Evaluation of Vanaraja female line chicken for growth, production, carcass and egg quality traits

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ABSTRACT

Vanaraja female line (PD-2) chicken was evaluated for growth, production, carcass and egg quality traits utilizing the data generated from 3,737 chicks and 599 hens produced in pedigreed mating with 50 sires and 250 dams at ICAR-Directorate of Poultry Research, Hyderabad, Telangana. Fertility was 86.63% and the hatchability was 86.72% on fertile egg set and 72.53% on total egg set basis in PD-2 line. The least squares means (LSM) for six week body weight and shank length were 662.38±2.54 g and 71.48±0.12 mm, respectively. Sex had significant influence on live weight, thigh and wing proportions wherein cocks had heavier and stronger legs and wings. Abdominal fat was significantly higher in females. The egg production up to 40 and 52 weeks of age was 80.29±0.03 and 133.16±0.05 eggs, respectively. The egg mass up to 52 weeks of age was 7447.41±2.98 g in PD-2 line. The heritability was low up to 15% for egg production and 17% for egg mass, the primary trait of selection in PD-2 line. Egg mass and egg weights at different ages had positive association as larger and high number of eggs contributed more to the egg mass. The egg mass and egg production had a significant positive association in PD-2 line. The egg quality was reasonably fair with average shape index of 75.22 and Haugh unit of 79.0±0.62. The albumen, yolk and shell weights were 30.20±0.14, 15.8±0.09, 0.40±0.02 g, respectively. The proportion of heritability and the magnitude of association between the important traits provide requisite information for implementing the breeding program for improvement of egg production in PD-2 line.

Keywords: Body weight, Egg mass, Egg production, Heritability, PD-2 line

Genetic evaluation of pure line chicken populations is very important to assess the population status with respect to different economic traits. The inheritance pattern of different economic traits and their association with other traits helps the breeder to plan the breeding programs for improving the productivity (Chandan *et al.* 2019). Pure lines developed through genetic selection are being used to develop crossbreds for backyard poultry farming involving native and exotic strains for backyard poultry farming (Padhi *et al.* 2016).

Backyard poultry development and propagation has been one of the thrust areas due to its proven potential for improving the nutritional and livelihood security of rural and tribal people across the developing and under developed countries (Rajkumar *et al.* 2010a). Vanaraja female line (PD-2) is the female parent line of Vanaraja; a proven dual purpose backyard chicken variety (Rajkumar *et al.* 2010a). Vanaraja development and introduction in to backyard has transformed the face of traditional backyard poultry in India (Rajkumar *et al.* 2010a). Genetic improvement in egg production without compromising the egg weight in female lines is very important to improve the productivity in terminal crosses (Chandan *et al.* 2019). Egg mass has been

the important economic trait in poultry to maintain the optimum standards for both egg production and egg weight in the population as heavier eggs in large numbers were desirable for sustainable rural poultry production.

Carcass traits play a major role in determining the meat quality and consumer preference of chicken meat. Studying the carcass quality is important in PD-2 line as it is the parent line of Vanaraja chicken variety which is known for its meat quality. Quality of eggs is one of the important attribute in breeder lines for realizing optimum number of saleable chicks per each dam (Rajaravindra *et al.* 2015). Many factors influence the egg quality, i.e. breed/strain/ variety, temperature, relative humidity, rearing practice, season, etc. in chicken (Niranjan *et al.* 2008).

The studies on female parent lines of rural poultry germplasm with respect to different economic traits and their inheritance pattern, carcass traits and egg quality are limited. Therefore, PD-2 line was evaluated with respect to reproduction, growth, production, carcass and egg quality traits.

MATERIALS AND METHODS

Experimental population: Vanaraja female line (PD-2) line was evolved from a multi coloured random bred control broiler population at ICAR-Directorate of Poultry Research,

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Hyderabad. The birds had multi coloured plumage with single comb predominantly. Birds lay brown coloured eggs. The PD-2 line was under selection for higher 52 week egg mass (EM52) for the last four generations, earlier the selection criterion was higher egg production up to 52 (EP52) weeks of age.

Rearing and management practices: The chicks were wing banded on day one and reared in a deep litter system of management, with a decreasing temperature schedule from 33°C during first week to 23°C at the end of fifth week in an open-sided house under standard management practices. The chicks were fed *ad-lib.* with broiler starter (2,900 Kcal ME and 22% CP) diet based on maize–soybean meal up to 6 weeks of age. The birds were maintained on a broiler grower ration (2,800 Kcal ME and 18% CP) upto 16 weeks of age and on broiler breeder ration (2,700 Kcal ME, 16.50% CP and Calcium 3.5%) up to the end of the 52 weeks of age on feed restriction schedule. The chicks were vaccinated against Marek's disease (1st day), Newcastle disease (ND) Lasota (7th and 30th day), infectious bursal disease (14th and 26th day), fowl pox (6th week), ND R_2B (9th week), infectious bronchitis (IB) and ND inactivated (18th week).

Traits measured: The data collected on 3,737 chicks for juvenile and 599 hens for production traits produced in a pedigreed mating with 50 sires and 250 dams in four hatches during S-15 generation were utilized in the present study. Juvenile growth traits such as body weight (day old, 2, 4 and 6 weeks); shank length (4 and 6 weeks); adult body weight (20, 40 and 52 weeks); production traits like age at sexual maturity (ASM), egg weight (24, 28, 32, 36, 40 and 52 weeks), egg production (40 and 52 weeks) and egg mass (52 weeks) were studied.

Birds (40), 20 from each sex were selected randomly and sacrificed by cervical dislocation for evaluating the carcass traits on 14 weeks of age. The carcass traits such as dressed weight, primal cuts (legs, wings, breast and back); giblets (gizzard, liver and heart) and other traits (feather and abdominal fat) were recorded and expressed as percentage of live weight. The data were analyzed after *arc-sine* transformation of percentage values to study the effect of sex.

Eggs (467) collected from 142 hens of first hatch at 40 weeks of age were utilized for estimation of various external and internal egg quality traits. The external characters like egg weight, length and width were measured. Thereafter the eggs were broken and the internal traits like albumen weight; yolk weights were recorded using standard procedure. Egg weight, Haugh unit, albumen height and yolk colour were measured using egg quality tester (EMT 5200, Japan).

Statistical analysis: The data were analyzed using least squares technique (Harvey 1990) with a computer package and the hatch corrected data were utilized for estimating the genetic parameters. The hatch corrected data were utilized for estimating the genetic parametres by variance component analysis (King and Henderson 1954). Genetic and phenotypic correlations were estimated from variance –covariance component analysis (Becker 1975). The

slaughter and egg quality traits were analyzed using the standard statistical methods (Snedecor and Cochran 1994).

RESULTS AND DISCUSSION

Reproductive parameters: The fertility was 86.63% during the S-15 generation. The hatchability was 86.72% on fertile egg set and 72.53% on total egg set basis. The fertility and hatchability were reasonably good in PD-2 line. These productive traits, viz. fertility and hatchability determine the reproductive efficiency of the line. Similar findings were observed in Dahlem Red chicken for both fertility and hatchability (Rajkumar *et al.* 2015). The fertility and hatchability observed in the present study were comparable to the findings of 86.96% fertility and 70.74% hatchability on fertile egg set in *Aseel* (Haunshi *et al.* 2012), while lower fertility (67.18%) and hatchability on total egg set (44.71%) was recorded in wild *Aseel* chickens (Rajkumar *et al.* 2017). Malago and Baitilwake (2009) observed higher fertility (91.1–94.5%) in local, Rhode Island Red and crossbreds from Tanzania than the present findings, however the hatchability was lower compared to the present study. The variations in the fertility and hatchability observed in different studies might be attributable to the breed, nutrition and environment conditions prevailed during the experiment (Rajkumar *et al.* 2015). Generally, fertility is influenced by genetic, physiological, environmental factors, egg production rate, nutritional status, lighting, sperm quality and age of hen (Faruque *et al.* 2013).

Juvenile traits: The least squares means (LSMs) for juvenile body weights, shank length and heritability estimates are presented in Table 1. Growth during early part of the life plays a very important role in realizing the optimum productivity from the birds. Hence, proper balanced ration with optimum protein and energy was essential during the juvenile phase for ideal growth which will also continue during growing and laying phases of chick's life. The body weights were comparable to the findings of Rajkumar *et al.* (2016a) in PD-1 chicken, in a three way cross (Rajkumar *et al.* 2019) and higher in two way crosses developed for rural poultry farming (Rajkumar

Table 1. Least squares means of body weight, shank length and their heritability estimates in PD-2 line

	LSM	h^2_S	h^2_D	h^2_{S+D}
Body weight (g)				
0 day	37.07±0.07	0.04±0.02	0.11±0.05	0.05±0.05
2 wks	147.13±0.61	0.16±0.05	0.13±0.03	0.15±0.12
4 wks	334.67±1.44	0.17±0.05	0.12±0.04	0.14±0.03
6 wks	662.38±2.54	0.36±0.10	0.09±0.05	0.23±0.05
Shank length (mm)				
4 wks	54.18±0.11	0.11±0.04	0.12±0.03	0.12±0.04
6 wks	71.48±0.12	0.27±0.03	0.11±0.02	0.20±0.04

LSM, Least squares mean; wks, weeks; h^2S, Heritability due to sire components; h^2D, Heritability due to dam components; h^2S+D, Heritability due to sire and dam components.

et al. 2018). The juvenile body weights in the present study were higher than the findings of the Jha et al. (2013) in Dahlem Red and its crosses with desi chicken which might be due to the presence of broiler inheritance in the PD-2 line. The reasonably higher body weights in PD-2 line was well justified as it was evolved from a fast growing coloured broiler population over the last 20 years.

The heritability estimates from sire and dam components of variance were moderate (Table 1) for both body weights and shank length. The sire component h^2 for body weights gradually increased from day old to six weeks of age indicating the presence of additive effects which were increasing with age. The dam component h^2 gradually decreased due to reduction of maternal effects as age advances. Similar trend was observed in shank length for sire components h^2. The body weight and shank length traits have reasonable additive variance indicating scope for improvement though these were not primary traits, but important for optimum growth and production during growing and laying phases. The findings of h^2 estimates were in agreement with the previous reports of moderate h^2 estimates for juvenile growth traits (Rajkumar et al. 2016a). Higher h^2 estimates than the present studies were reported by many authors for juvenile traits in chicken (Rajkumar et al. 2010b, 2012; Reddy et al. 2008). The growth traits are considered to be highly heritable traits with high variability which was also true in the present study also with moderate to high heritability estimates.

The correlation coefficients (genetic and phenotypic) between body weights and shank length were high in magnitude with significant positive association except with day old body weight (Table 2). The positive significant association between body weight and shank length in chicken was common as both are positively and highly correlated traits which will help the breeder to improve both the traits employing selection on either of the traits (Rajkumar et al. 2011, 2012). The body weight and shank length were not primary traits in PD-2 line, but definitely optimum growth rate during juvenile stage was essential for better growth and productivity during the laying stage.

Carcass traits: Carcass parameters expressed as proportion of live weight are presented in Table 3. Live

Table 2. Genetic (above the diagonal) and phonotypic (below) correlation coefficients for juvenile traits in PD-2 line

	BW0	BW2	SL4	BW4	SL6	BW6
BW0	*	0.56	0.39	0.43	0.42	0.37
BW2	0.16	*	0.77*	0.72*	0.70*	0.68*
SL4	0.10	0.59	*	0.93*	0.91*	0.93*
BW4	0.14	0.54	0.69	*	0.92*	0.99*
SL6	0.15	0.47	0.59	0.78	*	0.98*
BW6	0.15	0.46	0.55	0.76	0.80	*

*Significant P≤0.05. BW0, Day old body weight; BW2, Body weight at 2 weeks of age; BW4, Body weight at 4 weeks of age; BW6, Body weight at 6 weeks of age; SL4, Shank length at 4 weeks of age; SL6, Shank length at 6 weeks of age.

Table 3. Slaughter parameters in PD-2 chicken expressed as percentage (%) of live weight at 14 weeks of age

Trait	Male	Female	SEM	P
n	20	20	–	–
Live weight (g)	1,497.15[a]	1,271.75[b]	31.73	0.01
Carcass weight (g)	1,101.82	931.61	34.93	–
Dressing Percentage (%)	73.56	73.22	0.34	0.62
Breast	16.13	16.75	0.24	0.22
Thigh	22.31[a]	20.39[b]	0.24	0.01
Wing	10.39[a]	9.69[b]	0.12	0.03
Back	14.42	14.57	0.24	0.05
Neck	5.40	5.23	0.13	0.49
Heart	0.37	0.43	0.02	3.47
Liver	2.07[b]	2.45[a]	0.06	0.01
Gizzard	2.15[b]	2.45[a]	0.05	0.02
Abdominal fat	0.05[b]	0.82[a]	0.12	0.01
Bursa	0.06[b]	0.13[a]	0.01	0.01
Spleen	0.14[b]	0.22[a]	0.01	0.02
Feather	9.84	11.12	0.60	–
Blood	3.82	3.46	0.30	–

weight was significantly (P≤0.05) higher in males indicating the sexual dimorphism in chicken. Carcass weight, dressing percentage (DP) and breast muscle did not show any significant differences between the sexes. The present findings were comparable to estimates of DP (73–74%) in naked neck broilers and higher (69–71%) than that of normal broilers (Rajkumar et al. 2011). Sex had significant (P≤0.05) influence on thigh and wing proportions wherein cocks had heavier and stronger legs and wings. Liver and gizzard proportions were significantly higher in females while heart had no significant variation between sexes. Abdominal fat was significantly (P≤0.05) higher in females. Immune organs weight was significantly (P≤0.05) higher in females. Offals like feather and blood were statistically similar in both the sexes. Rajkumar et al. (2010c) reported lower DP and leg proportion than the present findings in PD-2, while similar proportion for breast meat in naked neck chicken. The present findings were in accordance with the reports of Rajkumar et al. (2016b) in Aseel chicken for primal cuts and other byproducts except for DP which was higher in PD-2 line. Higher proportion for breast, legs, wings, giblets were reported in crossbred chicken developed for backyard poultry than the present study (Padhi and Chatterjee 2013) which might be due to the heterosis effect of genotypes involved in the crosses. The abdominal fat was significantly lower (Table 3) in PD-2 chickens similar to the findings of Haunshi et al. (2013) and Rajkumar et al. (2016b) in Aseel. The lower abdominal fat in PD-2 was desirable as it might reduce the fat deposition in terminal cross Vanaraja. The variations in the proportion of different carcass traits might be attributable to the breed, type of bird, sex, feeding, season etc. which was true in the present study also.

Adult body weights: The LSMs for adult body weight at 20, 40 and 52 weeks of age are presented in Table 4. The body weight at 20 weeks of age was within the standard

Table 4. Least square means of growth and production traits
and their heritability estimates in PD-2 line

Traits	LSMs	Heritability		
		h^2_S	h^2_D	$h^2_{(S+D)}$
ASM (d)	157.01±0.01	0.29±0.14	0.46±0.18	0.37±0.12
Body weight (g)				
BW20	2164.78±0.34	0.39±0.17	0.55±0.19	0.47±0.13
BW40	2550.83±0.42	0.45±0.20	0.32±0.15	0.39±0.20
BW52	2842.34±0.54	–	0.34±0.14	–
Egg weight (g)				
EW24	42.95±0.006	0.43±0.15	0.32±0.19	0.36±0.12
EW28	47.51±0.004	0.39±0.16	0.39±0.15	0.39±0.16
EW32	48.44±0.005	0.36±0.15	0.35±0.18	0.36±0.17
EW36	50.23±0.004	0.33±0.14	0.27±0.17	0.30±0.15
EW40	52.64±0.005	0.36±0.17	0.36±0.17	0.36±0.17
EW52	56.00±0.006	0.54±0.19	0.45±0.17	0.49±0.16
Egg production (no.)				
EP40	80.29±0.03	0.10±0.13	0.19±0.14	0.15±0.12
EP52	133.16±0.05	0.05±0.11	0.18±0.16	0.10±0.10
EM52	7447.41±2.98	0.22±0.11	0.16±0.15	0.17±0.09

LSMs, Least squares means; ASM, Age at sexual maturity; BW20, Body weight at 20 weeks of age; BW40, Body weight at 40 weeks of age; BW52, Body weight at 52 weeks of age; EW24, Egg weight at 24 weeks of age; EW28, Egg weight at 28 weeks of age; EW32, Egg weight at 32 weeks of age; EW40, Egg weight at 40 weeks of age; EW52, Egg weight at 52 weeks of age; EP40, Egg production at 40 weeks of age; EP52, Egg production at 52 weeks of age; EM52, Egg mass at 52 weeks of age.

range (2,000 to 2,200 g) for a broiler based rural breeder female line for optimum production during the laying cycle. The optimum body weight at laying was important for onset of egg production and also to realize the higher number of eggs from a breeder hen. The body weight at laying was maintained by following the feed restriction from 6 weeks onwards in PD-2 line. The dietary nutrient should be optimum to maintain the metabolism, growth and production at different phases. The adult body weights in the present study were higher than that of a two way cross (Rajkumar *et al.* 2019); three way cross (Rajkumar *et al.* 2018); Dahlem Red chicken (Jha *et al.* 2013). The h^2 estimates of body weights at 20 and 40 weeks were high which was justified by the high heritable nature of the traits irrespective of the age. Moderate to high h^2 estimates for body weights were recorded by Reddy *et al.* (2008), Rajkumar *et al.* (2011; 2012) in naked neck chicken.

Production traits: ASM has been one of the important economic traits which determine the egg number in a laying cycle. ASM (157±0.01 days) in the present study was reasonable as the PD-2 line is a rural female line, wherein lower ASM was desirable for higher egg production. The ASM was comparable to the reports of Haunshi *et al.* (2019) in White Leghorn and Rajkumar *et al.* (2011, 2012) in naked neck chicken. Higher ASM than the present study was observed by Reddy *et al.* (2008). Chandan *et al.* (2019) in white Leghorn chicken (136.85 days) and Jha *et al.* (2013)

in Dahlem Red (143.65 days) recorded lower ASM than the present findings. The variations observed in ASM might be due to lighting schedule followed during the grower (pullets) stage of the birds, however, genetic makeup of the breed and feeding schedule also influence the ASM.

PD-2 hens laid bigger size eggs with an egg weight of 47.51 g as early as 28 weeks of age (Table 4). Better early egg weight allows the breeder to reproduce the birds at an early age in the breeders resulting in improved economics due to more number of saleable chicks. Egg weight has been one of the important parameters of selection in layers. The egg weights observed in the present study were comparable to the findings of Kumar *et al.* (2016) in Rhode Island Red and Haunshi *et al.* (2019) in White Leghorn. Jha *et al.* (2013) reported higher egg weight than the present study in Dahlem Red chicken. Lower egg weights than the present study were reported in Aseel chicken (Rajkumar *et al.* 2014) and in White Leghorn (Chandan *et al.* 2019). The variations in egg weights might be due to the type of chicken breed, body weight and feeding schedule followed during the study.

The egg production in PD-2 at 40 weeks of age was higher (80.29±0.03) than that reported in Dahlem Red (73 eggs) by Jha *et al.* (2013). Higher egg production at 40 weeks of age was reported in Rhode Island Red (95.4 eggs) by Kumar *et al.* (2016); in White Leghorn (103.92 eggs) by Chandan *et al.* (2019) and (117.9 eggs) by Haunshi *et al.* (2016) than the present findings. Higher EP 52 (156.8 to 188.8 eggs) was recorded in various White Leghorn strains (Haunshi *et al.* 2016) than the present findings (133.16 eggs) in PD-2 hens. Higher egg production was desirable in breeders for getting more number of saleable chicks per parent. The differences in egg production might be due to the genetic makeup of the lines, feeding, environment and management practices followed during the experiment period. Egg mass plays a vitol role in maintaining both egg weight and egg number. Egg mass is considered for selection when both egg weight and egg number needs to be maintained at optimum levels in the population. In PD-2 line, the egg mass was 7447±2.98 g at 52 weeks of age. Heritability enables the breeder to plan the breeding strategy for improvement of the productivity of the traits (Cilek and Tekin 2006). The ASM was highly heritable with 37% of variability expected to transfer to the offsprings. The h^2 estimates of egg weights were higher in magnitude (0.36 to 0.54) from sire, dam and sire & dam component of variance (Table 4) in PD-2 line. The higher h^2 for egg weights indicating the presence of additive genetic effects in addition to the maternal effects and non-genetic factors. Higher additive sire components indicate the scope for improvement of egg weights in PD-2 line. Reddy *et al.* (2008), Rajkumar *et al.* (2011), Chandan *et al.* 2019 observed comparable h^2 estimates for egg weights at different ages. The egg production and egg mass were lowly heritable traits with low to moderate h^2 estimates. The h^2 from dam component of variance was higher indicating the presence of maternal effects in addition to the additive

effects for egg production as it was a sex limited trait. However, the additive sire effects were more for EM 52 indicating the ample scope for improvement of egg mass leading to the improvement in both egg production and egg weight. The h^2 estimates observed in PD-2 line were in agreement with the findings of Niknafs *et al.* (2012) for EP 40 (0.17±0.01) and EM 40 (0.16±0.01) in Majandaran chicken from Iran. Varied h^2 estimates ranging from low to high were documented for egg production in the literature (Jilani *et al.* 2007, Reddy *et al.* 2008, Rajkumar *et al.* 2011, Haunshi *et al.* 2016). Kumar *et al.* (2016) observed very low (0.061) estimates of h^2 in RIR population. The variations in the heritability estimates might be attributed to breed, environmental effects and sampling errors during the experimentation. The non-genetic factors like environment and poor management might increase the residual variance and decrease the h^2 estimates (Adeyinka *et al.* 2006). Changes in heritability over time may result from activation of different genes during the production cycle like early stage production was influenced by genes related sexual maturity whereas later stage (after seven months) by the genes related to persistency of egg production (Niknafs *et al.* 2012).

Genetic and phenotypic correlations between various traits are presented in Table 5. The correlation coefficients between body weights at different ages were significantly (P≤0.05) and positively associated in PD-2 line. The correlation coefficients between body weights and egg weights were very low in magnitude contrary to the observations made by many authors (Rajkumar *et al.* 2011, 2012; Adeyinka *et al.* 2006, Reddy *et al.* 2008). The ASM and body weights at 40 and 52 weeks of age were negatively associated with low magnitude indicating that the heavier fast growing birds matured early, while ASM and BW 20 had positive association of low magnitude (r_g-0.20). The ASM and egg weights had positive association with low correlation coefficients. The egg weights at different ages

had significant (P≤0.05) positive association. The egg production at 40 weeks of age was negatively associated with ASM, body weights and egg weights at different ages. The EM 52 had negative association with body weights. Egg mass and ASM had negative association as the early-matured birds laid smaller eggs resulting in lower egg mass. Egg mass and egg weights at different ages had positive association as larger and high number of eggs contributed more to the egg mass. EP40 and EP 52 had positive association as the egg production at 40 weeks sustained till 52 weeks of age. The egg mass and egg production had a significant (P≤0.05) positive association in PD-2 line. The negative association of egg production with body weights and ASM is well established (Rajkumar *et al.* 2011, 2012; Reddy *et al.* 2008). The association between egg productions with all other traits was in agreement with the earlier studies in various chicken population (Jilani *et al.* 2007, Reddy *et al.* 2008). Highly significant positive association was observed between egg production and egg mass in the present study, which was in agreement with the reports of Niknafs *et al.* (2012) in Majandaran native chicken. The phenotypic correlations also showed similar trend with variations in the magnitude of correlation coefficients.

Egg quality traits: The important egg quality traits studied at 40 weeks of age are presented in Table 6. The egg weight observed was similar to the findings of Niranjan *et al.* (2008) in Vanaraja and Gramapriya chicken varieties and Haunshi *et al.* (2015) in PD-4 chicken. Lower egg weights than the present study were reported in Aseel (Haunshi *et al.* 2011, Rajkumar *et al.* 2014). Padhi *et al.* (2013) recorded higher egg weights in PD-1 chicken at 40 weeks of age. Haunshi *et al.* (2019) observed lower and higher egg weights in indigenous and White Leghorn chicken compared to the present findings. The observed variations in the egg weights in the present study might be due to the breed characteristic, body weight and feeding

Table 5. Genetic (above the diagonal) and phonotypic (below) correlation coefficients for production traits in PD–2 line

Trait	BW20	BW40	BW52	ASM	EW24	EW28	EW32	EW36	EW40	EW 52	EP40	EP52	EM52
BW20	*	0.77*	0.73*	0.20	0.17	–0.01	0.47	0.12	0.24	–0.23	–0.10	–0.16	–0.36
BW40	0.55	*	0.97**	–0.41	0.16	–0.06	0.29	0.04	0.06	0.05	–0.64*	–0.81**	–0.96**
BW52	0.50	0.82	*	–0.39	0.01	0.12	0.36	–0.04	0.20	0.10	–0.56	–0.75*	–0.91*
ASM	0.11	0.10	0.12	*	0.07	0.02	0.31	0.30	0.26	0.32	–0.88**	–0.88**	–0.75*
EW24	0.06	0.04	0.03	–0.08	*	0.80*	0.71*	0.82*	0.53	0.64	–0.27	–0.36	0.41
EW28	0.02	–0.02	0.04	0.06	0.30	*	0.92**	0.78*	0.80*	0.78*	–0.62	–0.18	0.44
EW32	–0.04	0.02	–0.02	0.04	0.27	0.52	*	0.89*	0.80*	0.80*	0.02	–0.23	0.79*
EW36	0.04	0.09	0.02	0.14	0.26	0.40	0.44	*	0.81*	0.78*	–0.19	–0.16	0.35
EW40	0.03	0.09	0.01	0.08	0.27	0.39	0.42	0.50	*	0.87*	–0.12	–0.16	0.42
EW52	0.01	0.07	0.05	0.04	0.26	0.42	0.38	0.47	0.53	*	–0.35	–0.47	0.15
EP40	0.16	–0.22	–0.14	–0.45	0.01	–0.02	0.01	–0.11	–0.09	–0.10	*	0.31	0.97*
EP52	0.05	–0.20	–0.17	–0.30	–0.02	0.01	0.04	–0.08	–0.08	–0.09	0.84	*	0.79*
EM52	0.18	0.18	–0.15	–0.28	0.07	0.12	0.14	0.05	0.04	0.18	0.81	0.96	*

ASM, Age at sexual maturity; BW20, Body weight at 20 weeks of age; BW40, Body weight at 40 weeks of age; BW52, Body weight at 52 weeks of age; EW24, Egg weight at 24 weeks of age; EW28, Egg weight at 28 weeks of age; EW32, Egg weight at 32 weeks of age; EW40, Egg weight at 40 weeks of age; EW52, Egg weight at 52 weeks of age; EP40, Egg production at 40 weeks of age; EP52, Egg production at 52 weeks of age; EM52, Egg mass at 52 weeks of age.

Table 6. Egg quality traits in PD-2 line at 40 weeks of age
(n=467 eggs)

Trait	Mean
Egg weight (g)	51.49±0.18
Shape index	75.22±0.19
Albumen weight (g)	30.20±0.14
Haugh unit	79.0±0.62
Yolk weight (g)	15.8±0.09
Yolk colour	7.84±0.07
Shell weight (g)	4.52±0.02
Shell thickness (mm)	0.40±0.02

regime followed during the experiment. Knowledge of egg quality was important in breeders to get optimum saleable chicks as well as to improve the egg quality traits by selection. The average shape index was 75.22 in PD-2 line. The shape index in PD-2 line was in agreement with findings in naked neck (74.65) from Nigeria (Yakubu *et al.* 2008). The shape index values reported by Haunshi *et al.* (2011) in Aseel eggs (77.36) at 40 weeks of age and Sohail *et al.* (2013) in indigenous Peshawar Aseel eggs (77.25–83.87) were higher than the present estimates. Rajkumar *et al.* (2010d) observed lower shape index (71.92) values in naked neck chicken. The higher shape index indicates more uniform shape and size of the eggs.

The albumen weight observed in the present study was comparable to the findings in rural varieties (Niranjan *et al.* 2008). Lower albumen weights (23.46 to 26.67 g) were recorded by Chatterjee *et al.* (2007) in indigenous fowls of Andaman and higher values were reported by Rajkumar *et al.* (2010d) and Padhi *et al.* (2013) than the present findings. Haugh unit is the measure of albumen quality which determines the quality of the egg. Lower Haugh unit score was reported in Aseel (75.43) by Haunshi *et al.* (2011); in naked neck (72.40) by Rajkumar *et al.* (2010b) compared to the present values. Wide range of Haugh unit values were observed in Kadaknath birds (62.58 to 90.00) from India (Parmar *et al.* 2006) and in Peshawar Aseel birds (71.93 to 84.96) from Pakistan (Sohial *et al.* 2013). Padhi *et al.* (2013) observed higher Haugh unit score in PD-1 chicken than that of present PD-2 chicken. The yolk weight in the present study was similar to that reported in Aseel at 40 weeks of age (Rajkumar *et al.* 2014). Padhi *et al.* (2013) observed higher yolk weights PD-1 chicken than the present findings. The shell thickness (0.40±0.02 mm) was similar to the findings (0.40) of Rajkumar *et al.* (2010d) in naked neck chicken and of Niranjan *et al.* (2008) in rural varieties at 40 weeks of age. Lower shell thickness values than the present study were observed in different chicken varieties by many authors (Nwachukwu *et al.* 2006, Parmar *et al.* 2006, Padhi *et al.* 2013). The variations in egg quality might be due to the breed, feeding and environment during the experiment period.

In conclusion, the performance of PD-2 line with respect to reproductive, juvenile, carcass, production and egg quality traits was optimum with reasonable heritability estimates for primary and other traits of economic importance. The proportion of heritability and the magnitude of association between the important traits provide requisite information for implementing the breeding program for improvement of egg production in the line.

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