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Prediction of live body weights in dromedary camels (*Camelus dromedarius*) from morphometric body measurements

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Authors' Contribution **Saleem, A. A. F.** conducted the experiment **and M. S. Mudarris** and **M.S. Hariri** helped in data analysis and wrote the manuscript

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ABSTRACT

To predict the live body weight (LBW) of a dromedary camel from morphometric body measurements (MBM) a regression equation was developed. A total of 223 camels (54 males and 169 females) from the Makkah region of Saudi Arabia were classified into three age groups; first (<5 years old), second (5-8 years old) and third (>8 years old); two groups according to sex (male, female). LBW and 10 MBM were obtained. Data were subjected to statistical analysis. Results showed a significant ($p<0.05$) high mean LBW and MBM in males compared to females. A significant ($p<0.05$) positive correlations were encountered between LBW and HRG in all age groups, BG in third age group and males in the second age group, HH and WH in the first age group. The best fir regression equations were found to include HRG, BG and HG in the first and third age groups with R^2 account for 90.59% and 93.82% respectively. Whereas in the second age group as well as pooled data the equation included HRG, BG, HH, HG and WH with R^2 at a level of 99.69% and 99.48% respectively. Multi-collinearity problem of MBM was not encountered as determined by VIF which was found to be less than 10. These formulas could be used for predicting LBW where weighing scales are not available.

Keywords: Live body weight, morphometric body measurement; regression equation; variance inflation factor; correlation coefficient

INTRODUCTION: Traditionally and historically camel is considered as the major livestock in the Kingdom of Saudi Arabia, where the arid environment favors the breeding and growth of the animal. Camel is also a major source of meat and milk in the kingdom where in recent years the production of both meat and milk has increased by 5.4% and 6.4%, respectively (Abdallah and Faye, 2012). Most of the farmers here use traditional techniques for production and the traders rely on visual inspection for evaluation of body weight and pricing. However, a number of studies have shown that live body weight played an important role in many livestock production systems. Assan (2013) reported a direct relationship between LBW and production and profitability. Pesmen and Yardimci (2008) determined several important economic characteristics of farm animals from LBW. LBW can be used for selecting animals for meat (Van *et al.*, 2000; Mendeş *et al.*, 2005; Abbasi and Ghafouri-Kesbi, 2011), as an index for health and production, as management tool to assess growth rate and feeding systems, prediction of carcass characteristics and body conformation (Abdallah and Faye, 2012) and a criteria for description of phenotypic characteristics. The use of MBM in estimating the LBW was reported to be more practical in areas where accurate weighing scales and animals restraining facilities are not available to livestock farmers and breeders. Several studies explained the use of linear body measurements as a tool for estimating and predicting the LBW of livestock animals (Tadesse and Gebremariam, 2010; Ishag *et al.*, 2011; Oke and Ogbonnaya, 2011). Live body weight was found to be closely correlated with body measurements (Singh and Mishra, 2004; Hamayun *et al.*, 2006; Mungai *et al.*, 2010). Multiple regression models were developed for predicting live body weight in various livestock using MBM, with ultimate interpretation of the relationship between LBW and MBM (Ozkaya and Bozkurt, 2009; Tadesse and Gebremariam, 2010; Yakubu *et al.*, 2012).

OBJECTIVES

The current study was conducted to develop predicting regression equations for the LBW from some MBM of Saudi camels and to explore the relationship between body weight and linear body measurements.

MATERIALS AND METHODS: Study site and data collection: The study was carried out in the Makkah region of Saudi Arabia and it covers an area extending between latitude 22^0 N to 23^0 N. Residents of the area, their activities, the methods of body measurements and definitions were described previously by Fadlelmoula *et al.* (2015). A total number of 223 Saudi camels (54 male and 169 females) aged between 4-13 years were investigated. Data were classified into three groups according to age (First=> 5 years, second=5-8 years, and third=< 8 years), two groups according to sex (males and females). Body traits measured were; live body weight (LBW), neck length (NL), heart girth (HRG), barrel girth (BG), hip girth (HG), body length (BL), leg length (LL), hip height (HH), wither height (WH), body height (BH) and arm length (AL). Morphometric body measurements (MBM) were determined using a measuring metric tape, while the age estimation was based on dentition, owner and livestock attendant's experience.

Data analysis: SAS-Package was used to perform the following statistical analyses: Descriptive statistics of LBW and MBM in males, females and combined male and female of the three age groups (first, second and third). Correlation between body weight and MBM to determine the traits showing strong correlation with body weight to be included in the regression model. Pearson's correlation coefficients were attained for each age group, sex and for the pooled data.

Best predictive regression equations of LBW as dependent variable and other MBM as independent variables for each age group and the pooled data irrespective of age and sex were

obtained according to the following regression model:
$Y_{ij}=b_0+bx_i+e_i$ Where,
Y_{ij}= the LBW of the j^{th} animal, b_0= the intercept;
b= the regression coefficient of live body weight (Y) on MBM (x),
x_i= the MBM (HRG, BG, HG, HH, WH, BL),
e_{ij}= the residual error.
Variance inflation factors (VIF) as multicollinearity diagnostic tool of the independents variables (MBM) incorporated in the multiple regression models.
Linear, quadratic and cubic effects of HRG and BG (independent variables) on live body weight (dependent variable) which were included in the following best fitted regression model:
$Y_{ij}=b_0+b_1x_i+b_2x_i^2+b_3x_i^3+e_{ij}$
Where,
Y_{ij}= the LBW of the j^{th} animal,
b_0= the intercept;
b_1,b_2 and b_3= the corresponding linear, quadratic and cubic regression coefficients,
x_i= the MBM (HRG, BG, HG, HH, WH, BL),
e_{ij}= the residual error.

RESULTS: table 1 showed the descriptive statistics of LBW and MBM in dromedary camels. It was observed that the traits studied were significantly higher in males than in females ($p<0.05$) and shows an increasing trend in males of all age groups compared to females. Age was found to exert a significant effect ($p<0.05$) on LBW and MBM measured except for LL and AL. The correlation coefficients of LBW and MBM are presented in table 2. Output results indicated that HRG, BG, HG and WH had moderate to strong positive correlations with LBW in all age groups. However, HRG had stronger significance ($p<0.05$) and a positive correlation with LBW in females and combined males and females in all age groups compared to males. The predictive regression equations and coefficient of determination of variation (R^2) expressed as percentage of variation for LBW using HRG, BG, HG, HH, WH and BL in the three age groups were shown in table 3. The model excluded the negatives as well as weakly correlated variables. Results indicated that using a combination of HRG, BG and HG account for 93.82% of the variation in LBW in camels aged more than 8 years old and those with less than 5 years old. The VIF ranges for both the age groups were 1.00 -1.49 and 1.16 – 1.50, respectively, indicating lack of multi-collinearity problem among the independent variables (Table 4). Whereas, using HRG, HH, WH, BG explained 99.69% of the total variation in LBW in individuals aged 5-8 years old, and the addition of BL seems not to affect the model in this group as the R^2 was not changed (99.69%). The VIF calculated for this age group was in the range 1.14 – 3.30 (Table 4).
Still no multi-collinearity problems among the independent variables were detected. With ignorance of sex and age; the best fit regression model was found to include HRG, BG, HG, HH and WH with R^2 account for 99.48% of the variation in LBW and VIF ranged 1.19–3.04, revealing the inexistence of multi-collinearity problem. It has been observed that R^2 increased as more independent variables added to the model; therefore R^2 alone could not be used to judge the accuracy and precision of the model. Hence; variance inflation factor (VIF) was used to detect the problem of multicollinearity and in this study only independent variables with VIF less than 10 and positively correlated with LBW were included in the model. Linear, quadratic and cubic coefficients of HRG and BG was found to be higher as determined by R^2 for camels with 5-8 years old followed by the camels of age more than 8 years old and then camels less than 5 years old (Table 5).

DIscussion: Inclusion of MBM in linear regression models has recently indicated as a useful tool for estimation and prediction of LBW in livestock animals (Keith *et al.*, 2009; Mungai *et al.*, 2010). In this study, the mean LBW and MBM were found to be significantly affected by sex and age of the animal; males were heavier and scored high measures than females and the same trend was shown by older animals compared to younger and middle age individuals, this variation could be attributed to the fact that at this age animals attained their mature body size and measures, the variations between sexes could be due to sexual dimorphism among camel types. Comparable results were reported by Yohannes and Gebru (2006), Ishag *et al.* (2011) and Yosef *et al.* (2014). From the correlation coefficients it was observed that HRG was the only MBM that shows significant positive correlation in males, females and their combination for all the three age groups. And the absolute high correlations between LBW, and HRG were recorded for females less than 5 years old, males, females and their combination with 5-8 years old and females more than 8 years old indicating that those individuals are likely to have high LBW, and also could be an explanation to the fact that at maturity HRG and LBW remain unchanged. LBW was also strongly positively correlated with BG, HG in individual camels more than 8 years old and males less than 5 years old, respectively, indicating that such body measurement could be good predictors of LBW. However, variable positive correlation coefficients ranged from medium to moderate were obtained for the rest of MBM.
This finding goes in line with Mungai *et al.* (2010) and Abdallah and Faye (2012) in dromedary camel. Similar observations in other livestock were demonstrated by Ozkaya and Bozkurt (2009) and Mahmud *et al.* (2014) in beef cattle, and in sheep by Boujenane and Halhaly (2015). Prediction of LBW from MBM was recognized using different multiple regression models for individual age group. It could be noticed that with the inclusion of HRG alone R^2 ranged between 70.00% - 76.20% in all the three age groups and increased up to 93.82% when BG and HG were included in the model in the first and third age groups. However, R^2 reached 99.69% of the total variation for the model, including HH, WH and BL in addition to HRG and BG in the second age group individuals.
This finding indicated that the model which includes HRG, BG and HG was the best fit for prediction of LBW in dromedary camels with less than fiver years old as well as individuals with more than eight years old; the result was also confirmed with VIF which was found to be less than 10. Comparable findings were reported by Kuria *et al.* (2007) and Mungai *et al.* (2010). For the pooled data (regardless of age and sex); a best fit regression model that include HRG, BG, HG, HH and WH was found to cause 99.48% of the total variation in LBW, which was in close resemblance to the best fit model in the second age group, indicating that in this study age played a little role in changing the structure of the model with inclusion of more MBM. The findings were like the one of Tadesse and Gebremariam (2010).

9	Sex	BWT (KG)	NL (M)	HRG (M)	BG (M)	HG (M)	BL (M)	LL (M)	HH (M)	WH (M)	BH (M)	AL (M)
< 5	Male (13)	526.71±108.25^{a}	1.35±0.81^{a}	2.11±0.32^{a}	2.53±0.14^{a}	1.54±0.20^{ab}	1.61±0.09^{a}	1.41±0.19^{NS}	1.81±0.15^{a}	1.85±0.15^{a}	2.22 ±0.29	1.31±0.15^{NS}
	Female (46)	465.69±86.38^{ab}	1.25±0.34^{ab}	2.02±0.27^{ab}	2.42±0.19^{ab}	1.52±0.12^{ac}	1.52±012^{ab}	1.40±0.18^{NS}	1.74±0.11^{ac}	1.78±0.10^{ac}	2.08±0.34^{ac}	1.29±0.18^{NS}
	Male+Female (59)	479.13±94.15^{ac}	1.31±0.58^{ac}	2.04±0.28^{ac}	2.45±0.18^{ac}	1.57±0.15^{a}	1.55±0.12^{ac}	1.47±0.19^{NS}	1.77±0.13^{ab}	1.80±0.11^{ab}	2.12 ±0.34^{ac}	1.30±0.18^{NS}
5-8	Male (24)	603.00±101.19^{a}	1.41±0.76^{a}	2.30±0.26^{a}	2.62±0.16^{a}	1.64±0.11^{a}	1.67±0.16^{a}	1.51±0.12^{NS}	1.86±0.11^{a}	1.89±0.11^{a}	2.24±0.29^{a}	1.39±0.14^{NS}
	Female (83)	509.67±115.64^{ab}	1.27±0.49^{ab}	2.09±0.35^{ab}	2.51±0.21^{ab}	1.63±0.18^{ab}	1.60±0.16^{ab}	1.49±0.20^{NS}	1.80±0.10^{ab}	1.82±0.10^{ac}	2.18±0.25^{ac}	1.39±0.19^{NS}
	Male+Female (107)	530.75±118.96^{ac}	1.34±0.59^{ac}	2.14±0.34^{ac}	2.53±0.20^{ac}	1.63±0.17^{ab}	1.61±0.16^{ab}	1.49±0.19^{NS}	1.81±0.11^{ab}	1.84±0.10^{ab}	2.19±0.26^{ac}	1.39±0.18^{NS}
> 8	Male (17)	636.19±118.51^{a}	1.39±0.48^{a}	2.35±0.17^{a}	2.66±0.22^{a}	1.74±0.12^{a}	1.96±0.33^{a}	1.54±0.18^{NS}	1.89±0.14^{a}	1.90±0.14^{a}	2.52±0.36^{a}	1.48±0.19^{NS}
	Female (40)	559.17±116.25^{ab}	1.29±0.64^{ab}	2.18±0.37^{ab}	2.62±0.16^{ac}	1.64±0.11^{ac}	1.67±0.15^{ac}	1.45±0.11^{NS}	1.81±0.13^{ac}	1.84±0.10^{ab}	2.28±0.37^{ac}	1.37±0.10^{NS}
	Male+Female (57)	582.15±121.19^{ac}	1.34±0.62^{ac}	2.23±0.34^{ac}	2.64±0.18^{ac}	1.67±0.12^{ab}	1.76±0.20^{ab}	1.48±0.14^{NS}	1.84±0.12^{ab}	1.86±0.12^{ab}	2.35±0.38^{ab}	1.40±0.14^{NS}

Table 1: Means and standard deviations (M±SD) of live body weight and MBM in dromedary camels at various age groups.

a, ab, ac Means bearing different superscript letters are significantly different ($p<0.05$), NS= Not significant, values between brackets represent number of records.

Age (years)	Sex	NL (M)	HRG (M)	BG (M)	HG (M)	BL (M)	LL (M)	HH (M)	WH (M)	BH (M)	AL (M)
< 5	Male (13)	**0.58****	**0.64*****	**0.84*****	**0.82*****	-0.02^{NS}	**0.75*****	**0.74*****	**0.82*****	0.49*	**0.68****
	Female (46)	0.38*	**0.91*****	0.28^{NS}	0.19^{NS}	0.24^{NS}	0.40*	**0.50****	**0.51****	-0.15^{NS}	0.36*
	Male+Female (59)	0.47*	**0.84*****	0.48*	0.45*	0.24^{NS}	**0.57****	**0.63****	**0.65****	0.12^{NS}	0.54**
5-8	Male (24)	0.24^{NS}	**0.90*****	**0.64****	0.40*	0.30^{NS}	0.27^{NS}	0.31*	**0.55****	0.25^{NS}	0.44*
	Female (83)	0.40*	**0.92*****	0.49*	0.39*	**0.56****	0.41*	**0.52****	**0.55****	0.14^{NS}	0.32*
	Male+Female (107)	0.42*	**0.92*****	**0.55****	0.38*	**0.54****	0.39*	**0.51****	**0.59****	0.19^{NS}	0.31*
> 8	Male (17)	0.47*	**0.83*****	**0.51****	0.39*	0.38*	0.29^{NS}	0.48*	0.49*	-0.20^{NS}	**0.61****
	Female (40)	0.19^{NS}	**0.90*****	**0.56****	**0.54****	0.41*	0.45*	0.34*	0.35*	0.04^{NS}	-0.18^{NS}
	Male+Female (57)	0.39*	**0.88*****	**0.57****	**0.54****	0.45*	0.42*	0.45*	0.44*	0.04^{NS}	-0.02^{NS}

Table 2: Correlation coefficients® of body weight and body morphometric measurements in dromedary camels at various age groups.

®Bold figures indicate moderate to strong positive correlation between the LBW and the corresponding MBM**.**

*=$p<0.05$, **=$p<0.01$, ***$p=<0.001$, ^{NS}= Not significant ($p>0.05$), values between brackets represent number of records.

Age (years)	Regression equations	R^2(%)
	Y= -111.61+289.17HRG*	76.20
<5 (59)	Y= -535.88+258.93HRG+198.47BG^{NS}	90.21
	Y= -553.35+252.41HRG*+180.78BG*+47.34HG^{NS}	90.59
	Y= -148.52+317.71HRG*	71.00
5-8 (107)	Y= -491.27+292.62HRG*+218.54HH*	87.27
	Y= -572.20+283.08HRG*-68.76HH^{NS}+203.16WH*	87.77
	Y=-1066.60+247.22HRG*-10.75HH^{NS}+307.23WH*+206.99BG*	99.69
	Y= -1064.20+247.17HRG*-12.22HH^{NS}+306.91WH*+206.34BG*+2.77BL^{NS}	99.69
	Y= -91.76+301.89HRG*	71.00
>8 (57)	Y= -871.41+297.03HRG*+299.59AG*	91.78
	Y= -1011.30+294.06HRG*+218.90BG*+215.16HG*	93.82
	Y= -148.77+317.74HRG*	78.86
	Y= -644.25+283.55HRG*+224.07BG*	92.72
All age groups (223)	Y= -687.12+278.17HRG*+201.30BG*+69.09HG*	93.34
	Y= -923.73+261.94HRG*+200.21BG*+02.52HG^{NS}+211.21HH*	96.53
	Y= -1083+252.15HRG*+210.41BG*-08.43HG^{NS}-12.30HH^{NS}+315.10WH*	99.48

Table 3: **.** Best prediction regression equations and coefficient of determination of variation (R^2) of live body weight in dromedary camels at different age groups

*= significant at $p<0.05$, ^{NS}= Not significant, values between brackets represent number of records.

Age (Years)	Independent variables (MBW)	Variance Inflation Factors (VIF)
	HRG*	1.00
<5 (59)	HRG*+BG*	1.06, 1.06
	HRG*+BG*+HG^{NS}	1.16, 1.36, 1.49
	HRG*	1.00
	HRG*+HH*	1.16, 1.16
5-8 (107)	HRG*+HH^{NS}+WH*	1.10, 2.67, 2.61
	HRG*+HH^{NS}+WH*+BG*	1.12, 2.89, 2.61, 1.24
	HRG*+HH^{NS}+WH*+BG*+BL^{NS}	1.14, 3.30, 2.64, 1.30, 1.27
>8 (57)	HRG*	1.00
	HRG*+BG*	1.00, 1.00
	HRG*+BG*+HG*	1.00, 1.50, 1.50
	HRG*	1.00
	+HRG*+BG*	1.07, 1.07
All age groups (223)	HRG*+BG*+HG*	1.10, 1.31, 1.33
	HRG*+BG*+HG^{NS}+HH*	1.17, 1.31, 1.57, 1.37
	RG*+BG*+HG^{NS}+HH^{NS}+WH*	1.19, 1.32, 1.58, 3.04, 2.87

Table 4: Variance inflation factors (VIF) of multiple regression models for MBM

*= significant at $p<0.05$, ^{NS}= Not significant, values between brackets represent number of records.

Age (years)	Body measurement (m)	Intercept (b_0)	Linear (x_1)	Quadratic (x_1^2)	Cubic (x_1^3)	R^2 (%)
< 5 (59)		-91.76	301.89*	-	-	70.00
5-8 (107)	HRG	-148.52	317.71*	-	-	84.02
> 8 (57)		-111.61	289.19*	-	-	76.61
< 5 (59)		214.38	-17.03^{NS}	79.66*	-	72.10
5-8 (107)	HRG	25.00	143.59^{NS}	42.40*	-	84.76
> 8 (57)		325.69	-204.18^{NS}	134.15*	-	81.32
< 5 (59)		1332.35	-1892.60^{NS}	1057.61^{NS}	-161.90^{NS}	72.94
5-8 (107)	HRG	1387.04	-2131.04*	1225.54*	-194.75*	87.66
> 8 (57)		2536.04	-4163.77*	2368.45*	-403.49*	85.32
< 5 (59)		-250.69	315.64*	-	-	23.00
5-8 (107)	BG	-277.46	319.16*	-	-	30.01
> 8 (57)		-248.41	297.08*	-	-	32.35
< 5 (59)		3028.45	-2191.93^{NS}	477.07^{NS}	-	24.68
5-8 (107)	BG	392.31	-271.52^{NS}	127.99^{NS}	-	31.78
> 8 (57)		1157.39	-847.36^{NS}	231.68^{NS}	-	33.36
< 5 (59)		-101615.00	116536.00*	-44276.00*	5608.76*	31.27
5-8 (107)	BG	646.77	-657.91^{NS}	313.14^{NS}	-28.49^{NS}	31.80
> 8 (57)		-11287.00	14106.00^{NS}	-5729.02^{NS}	788.21^{NS}	33.84

Table 5: Regressions of live body weight on linear, quadratic and cubic effects of HRG and BG at different age groups.

*= significant at $p<0.05$, ^{NS}= not significant, values between brackets represent number of records.

CONCLUSION: The study concluded that LBW in the dromedary camel could be predicted using MBM. MBM with moderate to high positive correlation with LBW can be included in the best fit regression model; as such relationship could predict the LBW fairly accurately.

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REFERENCES: Abbasi, M.-A. and F. Ghafouri-Kesbi, 2011. Genetic (CO) variance components for body weight and body measurements in makooei sheep. Asian-Australasian journal of animal sciences, 24(6): 739-743.

Abdallah, H. R. and B. Faye, 2012. Phenotypic classification of saudi arabian camel (*Camelus dromedarius*) by their body measurements. Emirates journal of food agriculture, 24(3): 272-280.

Assan, N., 2013. Bioprediction of body weight and carcass parameters from morphometric measurements in livestock and poultry. Scientific journal of review, 2(6): 140-150.

Boujenane, I. and S. Halhaly, 2015. Estimation of body weight from heart girth in sardi and timahdite sheep using different models. Iranian journal of applied animal science, 5(3): 639-646.

Fadlelmoula, A. A., M. S. Mudarris and M. S. Hariri, 2015. Phenotypic classification based on body measurements and body features of some saudi camel types (*Camelus dromedarius*). Journal of camel practice research, 22(2): 265-270.

Hamayun, K. F. M., R. Ahmad, G. Nawaz and M. Zubair, 2006. Relationship of body weight with linear body measurements in goats. In: Agriculture and biological Sciences. Journal of Agricultre and Biology Science, 1(3), 51-

55.
Ishag, I., M. Eisa and M. Ahmed, 2011. Effect of breed, sex and age on body measurements of sudanese camels (*Camelus dromedarius*). Australian journal of basic applied sciences, 5(6): 311-315.
Keith, L., C. Okere, S. Solaiman and O. Tiller, 2009. Accuracy of predicting body weights from body conformation and testicular morphometry in pubertal boer goats. Research journal of animal sciences, 3(2): 26-31.
Kuria, S., R. Wahome, C. Gachuiri, M. Wanyoike and J. Mwangi, 2007. Use of linear body measurements in estimating live weight of camel (*Camelus dromedarius*), calves in kenya. Journal of camel practice research, 14(1): 21-25.
Mahmud, M. A., P. Shaba, W. Abdulsalam, H. Y. Yisa, J. Gana, S. Ndagi and R. Ndagimba, 2014. Live body weight estimation using cannon bone length and other body linear measurements in nigerian breeds of sheep. Journal of advanced veterinary animal research, 1(4): 169-176.
Mendeş, M., A. Karabayir and A. Pala, 2005. Path analysis of the relationships between various body measures and live weight of american bronze turkeys under three different lighting programs. Tarım bilimleri dergisi, 11(2): 184-188.
Mungai, I. P., W. R. Githaiga and M. Wanyoike, 2010. Correlation of actual live weight and estimates of live weights of camel calves (*Camelus dromedarius*) in samburu district of northern kenya. Journal of camelid science, 3: 26-32.
Oke, U. and E. Ogbonnaya, 2011. Application of physical body traits in the assessment of breed and performance of wad sheep in a humid tropical environment. Livestock research for rural development, 23(2): 15-25.
Ozkaya, S. and Y. Bozkurt, 2009. The accuracy of prediction of body weight from body measurements in beef cattle. Archiv tierzucht, 52(4): 371-377.
Pesmen, G. and M. Yardimci, 2008. Estimating the live weight using some body measurements in saanen goats. Archiva zootechnica, 11(4): 30-40.
Singh, P. and A. Mishra, 2004. Prediction of body weight using conformation traits in barbari goats. The Indian journal of small ruminants, 10(2): 173-173.
Tadesse, A. and T. Gebremariam, 2010. Application of linear body measurements for live body weight estimation of highland sheep in tigray region, North-Ethiopia. Journal of the dry lands, 3(2): 203-207.
Van, M.-K., E, B. E. Mostert and Van der Westhuizen, 2000. Body measurements as selection criteria for growth in south african hereford cattle. Archive furit tierzucht, 43(1): 5-16.
Yakubu, A., S. A. Okunsebor, A. A. Kigbu, A. O. Sotolu and T. D. Imgbian, 2012. Use of factor scores for predicting body weight from some morphometric measurements of two fish species in nigeria. Journal of agricultural science, 4(8): 60.
Yohannes, M. Z. M. and G. Gebru, 2006. Camel and camel product marketing in babilie and kebribeyah woredas of the jijiga zone, somali region, ethiopia. Livestock research for rural development, 19(4): 1-9.
Yosef, T., K. Kefelegn, Y. Mohammed, U. Mengistu, A. Solomon, D. Tadelle and J. Han, 2014. Morphological diversities and eco-geographical structuring of ethiopian camel (*Camelus dromedarius*) populations. Emirates journal of food agriculture, 26(4): 371-389.