Turkish Journal of Veterinary and Animal Sciences

http://journals.tubitak.gov.tr/veterinary/

Research Article

Turk J Vet Anim Sci
(2022) 46: 356-365
© TÜBİTAK
doi:10.3906/vet-2108-25

Evaluation of morphological traits in Aseel and Kadaknath breeds under backyard poultry farming using principal component analysis

Manoj KUMAR[1,*], Satpal DAHIYA[2], Poonam RATWAN[2], Nancy SHEORAN[3]

[1]Department of Livestock Farm Complex, LUVAS, Hisar, Haryana, India
[2]Department of Animal Genetics and Breeding, LUVAS, Hisar, Haryana, India
[3]Department of Animal Nutrition, LUVAS, Hisar, Haryana, India

Received: 11.08.2021 • **Accepted/Published Online:** 24.01.2022 • **Final Version:** 25.04.2022

Abstract: Aseel and Kadaknath chickens are recognized for their hardiness and adaptability to warm and humid climates and are being used for genetic improvement of different breeds which are appropriate for backyard poultry farming in India. In the present study, an attempt was made for the first time in India to assess the relationship among morphological traits and to explain the body conformation of Aseel and Kadaknath breeds under backyard poultry farming using principal component analysis (PCA). Eleven different morphological traits viz., 24-week body weight, comb length, keel length, body length, back length, breast girth, breast angle, radius-ulna length, shank length, shank circumference, and tail length were measured in both breeds. In both breeds, the correlations between all morphological characteristics were found to be positive and significant ($p < 0.01$) and varied from 0.245 (tail length and breast girth) to 0.797 (shank circumference and shank length) in Aseel and 0.247 (shank length and 24-week body weight) to 0.768 (back length and body length) in Kadaknath. All morphological traits had a high correlation with 24-week body weight in both chicken breeds suggesting the probable use of morphometric traits in predicting body weight. The extracted two components accounted for 64.822% and 68.286% of the total variability present in the original traits in Aseel and Kadaknath, respectively. It was concluded that PCA is an interesting tool for evaluation and effective to reduce the number of variables required to explain the body conformation in Aseel and Kadaknath breeds.

Key words: Body weight, body conformation, back length, phenotypic correlation, shank length

1. Introduction

In India, the poultry industry is the fastest-growing business and the population of poultry in the country is 851.81 million comprised of 534.74 million commercial and 317.07 million backyard poultry [1]. There is a 45.78% increase in the population of backyard poultry in India as compared to the previous livestock census of 2012. Backyard poultry farming plays a crucial role in the economy and livelihood of poor families, reduction of poverty and unemployment as well as in improving the nutritional and economic status of rural people [2–3]. There is a need for awareness programs to improve the socio-economic and nutritional status of poor and rural farmers as they did not have sufficient knowledge about scientific backyard poultry practices [4]. Backyard poultry farming also has a significant role in women empowerment and nutritional security [5]. In India, Aseel and Kadaknath are important breeds of chicken which are suitable and adaptable under backyard poultry farming and are becoming popular because of their unique characteristics. Aseel is a game chicken breed known for its pugnacity, majestic gait, great stamina, aggressive fighting abilities, and has long legs and neck [6]. Kadaknath also known as *Kalmashi* in the local language is famous for its delicious black meat. This breed is famous among tribal people and they use Kadaknath meat for the treatment of various diseases [7]. Aseel chickens had better external and internal egg quality characteristics however egg yolk quality of Kadaknath eggs was found to be better as compared to Aseel eggs [8]. Both Aseel and Kadaknath are recognized for their endurance, tolerance of heat and stress conditions, and adaptability to warm and humid climate and are being used for propagation of superior germplasm which is appropriate for backyard poultry farming [9–12]. Knowledge related to the variation of morphometric traits in the existing genetic resources is most significant for the characterization of livestock including poultry [13]. Body weight and body conformation are significant factors for assessing growth in chickens since they have been proven to be useful in comparing the shape and size of animals and poultry [14].

* Correspondence: drmanojneemwal@gmail.com

A principal component analysis is a multivariate method that converts correlated variables into uncorrelated variables, which are then arranged so that the first few retain the majority of the original variables' variance [15–18]. Data reduction and interpretation are the general objectives of principal component analysis [19]. In poultry, principal component analysis was utilised to determine the phenotypic connection between body morphometric characteristics and body size i.e. chicken [20–25], turkey [26–27], duck [28–29], guinea pigs [30], and rabbits [31]. PCA has been used for the characterization of Haringhata Black chicken using different body morphometric traits [32–33]. Dalal et al. [34] observed in the synthetic White Leghorn strain that all body measurements exhibited a strong positive and considerable association with body weight at 40 weeks, showing those body measurements may be used to predict body weight. The present study was conducted to make morphological traits unrelated and reduce their number to the extent which could be used in explaining body conformation in Aseel and Kadaknath chickens maintained under backyard poultry farming using a multivariate approach of principal component analysis.

2. Materials and methods

2.1. Data

Chicks under the current study were procured from Poultry Farm, LUVAS, Hisar and distributed to the selected 16 rural families under Rashtriya Krishi Vikas Yojana- Remunerative Approaches for Agriculture and Allied Sectors Rejuvenation (RKVY-RAFTAAR) project. Chicks were reared under a backyard farming system and their body measurements were recorded at 24 weeks of age at farmers' doorstep. Eleven morphological traits were measured on 87 (74 female and 13 male) Aseel and 82 (70 female and 12 male) Kadaknath birds and data were pooled for both the sexes.

2.2. Traits

The traits recorded were 24-week body weight (24 BW), comb length (from the insertion of comb in beak to end of combs' lobe), keel length (distance between vertices of the sternum), body length (from the tip of beak through body trunk to the tail), back length (from the insertion of neck into the body to saddle), breast girth (circumference of the breast around its deepest region), breast angle (from the extreme of the keel of the sternum), radius-ulna length (from the tip of olecranon process to the tip of the styloid process), shank length (from the hock joint to the tarsus-metatarsus), shank circumference (width of shank), and tail length (from the tip of a central rectrix to the point where it emerges from the skin). At 24 weeks of age, body weight of each bird was recorded using electronic balance and breast angle was measured with the help of a goniometer. The measuring tape was used to record all other morphological traits in centimeter. To eliminate individual variations and reduce error, all body measurements were collected by the same person.

2.3. Statistical analyses

Descriptive statistics of different morphometric traits were calculated by using SPSS [35] statistical package. Phenotypic correlations among eleven morphological traits were calculated and the obtained correlation matrix was used for principal component analysis. Kaiser Meyer-Olkin (KMO) test of sampling adequacy was carried out to test the validity of data set. Bartlett's test of Sphericity [36] was performed to check whether the data set of 87 Aseel and 82 Kadaknath birds with eleven traits could be factored or not. The principal components were rotated using Varimax rotation after they were transformed using SPSS software.

3. Results

Means, standard deviations, and coefficients of variation of morphological traits of Aseel and Kadaknath chickens estimated at 24 weeks of age are presented in Table 1. Body measurements viz., 24-week body weight, comb length, keel length, body length, back length, breast girth, breast angle, radius-ulna length, shank length, shank circumference, and tail length were measured and descriptive statistics revealed the means for corresponding traits in Aseel as 1369.77 g, 3.12 cm, 16.81 cm, 35.32 cm, 20.62 cm, 27.87 cm, 60.75°, 14.05 cm, 8.19 cm, 4.63 cm, and 17.83 cm, respectively and 1167.07 g, 4.56 cm, 16.21 cm, 30.67 cm, 19.68 cm, 26.68 cm, 57.92°, 13.54 cm, 8.45 cm, 4.34 cm, and 17.48 cm, respectively in Kadaknath chicken.

Phenotypic correlations among different body measurements of Aseel and Kadaknath chickens were calculated and are presented in Table 2. All the correlations were found to be significant ($p < 0.01$) and positive in both Aseel and Kadaknath and varied from 0.245 (tail length and breast girth) to 0.797 (shank circumference and shank length) in Aseel and 0.247 (shank length and 24-week body weight) to 0.768 (back length and body length) in Kadaknath chickens. Significant ($p < 0.01$) and positive correlations between morphometric characteristics in Aseel and Kadaknath chickens show good predictability among the variables, which might be beneficial as selection criteria. All body measurements had a high correlation with 24-week body weight in Aseel and Kadaknath chicken. In the present study, the Kaiser-Meyer Olkin (KMO) measure of sample adequacy in Aseel chicken was 0.890, and the result of the Bartlett test of Sphericity was significant (chi-square 594.123; $p = 0.000$). The KMO measure of sample adequacy in Kadaknath chicken was 0.848, and the Bartlett test of Sphericity was similarly

Table 1. Descriptive analysis of the body morphometric traits of Aseel and Kadaknath chicken.

Traits	Observations	Mean	Std. Deviation	CV (%)
Aseel				
24-week body weight (g)	87	1369.77	257.43	18.79
Comb length (cm)	87	3.12	0.97	31.22
Keel length (cm)	87	16.81	1.85	10.98
Body length (cm)	87	35.32	3.09	8.76
Back length (cm)	87	20.62	1.89	9.18
Breast girth (cm)	87	27.87	2.66	9.55
Breast angle (degree)	87	60.75	4.71	7.75
Radius Ulna length (cm)	87	14.05	2.32	16.53
Shank length (cm)	87	8.19	1.28	15.58
Shank circumference (cm)	87	4.63	0.57	12.30
Tail length (cm)	87	17.83	3.16	17.74
Kadaknath				
24-week body weight (g)	82	1167.07	229.09	19.63
Comb length (cm)	82	4.56	1.54	33.84
Keel length (cm)	82	16.21	1.53	9.41
Body length (cm)	82	30.67	1.80	5.85
Back length (cm)	82	19.68	1.20	6.11
Breast girth (cm)	82	26.68	1.70	6.35
Breast angle (degree)	82	57.92	3.19	5.51
Radius Ulna length (cm)	82	13.54	1.26	9.32
Shank length (cm)	82	8.45	1.13	13.33
Shank circumference (cm)	82	4.34	0.40	9.21
Tail length (cm)	82	17.48	2.24	12.83

significant (chi-square 638.807; p = 0.000). Kaiser [37] considered a sample adequacy score of more than 0.80 to be commendable. The significance of the correlation matrices for the body measures of Aseel and Kadaknath chickens assessed with Bartlett's test of Sphericity gave enough evidence for the validity of employing factor analysis for the data set.

Eigenvalue represents the variability accounted by each factor out of total variability and two components having eigenvalue greater than one as shown in Table 3 and 4 for Aseel and Kadaknath, respectively were extracted based on Kaiser rule criterion as suggested by Johnson and Wichern [19]. The actual number of components to be retained can also be decided with the help of scree plot and the components having eigenvalue up to the bent of elbow are taken into consideration as shown in Figure 1 and 2 for Aseel and Kadaknath, respectively. Two common factors were identified with eigenvalues of 6.033 (PC1) and 1.097 (PC2) in Aseel and 6.485 (PC1) and 1.087 (PC2) in Kadaknath chicken. These extracted two factors collectively accounted for 64.822% of the total variability present in the parameters measured in Aseel and 68.286% in Kadaknath chicken. In Aseel, the first principal component accounted for the greatest proportion of the total variance (54.847%) and was highly correlated with body weight (0.854), back length (0.832), body length (0.794), breast girth (0.710), shank circumference (0.655), and breast angle (0.639) at 24 weeks of age, while PC2 had high positive loadings on comb length (0.822), tail length (0.805), shank length (0.638), keel length (0.592) and radius ulna length (0.475) (Table 5) and explained only 9.975% of the total variance. In Kadaknath chicken, the first principal component accounted for the greatest proportion of the total variance (58.954%) and was found to be highly correlated with back length (0.871), body length (0.857), shank circumference (0.753), radius ulna length (0.644), shank length (0.631) and breast angle (0.616) at 24th week of age, while PC2 had high positive loadings on tail length (0.814), body weight (0.800), comb length (0.726), breast girth (0.702) and keel length (0.633)

Table 2. Phenotypic correlation between different body measurements in Aseel and Kadaknath chicken.

Traits	24 BW	CL	KL	BoL	BL	BG	BA	RUL	SL	SC	TL
Aseel **24 BW**	1.00										
CL	0.398*	1.00									
KL	0.570*	0.521*	1.00								
BoL	0.651*	0.337*	0.577*	1.00							
BL	0.714*	0.379*	0.579*	0.792*	1.00						
BG	0.711*	0.275*	0.425*	0.338*	0.523*	1.00					
BA	0.617*	0.447*	0.537*	0.615*	0.555*	0.390*	1.00				
RUL	0.399*	0.372*	0.393*	0.397*	0.365*	0.288*	0.480*	1.00			
SL	0.649*	0.589*	0.641*	0.682*	0.670*	0.347*	0.646*	0.405*	1.00		
SC	0.635*	0.463*	0.526*	0.678*	0.644*	0.329*	0.557*	0.294*	0.797*	1.00	
TL	0.383*	0.522*	0.492*	0.287*	0.363*	0.245*	0.323*	0.312*	0.512*	0.386*	1.00
Kadaknath											
24 BW	1.00										
CL	0.642*	1.00									
KL	0.654*	0.498*	1.00								
BoL	0.381*	0.489*	0.496*	1.00							
BL	0.437*	0.522*	0.545*	0.768*	1.00						
BG	0.667*	0.608*	0.695*	0.608*	0.656*	1.00					
BA	0.586*	0.645*	0.486*	0.545*	0.633*	0.647*	1.00				
RUL	0.479*	0.570*	0.445*	0.465*	0.624*	0.589*	0.662*	1.00			
SL	0.247*	0.524*	0.505*	0.582*	0.560*	0.609*	0.509*	0.538*	1.00		
SC	0.468*	0.610*	0.525*	0.653*	0.637*	0.649*	0.628*	0.520*	0.524*	1.00	
TL	0.458*	0.637*	0.450*	0.345*	0.337*	0.675*	0.476*	0.345*	0.601*	0.333*	1.00

* Significant at the 0.01 level; 24 BW = 24-week body weight, CL = Comb length, KL= Keel length, BoL = Body length, BL = Back length, BG = Breast girth, BA = Breast angle, RUL = Radius Ulna length, SL = Shank length, SC = Shank circumference, TL = Tail length.

(Table 5) and explained only 9.332% of the total variance. Therefore, six variables viz. body weight, back length, body length, breast girth, shank circumference, and breast angle out of the total eleven characteristic traits at 24 weeks of age had maximum correlations with PC1 and these could be used in the characterization of Aseel chicken instead of the original interdependent traits. In Kadaknath chicken, traits namely, back length, body length, shank circumference, radius ulna length, shank length, and breast angle out of the total eleven characteristic traits at 24th week of age had maximum correlations with PC1 and these could be further used for characterization instead of originally considered interdependent traits. The component plot of the two components in rotated space for different morphometric traits is shown in Figures 3 and 4 for Aseel and Kadaknath, respectively.

4. Discussion

Aseel birds had more body weight at 24 weeks of age as compared to the Kadaknath in present study. Similarly, different researchers [9,11,38,39] reported higher body weight in Aseel than Kadaknath at various ages. The reason for this may be different genetic makeup and selection criteria for Aseel and Kadaknath over time. The current study reported a longer average comb length in Aseel and Kadaknath as compared to the results of Negassa et al. [40] and Bekele et al. [41] in indigenous chicken of Ethiopia (2.59 cm and 2.42 cm, respectively). Saikhom et al. [32] observed comb length as 0.96 cm in Harringhata Black chicken. Mean keel length in Aseel and Kadaknath chickens in the present study was comparable with the findings of Churchil et al. [42] in Aseel males (12.52 cm), however, other researchers [33,40,41,43]

Table 3. Different components in Aseel chicken explaining the total variance.

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total
1	6.033	54.847	54.847	6.033	54.847	54.847	4.189
2	1.097	9.975	64.822	1.097	9.975	64.822	2.941
3	0.887	8.06	72.882				
4	0.777	7.063	79.945				
5	0.514	4.671	84.617				
6	0.446	4.058	88.675				
7	0.402	3.655	92.33				
8	0.332	3.017	95.347				
9	0.192	1.743	97.089				
10	0.171	1.554	98.643				
11	0.149	1.357	100				

Table 4. Different components in Kadaknath chicken explaining the total variance.

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total
1	6.485	58.954	58.954	6.485	58.954	58.954	3.995
2	1.027	9.332	68.286	1.027	9.332	68.286	3.516
3	0.842	7.652	75.938				
4	0.675	6.136	82.073				
5	0.508	4.621	86.694				
6	0.387	3.514	90.208				
7	0.327	2.974	93.183				
8	0.275	2.501	95.683				
9	0.211	1.921	97.604				
10	0.157	1.428	99.032				
11	0.106	0.968	100				

reported comparatively lower keel length in different breeds of chicken. Mean body length as observed by Bekele et al. [41] in indigenous chickens of Ethiopia (36.78 cm) and Egena et al. [23] in indigenous Nigerian chickens (38.77 cm) was in concordance with the present findings. Churchil et al. [42] in Aseel chicken (53.80 cm) and Saikhom et al. [33] in Haringhata Black chicken (59.27) reported comparatively higher body length, although Negassa et al. [40] reported lower average body length in indigenous chicken of Ethiopia (22.6 cm). Tabassum et al. [44] reported a similar average back length in indigenous chicken of Bangladesh (15.27 cm), but a lower value for the same trait was observed by Saikhom et al. [33] in Haringhata Black chicken. Mean breast girth in Aseel and Kadaknath chicken in current research was equivalent with findings of Churchil et al. [42] in Aseel chicken (31.60 cm) and Egena et al. [23] in indigenous Nigerian chickens (25.30 cm), though, Tabassum et al. [44] and Saikhom et al. [33] reported less average breast girth in different chickens. Contrary to the present findings, Churchil et al. [42] and Negassa et al. [40] observed lower breast angle in Aseel (30.80°) and Ethiopian native chicken (41.10°). The present study revealed higher average radius ulna length as compared to the findings of Sarker et al. [43]. Mean shank

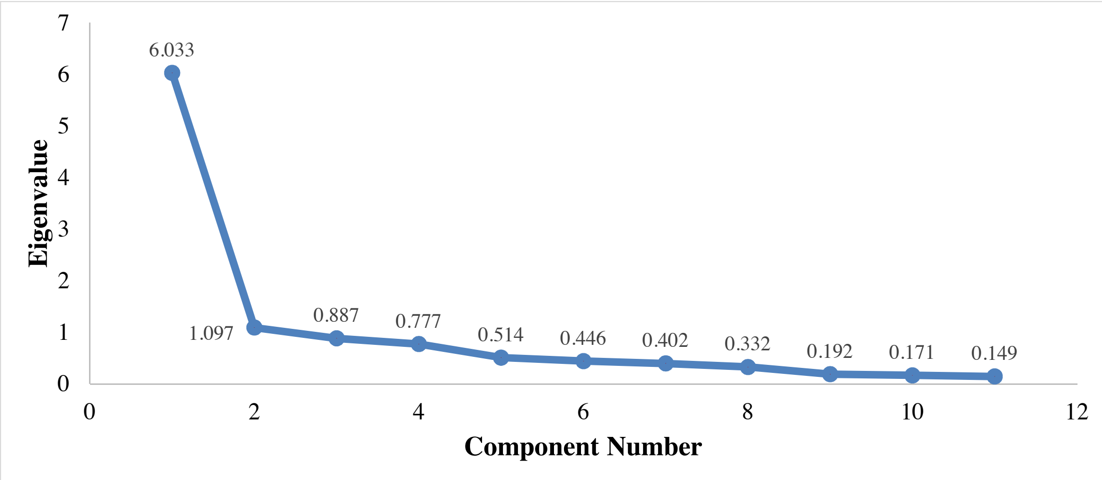

Figure 1. In Aseel, a scree plot depicting component number and eigenvalues

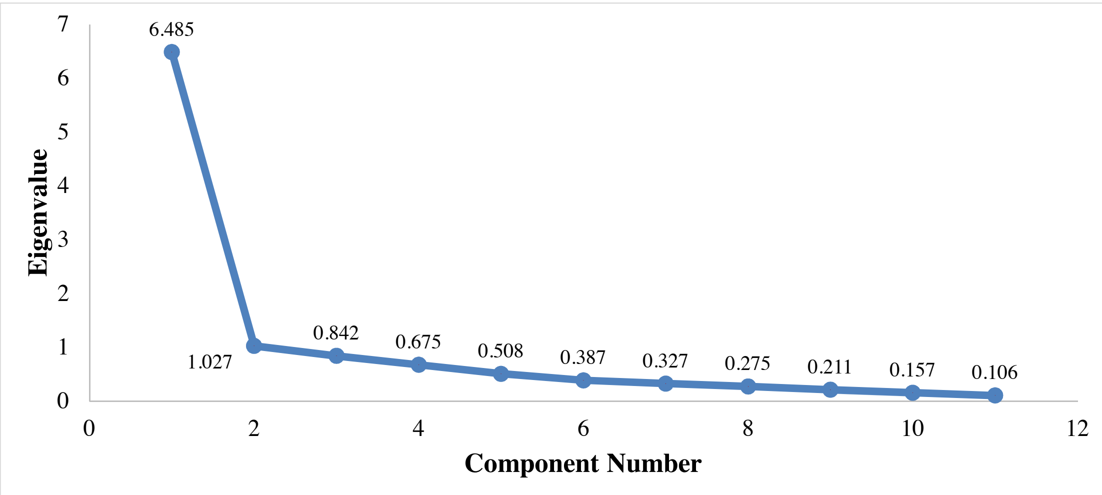

Figure 2. In Kadaknath, a scree plot depicting component number and eigenvalues

length in Aseel and Kadaknath chicken in the present study was equivalent with results observed by Churchil et al. [42], Bekele et al. [41] and Dana et al. [45], however, Egena et al. [23] and Sarker et al. [43] observed higher and Negassa et al. [40] observed lower shank length in different chicken breeds. Higher mean shank circumference as compared to the present study was reported by Sarker et al. [43] in Aseel chicken of Bangladesh. Comb length showed the maximum variation whereas minimum variation was observed for breast angle in both Aseel and Kadaknath chickens in the present study. Saikhom et al. [33] reported maximum variation in body weight (22.73%) while minimum variation for back length (4.80%) and Saikhom et al. [32] reported maximum variation in comb width (59.29%) while minimum variation was observed for ocular length (3.78%) in Haringhata Black chicken. Akporhuarho and Omoikhoje [24] reported maximum variation in chicken body weight (7.91%) and minimum variation in thigh-length (0.37%). Egena et al. [23] reported maximum and minimum variation in shank thickness (38.53%) and body girth (5.87%), respectively. Yakubu et al. [21] reported maximum variation in comb height while minimum variation was observed for body length in all three Nigerian chicken genotypes.

All body measurements had a high correlation with 24-week body weight in Aseel and Kadaknath chicken. Similarly, various researchers [14,22,23] observed a highly positive correlation of body weight with body measurements indicating the possible use of body measurements in predicting body weight. Saikhom et al. [33] reported the highest correlation among body weight and length ($r = 0.86$). Egena et al. [23] observed the highest

Table 5. Linear type characteristics in Aseel and Kadaknath chickens, using a Varimax rotational component matrix of different variables.

Aseel traits	Component		Kadaknath traits	Component	
	1	2		1	2
Body wt.	0.854	0.268	Back length	0.871	0.237
Back length	0.832	0.280	Body length	0.857	0.180
Body length	0.794	0.292	Shank circumference	0.753	0.335
Breast girth	0.710	0.048	Radius Ulna length	0.644	0.395
Shank circumference	0.655	0.459	Shank length	0.631	0.395
Breast angle	0.639	0.430	Breast angle	0.616	0.530
Comb length	0.174	0.822	Tail length	0.154	0.814
Tail length	0.104	0.805	Body wt.	0.233	0.800
Shank length	0.608	0.638	Comb length	0.418	0.726
Keel length	0.522	0.592	Breast girth	0.551	0.702
Radius Ulna length	0.338	0.475	Keel length	0.432	0.633

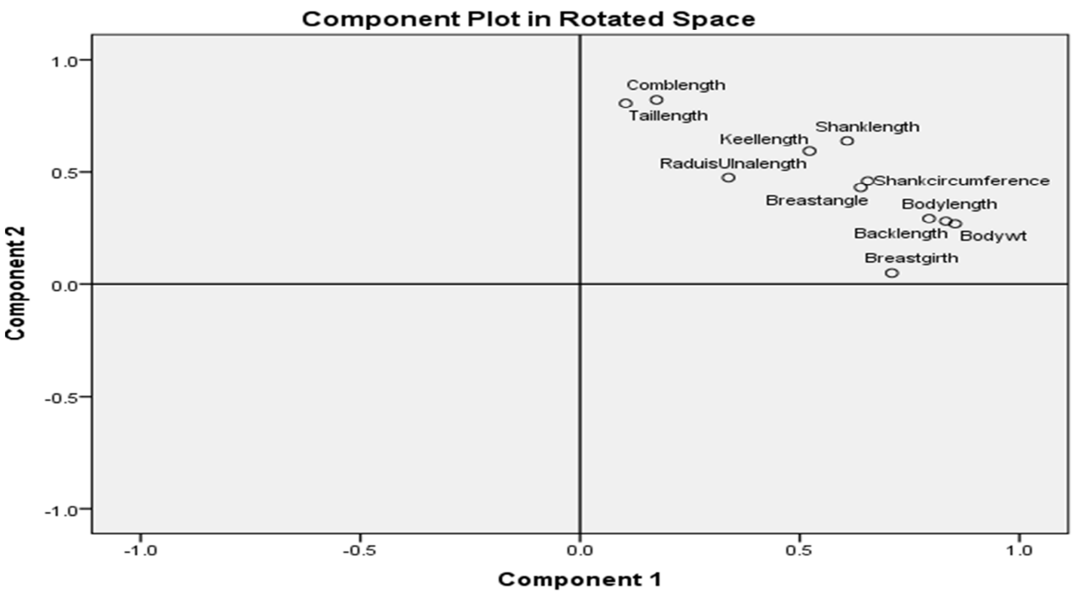

Figure 3. In Aseel, a component plot in rotated space depicts distinct linear type traits

correlation between body weight and body length while the correlation between shank length and shank thickness was observed to be least in their study. In their study, Egena et al. [23] found a strong association between body weight and length, but a low correlation between shank length and shank thickness. Similar KMO values and significant Bartlett test of Sphericity were observed by Amao [25] and Egena et al. [23]. Communalities and unique factors for body measurements of Aseel and Kadaknath chickens as obtained in this present study are depicted in Table 6. The communalities are the proportions of variance in the original variables that indicate the proportion of variation in the communalities, in Aseel, communalities varied from 0.340 (radius ulna length) to 0.800 (body weight), whereas in Kadaknath, communalities ranged from 0.554 (shank length) to 0.796 (breast girth). Similarly, Yakubu et al. [21] found strong communalities in Nigerian indigenous chickens and in diverse kinds of chickens [22, 46, 47]. Yakubu et al. [48] found a wide range of communalities (0.755–0.987) for Arbor Acre broiler body measures.

Similar to the present findings, two principal components were extracted in different chicken breeds that

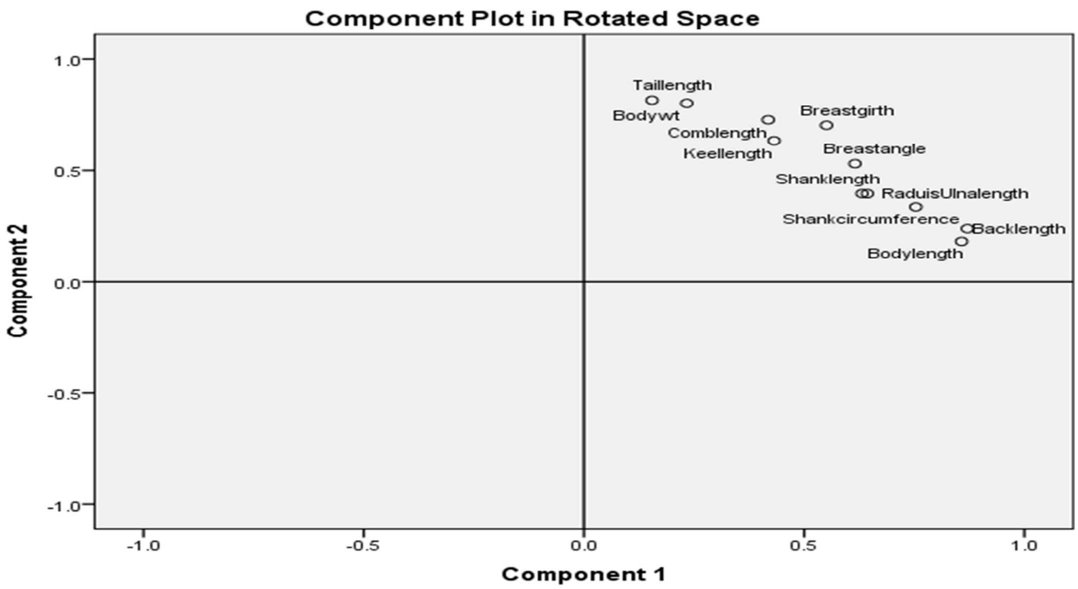

Figure 4. In Kadaknath, a component plot in rotated space depicts distinct linear type traits

Table 6. In Aseel and Kadaknath chickens, communalities and unique factors influence various morphometric traits.

Traits	Aseel		Kadaknath	
	Communalities	Unique factor	Communalities	Unique factor
Body weight	0.800	0.200	0.695	0.305
Comb length	0.705	0.295	0.702	0.298
Keel length	0.623	0.377	0.587	0.413
Body length	0.716	0.284	0.768	0.232
Back length	0.771	0.229	0.814	0.186
Breast girth	0.506	0.494	0.796	0.204
Breast angle	0.593	0.407	0.660	0.340
Radius Ulna length	0.340	0.660	0.570	0.430
Shank length	0.777	0.223	0.554	0.446
Shank circumference	0.639	0.361	0.680	0.320
Tail length	0.659	0.341	0.686	0.314

accounted for the maximum variation in the morphological traits [23,22,25,33]. According to Saikhom et al. [33], the first principal component exhibited strong positive loadings on body weight, body length, ornithological measurement, breast girth, and keel length, whereas the second component had significant positive loadings on beak width and beak length. According to Amao [25], PC1 and PC2 accounted for 83.14% of the overall variance, whereas PC1 accounted for 65.44%. These findings of PC1 having the largest variability out of all the variables were consistent with the findings of the current investigation. According to Egena et al. [23], two variables accounted for 66.40% of the overall variability in the characteristics studied. PC1 loaded strongly on wing length (0.840), body weight (0.826), and body length (0.814), whereas PC2 loaded orthogonal on shank length (0.997) and also, the first principal component (PC1) showed the most variability, which was strongly related to body weight, body length, and wing length. In Arbor Acre, Udeh and Ogbu [22] found that two main components explained 65% of the overall variance in the original variables. They found high PC1 loadings on Arbor Acre broiler breast width, wing length, and thigh length, Marshal broiler shank length and wing length, and Ross broiler breast width and body length. At 24 weeks of age, Saikhom et al. [32] discovered four components that explained 77.17% of the total variation in fourteen variables, with PC1 having the strongest correlations with comb length, comb width, wattle length, wattle width, earlobe length, and earlobe width, and PC2 having the strongest correlations with ocular width and beak length. According to Pinto et al. [20], five principal components accounted for 93.30% of the overall variation in morphological characteristics, with the first component accounting for 66.00%. Yakubu et al. [21] reported that the first principal component accounted for 42%, 65%, and 56% of the overall variability in body weight in the regular feathered, bare neck, and frizzled hens, respectively.

In conclusion, all morphometric traits had a high positive and significant correlation with 24-week body weight indicating the possible use of morphometric traits in predicting body weight in Aseel and Kadaknath chicken. The current study revealed that the extracted two PC had the largest share of the total variance and explained 64.822% in Aseel and 68.286% in Kadaknath chicken of the total variability present in the original morphological traits. It was concluded that PCA is an interesting tool for evaluation and effective to reduce the number of traits required to explain the body conformation in Aseel and Kadaknath chicken.

References

1. 20th Livestock Census All India Report, DAHD & F. 2019. Ministry of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India.
2. Rajkumar U, Rama Rao SV, Sharma RP. Backyard poultry farming-changing the face of rural and tribal livelihoods. Indian Farming 2010; 59: 20-24.
3. Alam MA, Ali, MS, Das NG, Rahman MM. Present status of rearing backyard poultry in selected areas of Mymensingh district. Bangladesh Journal of Animal Science 2014; 43: 30-37.
4. Kumar M, Dahiya SP, Sheoran N, Ratwan R, Kumar S. Appraisal of socio-economic profile and general knowledge of rural respondents about backyard poultry farming in northern India. Indian Journal of Extension Education 2021a; 57 (1): 108-114.
5. Kumar M, Dahiya SP, Ratwan P. Backyard poultry farming in India: A tool for nutritional security and women empowerment. Biological Rhythm Research 2021b; 52 (10): 1476-1491.
6. Singh DP. Aseel of India. In: Souvenir, National Seminar on Appropriate Poultry for Adverse Environment. Organized by Acharya N G Ranga Agricultural University and Project Directorate on Poultry, Hyderabad, 11th January 2001.
7. Thakur MS, Parmar SNS, Pillai PVA. Studies on growth performance in Kadaknath breed of poultry. Livestock Research for Rural Development 2006; 18: 1-9.
8. Kumar M, Dahiya SP, Ratwan P, Sheoran N, Kumar S, et al. Assessment of egg quality and biochemical parameters of Aseel and Kadaknath indigenous chicken breeds of India under backyard poultry farming. Poultry Science 2022; 101 (2): 101589.
9. Singh RV, Singh DP. Possibilities of exploitation of indigenous poultry germplasm. Proceedings of National Symposium on Livestock biodiversity vis-a-vis resource exploitation: An introspection, 11-12 February, Karnal, India. pp 2004; 21-30.
10. Haunshi S, Sunitha R, Shanmugam M, Padhi MK, Niranjan M. Carcass characteristics and chemical composition of breast and thigh muscles of native chicken breeds. Indian Journal of Poultry Science 2013; 48: 219-222.
11. Pathak P, Dubey PP, Dash SK, Chaudhary ML. Studies on growth and carcass traits of Aseel and Kadaknath chicken. Indian Journal of Poultry Science 2015; 50 (3): 327-328.
12. Kumar M, Ratwan P, Dahiya SP, Nehra AK. Climate change and heat stress: Impact on production, reproduction and growth performance of poultry and its mitigation using genetic strategies. Journal of Thermal Biology 2021c; 97: 102867.
13. Delgado JV, Barba C, Camacho ME, Sereno FTPS, Martinez A, et al. Characterization of domestic animals in Spain. Animal Genetic Resources Information 2001; 29: 7-18.
14. Ajayi FO, Ejiofor O, Ironkwe MO. Estimation of body weight from body measurements in two commercial meat-type chicken. Global journal of agricultural science 2008; 7 (1): 57-59.
15. Hotelling H. Analysis of the complex of statistical variables into principal components. Journal of Educational Psychology 1933; 24: 417- 441.
16. Rao CR. The use and interpretation of principal component analysis in applied research. SankhyaA 1964; 26: 329-358.
17. Jolliffe I. Principal component Analysis 2002; 2nd ed. Springer.
18. Lukibisi FB, Muhuyi WB, Muia JMK, Ole Sinkeet SN, Wekesa WF. Statistical use and interpretation of principal component analysis in applied research. Egerton University's 2008; 3rd Annual Research Week and International Conference.
19. Johnson RA, Wichern DW. Applied multivariate statistical analysis. Prentice Hall International. INC., 2007; New Jersey.
20. Pinto LFB, Parker IU, Melo CMR, Ledur MC, Coutinho LL. Principal component analysis applies to performance and carcass trait in chicken. Animal Research 2006; 55 (5): 419-425.
21. Yakubu A, Kuje D, Okpeku M. Principal components as measures of size and shape in Nigerian indigenous chickens. Thai Journal of Agricultural Science 2009; 42 (3): 167-176.
22. Udeh I, Ogbu CC. Principal component analysis of body measurements in three strains of broiler chicken. Science world journal 2011; 6 (2): 11-14.

23. Egena SSA, Ijaiya A, Ogah DM, Aya VE. Principal component analysis of body measurements in a population of indigenous Nigerian chickens raised under extensive management system. Slovak journal of animal science 2014; 47 (2): 77-82.

24. Akporhuarho PO, Omoikhoje SO. Principal component analysis of body weight and biometric traits of F1 crossbred of exotic broilers x local chickens. Nigerian Journal of Science and Environment 2017; 15 (1): 94-103.

25. Amao SR. Application of Principal Component Analysis on the Body Morphometric of Nigerian Indigenous Chickens reared intensively under Southern Guinea Savanna Condition of Nigeria. Journal of Environmental Issues and Agriculture in Developing Countries 2018; 10 (1): 1-12.

26. Ogah DM. Assessing size and conformation of the body of Nigerian indigenous turkey. Slovak Journal of Animal Science 2011; 44 (1): 21-27.

27. Dalton HA, Wood BJ, Widowski TM, Guerin MT, Torrey S. An analysis of beak shape variation in two ages of domestic turkeys (*Meleagrisgallopavo*) using landmark-based geometric morphometrics. PLOS ONE 2017; 12 (9): e0185159. 10.1371/journal.pone.0185159.

28. Ogah DM, Alaga AA, Momoh MO. Principal component factor analysis of the morphostructural traits of Muscovy duck. International Journal of Poultry Science 2009; 8 (11): 1100 -1103.

29. Maharani D, Hariyono DNH, Putra DDI, Lee JH, Sidadolog JHP. Phenotypic characterization of local female duck populations in Indonesia. Journal of Asia-Pacific Biodiversity 2019; 2 (4): 508-514.

30. Anye NH, Manjeli Y, Ebangi AL. Principal component analysis of body measurements in local Guinea pigs (Caviaporcellus L.) in the Western Highlands of Cameroon. Livestock Research for Rural Development. 2010; 22 (9).

31. Ajayi BA, Oseni SO. Morphological characterization and principal component analysis of body dimensions in Nigerian population of adult rabbits. World Rabbit Science Association Proceedings 10th World Rabbit Congress September 3 - 6, 2012 Sharm El- Sheikh Egypt, 2012; 229-233**.**

32. Saikhom R, Sahoo AK, Taraphder S, Pan S, Sarkar U, et al. Principal component factor analysis of morphostructural traits of HaringhataBlack chickens. Indian Journal of Animal Health 2017; 56 (2): 211-218.

33. Saikhom R, Sahoo AK, Taraphder S, Pan S, Sarkar U, et al. Principal component analysis of morphological traits of Haringhata Black chickens in an organized farm. Exploratory Animal and Medical Research 2018; 8 (1): 64-68.

34. Dalal DS, Ratwan P, Malik BS, Patil CS, Kumar M. Principal Component Analysis of morphological traits of synthetic White Leghorn chicken. Indian Journal of Animal Sciences 2020; 90 (11): 1551-1555.

35. SPSS. Statistical Package for Social Sciences. SPSS Inc., 444 Michigan Avenue, Chicago, IL, USA, 2001.

36. Bartlett MS. Tests of significance in factor analysis. British Journal of Psychology 1950; 3: 77-85.

37. Kaiser H. The application of electronic computers to factor analysis. Educational and Psychological Measurement 1960; 20: 141-151.

38. Dalal DS, Ratwan P, Yadav AS. Genetic evaluation of growth, production and reproduction traits in Aseel and Kadaknath chickens in agroclimatic conditions of northern India. Biological Rhythm Research 2019; 10.1080/09291016.2019.1621081.

39. Chatterjee RN, Sharma RP, Reddy MR, Niranjan M, Reddy BLN. Growth, body conformation and immune responsiveness in two Indian native chicken breeds. Livestock Research for Rural Development 2007; 19: 151.

40. Negassa D, Melesse A, Banerjee S. Phenotypic characterization of indigenous chicken populations in South eastern Oromia Regional State of Ethiopia. Animal Genetic Resources 2014; 55: 101-113.

41. Bekele G, Kebede K, Ameha N. On-farm phenotypic characterization of indigenous chicken and their production system in Bench Maji Zone, South Western Ethiopia. Science Technology and Arts Research Journal 2015; 4: 68-73.

42. Churchil RR, Jamima J, Machindra YS, Kanagaraju P, Srinivasan G. Qualitative and Morphometric Characters of Aseel Male Chicken. International Journal of Current Microbiology and Applied Sciences 2019; 8 (1): 1285-1289.

43. Sarkar MJA, Bhuiyan MSA, Faruque MO, Ali MA, Lee JH. Phenotypic characterization of Aseel chicken of Bangladesh. Korean Journal of Poultry Science 2012; 39: 9-15.

44. Tabassum T, Hoque MA, Islam F, Ritchil MCH, Faruque MO, et al. Phenotypic and morphometric characterization of indigenous chickens at JhenaigatiUpazila of Sherpur district in Bangladesh. Department of animal breeding and genetics, Bangladesh Agricultural University, Mymensingh. SAARC Journal of Agriculture 2014; 12 (2): 154-169.

45. Dana N, Dessie T, Van Der Waaij HL, Van Arendonk AMJ. Morphological features of indigenous chicken populations of Ethiopia. Animal Genetic Resources 2010; 46: 11-23.

46. Mendes M. Multivariate multiple regression analysis based on principal component scores to study relationship between some pre- and post- slaughter traits of broilers. Journal of Agricultural Science 2011; 17: 77-83.

47. Ajayi BA, Oseni SO. Morphological characterization and principal component analysis of body dimensions in Nigerian population of adult rabbits. World Rabbit Science Association Proceedings 10th World Rabbit Congress September 2012; 3-6.

48. Yakubu A, Idahor KO, Agade YI. Using factor scores in multiple linear regression models for predicting the carcass weight of broiler chickens using body measurement. Revista Cientifica Udo Agricola 2009; 9: 963-967.