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Genetics of Body Conformation and Feed Efficiency Characteristics in a Control Line of Rhode Island Red Chicken

Research Article

A.K. Das[1*], S. Kumar[1] and A. Rahim[1,2]

[1] Department of Avian Genetics and Breeding, Molecular Genetics Laboratory, Central Avian Research Institute, Izatnagar, Bareilly 243 122, Uttar Pradesh, India
[2] Department of Animal Genetics, Indian Veterinary Research Institute, Izatnagar, Bareilly 243 122, Uttar Pradesh, India

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*Correspondence E-mail: dasugenvet@gmail.com

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ABSTRACT

This investigation aimed to assess genetics of body conformation and feed efficiency traits in a control line of Rhode Island Red (RIR) chicken taking single hatched out pedigreed 100 chicks at Central Avian Research Institute, Izatnagar, India. Data was analyzed by least squares analysis of variance. Least squares means of chick weight (CW), body weight (BW), shank length (SL), keel length (KL), breast angle (BA), body weight gain (WG), feed intake (FC) and feed conversion ratio (FCR) were estimated at various weeks of age. Sex had significant effect on BA at 4th week, SL at 12th week, SL and KL at 16th week; males being better than females throughout the ages, but sex did not show any significant effect on any feed efficiency traits; though males performed better than females almost at all ages. Sire had significant effect on CW, KL at 6th week, SL, KL and BA at 12th week, BW and BA at 16th week. Sire also affected ($P<0.05$) WG at 8th week and FC throughout the ages; but not FCR at any age. FC also varied ($P<0.05$) among the feeding groups at 4th and 12th weeks. All the traits excluding FC were heritable at variable magnitude. The estimates of genetic (r_G) and phenotypic (r_P) correlations coefficients were positive in trends and high in magnitude uniformly among all the intra-week body weights and body conformation traits. The r_G estimates were also positive in trends and variable in magnitude at different weeks of age excepting at 16th week among various feed efficiency traits excluding WG *vs.* FC which could not follow any uniform trend throughout the ages. The r_P estimates were positive between FC and FCR and negative between FCR and WG excepting at 8th and 6th week, respectively. These findings may be helpful for improvement program of the chicken line.

KEY WORDS body conformation and feed efficiency traits, genetic and phenotypic correlation, heritability, RIR chicken, sire and sex effect.

INTRODUCTION

Rhode Island Red (RIR) chicken population brought at Central Avian Research Institute (CARI), Izatnagar ,India, almost three decades ago (1980) from USA was well adopted and acclimatized to Indian climate and backyard system. Indian farmers and consumers prefer brown egg and white meat of RIR chicken after Indian deshi (local) chicken. The RIR flock was genetically improved through 29 generations of selection for egg production up to 40 weeks of age along with some independent culling for egg weights at 28th week of age. A random bred control population is also being maintained since then. With the increasing popularity of cut up chicken, processors believe that a plump-breasted bird yields a greater percentage of breast meat than do birds with a less plump breast. Consumers also prefer a plump-breasted bird because of a preference for white meat. The desires of the consumer and processor are reflected back to the breeder, with the avowed intervention of increasing breast-plumpness of this dual purpose chicken flock. Measurements of body dimensions of the live chicken effectively predict body size and compactness components. The body size component, best predicted by trunk length, is highly correlated with body weight; the compactness component is best predicted by breast angle and either breast depth or shank thickness. Body dimensions could therefore be used to predict either conformation or percentage meat yield of the carcass if suitable correlations could be demonstrated (Das *et al.* 2014a). The layer stock is generally selected for high egg production, heavier egg, earlier sexual maturity, higher viability, strong eggshell and optimum body size. Most of these traits are related to the feed efficiency along with its genetic background (Niranjan and Kataria, 2008), though diverse environmental conditions and different cultural orientations contribute to the observed genetic variations of chickens (Getu and Birhan, 2014). Hence, improvement in these traits would also be expected to improve feed utilization and efficiency (Niranjan and Kataria, 2008). The knowledge of basic genetic parameters like heritability and correlation is of paramount importance to formulate effective breeding plans for improving these economic traits through selection and breeding (Paleja *et al.* 2008). The present investigation was carried out to evaluate body conformation traits and feed utilization efficiency, to assess genetic and non-genetic factors and to estimate their genetic parameters in a random bred control population of RIR chicken.

MATERIALS AND METHODS

Experimental birds

A total of 100 single hatched out pedigreed chicks of a control line of RIR chicken maintained at the experimental layer farm (ELF), CARI, Izatnagar, was investigated for this study.

Poultry husbandry adopted

The CARI itself maintains a control line of RIR chicken by mating the parental RIR control female line in individual laying cages artificially inseminating semen collected from the individual sires of RIR control male line taking records for dam and sire numbers. The day-old chicks were pedigreed by sire and dam, wing banded and vaccinated against RD and marek's disease (MD) in the hatchery itself before transferring on to the litter brooder having adjustable hover fitted with single infrared lamp of 250 watt. Standard floor space and brooding temperature were provided. Chicks were provided continuous light for 24 h in the first 3 weeks which was decreased to 2 h/week till 8 weeks so as to provide light for about 14 hours and thereafter maintained throughout its growing and laying stage. After attaining the 4 weeks of age the chicks were shifted in to new brooder house or colony house where maintained for 16 weeks before shifting in to cages for breeding, laying and pedigree maintenance. Fresh water and feed were provided *at libitum* twice daily. Birds were fed on CARI-formulated chick mash containing crude protein (CP): 20.65%, metabolic energy (ME): 2694.64 kcal/kg, calcium: 1.02%, available phosphorous (P): 0.45%, lysine (Lys): 1.05% and methionine (Met): 0.41% for 0-8 weeks of age, grower mash containing CP: 16.78%, ME: 2536.00 kcal/kg, Ca: 1.15%, P: 0.40%, Lys: 0.76% and Met: 0.37% for 9-20 weeks and layer mash containing CP: 18.18%, ME: 2676.52 kcal/kg, Ca: 3.61%, P: 0.34%, Lys: 0.83% and Met: 0.36% for 20 weeks onwards (Das, 2012). Chicks were vaccinated following standard vaccination schedule being followed at this institute, *viz.* vaccination for ranikhet disease (RD) and marek's disease (MD) at day old, infectious bursal disease (IBD) on 14-day, RD booster on 28-day, IBD booster on 35-day, fowl pox on 42-day, R_2B on 56-day, EDS at 18-19 weeks and IBD killed at 20-22 weeks of ages (Das, 2012).

Traits analyzed

Body weights and body conformation traits

Chick weight (CW), live body weight (BW), shank length (SL), keel length (KL) and breast angle (BA) at 4^{th} (BW4, SL4, KL4, BA4), 6^{th} (BW6, SL6, KL6, BA6), 8^{th} (BW8, SL8, KL8, BA8), 12^{th} (BW12, SL12, KL12, BA12) and 16^{th} (BW16, SL16, KL16, BA16) weeks of age were measured using digital weigh balance (capacity-0.5 g to 3 kg) for BW, vernier calipers for SL and KL and goniometer for BA-measurement.

Feed consumption and efficiency traits

Feeding trials (*ad libitum*) were conducted from day-1 to 16^{th} week of age on the basis of separate colony housing covering day-1 to 4^{th} week in battery brooding shelves and 5-16 weeks on litter at new brooder houses crucially maintaining four subgroups under two feeding groups. The birds were provided with weighed quantity of standard ration i.e. starter and grower feed for day-1 to 8^{th} week, 9-16 weeks of age, respectively. Feeding was done twice daily in morning and evening with all possible measures adopted to reduce wastage of feed. The feed residue was weighed after each recording period, followed by notice of any mortality on specific date, if any, the dead bird's(s) wing band number(s) and weight were date-wise recorded and the amount of feed consumed by individual birds per day was calculated. Feed consumption and efficiency was expressed as feed consumed/intake (g), live body weight gain (g) and feed conversion ratio (FCR; g feed intake/g weight gain) in different periods of ages (weeks).

Statistical treatments and analysis

Data on chick weight, body weights, body conformation traits and feed utilization efficiency traits was analyzed by least squares analysis of variance (Harvey, 1990) incorporating sire as random effect, sex and or feeding groups (where available) as fixed effects in the linear model:

$$Y_{ijk} = \mu + S_i + W_j + H_k + e_{ijkl}$$

Where:
Y_{ijkl}: value of a trait measured on l^{th} individual belonging to i^{th} sire, j^{th} sex and k^{th} feeding group.
μ: overall mean.
S_i: random effect of i^{th} sire.
W_j: fixed effect of j^{th} sex.
H_k: fixed effect of k^{th} feeding group.
e_{ijkl}: random error associated with mean zero and variance σ^2.

Genetic and phenotypic parameters were estimated using paternal half-sib correlation method (Becker, 1975) taking sire as random and sex as fixed effects in the linear model of least squares ANOVA.

RESULTS AND DISCUSSION

Body conformation traits

Least square means of chick weight, live body weights (BW), shank length (SL), keel length (KL) and breast angle (BA) were presented in Table 2. BA at 4^{th} week, SL at 12^{th} and 16^{th} week and KL at 16^{th} week demonstrated significant ($P<0.05$) higher estimates for males than females (Tables 1 and 2). The present estimate of chick weight was comparable to the earlier estimates (Das *et al.* 2014a; Das *et al.* 2014b; Hassen *et al.* 2006; Ashraf *et al.* 2003) and also better than the earlier reports of 30.12 ± 2.86 g (Malago and Baitilwake, 2009). The present estimates of body weights at 4 to 16^{th} week were also comparable to the earlier reports in RIR chicken (Das *et al.* 2014b) and White Leghorn chicken strain and or line (Jaya Laxmi *et al.* 2010; Chaudhary *et al.* 2009). Similar estimates of body weight at 16^{th} week of age were also reported in White Leghorn chicken strains (Qadri *et al.* 2013). The present estimate at 4^{th} week either in male or female was more than the reports for Ethiopian native chicken ecotypes and RIR chicken (Hassen *et al.* 2006). The present chicken line also performed better than indigenous chicken breed or its cross with RIR chicken as evident when compared to the earlier available reports for Kadaknath and Aseel chickens excepting 16^{th} week aged Aseel (Chatterjee *et al.* 2007), RIR × indigenous lines bareneck/betwil/large beladi crosses (Mohammed *et al.* 2005), Fayoumi (Fy) male × RIR female cross and its reciprocal (El-Maghraby *et al.* 1975). The present estimates of shank length, keel length and breast angle along with higher estimates in males than females might correspond to the earlier reports in RIR-white strain chicken (Das *et al.* 2014a); Libyan native chicken (El-Safty, 2012); Ardennaise chicken (Lariviere *et al.* 2009); Kadaknath and Aseel chicken (Chatterjee *et al.* 2007); Giriraja and WLH chicken (Adebambo *et al.* 2006) and CARI-Devendra chicken (Singh and Jilani, 2005). Difference in the estimates might be attributed due to strain line or breed difference and different management as well as rearing system.

Feed utilization and efficiency

Least squares means of live body weight gain (WG), feed intake (FC) and feed conversion ratio (FCR) for the period of 0-4, 5-6, 7-8, 9-12 and 13-16 weeks of age were presented in Table 4. The present FCR estimates were higher than the reports in RIR-White strain (excluding 12^{th} week FCR) (Das *et al.* 2014a) and Ardennaise chicken breed (Lariviere *et al.* 2009) indicating poor FCR in the present RIR flock.

The present estimates of WG, FC and FCR might also be compared to the earlier reports in four genetic groups of feathered, frizzled, naked neck and naked neck-frizzled chickens (Mahrous *et al.* 2008); estimates of WG in Kadaknath and Aseel chicken (Chatterjee *et al.* 2007). The present RIR flock gained more body weight throughout the ages as evident when compared to the Kadaknath chicken, whereas less than the Aseel chicken at later age. Mengesha (2012) reviewed corresponding 8^{th} and 12^{th} week's average FCR as 7.0 and 4.2 in intensive rearing system, and 3.04 and 5.6 in semi-intensive rearing system in some indigenous chicken in the tropical countries of Africa. Whatsoever, discrepancy might be attributed due to the strain, line or breed difference and different facets of management practices as well as rearing system.

Genetic and non-genetic factors

Influences of sire

Sire had significant effect on CW, KL6, SL12, KL12, BA12, BW16 and BA16. Sire also demonstrated its significant effect on live body weight gain at 8^{th} week of age, and on feed consumption throughout the ages; but sire did not affect FCR at any age. It was supposed to get uniform and significant sire effect on all quantitative traits studied throughout the ages but this hypothesis deviated in few cases might be due to small sample sizes and literature could not be made available to draw reference.

Influences of sex

Sex had significant effect on BA4, SL12, SL16 and KL16 (Table 1); males being better than females throughout the ages (Table 2), but sex did not show any significant effect on any feed efficiency traits (Table 3); though males performed better than females almost at all ages (Table 4).

Table 1 Least squares analysis of variance of various body conformation traits in RIR chicken control line

Source of variation	df	Mean sum of squares												
		CW	BW4	SL4	KL4	BA4	BW6	SL6	KL6	BA6	BW8	SL8	KL8	BA8
Sire	20	32.7***	647.1 (16)	0.05 (16)	0.11 (16)	4.8 (16)	2.1^{E+03} (20)	0.15 (20)	0.27* (20)	5.6 (20)	8.2^{E+03} (20)	0.31 (20)	0.36 (20)	15.0 (20)
Sex	1	0.16	3.6^{E+03}	0.11	0.12	12.9*	1.6^{E+03}	0.39	0.2	4.1	304.1	0.09	0.04	1.11
Remainder	78	6.48	1.0^{E+03} (39)	0.11 (39)	0.13 (39)	2.58 (39)	1.9^{E+03} (77)	0.15 (77)	0.16 (77)	5.42 (77)	4.9^{E+03} (77)	0.24 (77)	0.23 (77)	10.3 (77)

Source of variation	df	Mean sum of squares							
		BW12	SL12	KL12	BA12	BW16	SL16	KL16	BA16
Sire	20	2.6^{E+04} (20)	0.58* (20)	0.9*** (20)	21.3*** (20)	6.8^{E+04}* (20)	0.4 (20)	0.5 (20)	24.1** (20)
Sex	1	4.8^{E+03}	3.2**	0.89	2.85	6.8^{E+04}	6.76***	3.18**	10.11
Remainder	78	1.6^{E+04} (75)	0.31 (75)	0.30 (75)	7.78 (75)	3.5^{E+04} (71)	0.54 (71)	0.44 (71)	10.1 (71)

* (P<0.05); ** (P<0.01) and *** (P<0.001).
Figures within parenthesis denote degrees of freedom (df).
CW: chick weight; BW: body weight; SL: shank length; KL: keel length and BA: breast angle.

Table 2 Least squares means ± standard errors of various body conformation traits in RIR chicken control line

Factors	Least squares means ± standard errors												
	CW (g)	BW4 (g)	SL4 (cm)	KL4 (cm)	BA4 (°)	BW6 (g)	SL6 (cm)	KL6 (cm)	BA6 (°)	BW8 (g)	SL8 (cm)	KL8 (cm)	BA8 (°)
Overall	35.52 ±0.67 (100)	172.75 ±4.52 (57)	4.173 ±0.05 (57)	4.50 ±0.05 (57)	35.50 ±0.32 (57)	274.10 ±4.76 (99)	5.52 ±0.04 (99)	5.61 ±0.06 (99)	39.25 ±0.24 (99)	392.46 ±9.89 (99)	6.34 ±0.06 (99)	6.50 ±0.07 (99)	46.81 ±0.42 (99)
Sex													
Male	35.48 ±0.72 (55)	183.21 ±6.17 (38)	4.23 ±0.06 (38)	4.56 ±0.07 (38)	36.13 $\pm0.39^{a}$ (38)	278.60 ±6.55 (55)	5.59 ±0.06 (55)	5.66 ±0.07 (55)	39.48 ±0.34 (55)	394.44 ±12.23 (55)	6.38 ±0.08 (55)	6.52 ±0.08 (55)	46.93 ±0.53 (55)
Female	35.57 ±0.74 (45)	162.29 ±8.08 (19)	4.12 ±0.08 (19)	4.44 ±0.09 (19)	34.88 $\pm0.47^{b}$ (19)	269.59 ±7.18 (44)	5.44 ±0.06 (44)	5.56 ±0.07 (44)	39.02 ±0.38 (44)	390.48 ±13.10 (44)	6.31 ±0.08 (44)	6.48 ±0.09 (44)	46.70 ±0.57 (44)

Factors	Least squares means ± standard errors							
	BW12 (g)	SL12 (cm)	KL12 (cm)	BA12 (°)	BW16 (g)	SL16 (cm)	KL16 (cm)	BA16 (°)
Overall	731.89 ±17.68 (97)	7.86 ±0.09 (97)	7.91 ±0.11 (97)	50.18 ±0.53 (97)	1013.00 ±29.99 (93)	9.17 ±0.08 (93)	9.19 ±0.08 (93)	51.93 ±0.57 (93)
Sex								
Male	739.82 ±22.23 (53)	8.06 $\pm0.10^{a}$ (53)	8.01 ±0.12 (53)	50.37 ±0.61 (53)	1043.98 ±36.11 (52)	9.48 $\pm0.11^{a}$ (52)	9.40 $\pm0.10^{a}$ (52)	52.31 ±0.67 (52)
Female	723.97 ±23.60 (44)	7.65 $\pm0.11^{b}$ (44)	7.797 ±0.13 (44)	49.98 ±0.63 (44)	982.02 ±38.52 (41)	8.86 $\pm0.12^{b}$ (41)	8.97 $\pm0.11^{b}$ (41)	51.56 ±0.70 (41)

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
Figures within parenthesis denote number of observations.
CW: chick weight; BW: body weight; SL: shank length; KL: keel length and BA: breast angle.

Table 3 Least squares analysis of variance of various feed utilization and efficiency traits in RIR chicken control line

Source of variation	df	Mean sum of squares														
		WG4	FC4	FCR4	WG6	FC6	FCR6	WG8	FC8	FCR8	WG12	FC12	FCR12	WG16	FC16	FCR16
Sire	22	1.5^{E+03}	4.0^{E+03}***	5.95	665.0	8.1^{E+03}***	5.8	3.1^{E+03}**	1.2^{E+04}***	19.3€	9.4^{E+03}	7.1^{E+03}***	6.5	1.8^{E+04}	1.5^{E+04}***	11.6
Sex	1	1.6^{E+03}	9.8	14.8	24.4	0.6	0.03	110.2	23.4	0.04	2.7^{E+03}	24.8	0.94	1.0^{E+04}	313.7	9.04
Feeding group	1	983.2	1.7^{E+03}*	1.15	140.0	552.2	0.07	527.7	2.1^{E+03}#	5.7	275.1	1.7^{E+03}**	0.11	1.8^{E+03}	580.6	7.2
Remainder	74	1.1^{E+03}	300.1	5.88	933.4	560.5	14.9	1.4^{E+03}	709.4	12.05	9.2^{E+03}	143.3	6.0	1.3^{E+04}	1.1^{E+03}	8.8

(P<0.09); € (P<0.07); * (P<0.05); ** (P<0.01) and *** (P<0.001).
WG: body weight gain; FC: feed intake and FCR: feed conversion ratio.

Table 4 Least squares means ± standard errors of various feed utilization and efficiency traits in RIR chicken control line

Factors	Obs	Least squares means± standard errors														
		WG4 (g)	FC4 (g)	FCR4	WG6 (g)	FC6 (g)	FCR6	WG8 (g)	FC8 (g)	FCR8	WG12 (g)	FC12 (g)	FCR12	WG16 (g)	FC16 (g)	FCR16
Overall	99	148.83 ±4.15	517.94 ±8.13	3.90 ±0.25	90.96 ±3.08	630.21 ±11.56	7.89 ±0.39	124.35 ±6.50	1152.64 ±14.20	10.35 ±0.49	333.19 ±9.81	2040.65 ±10.91	6.74 ±0.26	301.60 ±14.67	1965.02 ±15.69	7.07 ±0.37
Sex																
Male	54	153.53 ±5.50	517.57 ±8.34	3.45 ±0.36	91.53 ±4.50	630.30 ±11.83	7.87 ±0.57	123.13 ±7.66	1152.08 ±14.48	10.33 ±0.62	339.15 ±14.22	2040.07 ±10.98	6.63 ±0.37	313.43 ±19.10	1962.98 ±16.10	6.72 ±0.49
Female	45	144.13 ±5.88	518.30 ±8.41	4.34 ±0.39	90.39 ±4.87	630.12 ±11.92	7.92 ±0.62	125.56 ±8.01	1153.20 ±14.58	10.37 ±0.65	327.23 ±15.40	2041.22 ±11.01	6.86 ±0.40	289.76 ±20.35	1967.07 ±16.23	7.42 ±0.52
Feeding group																
1	50	134.50 ±15.91	536.55 ±11.34[b]	4.39 ±1.13	96.36 ±14.28	640.94 ±15.82	8.01 ±1.81	134.84 ±18.45	1173.73 ±18.69	11.44 ±1.66	325.61 ±44.95	2059.24 ±12.20[b]	6.90 ±1.15	282.04 ±54.15	1976.03 ±21.95	8.29 ±1.41
2	49	163.15 ±15.93	499.33 ±11.35[a]	3.41 ±1.14	85.55 ±14.31	619.47 ±15.84	7.77 ±1.81	113.85 ±18.48	1131.55 ±18.71	9.26 ±1.66	340.77 ±45.03	2022.05 ±12.20[a]	6.59 ±1.15	321.15 ±54.24	1954.02 ±21.97	5.85 ±1.41

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
WG: body weight gain; FC: feed intake and FCR: feed conversion ratio.

Significant sex-differentiation in body weights and males being heavier than females was also observed at 8th week onwards in RIR-white strain chicken (Das *et al.* 2014a); at 6th week onwards in Libyan native chicken (El-Safty, 2012) and at 12 weeks onwards in Giriraja, Indian WLH and Nigerian improved indigenous chicken genotypes (F_1, F_2 and B-α chickens) (Adebambo *et al.* 2006). Mohammed *et al.* (2005) also reported that sex affected body weight non-significantly at hatching in some crosses of RIR and indigenous lines of Bare-neck, Betwil and Large Beladi; whereas the differences were significant (P<0.05) at 2 weeks of age and highly significant (P<0.01) for the subsequent ages.

Significant sex effect was reported in RIR-white strain to be initiated from 8th weeks onwards excluding feed intake (Das *et al.* 2014a) in accordance to the present findings for shank and keel lengths, breast angle, and feed efficiency traits. FCR was also affected (P<0.05) at 8th and 16th week and FCR for male birds being better than that of females throughout the ages (Das *et al.* 2014a). El-Safty (2012) reported that males had significantly greater values for keel and shank lengths of Libyan native chickens at different ages when compared with female counterparts. Lariviere *et al.* (2009) also reported that keel angle and keel length were all greater in males and significantly different between sexes (P<0.001) at 85 days in Ardennaise chicken. But Adebambo *et al.* (2006) observed that body conformation traits *viz.* breast girth, shank length and keel length not to be all significantly affected by sex excepting shank length for 12th, 15th and 18th week of ages in Giriraja, Indian WLH, and Nigerian improved indigenous chicken genotypes (F_1, F_2 and B-α chickens). Higher estimates of shank and keel lengths, and breast angle at 8-week of age in male birds were also reported in CARI-Devendra chicken (Singh and Jilani, 2005). Thus body conformation and feed efficacy traits of poultry birds were not sex-independent.

Influence of feeding groups

Only feed utilization criteria i.e. feed intake (FC) significantly (P<0.05) varied among the feeding groups at 4th and 12th week of age; whereas Das *et al.* (2014a) reported significant effect of feeding groups on FC in RIR-white strain chicken throughout the ages, affecting also body weight gain and or FCR. The findings indicated that feed intake might be affected by management of the birds-keepers. Affected feed intake might also affect the feed efficiency and thus weight gain. As measurement of feed consumption was laborious, reports in the literature were scanty in this field.

Genetic and phenotypic parameters

Heritability estimates

Body weight (BW) and conformation traits (SL, KL, BA; Table 5) and feed efficiency (WG, FCR; Table 6) at various weeks of age were heritable at variable (low to high) magnitude implying that there was low to sufficient scope for improvement of these traits. The heritability estimates ranged from 0.096 ± 0.325 to 0.730 ± 0.432 for BW; 0.006 ± 0.308 to 0.658 ± 0.413 for SL; 0.130 ± 0.354 to 0.541 ± 0.394 for KL; 0.033 ± 0.313 to 0.983 ± 0.451 for BA; 0.013 ± 0.341 to 0.909 ± 0.434 for WG and 0.012 ± 0.341 to 0.535 ± 0.407 for FCR at various weeks of ages. High heritability estimates across the ages indicated additive genetic variance had played important role in expression of the traits and there was significant scope for improvement of these traits. Most of the estimates in this study were associated with higher standard errors making them less precise which were due to less number of progeny per sire (Falconer, 1989). Rajkumar *et al.* (2011) estimated heritability from sire component of variance as 0.42 ± 0.41, 0.31 ± 0.22 and 0.36 ± 0.17 for BW at 4th week of age, BW and SL at 6th week of age, respectively in sex-linked dwarf chicken.

Table 5 Heritability estimates (at diagonal), genotypic (above diagonal) and phenotypic (below diagonal) correlations among various intra-week body conformation traits in RIR chicken control line

Traits	BW4	SL4	KL4	BA4
BW4	-	-	-	-
SL4	0.675 (57)	-	-	-
KL4	0.750 (57)	0.787 (57)	-	
BA4	0.771 (57)	0.642 (57)	0.679 (57)	0.845±0.597 (57)
Traits	BW6	SL6	KL6	BA6
BW6	0.096±0.325 (99)	-	-	-
SL6	0.737 (99)	0.006±0.308 (99)	-	-
KL6	0.644 (99)	0.832 (99)	0.541±0.394 (99)	-
BA6	0.817 (99)	0.590 (99)	0.434 (99)	0.033±0.313 (99)
Traits	BW8	SL8	KL8	BA8
BW8	0.519±0.391 (99)	0.954±0.238 (99)	-	0.705±0.280 (99)
SL8	0.804 (99)	0.238±0.350 (99)	-	0.640±0.496 (99)
KL8	0.799 (99)	0.871 (99)	0.469±0.385 (99)	0.727±0.324 (99)
BA8	0.889 (99)	0.718 (99)	0.724 (99)	0.363±0.370 (99)
Traits	BW12	SL12	KL12	BA12
BW12	0.469±0.391 (97)	-	-	0.803±0.211 (97)
SL12	0.730 (97)	0.658±0.413 (97)	-	0.780±0.196 (97)
KL12	0.723 (97)	0.874 (97)	-	0.810±0.142 (97)
BA12	0.699 (97)	0.657 (97)	0.680 (97)	-
Traits	BW16	SL16	KL16	BA16
BW16	0.730±0.432 (93)	-	-	0.826±0.127 (93)
SL16	0.659 (93)	-	-	-
KL16	0.703 (93)	0.818 (93)	0.130±0.354 (93)	0.958±0.830 (93)
BA16	0.875 (93)	0.588 (93)	0.627 (93)	0.983±0.451 (93)

Figures within parenthesis denote number of observations.
BW: body weight; SL: shank length; KL: keel length and BA: breast angle.

Table 6 Heritability estimates (at diagonal), genotypic (above diagonal) and phenotypic (below diagonal) correlations among various feed efficiency traits in RIR chicken control line

Traits	WG4	FC4	FCR4	WG6	FC6	FCR6	WG8	FC8	FCR8	WG12	FC12	FCR12	WG16	FC16	FCR16
WG4	0.287 ±0.380	-0.780 ±0.671	> -1.0	-	-0.742 ±0.652	-	-0.761 ±0.653	-0.743 ±0.649	0.729 ±0.945	> 1.0	-0.416 ±0.523	> -1.0	0.223 ±0.864	-0.646	-0.312 ±1.146
FC4	-0.216	>1.0	> 1.0	-	0.993 ±0.003	-	0.042 ±0.304	0.980 ±0.009	0.126 ±0.365	> -1.0	0.738 ±0.102	> 1.0	-0.012 ±0.428	0.967 ±0.017	0.274 ±0.453
FCR4	-0.690	0.318	0.012 ±0.341	-	> 1.0	-	> 1.0	> 1.0	> -1.0	> -1.0	> 1.0	> 1.0	> 1.0	> 1.0	-0.538 ±8.107
WG6	-0.139	0.057	0.241	-	-	-	-	-	-	-	-	-	-	-	-
FC6	-0.207	0.991	0.312	0.081	>1.0	-	0.060 ±0.303	0.994 ±0.003	0.084 ±0.365	> -1.0	0.804 ±0.080	> 1.0	0.058 ±0.428	0.989 ±0.008	0.211 ±0.453
FCR6	0.046	0.107	-0.074	-0.747	0.087	-	-	-	-	-	-	-	-	-	-
WG8	0.142	0.058	0.037	0.212	0.081	-0.014	0.909 ±0.434	0.091 ±0.300	> -1.0	> 1.0	0.158 ±0.290	0.395 ±1.558	0.175 ±0.572	0.030 ±0.305	0.451 ±0.695
FC8	-0.208	0.983	0.307	0.092	0.992	0.074	0.075	>1.0	0.058 ±0.362	> -1.0	0.856 ±0.060	>1.0	0.112 ±0.426	> 1.0	0.168 ±0.449
FCR8	-0.103	-0.024	-0.041	-0.313	-0.057	0.124	-0.880	-0.039	0.535 ±0.407	> -1.0	-0.078 ±0.354	-0.145 ±1.373	-0.259 ±0.747	0.111 ±0.366	-0.460 ±0.743
WG12	0.105	-0.103	0.092	0.113	-0.101	-0.071	0.251	-0.104	-0.235	0.013 ±0.341	> -1.0	> -1.0	> 1.0	> -1.0	> -1.0
FC12	-0.154	0.733	0.218	0.175	0.792	-0.042	0.107	0.841	-0.066	-0.064	> 1.0	> 1.0	0.464 ±0.430	0.894 ±0.046	-0.161 ±0.444
FCR12	-0.165	0.199	-0.012	-0.037	0.201	0.024	-0.144	0.206	0.150	-0.881	0.168	0.079 ±0.351	-0.513 ±2.188	> 1.0	0.005 ±1.774
WG16	0.274	-0.055	-0.172	0.119	-0.027	-0.102	0.140	-0.016	-0.100	0.116	0.059	-0.125	0.352 ±0.388	0.207 ±0.441	> -1.0
FC16	-0.221	0.945	0.303	0.126	0.960	0.034	0.078	0.973	-0.042	-0.094	0.877	0.204	-0.071	> 1.0	0.110 ±0.452
FCR16	-0.265	0.114	0.190	-0.169	0.085	0.160	-0.095	0.084	0.099	-0.072	0.009	0.087	-0.882	0.107	0.302 ±0.382

Number of observations was 99 in all estimations.
WG: body weight gain; FC: feed intake and FCR: feed conversion ratio.

Jaya Laxmi *et al.* (2010) estimated heritability of body weights from sire plus dam component as 0.243 ± 0.091, 0.298 ± 0.096 and 0.223 ± 0.089 at 4, 6 and 16th week of ages in IWK strain of White Leghorn chicken. Chaudhary *et al.* (2009) reported heritability of body weights from sire component ranged from 0.18 ± 0.11 to 0.83 ± 0.22 across the ages and strains in White Leghorn chicken with higher estimates from day-old to 8 week of age than from 16 to 40 weeks of age. In the present study there was no consistent pattern in heritability estimates among different ages. Niranjan and Kataria (2008) estimated heritability from sire component as 0.39 ± 0.23 and 0.34 ± 0.23 for net feed efficacy in laying stage in control and selected strain of White Leghorn chicken. Adebambo *et al.* (2006) estimated corresponding 3rd and 6th week's heritability estimates of SL as 0.916 and 0.761 in Giriraja, WLF and Nigerian improved indigenous chicken genotypes (F1, F2 and B-α). Singh and Jilani (2005) reported heritability estimates of 0.37 ± 0.069, 0.30 ± 0.322, 0.35 ± 0.663, 0.27 ± 0.055 and 0.45 ± 0.156 for BW at 6th week, BW, SL, KL and BA at 8th week of age from sire component in CARI-Devendra chicken. Falconer (1989) stated that heritability of a trait is a population parameter nourished by environmental circumstances. Thus any change in the components of variance would lead to likely change in the heritability estimates and this might explain the attributed differences in the estimates by different workers. Heritability estimates might also be influenced by other factors not considered in the model used in this study, the estimates in this study were in the expected range.

Estimates of heritability of a trait could vary considerably from study to study depending upon breed, strain, line, population sampled, environmental and management conditions and random as well as systematic errors in the estimation procedures (Mia *et al.* 2013). The numbers of progeny within a sire and the entire data set from which these estimates were obtained were relatively small and could have sampling errors.

Genetic correlation estimates

The estimates of genetic correlations coefficients (r_G) were positive in trends and high (ranged from 0.640±0.496 to 0.958±0.830) in magnitude uniformly among all the intra-week body weights and body conformation traits (Table 5) indicating changes in one trait would influence the other trait in the same direction in correspondence to the earlier reports in CARI-Devendra chicken (Singh and Jilani, 2005). Whereas, Adebambo *et al.* (2006) reported a range of r_G among body weight and other linear body measurements as -0.016 to 0.67 in Giriraja, Indian WLH and Nigerian improved indigenous chicken genotypes (F1, F2 and B-α chickens).

It was inferred by these r_G that the continuous selection of body weights at any age might improve the body conformation traits simultaneously. Similarly, for feed utilization efficiency traits (Table 6), the present r_G estimates ranged from 0.395 ± 1.558 to 0.729 ± 0.945 between WG and FCR and from 0.058 ± 0.362 to 0.274 ± 0.453 between FC and FCR at different weeks of age excepting at 16th weeks of age excluding other estimates being statistically non-precise might be due to less numbers of progeny under each sire (Table 6). The r_G estimates between WG and FC could not follow any uniform trend throughout the ages (Table 6). Previously, Niranjan and Kataria (2008) also reported that various feed efficiency traits were positively correlated with high r_G in White Leghorn chicken lines.

Phenotypic correlation estimates

The estimates of phenotypic correlations coefficients (r_P) were all invariably positive and high in magnitude uniformly among all the intra week body conformation traits (Table 5) indicating changes in one trait would influence the other trait in the same direction. The r_P estimates ranged from 0.659 to 0.804 between BW and SL, 0.644 to 0.799 between BW and KL, 0.588 to 0.817 between BW and BA, 0.787 to 0.874 between SL and KL, 0.434 to 0.724 between KL and BA, 0.588 to 0.718 between BA and SL at various weeks of age (Table 5). The continuous selection of body weights at any age might improve the body conformation traits simultaneously. The phenotypic correlations were influenced by the magnitude and signs of the genetic and environmental correlations. The present findings were in accordance to the earlier reports in RIR-White strain of Das *et al.* (2014a) and CARI-Devendra chicken (Singh and Jilani, 2005). Adebambo *et al.* (2006) found the r_P among body measurement parameters as lower at older ages (-0.018 to 0.711) than at younger ages (-0.081 to 0.828) in Giriraja, Indian WLH and Nigerian improved indigenous chicken genotypes (F1, F2 and B-α chickens). Lariviere *et al.* (2009) reported phenotypic association of body weight with keel angle and keel length in Ardennaise chicken. Banerjee (2010) reported positive r_P ($P<0.05$) between body weight and breast angle in Vigova Super M broiler ducks at various age groups.

Similarly, the r_P estimates were also positive and low in magnitude between FC and FCR at various weeks of age excepting at 8th week (Table 6). The r_P estimates between WG and FC were very low in magnitude and could not follow any uniform trend (Table 6). But FCR and WG were invariably negatively correlated by r_P at various weeks excepting at 6th week. In this field, Niranjan and Kataria (2008) also reported that various feed efficiency traits were positively correlated with high r_P in White Leghorn chicken lines.

CONCLUSION

It is concluded that the traits of shank length and keel length were not sex independent at older ages. Male birds demonstrated better estimates for body conformation traits and FCR than females throughout the ages. Sire played significant effect on various body conformation and feed efficiency traits excluding FCR. Birds keepers had a bit effect on feed consumption rate at some ages. Body weight, shank length, keel length, breast angle, body weight gain and FCR were heritable at variable (low to high) magnitude. The genetic and phenotypic correlation estimates among different intra-week body conformation traits and feed efficiency characteristics were encouraging and could therefore be used to predict either conformation or percentage meat yield of the carcass. This information might be useful for improvement of this RIR chicken line.

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