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Review article

Bioprediction of body weight and carcass parameters from morphometric measurements in livestock and poultry

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ABSTRACT

Body weight is an important attribute in animal production as it forms the basis for not only assessing growth and feed efficiency but also in making economic and management decisions. The major focus of this review is to look at bioprediction of body weight and carcass parameters from morphometric (linear body) measurements in livestock and poultry production. There is a consensus amongst researchers working with different livestock and poultry species that morphometric characteristics could serve as predictors of body weight and carcass parameters. Different studies have exploited correlations of morphometric measurements with body weight and carcass parameters to develop techniques for estimating body weight and carcass parameters in different livestock and poultry species, where weighing scales may not be available. The review highlights some of the factors which may influence the accuracy of prediction of body weight and carcass parameters using regression models. Categorization of data according to sex and age is necessary to improve prediction power of equations. The estimation of body weight using morphometric measurements becomes very useful in smallholder livestock and poultry producers who rarely keep birth records. Measurements of various morphometric traits are of value in estimating body weight and carcass parameters in livestock and poultry production and because of the relative ease in measurements they can be used as an indirect method of predicting body weight and carcass parameters. These will provide good information on performance, productivity and carcass characteristics of livestock and poultry. The review concludes that there is need to develop different predictive equation for various species since different species have different relationship between linear body measurements with body weight and carcass parameters. The use of morphometric measurements to predict body weight or carcass parameters would overcome many of the problems associated with visual assessment or evaluation.

1. Introduction

Body weight has a direct relation to the production and profitability of any livestock enterprise. It has been reported by Nwosu et al (1985) that body weight is the best parameter for making management, health and production and marketing decisions. As a result there is need to develop objective means for describing and evaluating body weight and conformation characteristics especially in smallholder livestock and poultry production sector where measuring scales are unavailable. Morphometric characteristics (linear body measurements) have been a recurring interest to livestock production either to supplement body weight as a measure of productivity or as predictors of some less visible characteristics (Supriyantono et al., 2012). Body weight measurement is used the most to evaluate body development in livestock and poultry production ((De Brito Ferreira et al., 2000), but it is not easily measured in the field. Several studies have shown that body weight has a direct relationship with morphometric characteristics and carcass parameters in cattle (Milla et al., 2012; Alphonsus et al., 2010; Bozkurt, 2006; Tennant et al., 2002), in goats (Mahieu et al., 2011; Otoikhain et al., 2008; Nsoso et al., 2004), in sheep (Sowande and Sobola, 2008; Baffour-Awuah et al., 2000; in pigs (Brannaman 1984), in rabbits (Chineke 2005; Pinna et al., 2004), in poultry (Ogah, 2011; Ige et al., 2006) and fish (Yakubu et al., 2012; Cherif et al., 2008).

In order to determine the body weight and carcass parameters of livestock and poultry numerous methods have been used by researchers. The essence of all these studies has been to establish relationship between the morphometric measurements which can be used in estimating body weight and carcass parameters in livestock and poultry, that are easy to obtain, practical and inexpensive. Therefore, studies have developed regression equations that could be used to predict body weight from some linear body measurements (Bhakat et al., 2008; Bassano et al., 2001) Typically body weight is regressed on morphometric measurements to determine a weight prediction equation. The correlation matrix of each of the morphometric measurements could be used in predicting body weight or carcass parameters in livestock or poultry species (Ojedapo et al 2007). Multiple regression analysis has been used to interpret the complex relationship among body weight and some morphometric measurements (Yakubu et al., 2012). However, its interpretation may be misleading where there exists multicollinearity among the predictor variables. In an organized livestock production enterprise weighing scale is routinely used to measure body weight but weight can seldom be measured in the field or remote areas due to lack of weighing facilities. It is therefore desirable to estimate body weight from simple traits such as linear body measurements using easily obtainable and cheaply available tape. Therefore this review focus on the potential of bioprediction of body weight and carcass parameters from morphometric measurements in livestock and poultry production.

2. Choice of morphometric characteristics

Morphometric measurements are an objective means for describing and evaluation of body weight and carcass parameters than visual evaluation. Different morphometric traits have been used in different studies to estimate body weight in different livestock and poultry species. El-Khidir (1977) enabled to estimate body weight of Butana heifers from hearth girth and body height. While Bushara et al., (2011) in Taggar goats, and Nicholson and Sayers (1987b) in Boran cattle both used heart girth and body condition score to estimate body weight.

Elsewhere ILACO (1982) estimated body weight from heart girth in cattle. Morphometric measurements such as length and height are related to bone growth and are closely related to body weight of growing animals (Essien and Adesope, 2003). The increased body length is due to skeletal growth, which increases in girth are due to muscle development plus accumulation of adipose tissue. The height at withers and rump height have been reported to be limited in their values as indicators of body weight, this is in contrary to observation made by Yakubu et al., (2011) who found them explaining variation in body weight in kids than body length and heart girth. Similar results which favour height at withers as a better predictor for body weight were reported by Aziz and Sharby (1993) in lambs. Boggs and Merkel noted that height at withers was the most accurate and repeatable measurement for frame size. However, the superiority of hearth girth over other linear body measurements have been reported by other workers (Topal et al., 2003; Thiruvenkadan, 2005). This is not unexpected considering the high environmental sensitivity of hearth girth. Salako (2004) reported that hearth girth and body weight grow in response to environmental components as feed and management, as such they are used to assess environmental impact on breeds. The higher association of body weight with chest girth could be attributed to relatively larger contribution in body weight by chest girth which consist of bones, muscles and visceral organs (Yakubu et al 2011). The various length, heights and girth of live animals are measured to assess the relationship between these variables and live weight in cattle (Abdelhadi and Babiker, 2009), in goats (Nsoso et al., 2004) and in sheep (Sowande and Sobola, 2008). Mukherjee et al., (1981) observed high and significant correlation coefficients between body weight and width at hip, width at shoulder and heart girth, which suggested that either any of these variables or their combination would provide a good estimate for predicting body weight in sheep. Signh et al (1985) reported the highest correlation value of body weight with chest circumference in various Indian goats. Heart girth and width at shoulder are closely related as both give a measure of the cross sectional area therefore show a high collinearity as a result width at shoulder can be dropped from the model without much effect. The morphometric characteristics can be categorized into three main groups according to those which are related to length, height and girth (cross sectional area), which suggest that their association may be high within each category and withdrawing one from the equation may not have much effect.

Rossouw, (1982) reported that nutritional regime imposed on pigs had no significant effect on the regression relationships hence the regression equation could therefore be calculated for all pigs. However the observed high correlation of variables in the study was due to the fact that the linear body measurements were taken over a wide range of body weights. It is suggested that if this range of body weight had been restricted it is possible that these high correlation coefficients would not have been obtained.

Momoh and Kershima (2008) reported correlation coefficient between body weight and body measurements which were both positive and significant in males. In females body weight was only positively and significantly correlated to body length, chest circumference, with femur, crus and tarso-metatarsus demonstrating non significant. Gueya et al (19890. Reported similar observations in indigenous Senegalese chickens. Their findings were congruous to the submission of Hassan and Adam (19970 who observed a strong and significant correlation of body length and chest width to body weight in indigenous pigeons. In a different study Teguia et al., (2008) working with African Muscovy ducks, reported highest correlation coefficients of body weight with wing length and thoracic perimeter in both males and females. The moderate to high correlation between body weight with morphometric measurements are expected given that the body conformation traits reflects element of size of animals (Berry et al., 2005). Body weight is also regarded as a function of frame work or size of the animal and its condition.

3. Influences of species or breed in accuracy of prediction of body weight

Working with cattle and sheep in Ghana, Balig (1970) and Ahunu and Kpesese (1995) showed a strong relation between hearth girth and live weight. Giroma (1992) indicated that based on the magnitude of the correlation coefficients, body length and height at withers could be used to predict live weight of Red Sokoto goats. Their comparing of Red Sokoto and West Dwarf goats height at withers, height at pelvis and length of leg where higher and significant in Red Sokoto than the West Dwarf gaot. Models correlating body weight and morphometric characteristics have been developed for different livestock species(Ilaco, 1982; Stamper, 2010; Ensminger 2002; Rahman, 2007; Attah et al., 2004; Thiruvenkadan et al., 2009; Singh and Mishra, 2004). Cattle, buffalo, goats, sheep, pigs and poultry producers need an accurate, inexpensive method of predicting the body weight of their animals. The height at withers observed in Red Sokoto and West African dwarf goats were not the same by Ngere et al., (1979) and Attah et al., (2004). This implies that linear body measurements of the same breed in different locality may not be similar as a result calls for application of different predictive models. Ago (2011) reported wing chest, chest circumference having lowest variability in guinea fowls and suggested that could have been a result of breed identity and specificity indicating homogeneity of the population. The breast and the thigh had higher muscle deposition in the body of birds hence their relationship with body weight was high.

4. Prediction model selection

Multiple regression analysis has been used to interpret the complex relationships among body weight and some morphometric measurements (Yakubu et al., 2012). However, its interpretation may be misleading where there exists multicollinearity among the predictor variables. Tabachnik and Fidell (2001) attempting to address the existence of multicollinearity among predictors variables used multivariate factor analysis which reduces a complex system of correlations into one of smaller dimensions through the extraction of few unobservable latent variables called factors. Factor scores can be derived from multivariate analysis which could be nearly uncorrelated or orthogonal hence such factors could be used for prediction , thereby giving a solution to the problem of collinearity. The use of interdependent explanatory variables to predict body weight should be treated with caution, since multicollinearity has been shown to be associated with unstable estimates of regression coefficients (Keskin et al., 2007; Yakubu et al., 2009) rendering the estimation effects of these predictors impossible. This justifies the use of factor scores for prediction (Yakubu et al 2012). Predictive equations with fewer variables are simple and easy to interpret (Baffour-Awuah et al., 2000). A crucial step in constructing a multiple regression model for predictive purposes is to determine those variables that contribute much to the response variable (body weight) with elimination of non significant variables. Using all possible selection approach will maximize the number of independent variables and their contribution in regression equation for predicting the dependent variable (body weight). Both linear and non linear models have been applied in estimation of body weight using morphometric characteristics, however their effectiveness depends on the morphometric characteristics under consideration. Most models were developed by multiple regression procedure where collinearity among the independent variables was no evaluated (Ogah, 2011). However, collinearity problem among the independent variables should be expected as there are both genetically and phenotypically correlated(Simm and Dingwall, 1989) and it is known that models based on multicollinearity variables can limit inference and the accuracy of prediction (Chatterjee et al., 2000). In fact the use of collinear variables as independent variables does not improve the model precision and create instability in the regression coefficients estimation (Shahin and Hassan, 2000). Mosteller and Turkey, (1987) suggested that prediction accuracy of predictive models should be assessed using a simple cross validation approach. Possible models to use in estimating body weight and carcass parameters include allometric, quadratic and linear models, however they should be tested for best fit. The allometric model seemed to produce a better goodness of fit followed by the quadratic and linear models, respectively in goats (Yakubu et al., 2011). Momoh and Kershima (2008) developed both linear and multiple regression as predictors of body weight in Nigerian local chickens , and found out that in both sexes the multiple regression equations when compared with the simple linear regression equations, multiple regression technique was better in predicting body weight from linear body measurements than simple linear regression technique.Body weight of non descript goats were predicted from linear body measurements such as rump height, withers height, heart girth and body length using different regression models (Yakubu et al., 2011).

Raji et al., (2009) and Wawro (1990) proposed that more accurate results in predicting body weight in turkey can be obtained when several parameters are used as independent variables in predicting and improving carcass performance, this was substantiated when multiple traits where used in a regression model. In a stepwise multiple regression of body weight, carcass weight and breast weight in guinea fowl on linear body measurements revealed that when chest circumference alone was used it accounted for 55% of the total variation in body weight, inclusion of keel length in the model increased the proportion of the explained variance to 74.3%. The accuracy of the model was further improved (R^2=80.9) when thigh length, body length and wing length were added to the equation. Their result indicate that body weight can be predicted with fair degree of accuracy from chest circumference, keel length and thigh length. Peter et al., (2006) and Yakubu et al., (2009) observed similar findings in Nigerian indigenous chicken genotypes. In Senegal Gueye et al.,(1998) in chicken and Teguia et al., (2007) in Muscovy duck reported that the relationship between live body measurements of carcass component in vivo depends on the correlation between body weight and chest circumference, keel length and thigh length. In vivo prediction of carcass components based on single trait are usually discouraged as not reliable (Ogah, 2011). Another parameter to consider in predictive equations is the Variance Inflation Factor (VIF)v values for interrelationship between traits which should be shown along stepwise multiple regression. It represents the increase in variance due to high correlation between predictors (Pimentel et al., 2007) or gives the indication of existence of severe collinearity. According to Gill (1986) VIF greater than 10 indicate severe collinearity rendering the reliability of the predictive equation not effective. Yakubu et al., (2012) used factor scores for predicting body weight from some morphometric measurements of two fish species in Nigeria by adopting a multivariate principal component factor analysis statistical technique. The respective factor scores fitted separately in a linear and multiple regression model as explanatory variables accounting for 76.6% and 84.5% of the variation in the body weight of fish species, respectively. Species or breed difference influencing type of prediction model

Regression models allow as fast evaluation of the body weight of an animal and are also used for the optimization of feeding, determination of optimum slaughtering age and selection criteria (Yakubu et al., 2011), however such measurements are not across breed on the choice of model that gives the best fit (Islam et al., 1991; Benyl, 1997). It is reasonable to suggest that there is need to develop different predictive models for different species or breeds of the same species.

5. The effect of sex on linear body measurements

The differences in linear body measurements between sexes in different studies was attributed to sex dimorphism (Gatford et al., 1998; Egena et al., 2010). Sexual dimorphism was observed in predicting body weight of two broiler strains (Adedibu and Ayorinde,). The relationship between live weight and morphometric characteristics as well as predictability of both live weight and linear body measurements were influenced by sex in broilers. However sexual dimorphism existed in relationships between live weights and linear body measurements on different ages. Hearth girth and body length measurements showed significant differences between sexes and between intact bulls and castrates (Milla et al., 2021). However these differences were not detected among growing calves. It is reasonable to suggest that the differences in morphometric characteristics in sexes is because on average males are heavier than females. Baffour-Awuah et al (2000) observed that females had longer bodies than males and this was also reflected in other measurements such as head length, rump length and tail length. Ngere et al., (1979) and Attah et al., (2004) working with goats also observed higher heights linear body measurements in males than females. From the regression analysis fitting all the variables in a full model, sex including body length, width at shoulder, hearth girth were significant (Baffaour-Awuah, 2000). Hassan and Giroma (1992) recommended that sex influence on morphometric characteristics should not be ignored to predict body weight in sheep and goats. Body weight of kids was better predicted from withers height while hearth girth was found to account more variation in body weight of the female adult goats. In contrary to the above observations Mahieu et al., (2011), reported that there was no sex effect on the hearth girth to live weight relationship hence there was no need for gender correction.

Momoh and Kershima (2008) working with local chickens in Nigeria showed that males had higher values for body weight and body measurements. This was attributed to the fact that males were heavier than females. Similar observation had been reported in indigenous chickens by Missohou et al., (1997) and Ngou Ngou-payou (19900. Elsewhere, Hassan and Adam (19970 also reported higher values for body weight and morphometric measurements in indigenous male pigeons when compared with the females. Comparing males and females on morphometric characters Ojedapo et al., (2007) reported that sexual dimorphism in body weight and other body linear measurements favoured females than males in goats. Ages on which dimorphism is expressed in predicting body weight in broilers differed according to the strain of broilers. Therefore it is reasonable to suggest that different equations should be developed for males and females in species considered.

6. Influence of age of animal on prediction

The morphometric measurements vary positively with age of the animals and the correlations of body weight with diagonal body length, height at wither, sac pelvic width and hearth girth were high, positive and significant (ojedapo et al., 2007). Measurement of some body parameters, the age of animals can be assessed and the timing for different management practices can be pegged accurately to bring animals to good and desired weight at maturity (Imasenen and Otoikhian, 2004).When heart girth and/or body length equations were used the corresponding weights were lower in adults and higher in calves (Mill;a et al., 2021). Paul and Das,(2012) working with buffaloes noted that from 6 to 24 months of age, the correlation coefficient of body weight of calves was positive and highly significant. But, the coefficient values were decreased gradually with the increase of age of calves. Earlier reports by Sethi et al., (1996) also supported these findings in buffaloes. Yakubu et al., (2011) showed that as age advanced coefficients of determination decreased while residual mean square increased. This was in agreement with the findings of Thiruvenkadan (20050 in Kanni Adu kids under farmers management in Southern part of India. Osinowo et al., \91989) also found that hearth girth gave best estimate for predicting body weight of Nigerian Red Sokoto goats at 1-2 years of age., but body length was a better predictor at later stages The prediction of body weight from linear body measurements seemed to be better in kids than adults goats. Animals of different age groups will have differences in measurements of body parts (Osinowo et al., 1989; Otoikhian et al., 2006). In adult animals body length assumes more important role as an indicator of body weight (Baffour-Awuah et al., 2000) and body weight was better estimated in kids than adult goats and wither height appeared as the highest single prediction variable in kids, while in adults goats hearth girth was found to account more for variation in body weight (Yakubu et al., 2011) Within adults differences were also observed by the same author in terms of wattle genes which impacted mostly on adult parameters where prediction accuracy appeared to be better in wattled adults compared to their non wattled counterparts. This points to say some morphological differences on animals of the same age may influence body weight prediction. Hall (1991) noted that height at withers rarely changes significantly with age. In fish size is generally more important than age mainly because several ecological and physiological factors are more size dependent than age dependent (Kalayci et al., 2007). Due to parameters reflecting associations changed by age categories, it was appropriate to use separate models to growing, market age and breeding age animals in pigs. A model was developed for age specific in pigs and weights estimation models developed in the Philippines were for pigs ≤ 5 months of age (Murillo et al., 2004).

7. Body condition score

Various methods to determine body composition have been evaluated including: weight to height ratios, visually assigned condition scores, condition scores assigned by palpation, ultrasound, liveweight and height girth (Thompson et al., 1983; Wright and Russel, 1984; Nelson et al., 1985). Assessment of condition score has proven superior to linear measurements as predictor of carcass energy and fat reserves (Wagner et al., 1988; Houghton et al., 1990). Though being subjective, condition score offered the advantage of being a rapid means for estimating body weight in absence of weighing scale or tape, since it requires no handling or straining of animals. But its usefulness in this regard is possible if and only if it is directly related to weight (Nicholson and Sayers 1987). The quadratic relationships between weights and condition scores depicted that at any condition score, weight loss was linear (Milla et al., 2012). Relationship of linear conformation traits with body weight body, condition score and milk yield in Friesian*Bunaji cows were positive indicating that taller, wider, deeper and fatter cows tended to be heavier (Alpphonsus et al., 2010). Adjustments for body weight changes to change body condition score are corrective measures needed by producers and researchers alike as practical tools to estimate body weight changes require to obtain a desired body condition score (Lalman et al., 1997; Northcutt et al., 1992). However, Kloster et al., (1968) stated that due to the effect of condition on body weight, weight alone was not a good measure of the mature size of the animal. Tennant et al., (2002) suggested that cow body weight was influenced by body condition score. Previous work had also reported condition score to be highly correlated with body weight (Buskirk et al., 1992). Explaining the direct relationship of body weight and body condition score observed by Lalman et al (1997). Wagner et al., (1988) reported changes in condition for thinner cows might reflect less body weight changes than do condition changes for fatter cows. Precaution should be taken on the relationship between body weight and body condition score because other studies used linear contrast rather than linear regression and suggested weight adjustments for changing body condition scores are not proportional across the condition scores. Weight adjustment for changing body condition scores are not consistent throughout the production year. This realization appears to be highly weight dependent as weight of animals is not constant year round especially on livestock production systems which are rangeland dependent.

8. Carcass prediction

Devendra (1966) could not associate morphometric characteristics of female goats with carcass values but Rusheed (1977) found that chest girth in Buffalo vealers was strongly correlated with dressing percentage. Body length, wing length and thigh length showed a higher positive and significant correlation with carcass components (Ogah (2011), similar findings were reported in broilers (Kleczek et al., 2006) and in Muscovy ducks by Wilkiewicz-Wawro and Szypulewska, (1999). This showed that these morphometric characteristics were also reliable predictors of carcass composition in the guinea fowl. In order to improve the methodologies for objective evaluation of rabbit meat production a series of linear measurements have been carried out on rabbit carcasses, integrating the carcass commercial traits usually evaluated at slaughter((Pinna et al., 2004). The average coefficients of correlation calculate between body length and chest depth with dressing percentage could represent an additional tool for supporting the evaluation of rabbit meat production. Ther was a significant body dimensions and carcass measurements of cattle selected for postweaning gain fed two different diets (Gilbert et al., 1993). Carcass meatiness in poultry depended on the components of breast and leg muscle (Wilkiewiez-Warro et al., 2003) hence suggested that selection could be aimed at these areas. Oga (2011) discouraged prediction of carcass components based on single linear body measurements as unreliable. The interpretation of several morphometric characteristics body weight prediction is difficult due to the high degree of correlation among them (Yakubu et al., 2012).

9. Final comment

Estimating body weight of animals using morphometric measurements is a suitable alternative to weighing scales. There is a potential use of morphometric characteristics as selection criteria which may go a long way in improving the accuracy of predicting body weight in livestock and poultry species, thus allowing breeders to make more informed selection decision. The relationships between morphometric characteristics with body weight and carcass parameters using different models for different species should be explored. Optimal models for predicting body weight and carcass parameters should take into account the differences in sex and also appropriate predictive models need to be developed to easily determine body weight for different classes of animals within the same species. Heart girth seemed to be a better predictor of body weight in ruminants than other linear body measurements, however better results could be obtained when other linear body measurements are included in the predictive model. Variables which are highly associated due to their description of length, width or cross sectional area, it would be necessary to consider one of the them in developing a model because removing one will not have much effect on the predictive power of the model. The results of the relationship between morphometric characteristics and body or carcass parameters could be exploited in designing appropriate management and selection programs. In birds wing length, and chest circumference are possible morphometric characteristic to consider in predicting body weight and can provide a platform for designing breeding index.

The use of factor scores in multiple regression models has an advantage because they eliminate the problem of collinearity, thereby facilitating accurate interpretation of the regression results. High positive relationships among traits suggest that an increase in one could lead to a corresponding increase in the other trait. As a result of such high correlations, it is possible to predict body weight of livestock or poultry from highly correlated morphometric measurements. The fact that morphometric measurements are highly correlated with body weight and carcass parameters and often can be recorded in a single assessment which makes them cheaper and more practicable to measure in the field than body weight and carcass parameters, they become important information that a producer may use to predict body weight and carcass weight in the field. This could assist the producer to make informed management decision, which include provision of adequate nutrition of livestock and poultry, correctly administer medication and better estimate of potential profit now that the relationships between morphometric characteristics and body weight and carcass parameters are better understood researchers should streamline the number of specific measurements needed to predict body weight and carcass parameters in different animal species. Body linear measurements becomes an indirect way of assessing body weights in livestock and poultry without recourse to the use of weighing scales. Morphometric measurements may differ within breeds or strains within the same species, hence it may reasonable to discourage the use of weight bands developed for one breed or strain within species for another group of animals within the same species, for example continental cattle versus the indigenous cattle. Apart from the breed or strain differences in linear body measurements, body weight may be influenced by the type of management of specific populations. This entails that animals that are fed commercial prepared complete diet adlibitum can reach a certain weight at a specific duration, which may be different from animals which are kept on range (outdoors) or animals which are fed a limited diet of household waste, weeds and seasonal fruits. Can conclude that application of models developed from animals of the same species with different management system may be misleading and may not be an accurate estimation of body weight in another group. Age specific models developed elsewhere may not predict weight of animals in another locality because of the obvious differences in breed, feeding and housing methods which influence the magnitude of linear body measurements. Variation in body weight within a population can be attributed to genetic variation and environmental factors that impinge on individual hence the morphometric measurements are potential characters for use in animal selection.

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