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Structural Traits, Structural Indices and Body Weight Prediction of Arsi Cows

Aman Gudeto^{1*} Tesfaye Alemu Aredo² Tadele Mirkena³ Sandip Banerjee⁴

1. Adami Tulu Agriculture Research Center, Adami Tulu Agricultural Research Center, Batu, Ethiopia

2. Oromia Agriculture Research Institute (IQQO), Addis Ababa, Ethiopia

3. Food and Agriculture Organization of United Nation (FAO), Addis Ababa, Ethiopia

4. College of Agriculture Science and Technology, India

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ABSTRACT

Structural measurements are indicators of animal performance, productivity and carcass characteristics. This study was conducted with the objectives of assessing structural measurements, developing body weight prediction and structural indices for cows of Arsi breed. The cows were purchased from highland and lowland agro-ecologies of Arsi and East Shoa zones of Oromia regional state, Ethiopia and kept in Adami Tulu Agricultural Research Center (ATARC) for the breed development purpose. Totally 222 cows were included in the structural traits measurement. Thirty four young heifers were also considered in the study. Twenty two structural traits were considered during observational survey. The structural index was calculated from the phenotypically correlated linear measurements. Structural traits were analyzed by T-test of SPSS version twenty four. The observed average values of height at wither, chest depth, heart girth, body length, pelvic width, cannon bone circumferences of the cows were 107, 55.62, 141.06, 117.82, 31.41 and 13.58cm, respectively. Heart girth (0.82), flank girth (0.73), hook circumferences (0.67), chest depth (0.65) and height at rump (0.64) were highly correlated ($P < 0.01$) to body weight of the cows. Regression analysis indicated that heart girth had the highest coefficient of determination for body weight of the cows and heifers. Accordingly, the simple linear equations were developed to predict the body weight of cows and heifers. Body weight of Arsi cow (y) = $-221.005 + 3.1(\text{heart girth})$ and Body weight of Arsi heifer (y) = $-188.452 + 2.75(\text{heart girth})$. Based on this, the measuring chart tape can be developed to estimate the body weight of Arsi cows and heifers at field condition where there is no access to weighing scales.

1. Background and Justification

Structural traits have been used for breed characterization and to describe changes in size and shape^[1]. It provides a scientific basis to describe biological variations between breeds as well as within a breed and

thus can serve as a basis for measuring the performance, productivity and carcass characteristics that vary due to genotypes, environment and nutrients^[2].

Structural measurements serve as an alternative option for the assessment of body weight^[3]. It is a best

*Corresponding Author:

Aman Gudeto,

Adami Tulu Agriculture Research Center, Adami Tulu Agricultural Research Center, Batu, Ethiopia;

Email: amangude13@gmail.com

option where there is no access to weighing scales to predict animal body weight. Knowing body weight of animals is important for management decisions such as breeding, culling, feeding and determination of selling prices^[4]. However, many farmers in developing countries grade their livestock using informal methods of quality estimation such as feeling the loin area or by visual estimation alone^[5,6] because of lack of weighing scales and, if available, the weighing scales are mostly inaccurate due to lack of maintenance and calibration. Under such conditions, the livestock keepers are usually unable to receive a fair price for their livestock.

The structural indices are the combinations of several linear measurements which collate with type and function of particular breed. As indicated by Alderson^[7], linear body measurements are used to calculate indices which show the structure and proportions of each animal. Structural indices are considered most useful because they have a neutral correlation with age. Consequently, assessment of structural indices is useful as a measure to select young animals for breeding purpose and predict mature rating. They provide a more realistic indicator for which a particular livestock breed was created and therefore provide a directional approach for further improvement of the same^[5].

Arsi cattle are widely reared in Arsi, West Arsi, Bale, some parts of East Shoa and East Hararghe Zones of Oromia regional state, Ethiopia^[8]. Adami Tulu Agriculture Research Center (ATARC) also handles Arsi cows at its farm for composite breed development. At ATARC, some morphometric measurements are being taken as baseline information for the breed improvement work being undertaken on this breed. Such information is necessary to see the differences attained after the breed improvement program. However, this breed has to be characterized phenotypically in detail using structural indices. Therefore, this study was designed to assess structural traits, develop body weight prediction and structural indices for Arsi cows.

2. Methodology

2.1 Study Area

Structural assessment was conducted at Adami Tulu Agricultural Research Center, which is located in mid rift valley at 167 km south from Addis Ababa, at an altitude of 1650 meter above sea level. The agro-ecological zone of the area is semi-arid and sub humid with acacia woodland vegetation type. The mean annual rain fall of the area is 760 mm and its mean minimum and maximum

temperatures are 12.6 and 27 °C, respectively.

2.2 Sampled Population

ATARC keeps Arsi cows with the aim of developing composite breed from Holstein Frisian-sire and Arsi-dam breeds. The Arsi cows were purchased from highlands of Arsi zone and lowland agro-ecologies of Arsi and East Shoa zones. All cows were kept under similar management conditions. The cows having permanent teeth were taken for linear measurements. Accordingly, 144 and 78 cows were represented from lowland agro ecology and Highland agro-ecologies respectively. Moreover, thirty four one to three years old female calves which were born from this herd were included in study.

2.3 Measurement of Structural Traits

Twenty two structural traits were considered during observational survey. Namely: height at wither, hip height, chest depth, chest width, rump width, heart girth, flank girth, body length, rump length, neck length, neck circumference, ear length, horn length, face length, muzzle circumference, forehead width, pelvic width, tail length, cannon bone length, cannon bone circumference, hock circumference and body weight.

The physical measurements such as height at wither (HW), rump height (HR), chest depth (CD), chest width (CW), rump width (RW) and rump length (RL) were measured using graduate measuring sticks whereas heart girth (HG), flank girth (FG), body length (BL), neck length (NL), neck circumference (NC), ear length (EL), horn length (HL), face length (FL), muzzle circumference (MC), tail length (TL), cannon bone length (CBL), cannon bone circumference (CBC), hock circumference (HC) were measured using plastic measuring tape. The pelvic width (PW) and forehead width (FW) measurement were assessed using a calibrated wooden caliper. Body weight (BW) of cows was taken by standard weighing scale.

2.4 Structural Indices

The structural indices were calculated from structural traits as follows^[7,9-11]:

Depth index = chest depth/height at wither,

Height index = height at withers/body length,

Rump length = rump length/body length

Body index = body length/heart girth

Weight index = ((body length x chest depth) x ((rump width + chest width)/ 2)/ 1050))

Relative cannon length = cannon bone circumference/ withers height

Body ratio index = height at withers/height at rump

Over increase index = height at rump/height at withers.

2.5 Statically Analysis

Structural traits were analyzed by T-test of SPSS version twenty four. The Pearson's correlation among various structural traits was estimated. The model used for the analysis of correlations among various structural traits was estimated. The model used for the analysis of structural measurement was: $y_{ijk} = \mu + a_i + e_{ij}$

Where, Y = is the phenotypic observation for one of the twenty two structural traits,

μ = is over all mean,

a_i = fixed effect of i th agro-ecology, while

e_{ij} = is random residual error associated with each observation.

3. Results and Discussions

3.1 Structural Traits

Structural traits of cows and heifers are listed in Table 1. The height at wither, height at rump, chest depth, rump width, heart girth, flack girth, body length, rump length, neck length, mouth circumference, pelvic width, body weight, cannon bone circumference and hock circumference had significant different across agro ecologies when chest width, neck circumference, ear length, horn length, face length and cannon bone length had not showed significant different at $P < 0.05$.

The height at wither of cows are presented in Table 1. The observed average value of height at wither of Arsi cows was shorter than Begait cows that reported by Teweldemedhn and Selam^[12] while, it was similar with report of Dessalegn *et al.*^[13] for Arado cows. However, the average height at wither obtained was taller than Malle cows^[14]. The average height at rump of Arsi cows was shorter than findings of Dereje^[15] for Horro cows. The observed value of height at rump was taller than Malle cows that reported from South Omo of Ethiopia^[14].

Height at wither and height at rump are important as they determine how tall the animals are^[16]. The height at wither and hip height are important skeletal measurements, which are associated with the skeletal dimension of the cattle. Some study indicated that animals adapted to the hot and humid climate have shorter height at wither while those adapted to the arid climate with sparse vegetation cover have higher height at withers and longer limbs^[17].

The average value of chest width obtained in this study is lower than those reported by Demerew *et al.*^[14] for Malle cows but higher than those reported by Worku^[16]

for Sheka cows. Further study indicated that Arsi cows have lower chest depth than Fogera cows^[18]. The average chest depth of Arsi cows was higher than those reported by Worku^[16] Sheka cows. The animals chest depth and chest width are correlated with the pleural capacity. Both traits are correlated with chest girth of animals and therefore have immense economic importance.

Study results indicated that Arsi cows have lower heart girth than those reported by Teweldemedhn and Selam^[12] for Begait cows; Fasil and Workneh^[19] for Fogera cows. However, it was observed that Arsi cows had higher heart girth than Arado cows^[13]. The observed value for heart girth was similar with the finding of Chenchu *et al.*^[20] for Goffa cows. Cattle with low chest girth usually have lower body weight as the pleural cavity houses many of the vital organs and the development of these organs influences their body weight^[21].

Values for average body length of Arsi cows are lower than those results reported by Shiferaw^[22]; Getinet *et al.*^[23] for Kereyu and Ogaden cows, respectively. The observed average body length was longer than Arado cows^[13]. Cows with longer body usually have better potential as meat animals provided that they are properly managed. Body length is correlated with the body weight of cattle^[6]. Cattle with large skeletal dimensions fetch higher price/value when compared to those with shorter skeletal dimensions^[3]. But cattle with short skeletal dimensions require low space and maintenance cost. The rump length of cows in the current study is lower than those reported by Abdulmojeed *et al.*^[24] for Bunaji and Red Angus cattle. The rump length has a significant importance for livestock as cows with optimal rump length usually have lower incidences of abortion and dystocia. This is so because of the fact that the fetus gets enough space to grow.

The average value of rump width observed for cows in this study was higher than what was reported for Mursi cows^[25] but lower than those reported for Sheka cows^[16]. It has been reported that cattle with narrower pelvic girth are prone to birth defects and that the trait shows sexual dimorphisms with the values being higher in females than in males^[12]. Average values for pelvic width of Arsi cows is in close accordance with the finding of Dessalegn *et al.*^[13] for Arado cows. However, the values are lower than those reported by Fasil and Workneh^[19] for Fogera cows.

Forehead width is one of the important features defining a breed. While the head width of beef breeds of cattle are wider than that of the dairy breeds, there exists sexual dimorphism for this trait too^[21]. The values pertaining to forehead width for the Arsi cows is higher than those for Sheka cows^[16] but lower than those for Begait cows^[21].

Table 1. Structural traits of cows and heifers (Mean ± SE)

	Structural traits (cm)										
	HW	HR	CD	HG	FG	BL	RL	NL	MC	PW	BW(kg)
Highland cows	108.3±0.5	113.6±0.4	56.3±0.3	143.3±0.8	147.5±0.9	119.6±0.7	36.5±0.2	34.9±0.3	38.7±0.3	32.1±0.3	223.4±2.99
Lowland cows	106.3±0.3	111.7±0.3	55.3±0.2	139.8±0.6	143.7±0.7	116.8±0.4	35.8±0.1	33.8±0.2	37.8±0.2	31.0±0.2	211.8±2.24
<i>P</i> values	0.001	0.001	0.002	0.001	0.001	0.001	0.009	0.006	0.003	0.001	0.002
Overall mean	107±0.3	112.4±0.3	55.6±0.2	141.1±0.5	145.1±0.6	117.8±0.4	36.1±0.1	34.2±0.2	38.2±0.1	31.41	215.98±1.8
Heifer	102.6±3.4	109.4±2.4	48.7±2.5	125.9±4.7	128.6±5.7	107.6±6.1	32.5±1.4	30.9±2.8	33.9±1.5	10.1±1.1	156.8±14.8
	Structural traits (cm)										
	CW	RW	NC	EL	HL	FL	FW	TL	CBL	CBC	HC
Highland cows	30.1±0.3	38.5± 0.3	71.7±0.8	18.9±0.2	27.5±0.6	40.6±0.2	17.5±0.1	73.5±0.7	18.6±0.1	13.7±0.1	23.7±0.1
Lowland cows	29.5±0.2	35.8±0.2	70.5±0.5	19.1±0.1	27.5±0.3	40.5±0.2	17.4±0.1	73.3±0.5	18.5±0.1	13.5±0.1	23.3±0.1
<i>P</i> values	0.12	0.04	0.12	0.73	0.99	0.74	0.41	0.81	0.51	0.03	0.004
Overall mean	29.7±0.2	36.1±0.2	70.9±0.4	19±0.1	27.5±0.4	40.5±0.1	17.4±0.1	73.3±0.4	18.6±0.1	13.58	23.4±0.1
Heifer	24.7±1.7	30.9±1.7	62.4±4.7	19±1.5	37.7±1.7	37.7±1.7	15.8±1	69.3±7.2	18.6±0.7	12.8±0.6	22.7±0.7

Some structural values of cows within the same column not vary significantly at $P < 0.05$

The average value of the cannon bone length of Arsi cows was shorter than that of Horro cows^[15]. The cannon bone circumferences observed for cows in this study were also narrower when compared to that reported for Begait cows^[21]. The animals with narrow cannon bone circumference usually have lower body weight as the space for muscle attachment is less in such types of animals. The cannon bone circumference observed for cows in this study are narrower than those reported by Dereje^[15] for Horro cows but similar to those reported by Endashaw *et al.*^[25] for Mursi cows.

The values pertaining to the neck circumference indicate that the neck is narrower when compared to that of the Begait breed^[26], but wider than that of Malle cattle^[14]. This may be ascribed to the breed character. Neck length is a trait which is correlated with the femineity and masculinity of cattle. The observed neck length of Arsi cow was shorter than that of the Begait cattle^[12]. Neck length values are correlated with development of cervical vertebrae^[16], which is helpful for draft purposes in cattle. Cows with long thin neck are usually preferred over those with short and thick necks^[27].

3.2 Correlations of Structural Traits for Cows

The correlation of biometric traits cows are listed in Table 2. Height at wither, height at rump, chest depth, chest width, rump width, heart girth, flank girth, body length, mouth circumference, pelvic width, cannon bone circumference and hook circumference of the cows are

positively correlated to each other and highly correlated ($P < 0.01$) to body weight. The findings indicated that rump length, neck length, neck circumference, ear length, horn length, face length, forehead width, tail length and cannon bone length have weak correlation coefficients to the live body weight.

The observed highest correlation between heart girth and body weight is in close accordance with the finding of Rashid *et al.*^[28] for Brahman crossed bred and Musa *et al.*^[29] for Kenana cattle. Bivariate correlation indicated that flank girth was the second highest correlated trait with live body weight than other structural traits. It was observed that hock circumference, chest depth, hip height, cannon circumference, chest width, weight at withers and rump width were highly correlated to body weight in a decreasing manner. It was also observed that ear length, horn length and dewlap width were not significantly correlated ($P < 0.01$) to body weight which might be due to their less association with body weight.

Table 2. Correlation between body weight and structural traits for cows

Traits	BW	Traits	BW	Traits	BW	Traits	BW
HW	.602	FG	.736	RL	.441	FL	.416
HR	.644	BL	.510	NL	.290	FW	.339
CD	.652	MC	.528	NC	.336	TL	.184
CW	.607	PW	.581	CBL	.207		
RW	.599	CBC	.608	EL	.051		
HG	.818	HC	.675	HL	.082		

All Correlation between body weight and structural traits are significant at 0.01 level (2-tailed).

3.3 Body Weight Prediction

3.3.1 Simple Linear Equation

The simple regression models are presented in Table 3. Simple linear regression results pertaining to the structural measurements indicated that cows from highland agro-ecology had lower coefficient of determination when compared to those from lowland agro-ecology. The multiple linear equations have more coefficient of determination in predicting the body weight of Arsi cows. However, taking multiple measurements in bovines are problematic especially under field conditions where the infrastructure is wanting and there are lack of crushes and appropriate livestock handling tools^[30]. Under such condition, single trait is preferable to predict body weights. The study showed that among the structural measurements, the best trait was the heart girth measurements, which are in close accordance with those of Lukuyu *et al.*^[6]; Rashid *et al.*^[31]. This may be ascribed to the fact that the thoracic cavity holds some of the most vital organs of the animals and weight of these organs are highly correlated with the live weight of the animals^[17].

Table 3. Simple linear regression of weight on heart girth for the cows and heifers

Cattle	R ²	Regression equation
Highland agro-ecology cows	0.777	-195.63 + 2.90(x)
Lowland agro-ecology cows	0.826	-232.65 + 3.18(x)
Combined equations	0.818	-221.005 + 3.10(x)
Heifers	0.723	-188.452 + 2.75(x)

x: heart girth

3.3.2 Multiple Linear Equations for Cows

Stepwise multiple linear regression models of cows are presented in Table 4. The coefficient of determination of multiple linear regressions increases as number of traits is added to models. The study indicated that single trait linear equation for Arsi cows has low coefficient compared to the multiple traits. The equation developed from heart girth alone has low coefficient of determination than the equation developed from rump width and heart girth. Furthermore, the study indicated that the accuracy of body weight prediction increases as the number of morphometric traits included in the linear equation increases. Both these scenarios are in close accordance with the finding of Rashid *et al.*^[31]. However, as livestock handling is difficult in rural areas due to lack of restraining

equipment and due the behavior of zebu breed^[30]; it becomes difficult to assess multiple measurements for an animal. Hence, relying on any single trait measurement which is highly correlated with body weight^[32] is inevitable.

3.3.3 Curve Fit Regression Equations

Linear and non linear regression models of few structural are listed in Table 5. The study indicated that heart girth was the best body weight predictor followed by flank girth and hock circumference in that order. Their respective non-linear regression equations have similar coefficient of determination with simple linear regression. Particularly, the quadratic regression equation has almost equal coefficient of determination to the linear equation. However, the result of this study disagrees with that reported by Banerjee *et al.*^[30], who stated that the quadratic regression equations have a better accuracy when compared to the linear measurements for Borana bulls. Further this study indicated that the single linear and non-linear equations have lower accuracy when compared to multiple linear regression equations.

Table 4. Stepwise multiple linear regression models

R ²	Multiple linear equations
0.818	-221 + 3.1HG
0.848	-256.1 + 2.6HG + 2.87RW
0.869	-310.6 + 2.2HG + 2.6RW + 8.85CBC
0.881	-318 + 1.68HG + 2.45RW + 7.74CBC + 0.74FG
0.887	-322.5 + 1.52HG + 2.4RW + 6.9CBC + 0.66FG + 1.5PW
0.892	-319.1 + 1.26HG + 1.87RW + 7CBC + 0.7FG + 1.5PW + 1.42CW
0.896	-357.7 + 1.1HG + 1.9RW + 6CBC + 0.68FG + 1.3PW + 1.5CW + 0.76HR

Table 5. Linear and non-linear regression models for different traits

Regression	Heart girth		Flank girth		Hock circumference	
	R ²	Equation	R ²	equation	R ²	Equation
Linear	0.818	-221.005 + 3.098(x)	0.736	96.14 + 0.226(x)	0.675	17.95 + 0.025(x)
Logarithmic	0.817	-1961.031 + 439.99ln(x)	0.734	-120.268 + 49.42ln(x)	0.669	-6.25 + 5.53ln(x)
Inverse	0.815	658.186 - 62219.6(1/x) - 106.375 +	0.728	194.5- 10529.9(1/x)	0.659	28.91- 1169.1(1/x) + 20.4+
Quadratic	0.818	1.486(x) + 0.006x ²	0.736	91.42-0.27(x) + -9.69x ²	0.677	0.003(x) + 5.1x ²
Exponential	0.813	29.476 + e ^{0.14(x)}	0.718	103.45 + e ^{0.002(x)}	0.674	18.52 + e ^{0.001(x)}

Notice x = heart girth, flank girth, hock circumference

3.4 Structural Indices

The structural indices of Arsi cows are listed in Table 6. Weight index was significantly different ($P < 0.05$) for cows in the two agro-ecologies. Depth index, rump length index, body index, relative cannon thickness index, body ration index and over increase index were not statically different between agro-ecologies.

The rump length index of the Arsi cows is quite smaller when compared to that of the other breeds. This is an indication of the compactness of the Arsi cows [7]. The results pertaining to the weight index showed that the weights of the Arsi cows are lower than that of the Malle cattle [14]. The difference in body weight index may be associated with the difference in agro-ecologies from where the cows came.

Table 6. Structural indices of the cows

Location	Index							
	DI	HI	RLI	BI	WI	RCT	BRI	OII
Highland	0.52	0.91	0.31	0.84	214.24 ^a	0.13	0.95	1.05
Lowland	0.52	0.91	0.31	0.84	201.43 ^b	0.13	0.95	1.05
Overall	0.52	0.91	0.31	0.84	205.93	0.13	0.95	1.05

DI: depth index, HI: height index, RLI: Rump length index, BI: body index, WI: body weight index, RCT: relative cannon thickness, BRI: body ratio index, OII: over increase index

The values observed for height and over increase indexes in this study were lower than those reported by Tariku [33]. The values for the over increase and body ratio indexes showed that the hind quarters of the cows are raised. The relative cannon thickness index obtained for cows in this study indicated that their cannon are quite narrow. The animals that have thin cannon bone are expected to be less masculinity and have low carcass yield [10]. The value for depth index was higher than that of the Sheka cows [16]. An observed value shows that chest depth was half height at wither.

4. Conclusions and Recommendation

The highland Arsi cows have wider chest and pelvic bone, longer rump and body length, bigger heart and flank girth, thicker cannon and hock bone, taller hip and heavier body than lowland Arsi cows. This might be correlated to the ecological adaption of the cattle. These variations in structural traits indicate the possibilities to undertake within breed selections.

The regression equations need to be validated at on-farm level to predict body weight of female Arsi cattle. Measuring chart tape should be developed to predict the body weight from heart girth of Arsi cows and heifer at field condition where there is no access of weighing

scales.

Depth index revealed that chest depth is half of the height at wither. This might show the body is balanced which may help animal to walk long distance. Thus might reason why animals distributed in areas of the country. Over-increase index indicated that the hip of Arsi cows is taller by 5% than height at wither. Further, rump length index indicated that rump length is 31% of the body length. Indices indicate that Arsi cows have compact and light which implies that the breed is suitable for crossing by virtue of being small dairy type breeds.

References

- [1] Pundir, R.K., Singh, P.K., Singh, K.P., Dangi, P.S., 2011. Factor analysis of biometric traits of Kankrej cows to explain body conformation. *Journal of Animal Science*. 24, 449-456.
- [2] Kugonza, D.R., Nabasiye, M., Mpairwe, D., Hannotte, O., Okeyo, A.M., 2011. Productivity and morphology of Ankole cattle in three livestock production systems in Uganda. *Animal Genetic Resources*. 48, 13-22.
- [3] Alsidding, M.A., Baker, S.A., Galal, M.Y., Mohamed, A.M., 2010. Phenotypic characterization of Sudan zebu cattle. *Research Journal of Animal and Veterinary science*. 5(2), 10-17.
- [4] Ozkaya, S., Bozkur, Y., 2008. The relationship of parameters of body measures and body weight by using digital image analysis in pre-slaughter cattle. *Arch. Tierz., Dummerstorf*. 51(2), 120-128.
- [5] Sandip Banerjee, Mohamed Beyan Ahmed, Girma Tefere, 2014. *Studies on morphometrical traits of Boran bulls reared on two feedlots in Southern Ethiopia*. Published online by Cambridge University Press. DOI: <https://doi.org/10.1017/S2078633614000095>.
- [6] Lukuyu, M.N., Gibson, J.P., Savage, D.B. et al., 2016. Use of body linear measurements to estimate liveweight of crossbred dairy cattle in small-holder farms in Kenya. *SpringerPlus* 5, 63. DOI: <https://doi.org/10.1186/s40064-016-1698-3>.
- [7] Alderson, G.L.H., 1999. The development of a system of linear measurements to provide an assessment of type and function of beef cattle. *Animal Genetic Resources Information*. 25, 45-55.
- [8] DAGRIS (Domestic Animal Genetic Resources Information System), 2018. *International Livestock Research Institute*, Addis Ababa, Ethiopia. Accessed date, April 9, 2018 <http://eth.dagris.info/species/85/breeds>.
- [9] Salako, A.E., 2006. Principal Component Factor Analysis of the Morpho-structure of immature Uda

- Sheep. *International Journal of Morphology*. 24(4), 571-774.
- [10] Chacon, E., Macedo, F., Velazquez, F., Rezende Paiva, S., Pineada, E., Mc Manus, C., 2011. Morphological measurements and body indices for Cuban creole goats and crossbreds. *R.Bras. Zootec*. 40(8), 321-327.
- [11] Pares-Casanova Pere, M., Mwaanga, E.S., Caballero, M., Sanbate, J., Valenzuela, S., 2013. Biometrical multivariate Study of the Indigenous fat-tailed Sheep. *International Journal of Livestock Production*. 4(9), 148-154.
- [12] Teweldemedhn Mekonnen, Selam Mesere, 2020. Characterization of Begait cattle using morphometric and qualitative traits in Western Zone of Tigray, Ethiopia. *International journal of livestock production*. 11(1), 21-33.
- [13] Dessalegn Genzabu, Mokonnen Hailemeriam, Kelay Behlihu, 2012. Morphometric Characteristics and Livestock keeper perception of Arado cattle in Northern Tigray, Ethiopia. *Livestock Research for Rural Development*. Volume 24, Article #101. Retrieved May 15, 2018, from <http://www.lrrd.org/lrrd24/1/balu24121.html>.
- [14] Demerew Getaneh, Sandip Banerjee, Mestawet Taye, 2019. Morphometric traits and structural indices of malle cattle reared in the south Omo zone of southwest Ethiopia. *International Journal of Veterinary Sciences Research*. 5(2), 32-47.
- [15] Dereje, B., 2015. On farm phenotypic characterization of indigenous cattle and their production systems in BakoTibe and Gobu Sayo districts of Oromia region, Ethiopia. MSc. thesis. Haramaya University, Ethiopia. pp. 68.
- [16] Worku Masho, 2017. Assessment of type, function and traditional selection methods of indigenous cattle reared in Sheka Zone, South West Ethiopia. MSc Thesis. Hawassa University. Hawassa. pp 107.
- [17] Mwacharo, J.M., Okeyo, A.M., Kamande, G.K., Rege, J.E.O., 2006. The small East African shorthorn zebu cows in Kenya. I: Linear body measurements *Trop Anim Health Prod*. 38, 65-74.
DOI: <https://doi.org/10.1007/s11250-006-4266-y>.
- [18] Zewdu, W., Workneh Ayalew, J., Hedge, B.P., 2008. Mehibere-Silassie Composite; some new cattle breed type in north western Ethiopia. *Journal of Animal production*. 8(1), 39-52.
- [19] Fasil Getachew Kebede, Workneh Ayalew, 2014. On-farm phenotypic characterization of indigenous cattle populations of Awi, East and West Gojjam Zones of Amhara Region, Ethiopia. *Research Journal of Agriculture and Environmental Management*. 3(4), 227-237.
- [20] Chenchu Chebo, Workneh Ayalew, Zewdu Wuletaw, 2013. On farm phenotypic characterization of indigenous cattle population of Gamo Goffa Zone. *Animal Genetic Resources*. 52, 71-82.
- [21] Tewelde Gebru, Sintayehu Yigrem, Sandip Banerjee, 2017. Some morphometrical, production and reproduction in Begait cattle reared at Tigray Region of Ethiopia. *Wayamba Journal of Animals Science*. 1498735834, 1571-1585.
- [22] Shiferaw, G., 2006. In-Situ characterization of Kereyu Cattle Type in Fentalle District of Oromia Region, Ethiopia. MSc. Thesis. Haramaya University, Ethiopia. pp. 122.
- [23] Getinet, M., Workneh, A., Hegde, B.P., 2009. Growth and reproductive performance of Ogaden cattle at Haramaya University, Ethiopia. *Ethiopian Journal of Animal Production*. 9(1), 13-38.
- [24] Abdulmojeed, Y., Kingsley Omogiade, I., Hadiza Salihu, H., Matthew, W., Samuel, A., 2010. Multivariate analysis of phenotypic differentiation in Bunaji and Sokoto Gudali cattle. *Acta Argiculturae Slovenica*. 96(2), 75-80.
- [25] Endashaw Terefe, Taddelle Dessie, Aynalem Haile, Wudyalew Mulatu, Ally Okeyo Mwai, 2015. On-farm phenotypic characterization of Mursi cattle in its production environment in South Omo Zone, Southwest Ethiopia. *Animal Genetic Resources*. 57, 15-24.
- [26] Mulgeta Ftiwi, Berhan Tamir, 2015. Phenotypic characterization of indigenous cattle in Western Tigray, Northern Ethiopia. *The Journal of Agriculture and Natural Science*. 2(1), 343-354.
- [27] Takele, T., 2005. On-farm Phenotypic Characterization of Sheko Breed of Cattle and their Habitat in Bench Maji Zone, Ethiopia. MSc Thesis. Haramaya University. Ethiopia. pp. 105.
- [28] Rashid, M.M., Hoque, M.A., Huque, K.S., Bhuiyan, A.K.F.H., 2016. Prediction of live weight for Brahman crossbred cattle using linear body measurements in rural area. *Adv. Anim. Vet. Sci*. 4(2), 99-106.
- [29] Musa, A.M., Elamin, K.M., Mohammed, S.A., Abdalla, H.O., 2011. Morphometric traits as indicators for body weight in Sudanese Kenana cattle. *Online J. Anim. Feed Res*. 1(5), 218-222.
- [30] Sandip Banerjee, Mohammed Beyan, Girma Terefe, 2016. Predictions of body weight of boran bulls reared at two feedlots of southern Ethiopia, using linear and curve fit regressions equations. *Wayamba Journal of Animal Science*—ISSN:2012-578X; P1467-P1474.

- [31] Md. Mahbubur Rashid, Md. Azharul Hoque, Khan Shahidul Huque, Md. Azharul Islam Talukder, Fazlul Huque Bhuiyan, A.K., 2015. Morphometric characterization of Brahman crossbred cattle and prediction of live weight using linear body measurements. *Asian J. Med. Biol. Res.* 1(3), 569-577.
DOI: <https://doi.org/10.3329/ajmbr.v1i3.26480>.
- [32] Gunawan, A., Jakaria, 2014. Application of Linear Body Measurements for Predicting Weaning and Yearling Weight of Bali Cattle. *Animal Production.* 12(3), 163-168.
- [33] Tariku Woldeyohannes, 2018. Production system, Morphological characterization and Structural indices of indigenous cattle in Hadiya Zone, Southern Ethiopia. pp 94.