“PREDICTION OF PRODUCTION PERFORMANCE IN SURTI BUFFALOES FROM BODY MORPHOMETRY”

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PREDICTION OF PRODUCTION PERFORMANCE IN SURTI BUFFALOES FROM BODY MORPHOMETRY

ABSTRACT

The present investigation entitled as “Prediction of production performance in Surti buffaloes from body morphometry” was carried out from January, 2021 to April, 2021 on Surti buffaloes maintained at Livestock Research Station, Navsari Agricultural University, Navsari, Gujarat. The objective of this study was to study of the body morphometry, find out relationship between body morphometry and production performance and to predict body weight from body morphometry in Surti buffaloes. Apparently 202 healthy Surti buffaloes belonging to group 1 (calved up to 3 months), group 2 (calved from 3 months to one year of age), group 3 (Surti buffaloes up to 1-3 years of age), group 4 (adult buffaloes above 3 years of age) were considered for this study. Body measurements like height at withers (HAW), body Length (BDL), heart girth (HG), fore cannon bone girth (FCBG), height at hipbone (HAHB), height at pin bone (HAPB), rump slope (RS), ischium width of the rump (ISWR), rump length (RL), ilium width of the rump (ILWR), medium width at Rump (MDR) were recorded on theseanimals. Further, udder length (UL), udder width (UW), udder depth (UD), udder circumference (UC), teat length (TL), teat diameter (TD) were recorded for lactating animals. Data pertaining to primary traits like birth weight, body weight at 3, 6, 12 months of age and body weight at first calving of those animals which were present atfarm during the period of this study were collected from the available records. Available records of lactation milk yield (LMY), 305 or 300-days lactation milk yield (MY 305), lactation length (LL), age at first calving, weight at first calving were recorded. Further, live body weight and milk yield of these animals were recorded on the same day onwhich their body measurements were taken. Statistical analysis of body measurements, growth, production and reproduction data was carried out by using SAS 4.3.

The overall least squares’ means for height at withers (HAW), heart girth (HG), body length (BDL), fore cannon bone girth (FCBG), height at hip bone (HAHB), height at pin bone (HAPB), rump slop (RS), ischium width of rump (ISWR), rump length (RL), illium width of rump (ILWR) and medium width of rump (MDWR) was found to be 106.77±1.36, 148.29±2.89, 121.52±2.30,18.17±0.25, 105.17±1.18, 93.54±0.92, 11.61±0.33, 11.63±0.38, 39.79±0.72, 37.59±0.95 and 77.7±2.31 cm, respectively.

The overall least squares’ mean for body weight (BW) of Surti buffaloes at birth (BWT), 3 (WT3), 6 (WT6), 12 (WT12) months of age and weight at 1st calving was

found to be 25.76±0.25, 52.96±0.63, 80.71±1.15, 137.41±1.91 and 366.781±7.45 kg, respectively. A positive and significant (P<0.05) correlation was found between body weight and HAW (0.586*) and BDL (0.659*) in group 1 animals. A positive and significant (P<0.01) correlation was found between body weight and HG, HAW, BDL, FCBG, HAHB and HAPB and it was found to be 0.953, 0.904, 0.869, 0.758, 0.876 and 0.840, respectively in group 2 animals. Correlation coefficient between body weight and HAW, HG, BDL, HAHB and HAPB was found to be 0.853, 0.621, 0.546, 0.810 and0.768 respectively, these were positive and significant (P<0.01) in group 3 animals. A positive and significant (P<0.01/0.05) correlation between body weight and HG, BDL, HAW, FCBG, HAHB, HAPB and it was 0.452, 0.544, 0.222, 0.214, 0.021 and 0.111, respectively in group 4 animals. A positive and significant (P<0.01/0.05) correlation between weight at 1st calving and BDL, RL, HAW, HG, ISWR and MDWR and it was found to be 0.457, 0.352, 0.309, 0.270, 0.311 and 0.236, respectively. Low, positive (r=0.096) and significant (P≤0.05) correlation between milk yield (MY) and udder length (UL) however correlation between milk yield (MY) and teat diameter (TD) was positive (r=0.415) and significant (P≤0.01). The accuracy of prediction equations ranged between 29.70 % for adult lactating buffaloes to 92.87 % for all animals under study irrespective of their ages. The accuracy of prediction equations for 0-3 months and 03 months-01year animals was 43.45 and 90.98%, respectively. For group 3 animals (01 year- 1st calving) the accuracy of prediction equation was 72.88 % when only heart girth was used but it improved to 75.54 % when HAHB was incorporated in the equation. Similarly, for group 4animals (adult lactating buffaloes) the accuracy of prediction equations was only 29.70% when only body length was used however, it improved to 35.24 % when heart girth was incorporated in the equation. From the findings of this study, it may be concluded thatlive body weights of Surti buffaloes could be predicted from HG, BDL and HAPB most accurately.

CERTIFICATE - I

This is to certify that the thesis entitled **"PREDICTION OF PRODUCTION PERFORMANCE IN SURTI BUFFALOES FROM BODY MORPHOMETRY"** submitted by **DEEKSHA PAL** in partial fulfillment of the requirements for the award of the degree of **" MASTER OF VETERINARY SCIENCE"** in the subject of **LIVESTOCK PRODUCTION AND MANAGEMENT** of the College of Veterinary Science and A. H., Navsari of the Kamdhenu University, Gandhinagar is a record of bonafide research work carried out by her under my guidance and supervision and the thesis has not been previously formed the basis for the award of any degree, diploma or has been published for other similar title.

Place: Navsari
Date: / /2021

Dr. Rana Ranjeet Singh
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DECLARATION

This is to declare that the whole of the research work reported here in this thesis for partial fulfillment of the requirement for the award of the degree of **"MASTER OF VETERINARY SCIENCE"** in **LIVESTOCK PRODUCTION AND MANAGEMENT** by the undersigned is the result of investigation carried out by me under direct guidance and supervision of **Dr. R. R. SINGH**, Associate Professor, Department of Livestock Production Management, College of Veterinary Science and Animal Husbandry, Navsari, Kamdhenu University, and no part of the work has been submitted for any other degree so far.

Place: Navsari
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Place : Navsari
Date : / /2021 (DEEKSHA PAL)

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LIST OF SYMBOLES AND ABBREVIATIONS

HAW	:	Height at Wither
HG	:	Heart Girth
BDL	:	Body Length
FCBG	:	Fore Cannon Bone Girth
HAHB	:	Height at Hip Bone
HAPB	:	Height at Pin Bone
RS	:	Rump Slope
ILWR	:	Ilium Width of Rump
ISWR	:	Ischium Width of Rump
RL	:	Rump Length
MDR	:	Medium Width of Rump
UL	:	Udder Length
UD	:	Udder Depth
UC	:	Udder Circumference
UW	:	Udder Width
TL	:	Teat Length
TD	:	Teat Diameter
KG	:	Kilogram
CM	:	Centimeter
MM	:	Millimeter

CHAPTER 1

INTRODUCTION

Water buffalo (*Bubalus bubalis*) is a multipurpose animal as their milk, meat, horns and skin can all be exploited along with the draft ability (Abd El-Salam and El- shibiny, 2011). The domestic buffalo plays an important role in the agricultural economy of many tropical and sub-tropical countries. The nutritive value of buffalo milk is also higher than cows because of the higher concentrations of protein, fat, lactose, mineralsand vitamins in buffalo milk. Buffalo milk and its derived products could be a good source of conjugated linoleic acid (Han. *et al*., 2012). Further, buffaloes have advantage over cattle in utilization of low-quality roughages to produce more protein and gain more body weight, more disease resistance power and outstanding draught capacity (Sarkar *et al.,* 2013).

India is considered as the home tract of some of the best water buffalo (*Bubalus bubalis*) breeds. There were about 17 indigenous standard breeds of buffaloes (NBAGR, 2020), which are well known for their milking qualities. Buffalo population in India was about 109.85 million (Livestock census, 2019). Currently, India is producing 187.7 million tons of milk and the buffalo contributes about 56% of total milk production(Livestock census, 2019).

Surti buffalo is a native breed of Kaira and Baroda district of South Western part of Gujarat. Surti buffalo is medium sized animal, well-shaped and the barrel is wedge shaped with two bands below the neck and sickle shape horn moderately long and flat. Coat colour varies from rusty brown to silver-grey. The head is long with prominent eyes and body weight of adult female is about 400 kg. The milk yield of this breed ranges from 900 to 1300 kg with good fat percentage (8-12per cent). The age at first calving is about 40-50 months with an inter-calving period of 400-500 days. They produce calves of body weight 21-25 kg (Thamil vanan *et al.,* 2003).

Body morphometry traits can be studied by using measurements with appropriate instruments, which are called morphometric traits. In animals, morphometric measurement research has their main objective to study the individual conformation, allowing the racial characterization and classification of the population (De Melo *et al.,* 2018). Further, reports are available about studies on body traits of buffaloes (Espinosa-Núnês *et al.,* 2011; Johari *et al.*,2009; Mirza *et al.,*2015; Dhillod *et al.*, 2017), however studied on correlation between them are scarce. The body measurements of female buffaloes and their correlations can aid in predicting the potential and aptitudes of these animals (Agudelo-Gómez *et al.*, 2015). Association between the body measurements, the productive and reproductive traits in buffaloes were reported by (Thomas and Chakravarty, 2000; Espinosa-Núnês *et al.*,2011; Kern. *et al.,*2014) and in cattle by (Wenceslau *et al.*, 2000; Rennó *et al.*,2003; Lagrotta *et al.,*2010; Silva *et al.*,2011)

Body measurements like body length (BL), heart girth (HG), abdominal girth (AG), height at wither (HW), height at hook (HH) etc. have close association with body weight (Desai *et al* .1992; Singh *et al.*1994). The HG has been reported to possess high coefficient of correlation (r) with live weight (LW) in many breeds of cattle. A high correlation between HG and BW was also found in Bali cattle (Gunawan and Jakaria, 2011), Ongole grade cow (Paputungan *et al.* 2013) and Tanzania Shorthorn Zebu cattle (Kashoma *et al.* 2011). Measurements are nearly correlated with body weight in buffaloes, cow and sheep (Moran, 1992; Al-khauzai *et al.* 2000; Al-Hellou *et al*. 2009; Al-Hellou and Al-khauzai, 2012; Paul and Das, 2012). Also, the measurements of various body conformations are useful in judging the quantitative characteristics of meat and also are helpful in developing suitable selection criteria (Bose and Basa,1984; Alves and Franzolin 2015).

Morphological characteristics of udder and teats have an immediate relation with milk production potential in dairy animals. Udder and teat measurements show variation between breeds and individuals within the same herd. This has utmost importance while selecting dairy animals which are to be used for future milk production. The milk production of multiparous animals is usually predicted on the idea of their previous lactation performance. However, in primiparous animals, because the direct performance data aren't available, stock persons/livestock owners use to determine the relationships among mammary morphological characteristics and milk production as a tool of selection. Many researchers correlated different udder traits and milk production in multiparous bovines and in crossbred primiparous cows. And determine the correlations of prepartum udder and teat measurements with subsequent milk production traits in primiparous Nili-Ravi buffaloes (Chandrasekhar, 2016).

Live body weight is one of the important indicative parameters to harvest maximum output from dairy animals as weight of a buffaloes in relation to its age and lactation stage ensures good milk yield. Body weight of animals provides reasonable idea about future performance of replacement herd and plays vital role in reproductive performance of a dairy animal and hence influences milk production (Kanuya *et al.*, 2006; Roche *et al.*, 2007).Nevertheless, most of the time under field condition weighing ofanimals is difficult to organize as it requires weighing scale which is costly to buy, heavyto transport, also need technical maintenance. Hence, farmers use his visual estimation of the body weight of their animals which could result into rough and inaccurate estimation thus lead to wrong decision making (Abdelhadi and Babiker,2009).Usually in absence of weighing scales, body weight of animals is predicted by morphometric measurementswhere body weight is regressed on a certain number of body measurements. Prediction of live body weight using morphometric measurements is practical, faster, easy to conductand cheaper in the rural areas where the resources are insufficient (Nsoso *et al.*, 2003). In some cases, estimate of body weight based on morphometric measurements can be more accurate than modern weighing machines as fullness of the gut may provide skewed results in latter (Obike *et al.*, 2010).However, predictive power of the models used to estimate body weight from body measurements found to be influenced by (Lukuyu *et al.*, 2016). body condition, age, breed and sex (Kuria *et al.*, 2007; Nesamvuni *et al.*, 2000; Ozkaya and Bozkurt 2009; Russell 1975). Hence, the regression equations need to determine separately for all cattle breed reared in several countries and locations. Many researchers have investigated the use of body linear measurements to estimate live body weight of exotic beef (Ozkaya and Bozkurt 2009; Van Marle-Köster *et al.*, 2000) dairy(Fall *et al.*, 1982; Dodo *et al.*, 2001; Yan *et al.*, 2009). indigenous cattle (Isik *et al.*, 2009; Lesosky *et al.*, 2012; Lukuyu *et al.*, 2016). and buffaloes (Shankar and Mandal, 2010).

Information on relationship between body morphometry and production performance of Surti buffalo is limited and no accessible reports are available for prediction of body weight of Surti buffaloes from morphometric measurements. Therefore, the present study was undertaken with the following objectives:

Objectives

1. To study body morphometry of Surti buffaloes.
2. To find out relationship between body morphometry and production performance in Surti buffaloes.
3. To predict body weight from body morphometry in Surti buffaloes.

CHAPTER 2

REVIEW OF LITERATURE

The detailed and systematic information regarding the morphometric characteristics of Surti buffaloes and relationship between body measurements and body weight, production, reproduction is scanty. Hence, the available literature concerning to various aspects under the present study has been reviewed under following headings:

2.1 Body morphometry

2.2 Body morphometry and production performance

2.3 Estimation of production performance from body morphometry

2.1 Body morphometry

Recorded data on Gir cows maintained at livestock Farm Krishina nagar, Jabalpur and utilized for studies on weight, height at withers, linear unit and heart girth. The mean weight of Gir cows were recorded to as 313.05 kg. The phenotypic correlations between weight and therefore the three body measurements were positive and highly significant.The correlation of linear unit with height at withers and with heart girth were also positive and significant. The correlations of weight with heart girth, linear unit and heightat withers and between height at withers and linear unit and between linear unit and heart girth were significant while the correlation between wither height and heart girth was low and not significant. The rectilinear regression of weight (Kg) on height at withers (cm), linear unit (cm) and heart girth (cm) was 2.18, 2.56 and 2.80. All the regressions were statistically significant (Tripathi, *et al.*1978).

Heart girth and weight of oxen, but the prediction equation was derived from only one set of measurements (Taylor and Galal, 1980).

The employed a pre-calibrated commercial weigh band to estimate weight of working use oxen over a 6-month period, however, no prediction equation was given. (Ogwang and Xaba 1996).

Heart girth (HG) are often used with great accuracy for estimating the BW of all classes of dairy cow, and for various buffalo breeds a high correlation between HG and BW (Msangi, *et al.* 1999).

Multiple recordings of heart girth and weight were made for an equivalent cattle population. during this study, Simple rectilinear regression equations derived from weight and heart girth measurements were significantly different between months. the only equation for the year predicted weight of oxen as a gaggle to within 627 kg of mean monthly weighbridge values, whereas for one animal the anticipated weight was 637 kgof the particular weight. The single equation was often wont to monitor mean weight of the oxen population equally well across working and nonworking periods of the year (Goe, 2001).

To develop rectilinear regression models for prediction of body weights of Eastern Anatolian Red Cattle from various body measurements taken at birth 3,6,9,12,15, 18 and 24 months aged and at mature cows that were older than 24 months of age. Among body measurements, heart girth resulted is highly significant ($P<0.01$) and the highest correlation coefficients with body weights. It was concluded that the models including heart girth alone could be used to predict precisely body weights of Eastern Anatolian Red Cattle (Ozluturk and Kopuzlu, 2006).

Strong linear relationship exists between bodyweight and therefore the different external body measurements. Heart girth was found to be the simplest single predictor of weight. In using two parameters in estimating weight, heart girth and width of shoulder seemed to be the foremost accurate external parameters. Using the formulas supported heart girth ($R^2 = 0.943$) and combination of heart girth and width of shoulder ($R^2 = 0.953$), the weight of locally-raised adult purebred Brahman cattle might be estimated (Bagui and Valdez, 2007).

The breed performance of Red Kandhari cattle in their native tract and located that linear unit, height at wither and heart girth were 109.3 ± 0.9 cm, 121.7 ± 1.2 cm and 149.8 ± 1.3 cm, respectively in adult cows (Pundir and Singh, 2008).

The connection between weight (BW) and body measurements like heart girth, linear unit, abdominal girth, height at hook and height at withers of Karan Fries (KF) of NDRI herd. The prediction equations developed to predict the weight from the measurements gave an accuracy of 72.24 percent (R2) in KF cows. Body measurements, mainly HG and AG were better related with BW in both the breeds, KF cows (r=0.78 and 0.74) (Bhakat, *et al.*,2008).

Event of a machine vision system that estimates the liveweight of cattle supported objective body measurements. The apparatus has potential use in pasture and feedlot situations with application to automated drafting. Recording was motion triggered and indexed by cattle identifications from an electronic ear tag reader at the entry of the laneway. linear unit was estimated because the distance between the approximate tailhead and shoulder positions in imagery. Body area was estimated using the body height and length. linear unit and area measured by the developed method was linearly associated with weight with coefficients of correlation of 0.52 and 0.53, respectively. Extending the system to estimate condition score and trialing different breeds (Carthy, 2009).

Different biometric traits in 407 Kankrej cows from their breeding zone, i.e. Palanpur district Gujarat, India, were recorded and analyzed by correlational analysis to elucidate body conformation. The averages of linear unit, height at withers, height at shoulder , height at knee, heart girth, paunch girth face length, face width, horn length, horn diameter, distance between horns, ear length, ear width, neck length, neck diameter, tail length with switch, tail length without switch and distance between hip bones were 123.44±0.37, 124.49±0.28, 94.68±0.30, 38.2±0.14, 162.56±0.56, 178.95±0.70, 44.09±0.10, 15.91±0.05 ,42.47±0.53, 26.07±0.19, 13.34±0.08, 31.24±0.12, 16.10±0.05, 50.63±0.18,73.21±0.32,111.62±0.53, 89.34±0.34 and17.28±0.10cm, respectively. The correlation coefficients between different traits ranged from -0.806 (horn diameter and distance between horns) to 0.815 (heart girth and paunch girth). Most of correlations were positive and significant (Pundir *et al.* 2011).

Found an in-depth correlation between the weight of Nili-Ravi buffaloes and therefore the morphometric variables including heart girth and linear unit also as body condition score (Tarik, *et al*. 2013).

Heart girth (HG), height at withers (HW) and body condition score (BCS) to predict the body weight (BW) of Brahman cattle bulls within the data obtained on thethree body measurements were fitted to simple and multiple rectilinear regression equations to predict BW. Linear regressions indicated that each one the three body measurements are often useful in predicting body weight; however, HG was the foremost accurate predictor as one explanatory variable (R^2 = 0.86) compared to HW (R^2 = 0.76)and BCS (R^2 = 0.55). it's concluded that body weight of Brahman cattle bulls are often accurately predicted from body measurements no matter breed type and feeding regime (Katongole, *et al.* 2013).

To estimate live weight in Ongole grade cow using its chest girth and linear unit. Data on animal live weight (LW), linear unit (BL) and chest girth (CG) were collected. multivariate analysis was administered to estimate LW from all linear body measurements. Data were classified supported age of animals consisted of 5 groups with the primary age bracket of two and half years old, to the fifth age bracket of seven andhalf years old. The results showed that age significantly ($P<0.05$) influenced all body measurements. Correlations between all pairs of measurements were highly significant ($P<0.001$) for all age groups. multivariate analysis showed that live weight might be predicted accurately from chest girth and linear unit (R2=0.97). multiple correlation model was often recommended to predict live weight of Ongole grade cows supported those variables with their age groups starting from 2.5 to ≥7.5 years old (Paputungan, *et al.* 2013).

Recorded data on live weight (LW) and body measurements like withers height (WH), linear unit (BL) and heart girth (HG), to estimate the LW from body measurements. the general means for LW, WH, BL and HG of Aceh cattle over sexes were 129.37 kg, 96.59cm, 93.10 cm and 118.15 respectively. The study revealed that HG was the simplest predictor of LW and this variable alone contributed 70% (female), 86% (male) and 74% (all animals) of the variation within the LW of Aceh cattle. it had been concluded that highest determination coefficient (R^2) value of straightforward rectilinear regression model was found on model LW (kg) = -172.47 + 2.59HG (cm), whereas this model was simpler and efficient for predicting the LW of male Aceh cattle (Bayu Putra,*et al.* 2014).

Estimate the live weight in Ongole crossbred cow using chest girth, linear unit and body volume model. Data on animal live weight (LW), linear unit (BL), chest girth (CG) and body volume were collected from cows. multivariate analysis was administered for LW with all linear body measurements. Age significantly ($P<0.05$) influenced allbody measurements. Correlations between all pairs of measurements were highly significant for all age groups, except between BL and CG also as LW at ages of three.5 to 7.5 years old. regression model being recommended to predict live weight of Ongole crossbred cows supported body volume with their age groups starting from 2.5to ≥ 7.5 years old (Paputungan, *et al.* 2015).

Predicted the weight using body measurements and to derive prediction equations for estimation of live weight by using the body measurements in Sahiwal cattle. Study was conducted at Okara, Pakistan. 300 and fifty animals of various ages were randomly selected. All the animals were weighed on a mechanical scale and their body measurements including linear unit (BL), heart girth (HG) and height at withers (WH)were recorded. Highly significant direct correlation (P<0.001) of weight was found with heart girth with coefficient of correlation (r) was 0.983. Simple rectilinear regression between BW and HG and multiple rectilinear regression of BW on two independent variables (HG and BCS), three independent variables (BL, HG and BCS) and 4 independent variables (BL, HG, WH and BCS) were significant (P<0.05) with R^2 values of 0.967, 0.973, 0.973 and 0.974, respectively (Siddiqui, *et al.* 2015).

Rectilinear regression equations for prediction of body weights of Sahiwal cattle by the body morphometry. The study showed that heart girth measurements were often wont to predict the body weight of Sahiwal woman cattle Linear regressions method for prediction of body weight is quick, cheap and practical under field conditions (Sahu,*et al.* 2016).

Quantified weight prediction using automatically measured morphological traits during a 3-dimensional (3-D) vision system and to assess the influence of varied sources of uncertainty on weight prediction. during this case study, a picture acquisition setup was createdin a cow selection box equipped with a top-view3-D camera (Song, *et al.* 2018).

Body measurements of Girolando cattle as measurements extracted from their images, to get a model to know which measures further explain the cattle weight. They physically measured 34 Girolando cattle for the subsequent traits: heart girth (HGP) circumference of the abdomen, linear unit, occipito-ischial length, wither height, and hip height. additionally, images of the dorsum and therefore the body lateral area of those animals allowed measurements of hip width (HWI), linear unit, tail distance to the neck, dorsum area (DAI), dorsum perimeter, wither height, hip height, body lateral area, perimeter of the lateral area, and rib height. The measurements extracted from the pictures were subjected to the stepwise regression method and regression-based machine learning algorithms. The HG was the physical measure with stronger direct correlation with reference to weight. The set of rules presented during this study are often recommended for estimating weight in Girolando cattle, at a coefficient of correlation of 0.71, by measurements of hip width and dorsum area, both extracted from cattle images (Weber, 2020).

2.2 Body morphometry and production performance

The milk yielding capacity of udder shape might be due to forward and backward extension of the udder (Bharadwaj, *et al.* 1987).

Udder and teat characteristics measurements could be used as a reliable criterion in selection of buffaloes for milk production at the field level also for cows that udder measurements could be reliable criteria while selecting cows for milk production. (Lin, *et al.* 1987)

Higher yield in bowl shaped udders in cows. similarly, cylindrical teats were more frequent with a percentage of 52.5 followed by pear, bottle, conical and funnel shape of teats with 18.0, 11.0, 10.5 and 8.0% respectively. The mean and S.E values of udder length, width and depth in Murrah buffaloes ranged from 51.5 ± 0.91 in goaty uddersto 54.7 ± 0.37cm in bowl shaped udders, 46.1 ± 0.51 to 51.5± 0.73 cm in goaty and pendulous udders and 14.8 ± 0.34 to 15.7 ± 0.28 cm in goaty and globular udders, respectively. Positive and significant correlations were observed among all the udder measurements. The average lengths of left fore, right fore, left hind and right hind teats respectively (Ghosh and Prasad, 1998).

A great variation in the udder shapes among various buffalo breeds. (Sonwane, *et al*. 2002)

Morphological and physiological mammary properties affect the milk yield in cattle. But not much research was done on the udder and teat morphology and their influence on the milk yield in buffaloes. (Tilki, *et al.* 2005).

The wither height and hearth girth were 89.03±11.11 and 112.09±16.68 cm, respectively. The average body length was 119.85±16.96 cm and the chest width were 32.48±6.48 cm. The milk production per day was 1.33±0.4 litres, lactation length was

187.94±14.77 days. The mean age at first calving was 44±1.6 months. The productive and reproductive performances of native cattle of Sylhet district (Koirala, *et al*. 2011).

MP relationship with the varied morphometric measurements of udder in Nili- Ravi buffaloes. the chosen animals were in several parities. the varied morphometric parameters for udder measurements utilized in this study were udder depth (UD), udder width (UW), udder length (UL), teat length (TL) and teat diameter (TD). Body Condition Score (BCS), udder and teat shape also gave better understanding of milk production enhancement. 78% of Nili-Ravi animals were found to be having bowl shape udder followed by 19.5 theater in the round and a couple of.5% goaty shape udder. Similarly, 89% Nili-Ravi buffalo were observed for cylindrical shape teat followed by 7% funneland 4% bottle shape teats. Results showed significant (P<0.01) and direct correlation of UW with MP (0.573) and lactation number (0.341). Milk vein (MV) size also did correlate significantly (P<0.01) and positively with various parameters like weight (BW), lactation number (LN) and milk production (MP) TL and TD showed positive and significant (P<0.01) relationship with MP (0.315 and 0.494, respectively) (Abdullah, *et al*. 2013).

Worked out the connection between udder traits and peak milk yield, udder parameters of 203 Dehong crossbred dairy buffaloes were measured. the typical peak milk yield (kg/day) of buffaloes was 9.60 ± 2.73, the height milk yield was negatively correlated with udder depth (r=-0.28, P<0.01) and positively correlated with other mammary parameters (rear udder width, r=0.24, P<0.01; rear udder height r=0.32, P<0.01; udder length r=0.34, P<0.01; distance of rear udder r=0.20, P<0.01; distance of fore-rear teats r=0.40, P<0.01; left fore teat length r=0.25, P<0.01; left rear teat length r=0.29, P<0.01; right fore teat length r=0.22, P<0.01 and right rear teat length r=0.25, P<0.01). However, no significant correlation was found between peak milk yield and mammary vein and teat conformation. The results of the present study indicated that udder length has the best association with peak milk yield. thanks to udder parameters fitting a traditional distribution, it's valid to create evaluation procedures for the first selection of high yielding dairy buffaloes supported the experiences of Holstein cows scoring rules (Gu.e*t al. 2*018).

Twelve pregnant Nili-Ravi buffalo heifers were selected from the Buffalo Farm, CIRB, Nabha at 60 days before their expected date of calving. this study revealed that udder and teat measurements particularly UL, UW, LF and RRTL, RRTD, and distance between LF to LR teat were positively related to subsequent milk production. The UL and UW depicted positive and non-significant correlation with PY. Fore TLs showed direct correlation whereas TDs also as distances had a indirect correlation with DPY. Therefore, it is often concluded that udder and teat measurements in pregnant Nili-Ravi buffalo heifers are useful for assessing the next milk production performance (Chandrasekar, 2016).

Investigated milking herd of Gir cows of Anand district and therefore the animals were selected on random basis and categorized into different parities. The target of study was to review the morphometric characteristics of udder and teat and its association with milk yield. Udder length, width, depth and Teat Length and diameter were measured 1 hour before milking and after milking the number of milk was measured by weight balance. the typical length, width and depth of udder were 61.95 ± 1.20, 62.99 ± 1.17,and 25.62 ± 0.43 cm, respectively. the typical length of fore teats was found to be non- significantly longer than rear teats (9.26 cm VS 8.64 cm). The correlations between milk yield and udder width (0.194) and was found positive and significant ($P<0.05$) while correlations between milk yield and udder length (0.128) and udder depth (0.157) was non-significant (Modh, *et al.* 2017).

Morphological measurements to evaluated 29 Djafun (Red Mbororo) and 19 Aku (White Fulani) cows with parity and lactation stage varying between one and three. The udder height was the sole morphological characteristic significantly influenced ($p<0.05$), the udder heights and diameters and teat lengths and diameters, regardless of the udder portion (left or right), were consistently higher ($p<0.05$) within the White Fulani than within the Red Mbororo. The study showed that fore teat means lengths and diameters were significantly higher ($p<0.05$) compared to hind teats. Udder characteristics varied with breed, udder portion, lactation stage, and parity. Low positive but significant correlations were recorded during this study between milk production and height at the whither (RP =0.13) and thoracic circumference (RP=0.12). This study ascertained udder morphological characteristics values in local zebu cows and showed that udder size is robust and positively correlated to exploit yield. These findings are useful in genetic improvement programs of zebu cows (Mingoas, *et al*. 2017).

Dairy type Ongole cows' phenotypic characters like coat colour, stature, external appearance which are being poorly correlated to take advantage of production and reproduction. predicting the association between milk yield and morphometry forms a possible tool for selection of dairy type Ongole cattle. the data on morphometric characters and milk production was recorded on 211 elite lactating Ongole cows withinthe breeding tract of Andhra Pradesh and correlation and regression coefficients were estimated. The lactation milk yield and lactation length were positively ($P<0.01$) correlated with udder area, udder length, face length and cephalic index and negatively correlated with skin fold thickness and tail length. The regression coefficients of udderarea, skin fold thickness, face length and tail length for lactation milk yield and lactation length were found to be significant ($P<0.01$). this study summarized that the udder area, skin fold thickness, face length and tail length could even be given more weightage in selection of dairy type Ongole cows (Rao, *et al*. 2020).

2.3 Estimation of production performance from body morphometry

To seek out possibility of estimating live-weights from chest girth measurement. The connection between live-weight and chest girth measurement was investigated in each of the five-weight periods (90-173,173-257, 257-318, 318-379 and 379-440 kg). Chest girth measurement was highly correlated with live-weight. For the amount 90-173 kg a pooled regression of y on x (all sexes) satisfactorily represented within the relationship between chest girth and live-weight. For the periods 173-440 kg it had been necessary to use separate regression equations to explain the connection between chest girth and live-weight in Friesian beef cattle (Arpacik, 1974).

Linearly measurements traits exhibited higher heritability's than subjectively scored traits and more recently used (Thompson, *et al*. 1983).

The estimation of body weights using linear body measurements might be beneficial for purposes of treating animals in remote areas with the acceptable doses of medicine and vaccine (Nwosu, *et al*. 1985).

The body measurements, milk production, and weight data were collected on1898 lactations of 771 Holstein dairy cows. Weight and therefore the body measurements of heart girth, paunch girth, wither height, chest depth, pelvic length, pelvic width, and linear unit were used. Milk production variables were milk yield, fat yield, 4% FCM, fat percentage, and SNF percentage. Estimated feed efficiency was expressed as ratio of milk energy content to net energy feed intake. Phenotypic correlations indicated a high positive relation between estimated feed efficiency and milk (.61), fat (.62), and 4% FCM (.63) yields. Uniformly negative correlations were found between estimated feed efficiency and every one seven body measurements and weight. multiple correlation analyses were conducted on a primary, second, and overall parity basis, showing that cows with smaller heart girth and bigger paunch girth had significantly higher yields. Taller cows produced more milk than shorter cows. Cows lighter in weight yielded greater FCM as first-calf heifers and through all lactations (Sieber, 1986).

Holstein heifers and found relationships between weight, wither height, and various other body traits, including heart girth, linear unit, and hip width. weight and wither height were regressed on the opposite body traits. Regressions of weight including the linear, quadratic, and cubic effects of one experimental variable (heart girth, wither height, hip width, or linear unit) indicated that every measurement would be useful in predicting weight the regression of weight on heart girth had the very best R^2. followedby hip width. Similarly, regressions of wither height on heart girth, wither height, hip width, or body length, including linear, quadratic, and cubic effects, yielded (R^2>0.99). Regressions considering multiple traits as independent variables showed that the additionof a second body trait added little to the already high multiple correlations found with one variable (Heinrichs, *et al.* 1992).

The regression equations must be determined for all beef breeds for different country and region. (Caglar and Sekerden, 1993).

Heritability of the growth traits likely live weight of the mature animal and of the height at rump is 0.47-0.51 and 0.62-0.88, respectively, and there is a close (r = 0.80) genetic correlation between the two characteristics (Wilson, 1996).

Body measurements as selection criteria for growth trait such as weaning and yearling weight in cattle (Van Marle-Koestzer, *et al.* 2000).

Linear body measurement such as chest girth and body length can be used as indirect selection criteria for genetic improvement of meat production in cattle and for prediction of live weight, growth traits and carcass traits in cattle (Kahi and Hirooka, 2005).

The accuracy of prediction of body weight from body measurements in beef cattle and showed that prediction accuracy of body weight using metric body measurements in Brown Swiss and crossbred was higher than Holstein. However, the prediction accuracy of chest girth was higher than other traits for prediction of body weight. However, prediction accuracy of body weight using metric body measurements was decreased inbig size animals (Bozkurt, *et al.* 2006).

Heart girth round the hump had the very best coefficient of correlation with live weight (r = 0.83) compared with other body measurements. Grouping of knowledge consistent with live weight indicated that heart girth round the hump in medium weight) and heavy weight had the closest coefficient of correlation with live weight (r = 0.66 and 0.86, respectively). This gave more confidence within the use of the previousmeasurement in prediction of live weight of humped cattle. The multivariate analysis of live weight on heart girth round the hump was highly significant, and therefore the regression lines indicated that a linear relationship existed. The regression equations were also obtained to estimate the live weight of the "heavy", "medium" and "light" weight bulls. Animal weighing instruments are costly to get, heavy to move and wish technical maintenance which frequently is beyond the reach of smallholders (Abdeihadi and Babiker, 2009).

The accuracy of prediction of weight from body measurements. Wither height, chest girth, linear unit, chest depth, hip width and hip height measurements were obtained from Holstein, Brown Swiss and crossbred (n=140). Determination coefficients (R^2) of regression of y on x that included all body measurements were higher in Brown Swiss and crossbred than Holstein (92.2, 95.0 and 68.2 %, respectively). However, it had been found that chest girth was the simplest parameter of all for prediction of weight in Brown Swiss (R^2=91.1 %) and crossbred cattle (R^2=88.8 %) as compared to Holstein (R^2=60.7%). Consistent with these results, the weight estimation of Brown Swiss and crossbred cattle using the body measurements produced higher prediction accuracies than Holstein but chest girth was the simplest parameter to prediction of weight among all body measurements. However, the prediction accuracy of prediction of weight from body measurements and also chest girth was decreased when the animals frame size was increased (Ozakaya and Bozkurt, 2009).

The weight depend on various genetic and environmental factors; among the previous are body size and other morphometric traits which also are related to productivity Morphometric measurements are simple and straightforward to conduct, and permit estimating the animal's BW with reasonable accuracy However, these approaches are susceptible to errors within the localization of reference points and should be biased by anatomical distortion thanks to animal movement (Shankar and Mandal, 2010).

Twelve different age brackets to review morphometric characteristics of Red Chittagong cattle during a nucleus herd. The age groups were 1-6, 7-12, 13-18, 19-24, 25-30, 31-36, 37-42, 43-48, 49-54, 55-60, 61-66 and over 66 months. Different body measurements were wither height, hip height, linear unit, chest diameter, chest width, hip width, thurl width and rump length. needless to say, it had been found that each one measurement significantly increased ($P<0.01$) with the advancement aged. All the estimates reached in maximum level at the very best class (66+ months) during this study except chest width and rump length (61-66- and 43-48-months class, respectively). It also observed that each one the estimates were gradually increased with age, but the speed of increment varied for various measurements for various age groups (Hadiuzzaman,*et al*. 2010).

Predicted weight using some morphometric traits in Sudanese Kenana cattle. Traits used were height at withers (HTW), heart girth circumference (HGC), abdominal girth circumference (ABGC) and linear unit (BL). the general means of body weight (WT) and of the studied morphometric traits (HGC, ABGC, BL and HTW), respectively, were 281.814±3.527kg,150.641±0.447,190.542±1.177,87.963±0.512 and 119.023±0.497 cm.The phenotypic correlation coefficients for body weight (BW) with HGC. ABGC, BL and HTW during this experiment were 0.98, 0.78, 0.64 and 0.70 respectively. Prediction equations were obtained for males and females. R^2 was high within the three equations (0.97, 0.98 and 0.97 respectively). It had been concluded that prediction equations are often used efficiently to estimate live weight in Kenana cattle (Mussa, *et al.* 2011).

The determination of weight (BW) of an animal is important to calculate its feed requirements, monitor growth, determine breeding age, marketing weight and estimate its cash value (Erat, 2011).

Developed prediction equations for body weight using linear unit, heart girth and height at hip for Vrindavani cattle. The prediction of weight of bulls was found to be most accurate, Whereas the prediction of weight of female calves of up to 3-month age was least accurate using heart girth, linear unit and height at hip bone. Validation of regression of y on x indicated that the number of animals that weight are often predicted accurately also increase with increase in age of the animals (Singh, *et al*. 2011).

Predicted the weaning and yearling weight of Bali cattle using simple linear body measurement. the peak wither (HW), linear unit (BL) and heart girth (HG) were measured, whereas weaning (WW) and yearling weight (YW) decided in kilograms employing a weighing scale. Results of the coefficient of correlation showed that fireplace girth (HG) highly correlated with weaning and yearling weight were 0.847 and 0.871 respectively. In all, the peak at wither (HW) had the smallest amount coefficient of correlation were 0.328 and 0.782 on weaning and yearling weight respectively. Results of the stepwise regression showed that HG was an honest estimator of WW and YW of Bali cattle followed by HW and BL (Gunawan and Jakaria, 2011).

The heart girth had high coefficient of correlation with live weight ($r=0.94$, $p<0.01$). Grouping of knowledge consistent with sex indicated that heart girth and live weight had closest coefficient of correlation in both male and female ($r=0.9385$ and $r=0.9318$), respectively .The multivariate analysis of live weight on heart girth was highly significant ($R^2=0.88$, $p<0.01$), and therefore the regression lines indicated that linear relationship existed. the overall equation for prediction of live weight of the Tanzania shorthorn zebu cattle (TSHZ) cattle was as fallow: $Y= 4.55X - 409$ (±17.9), Where, Y= live weight (kg), X= heart girth(cm).This implies that the utilization of the guts girth measurements in prediction of live weight of TSHZ cattle is credible (Kashoma, *et al*. 2011).

Dynamics and relative body weight (BW) changes after parturition and their relationships to milk yield in Holstein (H) and Czech Fleckvieh (F) cows, and also the relationships between their BW changes in the first 8 weeks of lactation and reproductive performance. A total of 475 calving interval records (F: N = 132; H: N = 343) Whereas BW changes in F first-parity cows significantly ($P < 0.01$) differed from those detected in greater-parity cows during the major part of lactation, no such differences were manifested for H first-parity animals. The average BW change in weeks 1 to 8 was closely correlated with the BW change in the lactation week, with the lowest BW (NADIR) ($r > 0.83$, $P < 0.0001$) in both breeds. In H cows, the average BW change in weeks 1 to 8 and in NADIR significantly ($P < 0.01$) negatively correlated with the lengthof postpartum anestrus, days between parturition and conception, days between first service and conception, and calving interval ($P < 0.05$ and $P < 0.01$, respectively). In F cows, the only significant correlations were those with days between parturition and first service ($P < 0.05$) and ($P < 0.01$) respectively. It was concluded that BW changes postpartum might indicate reproduction problems particularly in H cows (Rehak, 2012).

The phenotypic relationship between body weight (kg) and body measurements (cm) for Sudanese bulls was explored. The results revealed the simplest linear correlation between weight and measurements was heart girth at hump (0.65, 0.66 and 0.73) respectively, for body weight groups. The obtained linear correlation coefficients were relatively highly accurate indicators of body weight. this means that body weight mightbe estimated accurately by body measurements in Sudanese Kenana Bulls (Mussa, *et al*. 2012).

Estimated weight of Holstein- Frisian cattle by using multiple correlation analysis. For building multiple correlation equation, the info was collected from Holstein- Frisian aged one to 5 years for bulls and measured weight, body length, height at withers, chest girth heart girth and age and located that there was a relationship between variable, weight, and experimental variable, chest depth and age, then estimated multiple correlation equation was weight = -265.65 + 2.86 heart girth + 41.82 age with adjusted coefficient of determination 0.956 (Mekparyup, *et al*. 2013).

The relationships between weight and body measurements and predict weight. All simple correlation coefficients between weight and body measurements of Friesian crossbred. the very best estimates were between the guts girths (HG) and body weights in Friesian crossbred. HG was the simplest predictor of weight of Friesian crossbred calves (Hedainy, *et al*. 2013).

The prediction of live weight (LW) of dairy cow in low- to medium-input systems in Senegal, supported measurements of heart girth (HG) and height at the withers (HW). a complete no. of 459 female dairy cow, mainly including indigenous Zebu and their crosses with Guzerat or cattle, were weighed (kg), and their HG (cm) and HW (cm) determined. as compared, farmers could only estimate the LW of a few quarters of their animals within 20% of their true LW. This weight prediction equation, when translated into a weigh band, could provide an easy and reliable method for cattle keepers to estimate the load of studied cattle breed types (Tebug, *et al.* 2018).

Investigated the milking herd of crossbred cows and reported that the typicallength, width and depth of udder were 58.24 ± 0.68 cm, 65.45 ± 0.70 cm, 23.06 ± 0.34 cm, respectively. All the measurements were found to extend in lactation number. the typical length of fore teats was found to be non-significantly longer than rear teats (6.07 cm VS 5.39 cm). The correlations between milk yield and various udder measurements viz., udder length (0.499), udder width (0.413) and udder depth (0.178) were found positive and significant. ($P<0.05$) to highly significant ($P<0.01$) (Patel, *et al.* 2016).

The diameter and height of the udder, length and diameter of the teat, and the milk yield of zebu cow strong positive correlations were found in the zebu cows. Udder morphologic characteristics varied significantly according to breed, lactation stage and parity, and height at whither There was significant correlations between udder diameter and height with milk yield. This study ascertained udder morphological characteristics values in local zebu cows, and showed that udder size is strong and positively correlatedto milk yield. The findings are useful in genetic improvement programs of zebu cow (Mingoas, *et al.* 2017).

A total of 70 lactating Murrah buffaloes maintained at Buffalo Farm, Lala Lajpat Rai University of Veterinary and Animal Science, Hisar and were randomly selected in a range from first to fifth parity. Data were collected and statically analyzed by Pearson's correlation method. This study can be helpful as a selection tool to enhance and evaluate the production potential by setting standards of Murrah buffalo breed. BW, abdominal growth, muzzle thickness, and STK were found key factors while selecting a dairy Murrah buffaloes (Dhillod, *et al.* 2017).

Undertaken a study to characterize live weights and morphometric properties of the Anatolian water buffaloes, and determine to their manure productions counting on live weights which compose basic data for waste management within the water ox enterprises consistent with different seasons. Morphometric properties like withers height, rump height, linear unit, chest width and chest circumference were measured by measuring stick, compass and measuring tape so as to work out body measurements. Electronic weighing scale was wont to measure live weight of the Anatolian water buffaloes. The cell method was implemented to work out manure production of the Anatolian water buffaloes. At the results of this study, withers height, rump height and chest circumference of the Anatolian water buffaloes were measured between 130–148 cm, 134–159 cm and 192–223 cm respectively. Also, the typical of withers height, withers height and chest circumference of the Anatolian water buffaloes were found as 137.1 cm, 146.1 cm and 207.3 cm respectively. The live weights varied between 427 and 596 kg (Kocaman, *et al*. 2017).

To find out connection between linear unit (BL), heights at withers (HW), girth circumference (GC), Height at rump (HR), abdominal circumference (AC) neck length (NL), neck circumference (NC) with live weights and price of animals. Duncan Multiple Range Test was used to separate them. It had been found that length of animal (LA), girth circumference (GC) and neck circumference (NC) had highly positive significant ($P<0.01$) influences on weight while heights at rump (HR) and abdominal circumference (AC) had significant ($P<0.05$) influences on weight of the animals. However, there was no significant ($P>0.05$) correlation between height at wither (HW) and neck length (NL) with weight. The R^2 value was 92.23%, all their F-ratios were highly significant at ($P<0.01$), confirming the importance of those variables on the costs of the animals (Babale, 2015).

Undertaken a study to develop linear regression equations for prediction of body weights of HF crossbred cattle based on body measurements. All the data were grouped age wise. The present study showed that heart girth measurement can be used to predict the live body weight HF crossbred cattle age groups wise (Patel, *et al.* 2019).

Conducted a study at Al-Qadisiyah province during 2019 by using 90 buffalo calves, birth weight (BW) and their body measurements that was body length (BL), wither height (WH), hip height (HH), chest girth (CG) and hip girth (HG) are recorded. the present study aims to predict birth weight from their body measurements at an equivalent age. The results obtained of the present study are often summarized as follow: the general mean of (BW) was 37.159 kg, and therefore the overall mean for body measurements at birth is: 76.778 (BL) 73.088 (WH), 91.470 (HH), 104.274 (CG) and 112.780 (HG) cm respectively. Finally, the regression equations might be wont to predict weights from body measurements at birth, easily, cheaply, rabidly and well accepted by the breeds when weighing scales aren't available within the commercial herds (Al- Khauzai, *et al.* 2020).

CHAPTER - 3

MATERIALS AND METHODS

The present research work entitled as "Prediction of production performance in Surti buffaloes from body morphometry" was conducted on 202 Surti buffaloes during January, 2021 to April, 2021.The investigation was undertaken to study morphometric traits, relationships between morphometric traits & production performance and to develop linear regression equations in different groups of Surti buffaloes. The materials utilized and the methodology adopted in the present research work has been described in following paragraphs:

3.1 SOURCE OF ANIMALS

The present investigation was conducted on 202 true type Surti buffaloes maintained at Livestock Research Station (LRS) under Navsari Agricultural University, Navsari, Gujarat.

3.2 LOCATION AND CLIMATIC CONDITION

Gujarat falls under western coast of India and Navsari is situated at 20.07′ to 20.95° North (Latitude) and 72°56′to 72.93° East (longitude) in the South Eastern part of Gujarat state in the coastal low land along Purna river within a few kilometers of theriver's delta, which is West of the city. It is flanked by the Arabian Sea on the West, the dang district to its East, Surat and Valsad districts in the North and South respectively.The climate of the area forms a part of tropical and coastal area. In general Monsoon (June to September) is moderately warm and extremely humid. Winter (November to February) is fairly cold and dry while summer (March to May) is moderately hot and humid. The average maximum and minimum temperatures was 40 °C (104 °F) and 17 °C (62.6 °F) respectively.

3.3 MANAGEMENTAL PRACTICES

All these experimental animals were subjected to standard routine management practices followed at Livestock Research Station, NAU, Navsari.

3.4 DURATION OF STUDY

The duration of present investigation was from January, 2021 to April, 2021. Preliminary observations on pilot basis were conducted to accustom the observational procedures. The same herds were again visited to collect data for recording.

3.5 RESEARCH METHODOLOGY

Apparently healthy Surti buffalo calves up to 3 months, calves from 3 months to one year of age, Surti buffaloes up to 1-3 years of age, adult buffaloes above 3 years of age were considered for this study. Following parameters were studied as per the age group mentioned below.

3.5.1 BODY MEASUREMENTS

Body measurements of these animals were recorded with utmost precision to the nearest centimetre scale with the help of measuring tape and wooden height measuring stick. Measurements were taken when animal stands comfortably and evenly on his/her feet on hard plain ground with its neck elevated to a position level with its back for maximum precision. The definition of various body measurements which was recorded in this study are as follows;

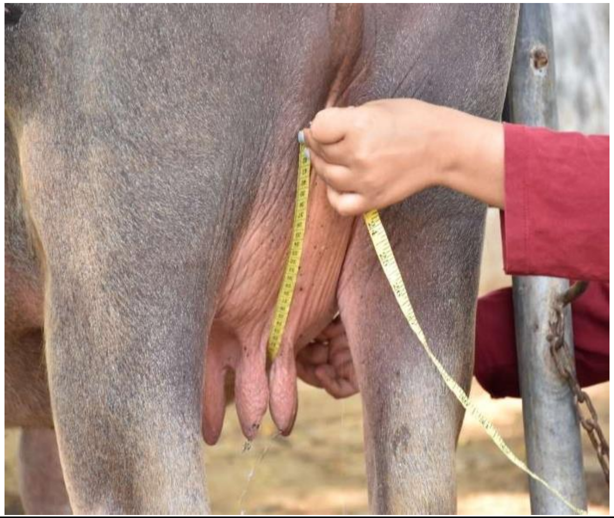
1) **Height at wither (HAW):** Vertical distance from ground to the highest point of the withers.
2) **Body Length (BDL):** Oblique distance between tip of the shoulder to the tip of the pin bone.
3) **Heart Girth (HG):** Circumference of chest just behind the point of elbow.
4) **Fore cannon bone girth (FCBG)**: Circumference of left cannon bone in the middle.
5) **Height at hipbone (HAHB)**: Vertical distance from ground to the highest point of hip bone.
6) **Height at pin bone (HAPB)**: Vertical distance from ground to the highest point of pin bone.
7) **Rump slope (RS):** Difference of height at hipbone and height at pin bone.
8) **Ischium Width of the Rump (ISWR)**: Measured between the two tips of the ischium (pinbones).
9) **Rump length (RL)**: Distance between the tip of the ilium and the tip of the ischium.
10) **Ilium width of the rump (ILWR)**: Measured between the two tips of the ilium (hipbones).
11) **Medium width at Rump (MDR)**: Measured between the trochanter (coxofemoral

articulation).

12) **Udder Length (UL)**: Distance between the rear and fore attachment of udder along the median line passing between the two halves of the udder (between left and right teats).
13) **Udder Width (UW)**: Distance between two lateral lines of attachment of the udder to the abdominal wall, under the flank along the median line passing between front and rear teats.
14) **Udder Depth (UD)**: By taking difference between the
    i) Distance from ground floor to the base of the udder
    ii) Distance from ground to the lowest point of the udder at the place of attachment of teats.
15) **Udder circumference (UC)**: By keeping a cloth tape around the base of udder.
16) **Teat Length (TL)**: Distance between bases of the teat to the tip of the teat.
17) **Teat Diameter (TD):** At the midpoint of the teat length by vernier caliper.

Measurement of Height at Wither	**Measurement of Heart Girth**
	
Measurement Of Fore Cannon Bone)	**Measurement Of Body Length**
	

Measurement of rump length	**Measurement of ischium width of rump**
	
Measurement of medium width of rump	**Measurement of ilium width of rump**
	

Measurement of udder depth	Measurement of udder length
	
Measurement of teat length	**Measurement of teat diameter**
	

3.5.2 PERFORMANCE TRAITS UNDER STUDY

Data pertaining to following primary traits of those animals which were present during the period of this study were collected from the available records for all animals, maintained at Livestock Research Station, NAU, Navsari.

3.5.2.1 BODY WEIGHTS

Available body weight of animals at different age was studied from growth/body weight register maintained at this farm**.** Further**,** live body weight of all animals under this study was recorded on the day their body morphometry was done.The constant weight was considered for recording. The weight of animals was measured in kilogram unit. Following data were recorded;

I. Live body weights of animals of 0-3 months of age group
II. Live body weights of animals of more than 3 months to 1 year of age
III. Live body weights of animals of more than 1 year to 3 years of age
IV. Live body weights of adult buffaloes (more than 3 years of age)
V. Birth weight
VI. Body weight at 3 months of age
VII. Body weight at 6 months of age
VIII. Body weight at 12 months of age
IX. Body weight at first calving

3.5.2.2 MILK PRODUCTION TRAITS

Available records of lactation milk yield (LMY), 305 or 300-days lactation milk yield (MY 305), Lactation length (LL) and available lactations were studied.

3.6 CLASSIFICATION OF DATA

For the analysis of the obtained biometry data animals were divided into five groups based upon their age on the date of measurement, which are as follows:

Group 1: Calves up to 0-3 months of age

Group 2: Calves of more than 3 months to 1 year of age

Group 3: Animals more than 1 year to 3 years of age

Group 4: Adult buffaloes (more than 3 years of age)

3.7 STATISTICAL ANALYSIS

Statistical analysis of obtained data was carried out by One-way ANOVA using PROC-GLM procedure using SAS (2004) 9.3 software for investigating effect of different groups on the traits under study. Duncan multiple range test (DMRT) was used for mean separation at 5% level of significance. Product moment correlations was carried out as per Snedecor and Chochran (1994). The morphometric traits which had significant correlations were used to predict the production traits.

CHAPTER - 4

RESULTS AND DISCUSSION

The present investigation entitled as "Prediction of production performance in Surti buffaloes from body morphometry" was carried out from January, 2021 to April, 2021 in Surti buffaloes maintained at Livestock Research Station, Navsari Agricultural University, Navsari, Gujarat. The objective of this study was to study of the body morphometry, find out relationship between body morphometry and production performance and to predict body weight from body morphometry in Surti buffaloes. The findings of the study have been presented and discussed under the following headings:

4.1 BODY MORPHOMETRY

4.2 BODY WEIGHTS AT DIFFERENT STAGES

4.3 RELATIONSHIP BETWEEN BODY MORPHOMETRIC TRAITS WITH PRODUCTION PARAMETERS

4.4 PREDICTION OF BODY WEIGHT FROM BODY MORPHOMETRY

4.1 BODY MORPHOMETRY

The overall least squares' mean for height at withers (HAW), heart girth (HG), body length (BDL), fore cannon bone girth (FCBG), height at hipbone (HAHB), height at pin bone (HAPB), rump slop (RS), ischium width of rump (ISWR), rump length (RL), illium width of rump (ILWR) and medium width of rump (MDWR) was found to be 106.77±1.36, 148.29±2.89, 121.52±2.30, 18.17±0.25, 105.17±1.18, 93.54±0.92, 11.61±0.33, 11.63±0.38, 39.79±0.72, 37.59±0.95 and 77.7±2.31 cm, respectively (Table 4.1).

Perusal of data revealed that the least squares' mean for HAW was 73.54±1.00, 83.75±0.83, 111.99±1.55, 122.72±0.35 cm for group 1 (0-3 months), 2 (03 months -1 year), 3 (1year- 1st calving) and 4 (adult lactating) animals, respectively (Table 4.1). We further observed that HAW values differed significantly ($P<0.05$) among all age groups and it was lowest for group 1 animals (73.54±1.00 cm) and highest for group 4 animals (122.72±0.35 cm).

We observed that least squares' mean for HG was found to be 80.25±1.01, 99.59±1.50, 153.87±2.73 and 184.13±0.96 cm for group 1, 2, 3 and 4 animals, respectively. We further observed that HG values differed significantly (P<0.05) among all age groups and it was lowest for group 1 animals (80.25±1.01 cm) and highest for group 4 animals (184±0.96 cm) as depicted in table 4.1.

We found that least squares' mean for BDL for group 1,2, 3, 4 animals was 69.25±0.91, 83.6±1.23, 126.24±2.17 and 149.17±1.39 cm, respectively (Table 4.1). We further observed that BDL values differed significantly (P<0.05) among all age groups and it was lowest for group 1 animals (69.25±0.91) and highest value in group 4 animals (149.17±1.39 cm).

We observed that least squares' means for FCBG was 12.88±0.24,13.82±0.18, 19.21±0.23 and 21.02±0.17 cm for group 1, 2, 3, and 4 animals, respectively.We further observed that BDL values differed significantly (P<0.05) among all age groups and it was lowest for group 1 animals (12.88±0.24 cm) and highest in group 4 animals (21.02±0.17 cm) as depicted in table 4.1.

Perusal of the data revealed that the least squares' mean for HAHB was found to be 74.58±1.08, 85.86±0.85, 110.00±1.04 and 118.74±0.38 cm in group 1, 2, 3, 4 animals, respectively (Table 4.1). We further observed that HAHB values differed significantly (P<0.05) among all age groups and it was lowest for group 1 animals (74.58±1.08) and highest for group 4 animals (118.74±0.38 cm).

We observed that least squares' means for HAPB for group 1, 2, 3, 4 animals was found to be 67.04±1.19, 79.24±0.74,98.39±0.87 and 103.55±0.32 cm, respectively. We further observed that HAPB values differed significantly (P<0.05) among all age groups and it was lowest for group 1 animals (67.04±1.19 cm) and highest for group 4 animals (103.55±0.32 cm) as depicted in table 4.1.

Least squares' mean for RS in group 1, 2, 3, 4 animals was 7.54±0.64, 6.63±0.28, 11.61±0.45 and 15.12±0.37cm, respectively (Table 4.1). We further observed that RS values differed significantly (P<0.05) among all age groups Group 2 animals (6.63±0.28) had lower value with RS than group 1 animals (7.54±0.64) and highest value in group 4 animals (15.12±0.37cm).

Assess of the data revealed that least squares' mean for ISWR was found to be 5.52±0.25, 7.84±0.99, 11.35±0.43 and 14.85±0.21 cm for group 1, 2, 3, 4 animals, respectively. We further observed that ISWR values differed significantly (P<0.05) among all age groups and it was lowest for group 1 animals (5.52±0.25 cm) and highest for group 4 animals (14.85±0.21 cm) as depicted in table 4.1.

Examination of the data revealed that least squares' mean for RL for group 1, 2, 3, 4 of animals was 24.47±0.36, 27.26±0.39, 41.19±0.64 and 48.72±0.32 cm, respectively (Table 4.1). We further observed that RL values differed significantly (P<0.05) among all age groups and it was lowest for group 1 animals (24.47±0.36, cm) and highest for group 4 animals (48.72±0.32 cm).

Glance of the data shown that least squares' mean for ILWR for group 1, 2, 3,4 animals was found to be 16.70±0.40, 21.28±0.39, 39.31±1.01, and 49.41±0.34 cm, respectively. We further observed that ILWR values differed significantly (P<0.05) among all age groups and it was lowest for group 1 animals (16.70±0.40, cm) and highest for group 4 animals (49.41±0.34 cm) as depicted in table 4.1.

We observed that least squares' mean for MDWR in group 1, 2, 3, 4 animals was found to be 41.77±3.75, 34.12±1.41,85.06±1.18 and 105.24±1.17 cm, respectively We further observed that MDWR values differed significantly (P<0.05) among all age groups. Group 1 animals (34.12±1.41) had lowest value and group 4 (105.24±1.17 cm) animals had highest value (Table 4.1).

All of the above-mentioned body measurements of Surti buffaloes shown in table 4.1 are related with growth performance of the animal which showed slow and gradual increasing trend in the body mass. Hence, all of these parameters had different means which differed significantly which was due to the age difference among them and consequently had different body masses.

According to ICAR network project on survey and characterization of Surti buffalo breed in Gujarat (2006), height at withers in birth to one-year age group, 1 to 3 years and adult buffaloes was 75.02 ± 0.95, 105.91 ± 0.74 and 129.85 ± 0.56 cm respectively. The body length in birth to one-year age group, heifers from one to three and half years of age and adult buffaloes was 64.19 ± 0.63 ,117.93 ± 0.77 and 148.58 ± 0.55 cm respectively. HG of Surti buffaloes in birth to one-year age group, heifers from one to three and half year of age and adult buffaloes was 95.45 ± 0.86, 129.81 ± 1.12 and 171.06 ± 1.08 cm, respectively.

Table 4.1: Least squares' means and standard error (LSM±SE) of different body morphometry: height at wither (HAW), heart girth (HG), body length (BDL), fore cannon bone girth (FCBG), height at hip bone (HAHB), height at pin bone (HAPB), rump slope (RS), ischium width of the rump (ISWR), rump length (RL), illium width of the rump (ILWR) and medium width of the rump(MDWR) for Surti buffaloes in different age groups.

Groups	HAW	HG	BDL	FCBG	HAHB	HAPB	RS	ISWR	RL	ILWR	MDWR
1 (0-3 months)	73.54^{d}± 1.00 (13)	80.25^{d}± 1.01 (13)	69.25^{d}± 0.91 (13)	12.88^{d}± 0.24 (13)	74.58^{d}± 1.08 (13)	67.04^{d}± 1.19 (13)	7.54^{c}± 0.64 (13)	5.52^{d}± 0.25 (13)	24.47^{d}± 0.36 (13)	16.70^{d}± 0.40 (13)	34.12^{d}± 1.41 (13)
2 (03 months - 1 year)	83.75^{c}± 0.83 (55)	99.59^{c}± 1.50 (55)	83.6^{c}± 1.23 (55)	13.82^{c}± 0.18 (55)	85.86^{c}± 0.85 (55)	79.24^{c}± 0.74 (55)	6.63^{c}± 0.28 (55)	7.84^{c}± 0.99 (55)	27.26^{c}± 0.39 (55)	21.28^{c}± 0.39 (55)	41.77^{c}± 3.75 (55)
3 (1 year- 1st calving)	111.99^{b}± 1.55 (41)	153.87^{b}± 2.73 (41)	126.24^{b}± 2.17 (41)	19.21^{b}± 0.23 (41)	110.00^{b}± 1.04 (41)	98.39^{b}± 0.87 (41)	11.61^{b}± 0.45 (41)	11.35^{b}± 0.43 (41)	41.19^{b}± 0.64 (41)	39.31^{b}± 1.01 (41)	85.06^{b}± 1.18 (41)
4 (adult lactating)	122.72^{a}± 0.35 (93)	184.13^{a}± 0.96 (93)	149.17^{a}± 1.39 (93)	21.02^{a}± 0.17 (93)	118.74^{a}± 0.38 (93)	103.55^{a}± 0.32 (93)	15.12^{a}± 0.37 (93)	14.85^{a}± 0.21 (93)	48.72^{a}± 0.32 (93)	49.41^{a}± 0.34 (93)	105.24^{a}± 1.17 (93)
Overall	106.77± 1.36 (202)	148.29± 2.89 (202)	121.52± 2.30 (202)	18.17± 0.25 (202)	105.17± 1.18 (202)	93.54± 0.92 (202)	11.61± 0.33 (202)	11.63± 0.38 (202)	39.79±0. 72 (202)	37.59± 0.95 (201)	77.7± 2.31 (202)
LSM showing different superscripts in lower case letters in a column differ significantly at P<0.05 Figures in parentheses are the number of animals used to derive LSM											

4.2 BODY WEIGHT AT DIFFERENT STAGES

The overall least squares' mean for body weight (BW) of Surti buffaloes at birth (BWT), 3 (WT3), 6 (WT6), 12 (WT12) months of age and weight at 1st calving was found to be 25.76±0.25, 52.96±0.63, 80.71±1.15, 137.41±1.91 and 366.781±7.45 kg, respectively. The live body weight of group 1, 2, 3 and 4 animals was found to be 50.031±2.12, 90.845±3.28, 238.077±10.43 and 408.528±5.93 kg, respectively (Table 4.2). We further observed that body weight values differed significantly (P<0.05) among all the age group and it was highest for the group 4 (408.528±5.93) and the lowest value in group 1 (50.031±2.12).

Above mentioned body weights of Surti buffaloes represent body weights at different stages of their life. Live body weights recorded in this study were almost corresponding to the body weights recorded at similar stages of their life. According to ICAR network project on survey and characterization of Surti buffalo breed in Gujarat (2006), the average body weight of buffaloes was 401.08 ± 1.52 kg. The males were found to be heavier than females in all groups. Pandya *et al*., (2015) reported birth weight, weight at 3, 6 and 12 months of age was 24.60±0.18, 49.93±0.36, 72.08±0.54 and 129.75±0.94 kg, respectively.

Table 4.2 Least squares' means and standard error (LSM±SE) of body weight of Surti buffaloes at birth (BWT), 3 (WT3), 6 (WT6), 12 (WT12) months of age, weight at 1st calving, and live body weight of group 1, 2, 3 and 4 animals.

Body weights (kg)	N	Overall (LSM±SE)	Live body weights (kg)	N	LSM±SE
BWT	195	25.76±0.25	Group 1	194	50.031±2.12
WT3	191	52.96±0.63	Group 2	194	90.845±3.28
WT6	157	80.71±1.15	Group 3	194	238.077±10.43
WT12	134	137.41±1.91	Group 4	194	408.528±5.93
First Calving	64	366.781±7.45			
Figures in parentheses are the number of animals used to derive LSM					

4.3 Relationship between body morphometric traits with production parameters

4.3.1 Relationship between live body weight and body measurements in group 1 of Surti buffaloes

A positive and significant (P<0.05) correlation was found between body weight and HAW (0.586*) and BDL (0.659*) in this group of animals. Further, we found positive but non-significant correlation between body weight and HG (0.459), HAHB (0.452) and HAPB (0.454) (Table 4.3.1). The FCBG (-0.349) was found to be negative and non-significantly correlated with body weight in this group of animals. The correlation between HG and HAW, HAHB and HAPB was positive and significant (P<0.01/0.05) with r value 0.865, 0.812 and 0.601, respectively. The correlation coefficient between HG and BDL, FCBG was positive and non-significant.

Table 4.3.1 Correlation coefficients between body weight and height at withers (HAW), heart girth (HG), body length (BDL), fore cannon bone girth (FCBG), height at hip bone (HAHB) and height at pin bone (HAPB) in group 1 Surti buffaloes.

Age Group 1	Body weight	HG	HAW	BDL	FCBG	HAHB	HAPB
HG	0.459 (13)	1					
HAW	0.586* (13)	0.865** (13)	1				
BDL	0.659* (13)	0.339 (13)	0.468 (13)	1			
FCBG	-0.349 (13)	0.002 (13)	-0.351 (13)	-0.295 (13)	1		
HAHB	0.452 (13)	0.810** (13)	0.940** (13)	0.321 (13)	-0.297 (13)	1	
HAPB	0.454 (13)	0.601* (13)	0.836** (13)	0.381 (13)	-0.458 (13)	0.846** (13)	1

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level
Figure in parentheses is the number of observations in each trait

4.3.2 Relationship between live body weight and body measurements in **group 2 of Surti buffaloes**

A positive and significant (P<0.01) correlation was found between body weight and HG, HAW, BDL, FCBG, HAHB and HAPB and it was found to be 0.953, 0.904, 0.869, 0.758, 0.876 and 0.840, respectively. All morphometric traits were positive and significantly (P<0.01) correlated with each other. Further, we observed highest and significant correlation between body weight and HG (r=0.953) and lowest correlation between body weight and FCBG (r=0.758) as shown in table 4.3.2.

Table 4.3.2 Correlation coefficient between body weight and height at withers (HAW), heart girth (HG), body length (BDL), fore cannon bone girth (FCBG), height at hip bone (HAHB) and height at pin bone (HAPB) in group 2 Surti buffaloes.

AGE GROUP 2	Body weight	HG	HAW	BDL	FCBG	HAHB	HAPB
HG	0.953** (55)	1					
HAW	0.904** (55)	0.920** (55)	1				
BDL	0.869** (55)	0.899** (55)	0.864** (55)	1			
FCBG	0.758** (55)	0762** (55)	0.785** (55)	0.729** (55)	1		
HAHB	0.876** (55)	0.902** (55)	0.975** (55)	0.847** (55)	0.726** (55)	1	
HAPB	0.840** (55)	0.858** (55)	0.924** (55)	0.806** (55)	0.667** (55)	0.667** (55)	1
**Correlation is significant at the 0.01 level Figure in parentheses is the number of observations in each trait							

4.3.3 Relationship between live body weight and body measurements in **group 3 of Surti buffaloes**

Correlation coefficient between body weight and HAW, HG, BDL, HAHB and HAPB was found to be 0.853, 0.621, 0.546, 0.810 and 0.768 respectively, results found were positive and significant ($p<0.01$) except correlation between body weight and FCBG (0.065) was positive and non-significant in group 3 of Surti buffaloes. Correlation among all morphometric traits was positive and significant ($P<0.01$) as depicted in table 4.3.3. Further, we detected highest correlation between BW and HAW (r= 0.853) and lowest correlation between BW and FCBG (r=0.065).

Table 4.3.3 Correlation coefficient Between Body Weight age group 3 (BD) and Body Measurements; height at wither (HAW), heart girth (HG), body length(BDL), fore cannon bone girth (FCBG), height at hip bone (HAHB) and height at pin bone (HAPB)

Age group 3	Body. wt.	HG	HAW	BDL	FCBG	HAHB	HAPB
HG	0.853** (39)	1					
HAW	0.621** (39)	0.698** (40)	1				
BDL	0.546** (39)	0.734** (40)	0.577** (40)	1			
FCBG	0.065 (39)	0.067 (40)	0.370* (40)	0.069 (40)	1		
HAHB	0.810** (39)	0.851** (40)	0.703** (40)	0.657** (40)	0.145 (40)	1	
HAPB	0.768** (39)	0.844** (40)	0.681** (40)	0.672** (40)	0.126 (40)	0.903** (40)	1

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level
Figure in parentheses is the number of observations in each trait

4.3.4. Relationship between live body weight and body measurements in **group 4 of Surti buffaloes**

We found positive and significant (P<0.01/0.05) correlation between body weight and HG, BDL, HAW, FCBG, HAHB, HAPB and it was 0.452, 0.544, 0.222, 0.214, 0.021 and 0.111, respectively. Correlation between all morphometric traits was positive and significant (P<0.01). Additionally, we observed highest and significant correlation between BW and BDL (r=0.544) and lowest correlation between BW and HAHB (r=0.021) as represented in table 4.3.4. The HG and HAW (r=0.473) was significant and most correlated traits among all the measurements. Positive and significant (p<0.01/0.05) correlation was observed between HAW and BDL, HAHB, HAPB and FCBG.

Table 4.3.4 Correlation coefficient Between Body Weight age group 4 (BD) and Body Measurements; height at wither (HAW), heart girth (HG), body length(BDL), fore cannon bone girth (FCBG), height at hip bone (HAHB) and height at pin bone (HAPB)

AGE GROUP 4	Body. wt.	HG	HAW	BDL	FCBG	HAHB	HAPB
HG	0.452** (87)	1					
HAW	0.222* (87)	0.473** (92)	1				
BDL	0.544** (87)	0.457** (92)	0.362** (92)	1			
FCBG	0.214* (87)	0.400** (92)	0.231* (92)	0.211** (92)	1		
HAHB	0.021 (87)	0.317** (92)	0.661** (92)	0.141 (92)	0.131 (92)	1	
HAPB	0.111 (87)	0.339** (92)	0.426** (92)	0.242* (92)	0.037 (92)	0.450** (92)	1

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level
Figure in parentheses is the number of observations in each trait

4.3.5 Relationship between live body weight and body measurements in Surti buffaloes irrespective of age group

A positive and significant (p<0.01) correlation was found between BW and HAW (r=922), HG (r=0.957), BDL (r=0.943), FCBG (r=0.871), HAHB (r=0.914), HAPB (r=0.890), RS (r=0.745), ISWR (r=0.645), RL (r=0.940), ILWR (r=0.946) and MDWR (r=0.860) as depicted in table 4.3.5 Correlations among all morphometric traits were mostly positive and significant (P<0.01/0.05). Further, we observed highest and significant correlation between body weight and HG (r=0.957) and lowest correlation between body weight and ISWR (r=0.645) as depicted in table 4.3.5.

The HAW and all body measurement were positive and significantly (P<0.01) correlated. Highest significant between HAW and HAHB (r=0.978) and lowest significant between HAW and ISWR (r=0.627) similarly, highest and significant correlation was observed between BDL and RL (r=0.963) and lowest between BDL and ISWR (r=0.624) as depicted in table 4.3.5

According to Sethi *et al.*, (1996), in buffaloes up to 24 months of age, body height is the most significant variable for predicting BW, whereas in heifers >24 months and in adult buffaloes HG is the most significant variable.

The result of present study is collaborated with Dhangar and Patel (1990) who observed the highest correlation between BW and BL (0.76) followed by HG (0.74) in Jersey and Kankrej half bred calves in 4-6 M of age. Bhagat *et al.,* (2016) observed correlation between BW and BL (0.810) in 0-6 M of female calves of Sahiwal cattle. Followed by Patel j. Ashwani *et al.*, (2019) found that highest correlation between BW and HG (0.975) followed by HAW (0.963) in HF crossbred cattle group 1 (0-6 M) of age group.

Bhagat *et al*, (2016) observed the highest correlation between body weight and HG (0.976 and 0.875) in 6-12 M of age in male Sahiwal calves respectively.and also, similar finding was reported by Paul and Das (2012) the highest correlation between body weight and HG (0.908) in 6-12 M Nili Ravi buffalo calves.

Patel j. Ashwani *et al*., (2019) obtain the nearly correlation between BW in age group 4 (1-2-year age) and BL (0.733) in HF crossbred cattle. and Sahu *et al.*, (2017) obtained the highest correlation between BW and BDL (0.76) in young Sahiwal cattle that is nearly similar to present study where correlation between BW and BL (0.544) in group 4 (> 1year age) in Surti buffaloes.

Several researchers worked on different breed reported similar findings Soysal and Konak (1992), Nesamvuni*et al.*, (2000), Varde *et al.,* (2002). Francis *et al*., (2002), Bagui and Valdez, (2007), Abdedelhadi and Babiker, (2009) indicated body weight was highly correlated with hearth girth. Van Marle-Koster*et al.* (2000) described body measurements as selection criteria for growth in cattle. Gilbert *et al.* (1993) reported that there is close correlation between body weight and body measurements. Brody, (1945) reported that among all linear measurements heart girth was found to be highly correlated with live weight in growing cattle.

We also observed highest and significant correlation between adult body weight and HG (r=0.957) of Surti buffaloes. Similar, finding was reported by Msangi *et al*. (1999) reported that heart girth (HG) can be used with great accuracy for estimating the BW of all classes of dairy cattle, and for various buffalo breeds a high correlation between, HG and BW was also reported Other authors reported a good relationship between the body condition score (BCS) and BW of cattle (Nesamvuni *et al.*, 2000; Abdelhadi and Babiker, 2009).

Table 4.3.5 Correlation coefficient Between Body Weight (BD) and Body Measurements; height at wither (HAW), heart girth (HG), body length (BDL), fore cannon bone girth (FCBG), height at hip bone (HAHB), height at pin bone (HAPB), rump slope (RS), ischiumwidth of the rump (ISWR), rump length (RL), illium width of the rump (ILWR) and medium width of the rump (MDWR)

	BD.WT	HAW	HG	BDL	FCBG	HAHB	HAPB	RS	ISWR	RL	ILWR	MDWR
HAW	0.922** (194)	1										
HG	0.957** (194)	0.970** (200)	1									
BDL	0.943** (194)	0.952** (200)	0.967** (200)	1								
FCBG	0.871**(194)	0.915**(200)	0.915** (200)	0.902** (200)	1							
HAHB	0.914**(194)	0.978**(200)	0.969** (200)	0.947** (200)	0.902** (200)	1						
HAPB	0.890**(194)	0.960**(200)	0.952** (200)	0.934** (200)	0.877** (200)	0.976** (200)	1					
RS	0.745**(194)	0.764**(200)	0.756** (200)	0.726** (200)	0.732** (200)	0.796** (200)	0.649** (200)	1				
ISWR	0.645**(194)	0.627**(200)	0.642** (200)	0.624** (200)	0.557** (200)	0.636** (200)	0.618** (200)	0.518** (200)	1			
RL	0.940**(194)	0.952**(200)	0.966** (200)	0.963** (200)	0.913** (200)	0.949** (200)	0.926** (200)	0.756** (200)	0.629** (200)	1		
ILWR	0.946**(194)	0.957**(200)	0.974** (200)	0.958** (200)	0.920** (200)	0.950** (200)	0.933** (200)	0.745** (200)	0.647** (200)	0.969** (200)	1	
MDWR	0.860**(194)	0.887**(200)	0.883** (200)	0.907** (200)	0.872** (200)	0.842** (200)	0.730** (200)	0.563** (200)	0.900** (200)	0.907** (200)	0.907** (200)	1

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level
Figure in parentheses is the number of observations in each trait

Khan *et al.,* (1978) they reported that among the various morphometric variables, HG was most closely correlated with BW in all three age groups, followed by BL, which agrees with previous findings (Singh *et al.,* 1994; Abdelhadi and Babiker, 2009). A positive correlation was also recorded between BW and the age of buffaloes. Indeed, BW, BL and all other body measurements increased with increased in animal age (Naz and Ahmad, 2006).

Similarly, Satyanarayana and Murty (1981) reported chest depth to be the best predictor of BW. Body condition score was positively and significantly correlated with BW of Nili-Ravi buffaloes in the present study, which agrees with various authors (Msangi *et al.,* 1999; Nesamvuni *et al.,* 2000; Abdelhadi and Babiker, 2009)

Findings of present study revealed that heart girth is a most correlated with the BW among all the body morphometric traits similarly, HG was found to be the better predictor of weight having the lower standard deviation residual. This concurred with other studies from Buvanendran *et al.* (1980), Johari *et al.* (2009), Wilson *et al.* (1997) and Yan *et al.* (2009).

4.3.6 Relationship between weight at 1st calving and body measurements in Surti buffaloes

We found positive and significant ($P<0.01/0.05$) correlation between weight at 1stcalving and BDL, RL, HAW, HG, ISWR and MDWR and it was found to be 0.457, 0.352, 0.309, 0.270, 0.311 and 0.236, respectively. We also observed positive but non-significant correlation between weight at 1st calving and FCBG (r=0.220), HAHB (r=0.154), RS (r=0.094) ILWR (r=0.140). Further we noticed that body weight at 1st calving and BDL (r=0.457) was highly significantly correlated among the all-body measurements. Lowest correlation was observed between weight at 1st calving and RS (r=0.044).

Table 4.3.6 Correlation coefficient Between 1st calving Weight and Body Measurements; height at wither (HAW), heart girth (HG), body length (BDL), fore cannon bone girth (FCBG), height at hip bone (HAHB) and height at pin bone (HAPB) rump slope (RS), ischium width of the rump (ISWR), rump length (RL), illium width of the rump (ILWR) and medium width of the rump (MDWR).

	1st calving	**HAW**	**HG**	**BDL**	**FCBG**	**HAHB**	**HAPB**	**RS**	**ISWR**	**RL**	**ILWR**	**MDWR**
HAW	0.309* (64)	1										
HG	0.270* (64))	0.970** (200)	1									
BDL	0.457** (64)	0.952** (200)	0.967** (200)	1								
FCBG	0.220 (64)	0.915** (200)	0.915** (200)	0.902** (200)	1							
HAHB	0.154 (64)	0.978** (200)	0.969** (200)	0.947** (200)	0.902** (200)	1						
HAPB	0.094 (64)	0.960** (200)	0.952** (200)	0.934** (200)	0.877** (200)	0.976** (200)	1					
RS	0.044 (64)	0.764** (200)	0.756** (200)	0.726** (200)	0.732** (200)	0.796** (200)	0.649** (200)	1				
ISWR	0.311* (64)	0.627** (200)	0.642** (200)	0.624** (200)	0.557** (200)	0.636** (200)	0.618** (200)	0.518** (200)	1			
RL	0.352** (64)	0.952** (200)	0.966** (200)	0.963** (200)	0.913** (200)	0.949** (200)	0.926** (200)	0.756** (200)	0.629** (200)	1		
ILWR	0.140 (64)	0.957** (200)	0.974** (200)	0.958** (200)	0.920** (200)	0.950** (200)	0.933** (200)	0.745** (200)	0.647** (200)	0.969** (200)	1	
MDWR	0.236* (64)	0.887** (200)	0.883** (200)	0.907** (200)	0.872** (200)	0.842** (200)	0.730** (200)	0.563** (200)	0.900** (200)	0.907** (200)	0.907** (200)	1

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level, Figure in parentheses is the number of observations in each trait

4.3.7 Relationship between body measurements and milk yield (MY) in Surti buffaloes

Among all body measurements, milk yield was positively and significantly (P<0.05) correlated with BDL (r=0.238). The correlation between MY and HAW, HG, FCBG and HAHB was 0.177, 0.198, 0.219 and 0.008 respectively, however these were statistically non-significant as presented in table 4.3.7

Similar finding was reported by Dhillon *et al.* (2017) in Murrah buffaloes and observed that buffaloes had positive significant (P<0.01) correlation with MY andBDL. Naz *et al*., (2006) also found relationship of BL with heart girth, pin to PBD and hook to hook bone distance was highly positive and significant and same with milk production.

Some author's reported different results than present studies may be due to difference of breeds, species and management. Lin *et al.* (1987) they found the correlations were greater than the genetic associations of yield traits with heart girth, withers height, and body length. Thus, rump length appears to possess a better predictive value of a heifer's production performance than the other three body dimensions (girth, height, and length), Rump length, as an indicator of size, may be useful as an additional trait to improve response to selection for milk yield. Sieber *et al.,* (1998) reported a positive correlation (P<.001) in the range from (.18 to .29) between milk yield, fat yield, and FCM and all body measurements and body weights. Correlation coefficients for % fat and body measurements were small (.04 to .09) and not significant for skeletal traits (wither height, chest depth, and body length).

Table 4.3.7 Correlation coefficient Between Milk Yield with Body Measurements; height at wither (HAW), heart girth (HG), body length (BDL) and fore cannon bone girth (FCBG).

	MY.	HAW	HG	BDL	FCBG
HAW	0.177 (68)	1			
HG	0.198 (68)	0.486**(70)	1		
BDL	0.238*(68)	0.307**(70)	0.224* (70)	1	
FCBG	0.219 (68)	0.228* (70)	0.438**(70)	0.002**(70)	1
HAHB	0.008 (68)	0.552**(70)	0.255* (70)	0.338**(70)	0.095 (70)

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level
Figure in parentheses is the number of observations in each trait

4.3.8 Relationship between milk yield (MY) and udder and teat measurements in Surti buffaloes

We observed a low, positive (r=0.096) and significant (P≤0.05) correlation between milk yield (MY) and udder length (UL) however, correlation between milk yield (MY) and teat diameter (TD) was positive (r=0.415) and significant (p≤0.01). Correlation between MY and udder circumference (UC), teat length average (TLA) wasfound to be 0.118 and 0.166 and these values were statistically non-significant. We also found very weak, negative and non-significant correlation between MY and udder width (r=-0.089), udder depth (r=-0.001). Further, we observed highest and significant correlation between MY and TD (r=0.415) and lowest correlation between MY and UD (r =0.001) as presented in table 4.3.8

The UL was significantly (P<0.01) correlated with UD, UC, UW and TL and valuewas 0.285, 0.361, 0.641 and 0.557, respectively. It also observed that UD was positively and significantly (P≤0.01) correlated with UC, UW, TL ad its values was 0.307, 0.285 and 0.418, respectively. TL and TD (r=0.363) had positive and significant (P<0.01) correlation between them.

Similar findings were reported by Prasad *et al.*, (2010) obtain the Positive and significant correlations were observed among all the udder measurements in Nili-Ravi buffaloes. Patel *et al.*, (2016) found that udder length was significantly (p<0.05) correlated only with teat diameter trait. The correlations between milk yield and various udder measurements viz., udder length (0.499), udder width (0.413) and udder depth (0.178) were found positive and significant (P<0.05) to highly significant (P<0.01). These findings reflected that all the three udder measurements should be the important criteria for selection of dairy cows as the udder length, width and depth decides the capacity of udder which reflects the milk yield. Ghosh and Prasad (1998) also found a positive and significant (P<0.01) association between udder length, width and depth with test day milk yield in Jersey × Red Sindhi crossbred cows.

Strong correlation of milk yield with udder length (0.49), width (0.44) and depth (0.52) in Holdeo crossbred cows Waghmore *et al.,* (2000) Similar findings has been reported in Vrindavani cattle Singh *et al*., (2009) Deng *et al.,* (2012) Significant (p<0.05) correlation of udder length (0.64) with milk yield in Kenana × Friesiancrossbred cows.

In present study, all the teat measurements showed a non-significant relation with milk yield except the udder length and teat diameter which had positive and significant (P<0.05) association with milk yield. Some author's reported different results than present study may be due to difference of breeds, species and management Gupta *et al*. (1991) while working on Karan-Fries cows, reported that an all four teats diameter were almost same and the correlation coefficient of teat length and diameter with milk production was not encouraging. Tilki *et al*., (2005) reported mean values before milking for front and rear teat length, front and rear teat diameter, front and rear teat udder height, distance between front teats, distance between rearteats, distance between front and rear teats and mammary type score at general lactation were 59.45 and 49.72 mm, 22.14 and 21.53 mm, 47.96 and 47.59 cm, 12.29 cm, 7.76 cm, 9.58 cm and 23.65, respectively. In conclusion, teat and udder measurements and mammary type scores significantly affected milk yield. However, Modh *et al*., ((2017) reported correlations between milk yield and udder width (0.194) and was found positive and significant (P<0.05) while correlations between milk yield and udder length (0.128) and udder depth (0.157) was non-significant.

Table 4.3.8 Correlation coefficient among milk yield with udder measurements: udder length (UL), udder depth (UD), udder circumference (UC), udder width (UW), teat length (TL) and teat diameter (TD)

	MY	**UL**	**UD**	**UC**	**UW**	**TLA**	**TDA**
UL	0.096* (68)	1					
UD	-0.001 (68)	0.285* (70)	1				
UC	0.118 (68)	0.361** (70)	0.307** (70)	1			
UW	-0.089 (68)	0.641** (70)	0.285* (70)	0.164 (70)	1		
TL	0.166 (68)	0.557** (70)	0.418** (70)	0.343* (70)	0.410** (70)	1	
TD	0.415** (68)	0.204 (70)	0.091 (70)	0.152 (70)	0.104 (70)	0.363** (70)	1

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level
Figure in parentheses is the number of observations in each trait

4.4 PREDICTION OF LIVE BODY WEIGHT FROM BODY MORPHOMETRY

As we mentioned in materials and methods various measurements were recorded and based on relationship between these measured traits and live body weights, we tried to evolve regression equations to predict live body weights for Surti buffaloes. While doing so we tried combination of various body measurement traits andfinally selected only those equations whose intercept and coefficient of regressions were significant ($P<0.01/0.05$).Further, we divided data into four age groups *viz.* group 1 (0-3 months), 2 (03 months -1 year), 3 (1 year- 1st calving) and 4 (adult lactating animals). We also evolved regression equation for all animals irrespective of their age. Following regression equations were developed to predict body weights in Surti buffaloes

$BW = a+b_1x_1+b_2x_2+b_3x_3$

a = Intercepts of prediction equations

b_1 = Regression coefficient/slope of x_1

b_2 = Regression coefficient/slope of x_2

b_3 = Regression coefficient/slope of x_3

The intercepts, slope/regression coefficients, accuracy of the prediction equations of the body weights and number of Surti buffaloes have been summarized in Table 4.4 The intercepts and regression coefficients of the all-prediction equations of body weights were significant ($P<0.01/0.05$).

Table 4.4 Prediction equations at different ages in Surti buffaloes using morphometric measurements

Age groups	**Regression equations**
1. 0-3 months	**BW=-56.89+1.54×BDL** (R-Square = 0.4345, Pr> F= 0.0143, N=13)
2. 03 months -01 year	**BW = -117.11+ 2.09×HG** (R-Square = 0.9098, Pr> F= <.0001, N=54)
3. 01 year- 1st calving	**a. BW = -254.96+ 3.22×HG** (R-Square = 0.7288, Pr> F= <.0001, N=38) **b. BW =-430.84+2.23×HG+2.97×HAHB** (R-Square = 0.7554, Pr> F= 0.0005, N=38)
4. Adult lactating buffaloes	**a. BW = -6.63 + 2.82×BDL** (R-Square = 0.2970, Pr> F= <.0001, N=86) **b. BW = -198.16+ 1.51×HG + 2.22×BDL** (R-Square = 0.3524, Pr> F= <.0001, N=86)
5. Overall	**BW = -121.35+ 3.34×HG + 1.61×BDL-3.26 ×HAPB** (R-Square = 0.9287, Pr> F= <.0001, N=193)
BW: predicted body weight (in kg), BDL: body length (in cm) HG: heart girth (in cm), HAHB: height at pin bone (in cm).	

The accuracy of prediction equations ranged between 29.70 % for adult lactating buffaloes to 92. 87 % for all animals under study irrespective of their ages.The accuracy of prediction equations for 0-3 months and 03 months-01-year animals was 43.45 and 90. 98 %, respectively. For group 3 animals (01 year- 1st calving) the accuracy of prediction equations was 72. 88 % when only heart girth was used but it improved to 75.54 % when HAHB was incorporated in the equation. Similarly, for group 4 animals (adult lactating buffaloes) the accuracy of prediction equations was only 29.70 % when only body length was used however it improved to 35.24 % when heart girth was incorporated in the equation.

Many researchers tried to evolve prediction equation to estimate body weight of animals using their body measurements in various species and breeds of animals across age groups. Some of them are in agreement with of our findings while others in contrast to our findings. This may be due to difference in breed and other factors. Some of these finding are as follows. Weerasinghe *et al.*, (2009) also reported lower accuracy of prediction of body weight in calves than the other age group. The regression coefficient of heart girth (6.08) was found to be highly significant ($P<0.01$) and regression coefficients of body length (1.00) and height at hip bone (2.08) was non-significant in prediction of the body weights of adult bulls. Francis et al., (2002) also showed that the most significant single measure for estimating weight was the heart girth measurement.

Heinrichs, *et al.* (1992) in Holstein heifers found relationships between weight, wither height and various other body traits, including heart girth, linear unit, and hip width. weight and wither height were regressed on the opposite body traits. Regressions of weight including the linear, quadratic, and cubic effects of one experimental variable (heart girth, wither height, hip width, or linear unit) indicated that every measurement would be useful in predicting weight the regression of weight on heart girth had the very best R^2. followed by hip width. Similarly, regressions of wither height on heart girth, wither height, hip width, or body length, including linear, quadratic, and cubic effects, yielded ($R^2>0.99$). Regressions considering multiple traits as independent variables showed that the addition of a second body trait added little to the already high multiple correlations found with one variable. Abdeihadi and Babiker, (2009) reported heart girth round the hump had the very best coefficient of correlation with live weight ($r = 0.83$) compared with other body measurements. Grouping of knowledge consistent with live weight indicated that heart girth round the hump in medium weight) and heavy weight had the closest coefficient of correlation with live weight (r = 0.66 and

0.86, respectively). This gave more confidence within the use of the previous measurement in prediction of live weight of humped cattle. The multivariate analysis of live weight on heart girth round the hump was highly significant and therefore the regression lines indicated that a linear relationship existed. Ozakaya and Bozkurt (2009) reported that accuracy of prediction of weight from body measurements. Wither height, chest girth, linear unit, chest depth, hip width and hip height measurements wereobtained from Holstein, Brown Swiss and crossbred (n=140). Determination coefficients (R^2) of regression of y on x that included all body measurements were higher in Brown Swiss and crossbred than Holstein (92.2, 95.0 and 68.2 %, respectively). However, it had been found that chest girth was the simplest parameter ofall for prediction of weight in Brown Swiss (R^2=91.1 %) and crossbred cattle (R^2=88.8 %) as compared to Holstein (R^2=60.7 %).Singh, *et al*. (2011) developed prediction equations for body weight using linear unit, heart girth and height at hip for Vrindavani cattle. The prediction of weight of bulls was found to be most accurate, Whereas the prediction of weight of female calves of up to 3-month age was least accurate using heart girth, linear unit and height at hip bone. Validation of regression of y on x indicated that the number of animals that weight are often predicted accurately also increase with increase in age of the animals. Babale (2015) reported that length of animal (LA), girth circumference (GC) and neck circumference (NC) had highly positive significant ($P<0.01$) influences on weight while heights at rump (HR) and abdominal circumference (AC) had significant ($P<0.05$) influences on weight of the animals. However, there was no significant ($P>0.05$) correlation between height at wither (HW) and neck length (NL) with weight. The R^2 value was 92.23%, all their F-ratios were highly significant at ($P<0.01$), confirming the importance of those variables on the costs of the animals.

CHAPTER - 5

SUMMARY AND CONCLUSIONS

The present investigation entitled as "Prediction of production performance in Surti buffaloes from body morphometry" was carried out from January, 2021 to April, 2021 on Surti buffaloes maintained at Livestock Research Station, Navsari Agricultural University, Navsari, Gujarat. The objective of this study was to study of the body morphometry, find out relationship between body morphometry and production performance and to predict body weight from body morphometry in Surti buffaloes. Apparently 202 healthy Surti buffaloes belonging to group 1 (calves up to 3 months), group 2 (calves from 3 months to one year of age), group 3 (Surti buffaloes up to 1-3 years of age), group 4 (adult buffaloes above 3 years of age) were considered for this study. Body measurements like height at withers (HAW), body Length (BDL), heart girth (HG), fore cannon bone girth (FCBG), height at hipbone (HAHB), height at pin bone (HAPB), rump slope (RS), ischium width of the rump (ISWR), rump length (RL), ilium width of the rump (ILWR), medium width at Rump (MDR) were recorded on these animals. Further, udder length (UL), udder width (UW), udder depth (UD), udder circumference (UC), teat length (TL), teat diameter (TD) were recorded for lactating animals. Data pertaining to primary traits like birth weight, body weight at 3, 6, 12 months of age and body weight at first calving of those animals which were present at farm during the period of this study were collected from the available records. Available records of lactation milk yield (LMY), 305 or 300-days lactation milk yield (MY 305), lactation length (LL), age at first calving, weight at first calving were recorded. Further, live body weight and milk yield of these animals were recorded on the same day on which their body measurements were taken. Statistical analysis of body measurements, growth, production and reproduction data was carried out by using SAS 9.3. to find least square mean (LSM). Product moment correlations was carried out as per Snedecor and Chochran (1994). The morphometric traits which have significant correlations were used to predict the production traits.

The overall least squares' mean for height at withers (HAW), heart girth (HG), body length (BDL), fore cannon bone girth (FCBG), height at hip bone (HAHB), height at pin bone (HAPB), rump slop (RS), ischium width of rump (ISWR), rump length (RL), illium width of rump (ILWR) and medium width of rump (MDWR) was found to be 106.77±1.36, 148.29±2.89, 121.52± 2.30, 18.17±0.25, 105.17±1.18

93.54±0.92, 11.61±0.33, 11.63±0.38, 39.79±0.72, 37.59±0.95 and 77.7±2.31 cm, respectively. Perusal of data revealed that the least squares' mean for HAW was 73.54±1.00, 83.75±0.83, 111.99±1.55 and 122.72±0.35 cm for group 1 (0-3 months), 2 (03 months -1 year), 3 (1 year- 1st calving) and 4 (adult lactating) animals, respectively. Wefurther observed that HAW values differed significantly ($P<0.05$) among all age group and it was lowest for group 1 animals (73.54±1.00 cm) and highest for group 4 animals (122.72±0.35 cm). We observed that least squares' mean for HG was found to be 80.25±1.01, 99.59±1.50, 153.87±2.73 and 184.13±0.96 cm for group 1, 2, 3 and 4 animals, respectively. We further observed that HG values differed significantly ($P<0.05$) among all age groups and it was lowest for group 1 animals (80.25±1.01 cm) and highest for group 4 animals (184±0.96 cm). We found that least squares' mean for BDL for group 1, 2, 3, 4 animals was 69.25±0.91, 83.6±1.23, 126.24±2.17, 149.17±1.39 cm, respectively (Table 4.1). We further observed that BDL values differed significantly ($p<0.05$) among all age groups and it was lowest for group 1 animals (69.25±0.91) and highest value in group 4 animals (149.17±1.39 cm). We observed that least squares' means for FCBG were 12.88±0.24, 13.82±0.18, 19.21±0.23 and 21.02±0.17 cm for group 1, 2, 3, and 4 animals, respectively. We further observed that BDL values differed significantly ($P<0.05$) among all age groups and it was lowest for group 1 animals (12.88±0.24 cm) and highest in group 4 animals(21.02±0.17 cm).Perusal of the data revealed that the least squares' mean for HAHB was found to be 74.58±1.08, 85.86±0.85, 110.00±1.04 and 118.74±0.38 cm in group 1,2, 3,4 animals, respectively (Table 4.1). We further observed that HAHB values differed significantly ($P<0.05$) among all age groups and it was lowest for group 1 animals (74.58±1.08) and highest for group 4 animals (118.74±0.38 cm).We observed that least squares' mean for HAPB for group 1, 2, 3, 4 animals were found to be 67.04±1.19, 79.24±0.74, 98.39±0.87 and 103.55±0.32 cm, respectively. We further observed that HAPB values differed significantly ($P<0.05$) among all age groups and it was lowest for group 1 animals (67.04±1.19 cm) and highest for group 4 animals (103.55±0.32 cm).Least squares' mean for RS in group 1, 2, 3, 4 animals were 7.54±0.64, 6.63±0.28, 11.61±0.45 and 15.12±0.37 cm, respectively. We further observed that RS values differed significantly ($P<0.05$) among all age groups Group 2 animal (6.63±0.28) had lower value with RS than group 1 animals (7.54±0.64) and highest value in group 4 animals (15.12±0.37cm).Assess of the data revealed that least squares'mean for ISWR was found to be 5.52±0.25, 7.84±0.99, 11.35±0.43 and 14.85±0.21 cm for group 1, 2, 3, 4 animals, respectively. We further observed that ISWR values differed significantly ($P<0.05$) among all age groups and it was lowest for group 1 animals (5.52±0.25 cm) and highest for group 4 animals (14.85±0.21 cm).Examination of the data revealed that least squares' mean for RL for group 1, 2, 3, 4 of animals was 24.47±0.36, 27.26±0.39, 41.19±0.64 and 48.72±0.32 cm, respectively. We further observed that RL values differed significantly ($P<0.05$) among all age groups and itwas lowest for group 1 animals (24.47±0.36, cm) and highest for group 4 animals (48.72±0.32 cm).Glance of the data shown that least squares' mean for ILWR for group 1, 2, 3, 4 animals was found to be 16.70±0.40, 21.28±0.39, 39.31±1.01 and 49.41±0.34 cm, respectively. We further observed that ILWR values differed significantly ($P<0.05$) among all age groups and it was lowest for group 1 animals (16.70±0.40, cm) and highest for group 4 animals (49.41±0.34 cm).We observed that least squares' mean for MDWR in group 1, 2, 3, 4 animals were found to be 41.77±3.75, 34.12±1.41, 85.06±1.18 and 105.24±1.17 cm, respectively We further observed that MDWR values differed significantly ($P<0.05$) among all age groups. Group 1 animals (34.12±1.41) had lowest value and group 4 (105.24±1.17 cm) animals had highest value.

The overall least squares' mean for body weight (BW) of Surti buffaloes at birth (BWT), 3 (WT3), 6 (WT6), 12 (WT12) months of age and weight at 1st calving was found to be 25.76±0.25, 52.96±0.63, 80.71±1.15, 137.41±1.91 and 366.781±7.45 kg, respectively. The live body weight of group 1, 2, 3 and 4 animals was found to be 50.031±2.12, 90.845±3.28, 238.077±10.43 and 408.528±5.93 kg, respectively. We further observed that body weight values differed significantly ($p<0.05$) among all the age group and it was highest for the group 4 (408.528±5.93) and the lowest value in group 1 (50.031±2.12).

A positive and significant ($P<0.05$) correlation was found between body weight and HAW (0.586*) and BDL (0.659*) in this group of animals. Further, we found positive but non-significant correlation between body weight and HG (0.459), HAHB (0.452) and HAPB (0.454). The FCBG (-0.349) was found to be negative and non-significantly correlated with body weight in this group of animals. The correlation between HG and HAW, HAHB and HAPB was positive and significant ($P<0.01/0.05$) with r value 0.865, 0.812 and 0.601, respectively. The correlation coefficient between HG and BDL, FCBG was positive and non-significant.

A positive and significant (P<0.01) correlation was found between body weight and HG, HAW, BDL, FCBG, HAHB and HAPB and it was found to be 0.953, 0.904, 0.869, 0.758, 0.876 and 0.840, respectively. All morphometric traits were positive and significantly (P<0.01) correlated with each other. Further, we observed highest and significant correlation between body weight and HG (r=0.953) and lowest correlation between body weight and FCBG (r=0.758).

Correlation coefficient between body weight and HAW, HG, BDL, HAHB and HAPB was found to be 0.853, 0.621, 0.546, 0.810 and 0.768 respectively, results found were positive and significant (P<0.01) except correlation between body weight and FCBG (0.065) was positive and non-significant in group 3 of Surti buffaloes. Correlation among all morphometric traits was positive and significant (P<0.01). Further, we detected highest correlation between BW and HAW (r= 0.853) and lowest correlation between BW and FCBG (r=0.065).

We found positive and significant (P<0.01/0.05) correlation between body weight and HG, BDL, HAW, FCBG, HAHB, HAPB and it was 0.452, 0.544, 0.222, 0.214, 0.021 and 0.111, respectively. Correlation between all morphometric traits was positive and significant (P<0.01). Additionally, we observed highest and significant correlation between BW and BDL (r=0.544) and lowest correlation between BW and HAHB (r=0.021). The HG and HAW (r=0.473) was significant and most correlated traits among all the measurements. Positive and significant (P<0.01/0.05) correlation was observed between HAW and BDL, HAHB, HAPB and FCBG.

A positive and significant (P<0.01) correlation was found between BW and HAW (r=922), HG (r=0.957), BDL (r=0.943), FCBG (r=0.871), HAHB (r=0.914), HAPB (r=0.890), RS (r=0.745), ISWR (r=0.645), RL (r=0.940), ILWR (r=0.946) and MDWR (r=0.860). Correlation among all morphometric traits were mostly positive and significant (P<0.01/0.05). Further, we observed highest and significant correlation between body weight and HG (r=0.957) and lowest correlation between body weight and ISWR (r=0.645).

We found positive and significant (P<0.01/0.05) correlation between weight at 1st calving and BDL, RL, HAW, HG, ISWR and MDWR and it was found to be 0.457, 0.352, 0.309, 0.270, 0.311 and 0.236, respectively. We also observed positive but non-significant correlation between weight at 1st calving and FCBG (r=0.220), HAHB (r=0.154), RS (r=0.094) ILWR (r=0.140). Further we noticed that body weight at 1st calving and BDL (r=0.457) was highly significantly correlated among the all-body measurements. Lowest correlation was observed between weight at 1st calving and RS (r=0.044).

We observed a low, positive (r=0.096) and significant ($P \leq 0.05$) correlation between milk yield (MY) and udder length (UL) however correlation between milk yield (MY) and teat diameter (TD) was positive (r=0.415) and significant ($P \leq 0.01$). Correlation between MY and udder circumference (UC), teat length average (TLA) wasfound to be 0.118, 0.166 and these values were statistically non-significant. We also found very weak, negative and nonsignificant correlation between MY and udder width(r=-0.089), udder depth (r=-0.001). Further, we observed highest and significant correlation between MY and TD (r=0.415) and lowest correlation between MY and UD (r =0.001) as presented in table 4.3.8.

The intercepts and slope/regression coefficients of the all-prediction equations of body weights were significant ($P<0.01/0.05$). The accuracy of prediction equations ranged between 29.70 % for adult lactating buffaloes to 92. 87 % for all animals under study irrespective of their ages. The accuracy of prediction equations for 0-3 months and 03 months-01 year animals was 43.45 and 90. 98 %, respectively. For group 3 animals (01 year- 1st calving) the accuracy of prediction equations was 72. 88 % when only heart girth was used but it improved to 75.54 % when HAHB was incorporated in the equation. Similarly, for group 4 animals (adult lactating buffaloes) the accuracy of prediction equations was only 29.70 % when only body length was used however it improved to 35.24 % when heart girth was incorporated in the equation.

Conclusions

1. All body measurements differed significantly among groups and it was highest for group 4 and lowest for group 1 animals.
2. The overall least squares' mean for body weight (BW) of Surti buffaloes at birth (BWT), 3 (WT3), 6 (WT6), 12 (WT12) months of age and weight at 1st calving was found to be 25.76±0.25, 52.96±0.63, 80.71±1.15, 137.41±1.91, 366.781±7.45 kg, respectively.
3. A positive and significant ($P<0.05$) correlation was found between body weight and HAW (0.586*) and BDL (0.659*) in group 1 animals.
4. A positive and significant ($P<0.01$) correlation was found between body weight and HG, HAW, BDL, FCBG, HAHB and HAPB and it was found to be 0.953, 0.904, 0.869, 0.758, 0.876 and 0.840 respectively in group 2 animals.
5. Correlation coefficient between body weight and HAW, HG, BDL, HAHB and HAPB was found to be 0.853, 0.621, 0.546, 0.810 and 0.768 respectively, results found were positive and significant ($P<0.01$) in group 3 animals.
6. A positive and significant (P<0.01/0.05) correlation between body weight and HG, BDL, HAW, FCBG, HAHB, HAPB and it was 0.452, 0.544, 0.222, 0.214, 0.021, 0.111 respectively in group 4 animals.
7. A positive and significant (P<0.01/0.05) correlation between weight at 1st calving and BDL, RL, HAW, HG, ISWR and MDWR and it was found to be 0.457, 0.352, 0.309, 0.270, 0.311 and 0.236 respectively.
8. There was Low and positive ($r=0.096$) and significant ($P\leq0.05$) correlation between milk yield (MY) and udder length (UL). However, correlation between milk yield (MY) andteat diameter (TD) was positive ($r=0.415$) and significant ($P\leq0.01$).
9. The accuracy of prediction equations ranged between 29.70 % for adult lactating buffaloes to 92. 87 % for all animals under study irrespective of their ages. The accuracy of prediction equation for 0-3 months and 03 months-01-year animals was 43.45 and 90. 98 %, respectively. For group 3 animals (01 year- 1st calving) the accuracy of prediction equation was 72. 88 % when only heart girth was used but it improved to 75.54 % when HAHB was incorporated in the equation. Similarly, for group 4 animals (adult lactating buffaloes) the accuracy of prediction equations was only 29.70 % when only body length was used however it improved to 35.24 % when heart girth was incorporated in the equation.

From the findings of this study, it may be concluded that live body weights of Surti buffaloes can be predicted from HG, BDL and HAPB most accurately.

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