Wayamba Journal of Animal Science – ISSN: 2012-578X; P1467 - P1474, 2016
First Submitted October 20, 2016; Number 1479801685

PREDICTIONS OF BODY WEIGHT OF BORAN BULLS REARED AT TWO FEEDLOTS OF SOUTHERN ETHIOPIA, USING LINEAR AND CURVEFIT REGRESSIONS EQUATIONS

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The study pertains to assessment of body weight of Boran bulls reared at two feedlots of Southern Ethiopia. Boran cattle are raised by the pastoralists under extensive management system and the region lacks even the basic restraining chutes and weighing balances. Thus, the study was conducted to predict the body weight of the bulls reared in two locations of Southern Ethiopia using linear body measurements of bulls aged 2 and 3 years of age and to predict the body weight at 3 and 4 years of age and 4 years of age respectively using linear and some curvefit regression equations. The study was conducted at two locations the first location was devoid of any wind breaks and was bitterly cold in the night which was uncomfortable for the bulls while the second location had well built infrastructures and hence was quite comfortable for the bulls. The results indicated that the morphometical traits and body weight varied across the two locations, indicating a significant genotype by environment interactions for the traits. The findings also indicated that the predictors for assessing the body weight varied according to the age and location. The rump length of the bulls reared at the first location and aged 2 years was significantly correlated with their body weight , while for the bulls aged 3 and 4 years respectively years and reared in the first location the traits significantly correlated with body weight were the heart girth and flank width respectively. While body depth and heart girth respectively were the traits which were significantly correlated with the body weight of the bulls aged 3 and 4 years respectively. The results also indicated that the height at withers and heart girth of the bulls aged 3 years and reared in the first and second locations were best predictors for assessing the body weight of the bulls aged 4 years and in the respective locations. The results also indicated that among the regression equations the accuracy was higher using quadratic regression equations among the bulls across all the age groups. However, the body weight of the bulls aged 3 years and reared at the second location was best assessed using exponential and power regression.

Keywords: Boran bulls, different age groups, linear and non linear regression

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Boran is a dual purpose cattle breed native of Borana region of Southern Ethiopia. Boran cattle are reared under extensive management by the pastoralists of the region. The bulls of this breed are in high demand for their beef and live animals are exported to nearby countries too for slaughtering purpose (Aynalem *et al.*2011). The bulls are often fattened at feedlots, where they are stall fed for a couple of months prior to slaughtering (Banerjee *et al.* 2014). In the way these animals exchange several hands before being supplied to the feedlots, thus the price received by the pastoralists are significantly lower than those paid by the feedlot owners. As in most of the developing countries the livestock are usually sold by visual assessment and weighing scales are absent or in many cases defunct even in the markets where the livestock are traded (Nesamvuni *et al.*2000). Thus in most of the cases the actual market worth of the animals are improperly assessed .The market worth of an animal reared at a farm is one of the primordial activities to assess the functional efficacy of a farm (Moore 1985; Blasco and Gomes 1993;

Bathaei and Leroy, 1996; Topal *et al*. 2004). The market worth of an animal is ascribed by its growth which in turn is closely associated with its body weight, influenced by both genetic and non genetic factors (Ulutas *et al.*2001). The growth of the bulls and the veterinary care associated with it is also difficult to assess in absence of reliable weighing scales. The use of indirect (using morphometical traits) approach to assess the body weight of livestock has been carried out since long (Touchberry and Lush, 1949; Goe *et al.* 2001; Adeyinka and Mohammed 2006; Ojedapo *et al.* 2007; Sownade and Sobola 2008; Salim 2014).

Most of the earlier studies to assess the body weight of livestock included the use of several morphometical measurements. However, handling of livestock is difficult in the rural areas due to lack of restraining equipments besides the zebu cattle by nature are usually apprehensive when handled. Therefore, it becomes difficult to assess multiple measurements on an animal thereby relying on any single measurement which is highly correlated with body weight .Thus, under such circumstances it becomes necessary to develop techniques by which a single measurement can provide an assessment for the body weight of the cattle.

Thus, the study was conducted to predict the slaughter weight of Boran bulls from body/slaughter weight at different stages of their rearing. The study can therefore assist the rearers and purchasers alike to decide the potential of the animal for fattening.

Finding of a study by Van Marle-Köster *et al.*(2000) indicated that body measurements can be considered as selection criteria for the growth in livestock. The use of non linear regression methods to assess body weight is based on the principle that growth is a complex biological phenomenon involving both hypertrophy (increase in cell size) and hyperplasy (increase in the numbers of cells).The basic hypothesis behind the classical growth models are that the post natal growth follows a sigmoid pattern, before it reaches a pattern of no growth, Neštřilová (2005). The classical growth model assumes that the post natal growth is uniform till it peaks and then ceases (Zeger *et al.* 1987). Studies by Neštřilová (2005) indicated that the growth of the Czech Pied bulls was multiphasic (i.e. periods where the growth is higher while at some other periods the growth is relatively lesser), similar observations have been reported in several studies (Grossman and Koops, 1988; Koops and Grossman 1991; Hyánek and Hyánková 1995). Therefore, linearity in growth is never achieved, in the terms of quantitative genetics this may be attributed to asymmetry of response which may be attributed to several genetic and non genetic factors (Falconer1989).

The most common linear measurement to assess the body weight as have been reported in earlier studies was the heart girth of the livestock ,Neštřilová (2005) . However, the processes of growth depend on various factors which are both genetic and non genetic in nature. The non genetic factors lead to difference in growth at different phases of life mainly depending on the availability of feed/fodder, diseases and also other managerial activities (Heinrichs *et al.*1992; Yanar *et al.*1995, Van Marle-Köster *et al.* 2000). The influence of location/herd on differences in morphometical traits have been reported in several studies (Thompson *et al.* 1981; Bowden 1982; Lucas *et al.* 1984; Foster *et al.* 1988; Khan and Khan 2015). The study encompassed the use of linear and non linear(log, inverse, quadratic, power and exponential) curve fit equations to assess the body weight of Boran bulls at 3 and 4 years of age using linear measurements at 2 years (to estimate the body weights at 3 and 4 years of age)and 3 years (to assess the body weight at 4 years of age) of the Boran bulls.

MATERIALS AND METHODS

The study was conducted at Maki district of Oromia region. The two feedlots where the study was conducted are situated at a distance of 133 km south of Addis Ababa. The climate of the two feedlots varied significantly while first feedlot is situated near to the Lake Ziway (7°59'19"N 38°50'30"E) in an area which is devoid of any vegetation or wind breaks; cold winds blow from the lake to the feedlot especially during the night, and is hence uncomfortable to the bulls. While the second feedlot is situated 25 km west of the first feedlot , the conditions of the second feed lot is quite favorable for the livestock as it is surrounded by many trees which serve as wind break, hence the cattle are comfortable especially during the night.

The study was conducted between January and April months of 2012, which is considered as the dry season in the region. In both the feedlots the bulls were grouped in three age groups i.e. 2 years, 3 years and 4 years respectively, the age of the animals were assessed through their dentition as per methods suggested by Hammond *et al.*(1971).

Within the feedlots the bulls were separated in different pens by their ages.

The Boran bulls were purchased from their breeding tract the average period of time they spent at the feedlots were around 6 months, where they were fattened prior to slaughtering. On their arrival to the feedlots, the bulls were sprayed with acaricides and also drenched with antihelmenthics, the concentrations of both was based on the manufacturer's recommendation. The cattle were provided with concentrate supplements which comprised of rice and wheat bran besides hulls from different pulses viz. haricot bean (*Phaseolus vulgaris*), lentil (*Lens culinaris*) and peas (*Pisum sativum*) , cotton seed cake and common salt, the roughage consisted of straws of teff (*Eragrostis tef*), wheat (*Triticum sp.*) and barley(*Hordeum vulgare*)while water was provided adlib, the proximate analysis of the feed showed that it contained 19% crude protein, 2.5% crude fat, 16.5% crude fiber on dry matter basis, the results as assessed was in close accordance with the recommendation of Hutcheson (2006) for Boran bulls reared for fattening purpose under Ethiopian condition. The concentrate feed was provided twice a day and the animals were group fed according to their respective age categories.

The body weight and linear measurements were taken early in the morning after the bulls were fasted for 12 hours so as to ensure minimum gut content. The body weight of the bulls was assessed using a platform balance which was calibrated prior to being used. The linear measurements were taken according to the methods suggested by Macjowski and Zieba (1982) and Tolenkhomba *et al.* (2012).

The measurements were conducted by the same enumerator in both the farms and across all the bulls. The traits included in the study were: height at withers (HW), height at rump (RH), body length (BL),heart girth (HG), head width (WFH), neck circumference (NC),neck length (NL), chest width (CW), rump length (RL), hip width (WH), flank width (FW) and body weight of (BW) the bulls.

The data was analyzed statistically using SPPS V 12 for Windows (SPSS 2003). The data was analyzed using descriptive statistics, the effect of feedlots on morphometical traits and body weight of Boran cattle from various age groups were compared using one way analysis of variance and were considered significant both at 1 and 5% levels. The prediction equations were assessed using curve fit regression analysis; the best predictor for each age category was assessed based on the values with highest correlation with the body weight. The prediction of body weight was then carried out using linear, logarithmic, inverse, quadratic, power and exponential curve fit regression equation, the accuracy of prediction was assessed by the coefficient of determination (R^2) values as suggested by Keskin *et al.* (2009).

RESULTS AND DISCUSSION

The morphometical traits and body weight of the Boran bulls reared in the two feedlots(Table-1) indicates that there was difference ($P<0.01$) in the heart girth (HG), neck circumference (NC), chest width (CW), hip width (WH), flank width (FW) and body weight (BW) of the bulls. The bulls reared at the second feedlot had higher values for most of the morphometical traits and body weight across all the ages.

Table 1. Morphometrical measurements and body weight of Boran bulls at different ages and reared at the first feed

	Age-2		Age-3		Age-4	
Traits	Feedlot-1 (N=49)	Feedlot-2 (N=10)	Feedlot-1 (N=181)	Feedlot-2 (N=85)	Feedlot-1 (N=127)	Feedlot-2 (N=253)
HW	117.3±3.4	117.2±2.3	118.5±5.0	119.1±5.1	118.9±6.2	119.6±5.9
RH	118.7±4.2	117.1±4.0	120.1±4.0	121.2±4.9	120.6±4.8	121.2±8.1
BL	125.8±7.9	123.0±6.7	130.3±11.1	129.6±9.2	128.7±16.8	129.5±8.0
HG	151.4±9.1	160.6±8.0**	156.8±9.8	164.3±9**	158.0±8.3	164.3±8.0**
WFH	19.5±1.2	19.5±2.3	19.7±1.1	21.1±2.19*	19.7±1.2	21.5±2.2*
NC	72.4±8.4	75.9±7.4**	75.5±8.5	79.1±8.6**	77.9±8.4	83.7±7.5**
NL	36.6±2.8	37.0±6.8	38.1±2.8	40.8±6.1**	38.1±3.5	41.9±5.6**
CW	54.2±5.3	57.1±3.2*	55.2±3.5	59.3±3.7**	56.0±3.2	58.1±4.1**
BD	58.55±3.5	63.9±2.2	58.85±4.2	58.58±2.6	59.83±4.2	59.0±2.8
RL	45.5±2.3*	42.5±3.4	45.9±2.6	46.3±3.6	46.5±2.7	46.3±3.8
WH	29.9±3.0	35.3±4.0**	30.2±2.7	36.8±3.7**	30.2±3.9	37.8±3.2**
FW	56.9±5.2	60.2±5.1**	57.7±5.9	62.2±5.8**	58.3±7.1	62.9±4.7**
BW	248.0±19.6	278.1±23.8**	298.0±43.9	326.4±52.1**	316.5±43.4	374.4±39.5**

*P<0.05, ** P<0.01, Values across locations within same age group are significantly different, morphometical measurements in cms, body weight in Kg. Height at withers (HW), Rump height (RH), Body length (BL), Heart girth (HG), Width of forehead (WFH), Neck circumference (NC), Neck length (NL), Body Depth (BD), Chest width (CW), Rump length (RL). Width of hips (WH), Flank width (FW), Body weight (BW)

Table 2. Correlation of body weight and linear measurements of Boran bulls reared in the two locations and body weight at different ages

Traits	**A**		**B**		**C**	
	Location 1	Location 2	Location 1	Location 2	Location 1	Location 2
HW	-.054	.532	-.160	-.020	.138	.007
RL	-.111	.228	-.094	-.180	.136	.254*
BL	-.190	.115	-.041	.067	.097	.197
HG	.192	.612	.138	-.595	.007	.272*
WFH	-.127	.284	-.131	-.094	.017	.120
NC	.180	.351	.113	-.359	-.012	.126
NL	-.090	.318	.073	-.033	.061	.181
CW	.036	.044	.069	.407	-.092	-.047
BD	.023	.750*	.076	-.379	-.029	.039
RL	.104	-.046	.165	-.540	.066	.032
WH	-.169	.330	-.063	.156	.052	.242*
FW	.157	.277	-.298*	.234	-.127	.142

[A] Correlation between morphometical traits and body weight at 2 years of age to predict body weight at 3 years

[B] Correlation between morphometical traits and body weight at 2years of age to predict body weight at 4 years

[C] Correlation between morphometical traits and body weight at 3 years of age to predict body weight at 4 years

The differences in the morphometrical traits and body weight may be attributed to genotype by environmental influences. The bulls reared at the second feedlot could assimilate higher body weight as the barn was comfortable , the findings are in consonance with the findings of Sawanon *et al.* (2011) who also observed differences in body weight of the Kamphaengsaen bulls reared on grassland and feedlot.

The results as presented in Table 2 indicated that the correlation of the linear measurements and body weight varied across the two locations even within bulls of

Table 3: Prediction equation for assessment of body weight of Boran bulls reared in the first location using morphometrical traits of 2 years

Type	3Years (***Predictor***: Heart Girth)		4Years(***Predictor***: Flank Width)	
	R^2_{adj}	Equation	R^2_{adj}	Equation
Linear	0.40	234.17+0.634(x)	0.20	430.051-1.944(x)
Log	0.43	-192.43+(104.126 In(x))	0.17	797.86-(118.502 In(x))
Inverse	0.49	441.35-16785.61 X1/ (x)	0.16	195.54-6994.54 X1/ (x)
Quadratic	0.58	$-1170.76+19.04\ (x)-0.06\ (x^2)$	0.32	$889.12-17.6\ (x)+0.132(x^2)$
Power	0.43	$68.52\ (x)^{0.313}$	0.19	$1445.7(x)^{-.0.375}$
Exponential	0.37	$246.57e^{0.002(x)}$	0.20	$451.46e^{-0.006(x)}$

Table 4: Prediction equation for assessment of body weight of Boran bulls reared in the second location using morphometical traits of 2 years

Type	3Years (***Predictor***: Body Depth)		4Years(***Predictor***: Heart Girth)	
	R^2_{adj}	Equation	R^2_{adj}	Equation
Linear	0.56	70.473+4.858(x)	0.35	806.73-2.596(x)
Log	0.56	-878.62+(303.209 In(x)	0.36	2563.08-(427.99 In(x))
Inverse	0.56	676.37-18784X1/ (x)	0.37	-49.33+70373.7X1/ (x)
Quadratic	0.56	$153.5+2.205\ (x)+0.0212(x^2)$	0.48	$6719.9-75.24\ (x)+0.2226(x^2)$
Power	0.57	$13.3787(x)^{0.8057}$	0.36	$111710(x)^{-.1.115}$
Exponential	0.57	$166.604e^{0.0129(x)}$	0.35	$1150.46e^{-0.0068(x)}$

Table 5: Prediction equation for assessment of body weight of Boran bulls aged 4 years and reared in the two locations using morphometical traits of 3 years

Type	Location 1 (***Predictor***: Height at withers)		Location 2 (***Predictor***: Heart Girth)	
	R^2_{adj}	Equation	R^2_{adj}	Equation
Linear	0.20	158.27+1.35(x)	0.64	245.627+.7681(x)
Log	0.20	-425.13+(155.71 In(x))	0.63	-277.0+(127.22ln (x))
Inverse	0.20	469.52-17901.97/ (x)	0.61	499.554-20911/(x)
Quadratic	0.35	$2300.87-34.63(x)+0.151\ (x^2)$	0.67	$-523.7+10.263(x)-.03(\ x^2)$
Power	0.20	$26.72(x)^{0.52}$	0.62	$58.0332\ (x)^{.3637}$
Exponential	0.21	$186.15e^{0.004(X)}$	0.64	$258.62e^{.0022(x)}$

the same age category. This might be attributed to differences in their skeletal and muscular development as suggested by Taiwo *et al.* (2010); Khan and Khan (2015).

The results further indicate that assessment of bodyweight using the heart girth measurement is influenced by non genetic factors. The findings from Table 3 indicate that the best predictor for assessment of body weight of Boran bulls at two years of age and reared in the first location indicate that while heart girth was the best predictor for body weight at three years of age, it was the flank width which served as the best predictor of the bulls aged four years. The best predictor for the assessment of body weight of the bulls across the different ages was by using the quadratic regression, the observation are in accordance with those of (Banerjee 2011; Sintayehu *et al.* 2013).

The higher accuracy of quadratic regression equation over the linear regression is attributed to allometric differences in growth (bones and tissues) of the predictor vis-a-vis predicted parameters, findings are in accordance with those of Akbaş *et al*. (1999); Bilgin and Esenbuğa (2003); Topal *et al*. (2004) ; Keskin *et al.* (2009).

The findings from Table 4 indicate that the best predictor of body weight of bulls aged three years and reared at the second location was the power/exponential regression equation while the body weight at four years of age was best predicted using the quadratic regression equation.

The body weight of the bulls aged four years was best assessed using height at withers and heart girth respectively for location 1 and 2 considering the linear measurements of the bulls aged t 3 years, in both the cases the best prediction equation was obtained considering the quadratic regression.

The results across all the tables indicate that non linear methods are better predictors in assessment of growth and mature body weight when compared to the linear regression equations, the findings are in close accordance with those of Tholon *et al.* (2012).

CONCLUSION

The results from the study indicate that non genetic factors influence growth of the livestock. As the growth is not isometric the morphometical traits used to assess the body weight vary with age and management of the animals. The coefficient of determination (R^2) values indicated that quadratic regression equation was the better predictor for most of the cases, however the R^2 values were higher using power/exponential regression analysis for assessment of body weight of Boran bulls aged 3 years and reared in the second location. The differences as observed may be attributed to genotype by environmental effect on allometric growth of different organs .

REFERENCES

1. Adeyinka, I.A. and I.D. Mohammed. 2006. Accuracy of body weight prediction in Nigerian red Sokoto goats raised in northeastern Nigeria using linear body measurement *Pakistan Journal of Biological Sciences* 9(15): 2828–2830.
2. Akbaş, Y., Taşkın, T. & Demirören, E. 1999. Comparison of several models to fit the growth curves of Kıvırcık and Dağlıç male lambs. Turkish Journal of Veterinary and Animal Sciences 23 (Suppl. 3): 537-544.
3. Aynalem Haile, Azage Tegegne, WorknehAyalew, Noah Kebede and Tadelle Dessie. 2011. Breeding strategy to improve Ethiopian Boran cattle for meat and milk production. IPMS Working Paper No. 26. 56 p.
4. Banerjee S., Ahmed M. B. and Tefere G. 2014 Studies on morphometrical traits of Boran bulls reared on two feedlots in Southern Ethiopia. Animal Genetic Resources 54: 53-63.
5. Banerjee, S. 2011. Estimation of Body Weight at Different Ages Using Linear and Some non Linear Regression Equations in a Duck Breed Reared in Hot and Humid Climate of Eastern India. American-Eurasian Journal of Scientific Research 6 (4): 201-204.
6. Bathaei, S.S. and Leroy, P.L. (1996). Growth and mature weight of Mehraban Iranian fat- tailed sheep. Small Rumin. Res.22: 155-162.
7. Bilgin, Ö.C. and Esenbuğa, N., 2003. Parameter estimation in nonlinear growth models. Hayvansal Üretim 44 (2): 81-90.
8. Blasco, A. and Gomes, E., 1993. A note on growth curves of rabbit lines selected on growth rate or litter size. Journal of Animal Production 57: 332-334.
9. Bowden, V. 1982. Type classification in dairy cattle: a review. Animal Breeding Abstract50:147-162.
10. Falconer, D.S. 1989. Introduction to Quantitative Genetics, 3rd Edition. Longman Scientific and Technical. 438.
11. Foster, W.W., A.E. Freeman, P.J. Berger, and A. Kuck. (1988). Linear type trait analysis with genetic parameter estimation. Journal of Dairy Science 71:223-231.
12. Goe, M.R., J.R. Alldredge and D. Light. 2001.Use of heart to predict

body weight of working oxen in the Ethiopian highlands. Livestock Production Science 69: 187–195.

13. Grossman, M. and W. J. Koops. 1988. Multiphasic analysis of growth curves in chickens. Poultry Science 67:33-42.
14. Hammond, J. Jr., I.L. Mason and T.J. Robinson. 1971. Hammonds Farm Animals. 4th Edn., Edward Arnolds Publishers Ltd., London.
15. Heinrichs A.J., Rogers G.W., Cooper J.B .1992. Predicting body weight and wither height in Holstein heifers using body measurements. Journal of Dairy Science 75: 3576-81.
16. Hutcheson, D. 2006. Feeding to produce export quality Ethiopian beef requirements and recommendations. Ethiopia Sanitary and Phytosanitary standards and livestock and meat marketing program (SPS-LMM) .
17. Hyánek J., Hyánková L. 1995. Multifázické růstové křivky. Živoč. Výr., 40, 283–286.
18. Keskin, I. , Dag, B. , Sariyel , V. and Gokmen, M. 2009. Estimation of growth curve parameters in Konya Merino sheep. South African Journal of Animal Sciences 39 (2): 163-168
19. Keskin, I. , Dag, B. , Sariyel , V. and Gokmen, M. 2009. Estimation of growth curve parameters in Konya Merino sheep. South African Journal of Animal Sciences 39 (2): 163-168.
20. Khan, M.A. and Khan M.S. 2015. Non Genetic factors affecting linear type traits in Sahiwal cows . The Journal of Animal and Plant Sciences 25(1): 29-36.
21. Koops W.J., Grossman M. 1993. Multiphasic allometry. Growth 57: 183–192.
22. Lucas, J.L., R.E. Pearson, W.E. Vinson, and L.P. Johnson. 1984. Experimental linear descriptive type classification. Journal of Dairy Science 67:1767-1775.
23. Maciejowski, J. and Zieba, J. Genetics and Animal Breeding, Part A. Biological and genetics foundations of animal breeding. Polish Scientific Publishers, 1982.
24. Moore, A.J., 1985. A mathematical equation for animal growth from embryo to adult. Journal of Animal Production 40:441-453.
25. Nesamvuni A. E, Mulaudzi J., Ramanyimi N. D. and Taylor G. J. 2000. Estimation of body weight in Nguni-type cattle under communal management Conditions. South African Journal of Animal Sciences 30:97-98.
26. Nešetřilová H. 2005.Multiphasic growth models for cattle. Czech Journal of Animal Sciences 50: 347–354.
27. Ojedapo, L.O., T.A. Adedeji, T.B. Olayeni, O.S. Adedeji, A.R. Abdullah and O.O. Ojebiyi.2007. Influence of age and sex on body weight and some body linear measurements of extensively reared Wad goats in derived savanna zone of Nigeria. Journal of Animal and Veterinary Advances 6: 114–117.
28. Salim Bahashwan. 2014. Application of Morphometical traits for Live Body Weight Estimation in Dhofari Calves. International Journal of Scientific Research in Agricultural Sciences 1(5): 90-96.
29. Sawanon, S. , Boonsaen, P. and Innurok, P. 2011. Body measurements or male Kamphaengsaen beef cattle as parameters of estimation of live weight. Kasetsart Journal (Natural science) 45: 428- 434.
30. Sintayehu Yigrem , Sandip Banerjee and Kefyalew Berihun. 2011 Comparison of linear with some non linear regression

methods to estimate hot carcass weight using live weight in Arsi-Bale sheep and goats of both sexes. World Applied Sciences Journal 21 (11): 1603-1608.

31. Sowande, O.S. and O.S. Sobola. 2008. Body measurements of West African dwarf sheep as parameters for estimation of live weight. Tropical Animal Health and Production 40: 433–439.
32. Taiwo B.B.A., Olaniran O.D.D., Aluko F.A. 2010 .Breed and environmental factors affecting body measurements of beef cattle in Yewa, Nigeria. Agric J. 5:211–214.
33. Tholon, P.; Paiva, R. D. M.; Mendes, A. R. A.;Barrozo, D. 2012.Utilização de funções lineares e não lineares para ajuste do crescimento de bovinos Santa Gertrudis, criados a pasto. ARS Veterinaria, Jaboticabal 28, (4), 234-239.
34. Thompson, J. R., A.E. Freeman, D.J. Wilson, C.A. Chapin, P.J. Berger, and A. Kuck. 1981. Evaluation of a linear type program in Holsteins. Journal of Dairy Science 64:1610-1617.
35. Tolenkhomba, T. C., D. S. Konsam, N. S. Singh, M. Prava, Y. D. Damodor Singh, A. M. Ali, and E. Motina. 2012. Factor analysis of body measurements of local cows of Manipur, India. International Multidisciplinary Research Journal 2(2):77 82.
36. Topal, M.; Ozdemir, M.; Aksakal, V.; Yildiz, N. and Dogru, U. 2004. Determination of the best nonlinear function in order to estimate growth in Morkaraman and Awassi lambs. Small Rumin. Res. 55: 229-32.
37. Touchberry, R.W. and J.L. Lush. 1949. The accuracy of live linear body measurements of dairy cattle. Journal Paper No. J-1691 of the Iowa Agricultural Station, Ames. 72–80.
38. Ulutas, Z., Saatci, M. and Ozluturk, A. 2001. Prediction of body weights from body measurements in east Anatolian red calves. Ataturk Unv. Ziraat Fak. Dergisi. 32: 61-65.
39. Van Marle-Köster E, Mostert BE, Van der Westhuizen J. 2000.Body measurements as selection criteria for growth in South African Hereford cattle. Arch Tierz Dummerstorf. 2000;43:5–15.
40. Yanar M, Tuzemen N, Ozkan M, Aydin R, Ugur F 1995 Prediction of body weights from body measurements in Brown Swiss cattle. Turkish J Vet Anim Sci 19, 357-60.
41. Zeger Scott L., Harlow S.D., Siobán D. 1987. Mathematical models from laws of growth to tools for biological analysis: fifty years of Growth. Growth 51:1–21.

