Pakistan J. Zool., vol. 56(4), pp 1711-1716, 2024 **DOI**: https://dx.doi.org/10.17582/journal.pjz/20200608090631

Phenotypic Characterization and Weight Estimation of Young Thalli Sheep Through Multivariate Traits

Muhammad Arslan Akbar[1], Khalid Javed[2], Asim Faraz[3], Abdul Waheed[3]*, Ecevit Eyduran[4] and Muhammad Tariq[5]

[1]*Department of Breeding and Genetics, Cholistan University of Veterinary Sciences, Bahawalpur, Pakistan*

[2]*Department of Livestock Production, University of Veterinary and Animal Sciences, Lahore, Pakistan*

[3]*Department of Livestock and Poultry Production, Bahauddin Zakariya University, Multan, Pakistan*

[4]*Biometry and Genetics Unit, Department of Animal Science, Faculty of Agriculture. Iğdır University, Iğdır-Turkey*

[5]*Livestock and Dairy Development Department, Punjab, Pakistan*

ABSTRACT

The aim of this study was to evaluate the multivariate traits in Thalli sheep for phenotypic characterization and their association with the live bodyweight of the animals for the selection of superior individuals by using the principal component analysis (PCA) technique and regression equation. Twenty-one (21) multivariate traits were taken of young Thalli sheep aged 0-12 months in Thall area of Punjab, Pakistan. Morphometric traits measured were withers height (WH), head width (HW), head length (HL), body length (BL), ear width (EW), ear length (EL), neck width (NW), neck length (NL), heart girth (HG), rump length (RL), tail length (TL), rump width (RW), barrel depth (BD), birth weight (BiW), live body weight (BW), sacral pelvic width (SPW), teat diameter (TED), teat length (TEL), testes length (TsL), scrotal circumference (SC) and testes width (TsW). Positive and highly significant (P≤0.01) correlations among different morphometric traits were present in overall animals of 0-12-month age groups of Thalli sheep such as WH, BL, HL, HW, EL, EW, NL, NW, HG, RL, BD, SPW, BiW and BW. The results of principal component analysis of data for all age groups of young Thalli sheep were showed that three principal components (PCs) were extracted as PC1, PC2, and PC3. For the 0-3-month age group, PC1 showed high variance before and after rotation (44.33% and 37.68%), for 4-6-month age group, PC1 had a high value of variance as 58.45% and PC2 had 15.17%, for 7-9-month age group, three principal components were extracted with high eigenvalues (7.56) for PC1 and high variance 50.45% and for 10-12-month age group, PC1 had a high value of variance as 50.05% and PC2 and PC3 had values as 10.67% and 9.05% respectively and their cumulative variance was 69.79%. Regression equations for all age groups of young Thalli sheep presented a very close relationship between predicted bodyweight and actual live bodyweight. The present study showed that hearth girth, body length, and withers height are very important parameters for the estimation of body weight and phenotypical characterization.

Article Information
Received June 08 2020
Revised May 18 2021
Accepted July 09 2021
Available online 20 March 2023 (early access)
Published 03 June 2024

Authors' Contribution
MAA conducted research. MT helped in conduct of research. KJ supervised the research. A.W. analyzed the data. AF wrote the paper. EE reviewed the article.

Key words
Thalli sheep, Phenotypic characterization, Body conformation, Body weight estimation, Multivariate traits

INTRODUCTION

Naturally sheep are gregarious animals. Sheep contribute a large quota to the national economy of Pakistan as the current population of sheep is 31.6 million numbers (Anonymous, 2021). Sheep are the major source of income in smallholdings specially in nomadic lifestyles (Kakar *et al*., 2011). Tariq *et al*. (2012) reported 31 sheep breeds present in Pakistan that provide milk, wool and meat. These breeds belong to two main categories, fat-tailed and thin-tailed (Ibrahim *et al*., 2011). Medium sized Thalli sheep breed is found in the desert area of Thall, Bhakar, Mianwali, Muzaffargarh, Layyah districts and some animals are also found in Multan, Jhang and Sargodha districts (Khan *et al*., 2003). Mutton and wool are two major products of Thalli sheep (Khan *et al*., 2007).

The relationship between morphometric traits and live bodyweight of animals plays a vital role in the determination of genetic potential of elite animals and

* Corresponding author: drabdulwaheed@bzu.edu.pk
0030-9923/2024/0004-1711 $ 9.00/0

breeding programs in meat animals (Younas *et al*., 2013). In developing countries, record-keeping is at the initial level and the records about pedigree and progeny of individuals are insufficient and do not provide the estimation about genetic parameters. Therefore, phenotypic characterization is compulsory for the explanation of relationships among linear type traits (Ali *et al*., 1995). Bodyweight is necessary to make decisions related to feeding, health care, and selection (Slippers *et al*., 2000).. An interdependence technique, principal component analysis (PCA) has been used by different scientists to explain the sets of variables in the analysis of data that are highly interrelated (Yunusa *et al*., 2013). The principal component analysis technique is used to identify the body size, body shape, head size, and overall phenotypic characterization in Zulu sheep (Mavule *et al*., 2013). Phenotypic characterization can be based on animal conformation and genetic parameters can be evaluated by using morphometric traits because these traits play vital role in selection of superior animals (Akbar *et al*., 2022).

Evaluation of multivariate traits in Thalli sheep and their association with the live bodyweight of the animals for the selection of elite individuals is the main objective of the present study using principal component analysis technique and regression equation.

MATERIALS AND METHODS

Experimental site

The data were collected from two livestock farms; Livestock Experiment Station, Rakh Ghulaman, District Bhakkar, and Small Ruminant Research and Development Centre, Rakh Khairewala, District Layyah, Punjab, Pakistan. The temperature of both areas is raised during the summer season, which may reach up to 50-55°C during day time. Natural grazing procedure has been adopted during day time and concentrate ration has also been offered to the animals as supplementary feed.

Data collection

The data of Thalli sheep were recorded on the basis of multivariate traits. One hundred and sixty-three young Thalli sheep were selected for data collection. A measuring tape was used to record the different multivariate traits and digital weighing balance was used for the determination of live body weight (Iqbal *et al*., 2014). Standards for phenotypic characterization of breeds as described by FAO (2012), the following parameters were taken.

Twenty-one (21) body measurements were recorded on each animal. Morphometric traits measured were withers height (WH), head width (HW), head length (HL), body length (BL), ear width (EW), ear length (EL), neck width (NW), neck length (NL), heart girth (HG), rump length (RL), tail length (TL), rump width (RW), barrel depth (BD), birth weight (BiW), live bodyweight (BW), sacral pelvic width (SPW), teat diameter (TED), teat length (TEL), testes length (TsL), scrotal circumference (SC) and testes width (TsW).

Data structure

Animals of different age groups were reared at both research stations. Animals were divided into different groups according to their age as 0-3, 4-6, 7-9 and 10-12 (Iqbal, 2010). Each group was further divided into two sub-groups of male and female animals (Table I).

Statistical analysis

The normality of overall data was checked through a normality test using SPSS 20.0 and all animals were fallen in ±3SD. SPSS software 20.0 was used for statistical analysis of morphometric traits. Data were analyzed statistically for mean, coefficient of variation, standard deviation, and Pearson's coefficient of correlation among different multivariate traits was estimated and data were generated for principal component analysis (PCA) from the correlation matrix. Regression equations were used for the estimation of live body weight.

RESULTS AND DISCUSSION

Descriptive statistics of young Thalli sheep

Descriptive statistics (mean, standard deviation, and coefficient of variation) of multivariate traits of all young Thalli sheep are given in Table II. Coefficient of variation (CV) for 0-3-month lambs of linear body measurements ranged 10-15% but its percentage was 18.52, 21.24, and 22.20 for TL, BiW, and BW as the range of these traits were 8.89cm 2kg and 11kg, respectively. For animals of 4-6-month age group, CV of linear body measurements was ranged from 10-20% and BW, TL, and RW had medium values as 25.13%, 27.40%, and 28.76% respectively. For animals of 7-9-month age group, CV of different multivariate traits ranged from 8.18-21.51% (BW). For animals of 10-12-month age group, CV of for linear body measurements was ranged 10-20% and HW, BW, TL, and RW had medium values as 21.54% 24.54%, 21.09%, and 24.02% as their ranges were 6.6cm, 1kg, 8.89cm, and 13.21cm, respectively. Yakubu *et al*. (2011) have reported WH and BL as 63com (7-9 age group) and 57cm (4-6 age group), respectively. Yakubu *et al*. (2011) has reported CV of RW and WH as 13% (0-3 age group) and 9.7% (10-12 age group), respectively. The present study is also similar to that of Lopez-Carlos *et al*. (2010) in Blackbelly lambs. The results of current are not in line with Iqbal *et al*. (2014) as means of HG, BL and WH as 47.49cm, 44.60cm, and 49.10cm, respectively. Younas *et al*. (2013) reported the means of BW, HG, and WH 10kg,48.17cm and 48.85cm respectively, these variations are indication of age and breed differences.

Table I. Pooled data of both farms and regression equations for all age group of young Thalli sheep.

Age group (Months)	n	Equations	Predicted weight (kg)	Actual weight (kg)
0-3 month	46	BW= 25.74-0.67 HL	13.45	13.37
4-6 month (overall)	50	BW= -7.37+0.41WH	17.07	17.06
4-6 month (female)	28	BW= -4.34+0.36WH	16.53	16.79
4-6 month (male)	22	BW= -14.48+0.52WH	17.62	17.41
7-9 month (overall)	33	BW= 0.612+0.30BL	19.13	18.88
7-9 month (female)	18	BW= -12.23+0.51BL	17.67	17.67
7-9 month (male)	15	BW= -13.31+0.48HG	19.61	20.33
10-12 month (overall)	34	BW= -24.804+0.42WH+0.276HG	21.18	21.24
10-12 month (female)	09	BW= -33.27+0.89BL	20.81	20.89
10-12 month (male)	25	BW= -23.93+0.316WH+0.36HG	21.67	21.36

Table II. Multivariate traits of young Thalli sheep.

Body measurements	0-3 Age group (n=46)		4-6 Age group (n=50)		7-9 Age group (n=33)		10-12 Age group (n=34)	
	Mean±SD	C.V (%)	Mean±SD	C.V (%)	Mean±SD	C.V (%)	Mean±SD	C.V (%)
WH (cm)	51.36±5.15	10.03	59.61±7.21	12.09	63.25±6.21	09.82	64.75±6.26	09.67
BL (cm)	48.80±6.20	12.72	57.45±8.77	15.26	61.73±7.97	12.92	62.95±6.85	10.88
HG (cm)	52.40±5.38	10.27	62.87±8.54	13.58	67.74±7.37	10.88	68.09±7.47	10.97
HL (cm)	18.88±1.92	10.17	20.09±3.17	15.78	21.74±2.68	12.33	23.39±3.39	14.52
HW (cm)	07.03±1.06	15.18	9.098±2.02	22.01	09.44±1.91	20.19	09.74±2.09	21.54
EL (cm)	23.60±2.52	10.68	25.56±2.88	11.28	26.84±2.19	08.18	27.04±1.93	07.15
EW (cm)	10.02±1.07	10.62	11.32±1.40	12.39	11.95±1.01	08.48	12.08±1.02	08.44
NL (cm)	18.87±2.55	13.50	22.72±3.31	14.58	23.67±3.46	14.63	24.04±3.44	14.32
NW (cm)	12.17±1.22	10.04	14.47±2.16	14.93	15.48±1.53	09.91	15.92±2.24	14.05
RL (cm)	10.18±1.25	12.28	11.29±2.42	21.46	12.52±2.13	17.06	12.35±1.67	13.49
RW (cm)	16.16±2.15	13.29	13.09±3.76	28.76	14.83±3.78	25.47	14.59±3.50	24.02
TL (cm)	09.78±2.07 (n=44)	21.24	10.03±2.75	27.40	11.09±2.51	22.61	10.53±2.22	21.09
BD (cm)	31.26±4.32	13.80	37.85±6.62 (n=47)	17.49	41.44±5.05	12.18	41.36±5.07	12.26
SPD (cm)	55.03±7.07 (n=30)	12.84	68.23±11.5	16.91	74.44±9.16 (n=28)	12.31	74.97±8.83 (n=28)	11.77
BiW (kg)	02.62±0.48	18.52	03.49±0.76 (n=43)	21.97	03.23±0.53	16.47	02.76±0.28 (n=33)	10.26
BWt (kg)	13.61±3.02	22.20	17.06±4.28	25.13	18.88±4.06	21.51	21.24±5.21	24.54
TL (cm)	0.350±0.13 (n=30)	35.59	0.470±0.20 (n=28)	43.26	0.450±0.21 (n=18)	45.47	0.740±0.52 (n=9)	70.19
TD (cm)	0.350±0.12 (n=30)	35.59	0.480±0.26 (n=28)	54.45	0.630±0.27 (n=17)	43.21	0.930±0.83 (n=9)	89.42
TL (cm)	03.32±1.20 (n=12)	36.36	06.09±2.53 (n=22)	41.58	07.58±2.54 (n=15)	33.48	09.95±3.85 (n=25)	38.67
TW (cm)	02.41±0.79 (n=12)	32.83	03.04±1.47 (n=22)	48.36	04.52±1.57 (n=15)	34.77	05.35±2.89 (n=25)	53.97
SC (cm)	08.95±1.93 (n=12)	21.54	11.30±4.81 (n=22)	42.49	15.96±4.32 (n=15)	27.02	17.95±6.98 (n=25)	38.91

WH, withers height; HW, head width; HL, head length; EL, ear length; EW, ear width; BL, body length; NW, neck width; NL, neck length; HG, heart girth; RW, rump width; RL, rump length; BD, barrel depth; TL, tail length; SPW, sacral pelvic width; BW, live body weight; BiW, birth weight; TEL, teat length; TED, teat diameter; TsL, testes length; TsW, testes width; SC, scrotal circumference.

Correlation coefficients among multivariate traits of young Thalli sheep

Correlation coefficients of multivariate traits of 0-3, 4-6, 7-9, and 10-12 month age groups of Thalli sheep are shown in Supplementary Tables I-IV. In overall animals (male and female) of 0-3-month age group of Thalli sheep, there were positive and highly significant (P≤0.01) correlations among WH, BL, HW, EL, EW, NL, NW, HG, RL, SPW and BD (0.50-0.87). Most results of the current study are similar to Salako (2006), Iqbal *et al*. (2014) and Yakubu (2010).

Correlation coefficients of 4-6-month age group of Thalli sheep were positive and highly significant (P≤0.01) for WH, BL, HL, HW, EL, EW, NL, NW, HG, RL, BD, SPW, BiW and BW (0.51-0.86). Most results of our study are in line with Salako (2006), Yunusa *et al*. (2013),

Yakubu (2010) and reported by Younas *et al*. (2013).

Likewise, correlation coefficients of morphometric traits of 7-9-month age group animals of Thalli sheep had highly significant (P≤0.01) and positive correlations among WH, BL, HL, HW, EL, EW, NL, NW, HG, RL, SPW, RW, BD and BW (0.47-0.86). The findings of the present study are similar to reported by Salako (2006) and results are not in line as reported by Younas *et al*. (2013) which may be due to breed differences.

The correlations among different morphometric traits of 10-12-month age group of Thalli sheep such as WH, BL, HL, HW, EL, EW, NL, NW, HG, RL, BD, SPW, BiW, and BW. A similar type of results was reported by Salako (2006), Vincent *et al*. (2014), Pesmen and Yardimci (2008), Eyduran *et al*. (2013), Birteeb and Lomo (2015) and Yakubu (2010).

Principal component analysis of multivariate traits of young Thalli sheep

Principal component analysis of 0-3, 4-6, 7-9, and 10-12 month age groups of Thalli sheep are shown in Table VII The results of 0-3 month age group showed that four principal components (PC) were extracted with eigenvalues greater than 1 for principal component 1 (PC1), principal component 2 (PC2), and principal component 3 (PC3). PC1 showed a high variance before and after rotation (44.33% and 37.68%). Yakubu *et al*. (2011) reported similar results as four principal components were extracted with high values of commonalities. The results of present study are not in line with those of Salako (2006) which may be due to the difference in the environmental area.

For 4-6 month age group animals, there were two PC extracted and PC1 had a high value of variance as 58.45% and PC2 had 15.17% and their cumulative variance was 73.63%. Yakubu *et al*. (2011) supported the results of current study. Lopez-Carlos *et al*. (2010) reported low values of morphometric traits in PC1 which are not in line with current study. These differences may occur due to environmental factors.

For 7-9 month age group animals, three PCs were extracted with high eigenvalues (7.56) for PC1 and high variance of 50.45%. PC2 and PC3 had variances of 14.18% and 7.86%, respectively and their cumulative variance was 72.50%. Khan *et al*. (2014) reported that BL and WH had major contributions in PC which supports the results of the present study.

For animals of 10-12 month age group, PC 1 had a high value of variance as 50.05% and PC2 and PC3 had values as 10.67% and 9.05% respectively and their cumulative variance was 69.79%. WH, HG, and BL had high variance and high commonalities, and our results are also supported by Mavule *et al*. (2013), Khan *et al*. (2014), Eyduran *et al*. (2013) and Birteeb and Lomo (2015).

Regression equation for young Thalli sheep

Regression equations for 0-3, 4-6, 7-9, and 10-12 month age groups of Thalli sheep were studied as shown in Table I. The predicted weight and actual BW of all age groups of animals were very close which showed the efficiency of results. The present study showed that HG, BL, and WH are very important for the estimation of BW.

A strong relationship has been determined between BL and BW (Tadesse and Gebremariam, 2010; Yakubu and Mohammed, 2012), between HG and live BW in sheep (Birteeb and Ozoje, 2012; Mavule *et al*., 2013; Mohammed and Amine, 1996; Suhaila *et al*., 2013). HG explains a close estimation of BW without using a weighing scale.

CONCLUSION

From the current study, it was concluded that multivariate traits such as HG, WH, and BL had high correlations with BW and among each other in almost all age groups of Thalli sheep. PCA of multivariate traits was explained the variations by PC1 and in some groups, PC2 and PC3 had also some effects. PC1 for WH, BL, and HG had high values which showed maximum variations. Multivariate traits are used for the selection of genetically superior animals for breed improvement and estimation of live body weight in field conditions, so that young animals could be selected early in lives to show their maximum performance.

ACKNOWLEDGEMENT

Special thanks to the management of Small Ruminant Research and Development Centre, Rakh Khairewala, District Layyah and Livestock Experiment Station, Rakh Ghulaman, District Bhakkar, Punjab, Pakistan.

Supplementary material

There is supplementary material associated with this article. Access the material online at: https://dx.doi.org/10.17582/journal.pjz/20200608090631

Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Akbar, M.A., Javed, K., Faraz, A. and Waheed, A., 2022. Principal component analysis of morphometric traits explain the morphological structure of Thalli sheep. *Pakistan J. Zool.,* **54**: 207-212.

Ali, A.K.A., Al-Enazi, M., Hayes, E. and Al-Saidy, M., 1995. Phenotypic factor and image analysis of type traits of Holstein cows in the Masstock Saudi herds. *J. King Saud Univ. Agric. Sci*., **7**: 143-161.

Anonymous. 2021. *Economic survey of Pakistan*. Ministry of Finance, Planning Division, Govt. of Pakistan, Islamabad.

Birteeb, P.T. and Lomo, R., 2015. Phenotypic characterization and weight estimation from linear body traits of West African Dwarf goats reared in the transitional zone of Ghana. *Livest. Res. Rural Develop*., **27**: 175.

Birteeb, P.T. and Ozoje, M.O., 2012. Prediction of live body weight from linear measurements of West African long-legged and West African dwarf sheep in northern Ghana. *Online J. Anim. Feed Res*., **2**: 427-434.

Eyduran, E., Waheed, A., Tariq, M.M., Iqbal, F. and Ahmad, S., 2013. Prediction of live weight from morphological characteristics of commercial goat in Pakistan using factor and principal component scores in multiple linear regression. *J. Anim. Pl. Sci*., **23**: 1532-1540.

FAO, 2012. *Phenotypic characterization of animal genetic resources*. FAO Anim. Prod. Health Guidelines. 11. Rome.

Ibrahim, M., Ahmad, S., Swati, Z.A. and Ullah, G., 2011. Fat-tailed sheep production systems in the Khyber Pakhtunkhwa Provice of Pakistan. *Trop. Anim. Hlth. Prod*., **43**: 1395-1403. https://doi.org/10.1007/s11250-011-9867-4

Iqbal, Z.M., 2010. *Relationship between live body weight and body measurements in Kajli sheep*. M.Phil. thesis, Dept. of Livestock Production, University of Veterinary and Animal Sciences, Lahore.

Iqbal, Z.M., Javed, K., Abdullah, M., Ahmad, N., Ali, A., Khalique, A., Aslam, N. and Younas, U., 2014. Estimation of body weight from different morphometric measurements in Kajli lambs. *J. Anim. Pl. Sci.,* **24**: 700-703.

Kakar, M.S., Waheed, A., Bajwa, M.A., Awan, M.A., Kakar, M.A., Bukhari, F.A., Marghazani, I.B., Rashid, N., Hameed, T., Shafee, M. and Javed, Y., 2011. Evaluation of economic traits of Balochi and Bibrik (Beverigh) sheep breeds of Balochistan, Pakistan. *Igdir Univ. J. Inst. Sci. Tech*., **1**: 133-139.

Khan, B.B., Iqbal, A. and Mustufa, M.I., 2003. *Sheep and goat production*. Department of Livestock Management, University of Agriculture Faisalabad, Pakistan.

Khan, M.A., Tariq, M.M., Eyduran, E., Tatliyer, A., Rafeeq, M., Abbas, F., Rashid, N., Awan, M.A. and Javed, K., 2014. Estimating body weight from several body measurements in Harnai sheep without multicollinearity problem. *J. Anim. Pl. Sci*., **24**: 120-126.

Khan, M.S., Khan, M.A., Ahmad, S. and Mahmood, S., 2007. Genetic resources and diversity in Pakistani sheep. *Int. J. Agric. Biol*., **9**: 941-944.

Lopez-Carlos, M.A., Ramirez, R.G., Aguilera-Soto, J.I., Arechiga, C.A. and Rodriguez, H., 2010. Size and shape analyses in hairy sheep ram lambs and its relationships with growth performance. *Livest. Sci*., **131**: 203-211. https://doi.org/10.1016/j.livsci.2010.04.001

Mavule, B.S., Muchenje, V., Bezuidenhout, C.C. and Kunene, N.W., 2013. Morphological structure of Zulu sheep based on principal component analysis of body measurements. *Small Rumin. Res*., **111**: 23-30. https://doi.org/10.1016/j.smallrumres.2012.09.008

Mohammed, I.D. and Amine, J.D., 1996. Estimating body weight from morphometric measurements of Sahel (Borno White) goats. *Small Rumin. Res.*, **24**: 1-5. https://doi.org/10.1016/S0921-4488(96)00920-0

Pesmen, G. and Yardimci, M., 2008. Estimating the live weight using some body measurements in Saanen goats. *Arch. Zootech*., **11**: 30-40.

Salako, A.E., 2006. Principal component factor analysis of the morpho-structure of immature Uda sheep. *Int. J. Morphol*., **24**: 571-574. https://doi.org/10.4067/S0717-95022006000500009

Slippers, S.C., Letty, B.A. and de Villiers, J.F., 2000. Prediction of the body weight of Nguni goats. *S. Afr. J. Anim. Sci*., **30**: 127-128. https://doi.org/10.4314/sajas.v30i4.3940

SPSS, 2011. *Statistical package for social sciences*. SPSS Inc. Cary, NY, USA.

Suhaila, N.S., Azizah, D., Zamila, Z., Azila, Z. and Mastura, Y., 2013. Relationship of live body weight and heart girth measurement in Dopper sheep. *Malays. J. Vet. Res*., **4**: 45-50.

Tadesse, A. and Gebremariam, T., 2010. Application of linear body measurements for live body weight estimation of highland sheep in Tigray region, North-Ethiopia. *J. Drylands*, **3**: 203-207.

Tariq, M.M., Bajwa, M.A., Jawasreh, K., Awan, M.A., Abbas, F., Waheed, A., Rafeeq, M., Wadood. A., Khan, K.U., Rashid, N., Atique, M.A. and Bukhari, F.A., 2012. Characterization of four indigenous sheep breeds of Balochistan, Pakistan by random amplified polymorphic DNAs. *Afr. J. Biotechnol*., **11**: 2581-2586. https://doi.org/10.5897/

AJB11.3196

Vincent, S.T., Araku, J.O., Ayongu, F., Chia, S.S., Momoh, O.M., and Yakubu, A., 2014. Redundancy elimination from morpho-stuctures of Nigerian Uda rams using principal component analysis. *J. Anim. Prod. Adv.*, **4**: 520-526. https://doi.org/10.5455/japa.20141028013720

Yakubu, A. and Mohammed, G.L., 2012. Application of path analysis methodology in assessing the relationship between body weight and biometric traits of red Sokoto goats in northern Nigeria. *Biotechnol. Anim. Husb.*, **28**: 107-117. https://doi.org/10.2298/BAH1201107Y

Yakubu, A., 2010. Path coefficient and path analysis of body weight and biometric traits in Yankasa lambs. *Slovak J. Anim. Sci.*, **43**: 17-25.

Yakubu, A., Salako, A.E. and Abdullah, A.R., 2011. Varimax rotated principal component factor analysis of the zoometrical traits of Uda sheep. *Arch. Zootech.*, **60**: 813-816. https://doi.org/10.4321/S0004-05922011000300069

Younas, U., Abdullah, M., Bhatti, J.A., Pasha, T.N., Ahmad, N., Nisar, M. and Hussain, A., 2013. Interrelationship of body weight with linear body measurements in Hissardale sheep at different stages of life. *J. Anim. Pl. Sci.*, **23**: 40-44.

Yunusa, A.J., Salako, A.E. and Oladejo, O.A., 2013. Principal component analysis of the morphostructure of Uda and Balami sheep of Nigeria. *Int. Res. J. agric. Sci.*, **1**: 45-51.