was significantly ($P < 0.008$) higher in the present generation. Proportion of giblets, gizzard and liver were significantly higher in the present generation as compared to those observed in S-1 generation (Table 5).

Egg quality traits

The results of egg quality study carried out at 40 weeks of age (Table 6) revealed that eggs of *Vanashree* are of medium size and they had better internal and external quality traits in terms of better yolk index, albumen index, Haugh unit, shell thickness and shape index. The colour of the egg shells ranged from light brown to dark brown with occasional tints (dark brown-coloured spots on the shells). There was significant increase in Haugh unit ($P < 0.001$), albumen index ($P < 0.01$), yolk percentage ($P < 0.003$), yolk to albumen ratio ($P < 0.02$) and yolk colour ($P < 0.03$), while there was reduction in the shape index ($P < 0.05$) and shell percentage ($P < 0.001$) in the present generation as compared to S-0 generation. However, there was no significant change in egg weight, yolk index and albumen percentage.

Discussion

Vanashree, an improved IC evolved from *Aseel-Peela* (PD-4), underwent selection for higher body weight at 8 weeks of age and egg production up to 40 weeks of age through independent culling level selection since last nine generations (Haunshi et al. 2019a). Most of the physical and behavioural characters of *Vanashree* were similar to those seen in *Aseel-Peela* (*Aseel*-yellow) breed of chicken. It is important to retain unique physical and behavioural characteristics of indigenous chicken during improvement so as to make them attractive to the consumers and farmers alike and also to make it profitable to rear them. Male birds of *Vanashree* are known for pugnacity, majestic gait and aggressive behaviour which are the primary behavioural traits of *Aseel* male birds (Panda and Mohapatra 1989; Mohan et al. 2008). Aggressive behaviour will help in protecting themselves as well as young ones from

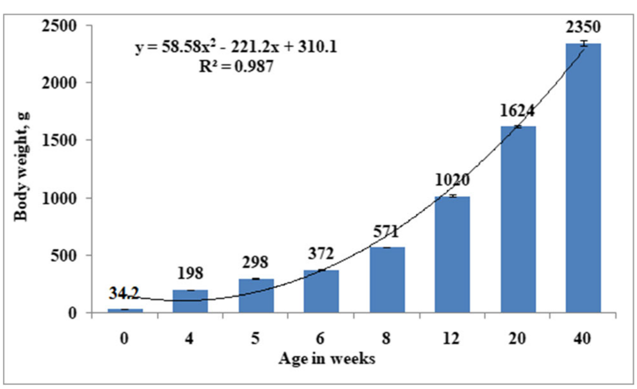

Fig. 2 Body weight (g) at different weeks of age on pooled sex in *Vanashree* birds

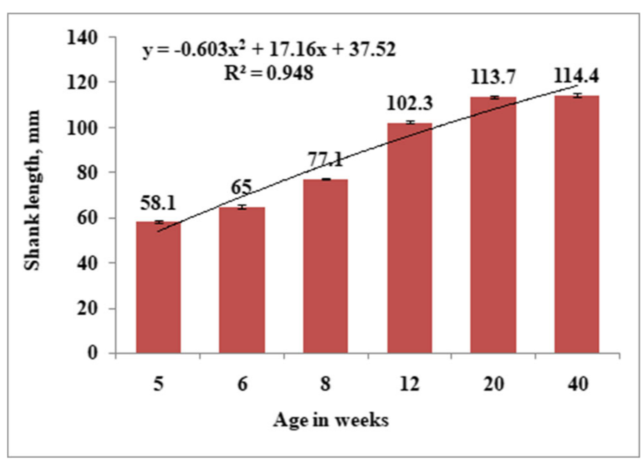

Fig. 3 Shank length (mm) at different weeks of age on pooled sex in *Vanashree* birds

Table 3 Means of growth traits of adult male and female *Vanashree* birds

Traits	Male	Female
Body weight, g		
20 wks	1797±15.9	1498±10.7
40 wks	2956±29.6	2071±14.0
Body weight gain, g	1159	573
Shank length, mm		
20 wks	126.3±0.34	104.5±0.23
40 wks	132.0±0.59	106.3±0.24
Shank length gain, mm	5.7	1.8

predators in the semi-intensive and free range systems of rearing.

Growth and production traits

Heritability estimates on sire component of variance were higher than those of dam and sire + dam components of variance for all growth traits except for body weight at 8 weeks of age. This indicates that additive genetic variance is higher for all these traits. Moderate heritability estimate observed for 8th week body weight can be explained from the fact that this population underwent selection for higher body weight at 8 weeks of age and hence that might have affected the variability in this trait. However, higher estimates of heritability was continued to be observed for juvenile growth traits similar to those observed during S-1 generation. Heritability estimates of body weight at 4 weeks and 6 weeks of age in *Aseel* (PD-4) population determined during S-1 generation (about 8 generations back) was 0.37 ± 0.22 and 0.42 ± 0.18, respectively, on sire component of variance (Haunshi et al. 2012). Similarly, higher estimates of heritability (0.39 to 0.70) were reported for growth traits in *Aseel-Peela* breed of chicken in a recent study (Dalal et al. 2019). Estimates of heritability were also high for body weight at same age in Kadaknath, another important indigenous breed of chicken (Haunshi et al. 2012). Higher estimates of heritability on sire component of variance (additive genetic variation) for body weight at 4 and 6 weeks of age and moderate estimate for body weight at 8 weeks of age as observed in the present study were also reported in male line (PD1) of *Vanaraja* (Padhi et al. 2015).

The finding of positive correlation between body weights and shank length during growing stage with EP40w explained from the fact that birds with higher body weight at growing stage tend to mature early as supported by the observation of negative correlation between body weights and AFE. Similar to the findings of the present study, positive correlations between body weight at 6 and 8 weeks of age with egg production up to 40 weeks of age was reported previously in *Horro* chicken of Ethiopia (Dana et al. 2011). Similarly, positive genetic correlation between body weight at 4 and 16 weeks of age with egg production up to 40 and 56 weeks of age was reported in IWH and IWI strains of White Leghorn (Reddy et al. 2001). Recently, positive genetic correlation between body weight at 12 and 16 weeks of age with egg production up to 40 weeks of age was also reported in *Aseel-Peela* (Dalal et al. 2019). In the present study, we could not determine the genetic correlations between growth and production traits due to insufficient observations in all sire/dam families in a nested/hierarchical design. Therefore, detailed study using more number of hens representing all sire/dam families is required to determine the genetic correlations among growth and production traits in IC breeds. This positive relationship if confirmed could be useful in improving the IC for both meat and

Table 4 Correlations (Pearson) among various growth and production traits in *Vanashree* hens

	4 wks bwt	5 wks bwt	6 wks bwt	8 wks bwt	8 wks SL	20 wks bwt	20 wks SL	40 wks bwt	AFE
4wks bwt									
5 wks bwt	0.49**								
6 wks bwt	0.74**	0.52**							
8 wks bwt	0.50**	0.34**	0.71**						
8 wks SL	0.42**	0.38**	0.60**	0.68**					
20 wks bwt	0.24**	0.09	0.36**	0.31**	0.21**				
20 wks SL	0.06	−0.07	0.01	0.11	−0.03	0.25**			
40 wks bwt	0.07	−0.07	0.15*	0.16*	0.04	.38**	0.21**		
40 wks SL	0.06	−0.03	0.04	0.14*	0.02	0.15*	0.70**	0.20**	
AFE	−0.15*	−0.07	−0.21**	−0.12	−0.11	−0.41**	0.08	0.09	
EP40w	0.15*	0.12	0.16*	0.13	0.15*	0.20**	−0.05	−0.14*	−0.69**

**Correlation is significant at $P < 0.01$ level (2-tailed)

*Correlation is significant at $P < 0.05$ level (2-tailed)

Correlations were not significant for figures with no asterisk. *bwt* body weight, *SL* shank length, *wks* weeks, *AFE* age at first egg, *EP40w* egg production up to 40 weeks of age

Table 5 Carcass characteristics of *Vanashree* birds at 20 weeks of age

Traits	Males	Females	*P* value	S-9 Gen. Males	S-1 Gen. Males	*P* value
Body weight, g	1796 ± 59.5	1256±40.9	0.001	1796±59.5	1655±51.7	NS
Dressing (w/o skin) %	68.6 ± 0.67	68.7±0.27	NS	68.6±0.67	66.96±0.63	NS
Breast %	15.4 ± 0.25[b]	16.6±0.29[a]	0.041	15.4±0.25[b]	14.2±0.25[b]	0.008
Legs %	23.2 ± 0.27[a]	21.1±0.17[b]	0.001	23.2±0.27[a]	23.3±0.36	NS
Neck and back %	17.6 ± 0.24	18.2±0.17	NS	17.6±0.24	17.6±0.40	NS
Wing %	7.77 ± 0.16	7.40±0.11	NS	7.77±0.16	8.05±0.32	NS
Giblet %	3.94 ± 0.08	3.91±0.05	NS	3.94±0.08[a]	3.45±0.10[b]	0.001
Gizzard %	1.77 ± 0.05[b]	1.98±0.04[a]	0.002	1.77±0.05[a]	1.58±0.07[b]	0.03
Liver %	1.70 ± 0.05[a]	1.56±0.03[b]	0.032	1.70±0.05[a]	1.39±0.06[b]	0.001
Heart %	0.47 ± 0.03[a]	0.38±0.01[b]	0.009	0.47±0.03	0.47±0.02	NS
Spleen %	0.13 ± 0.01	0.14±0.01	NS	0.13±0.01	0.13±0.01	NS
Abdominal fat %	0.25 ± 0.07[b]	0.53±0.13[a]	0.05	–	–	
Testis %	0.34 ± 0.05	–		0.34±0.05[b]	0.78±0.07[a]	0.001

[a, b] Figures bearing different superscript row wise differ significantly

P value of 2-tailed *t* test, *NS* non-significant

eggs as birds developed for free range and semi-intensive systems must be of dual purpose type, i.e. they must have a potential to grow relatively faster and lay more number of eggs.

Both body weight (meat) and egg production are the important economic traits in this variety as it is a dual purpose bird. Besides improvement of these two traits, carcass characteristics and egg quality traits are also required to be improved or maintained at the level observed before the initiation of selective breeding. Therefore, carcass characteristics and egg quality traits were studied at the beginning of the selection and in the present generation to study the effect of selection on these two traits.

Carcass characteristics

Various factors such as genotype, sex, environment and age influence the carcass characteristics in chicken. In broilers, sex effects on various carcass parameters were reported (Madilindi et al. 2018; Hussein et al. 2019). Similar to the broilers, leg percentage was higher in males, while the breast, gizzard and abdominal fat percentage were significantly higher in females. Studies on effect of sex on carcass characteristics in IC were scarce in the literature to compare the findings of the present study. Almost similar dressing percentage and breast, leg and liver percentage were reported in *Aseel* breed of chicken (Rajkumar et al. 2016). However, abdominal fat, gizzard, heart and wings percentages were somewhat lesser in *Vanashree* as compared to the *Aseel* breed (Rajkumar et al. 2016). Lesser fat percentage observed in the *Vanashree* appeals to the health conscious consumers who prefer lean meat. There were no significant changes in various carcass parameters studied in recent generation as compared to those observed in the beginning of selection. Dressing percentage in the present generation was slightly higher than that observed during S-2 generation in male birds at 20 weeks of age (Haunshi et al. 2013). This can be explained from the fact that improvement in the body weight might have contributed to the slight increase in the dressing percentage.

Table 6 Egg quality traits of *Vanashree* hens at 40 weeks of age

Traits	Mean ± S.E.
Egg weight, g	49.89 ± 0.39
Shape index	75.88 ± 0.54
Yolk index	0.39 ± 0.005
Albumen index	0.084 ± 0.002
Haugh unit	80.84 ± 0.95
Yolk colour	7.85 ± 0.13
Shell weight, g	4.54 ± 0.05
Albumen weight, g	28.05 ± 0.29
Yolk weight, g	17.27 ± 0.19
Shell thickness, mm	0.35 ± 0.002
Yolk %	34.66 ± 0.31
Albumen %	56.19 ± 0.30
Shell %	9.14 ± 0.08
Yolk to albumen ratio, %	0.62 ± 0.009

Egg quality traits

All the egg quality traits were within optimum range. Average shape index falls under normal (standard) category (Shape index: 72 to 76). However, 44% of the eggs were of normal (standard) shape (SI = 72 to 76), 41% were of round type (SI > 76) and 15% were of sharp shape (SI < 72). It was reported that the greatest force was needed to rupture eggs with high SI values (Altuntas and Sekeroglu 2008). As compared to the egg quality traits observed in the S-0 generation (Haunshi et al. 2011), there was no significant change in egg weight, yolk index and albumen weight and albumen percentage. Overall, there was improvement in most of the egg quality traits (except shape index and shell percentage) over the generations. Egg quality traits of *Vanashree* hens in the latest generation were comparable to those reported for *Aseel* breed except that Haugh unit and yolk index were higher, while shell percentage was somewhat lesser in *Vanashree* as compared to *Aseel* breed of chicken (Rajkumar et al. 2014).

Conclusion

The results suggest that there is adequate additive genetic variation for growth traits such as body weight and shank length and there is a favourable association among them. Furthermore, the genetic improvement had no significant impact on most of the carcass characteristics and egg quality traits. This study hence makes a case for improvement of indigenous chicken for growth and production traits through within population selective breeding. This approach helps the farmers to rear self-propagating improved indigenous chickens in free range or semi-intensive systems without requiring for them to approach the commercial hatcheries again to raise the fresh batch of chicks. It is expected that there will be no loss in production potential of these purebred chickens in subsequent generations due to loss of heterosis as observed in the crossbred chicken varieties developed for free range or backyard systems of rearing.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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