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Statistical tool for the estimation of body weight of lactating cows from 2D photographs

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Abstract

Estimating the body weights of animals is an arduous task in livestock management. However, it is a vital tool in developing suitable breeding programmes,calculating the nutritional requirements, determining pharmaceutical doses of drugs and assessing feed conversion efficiency and carcass quality. In this study, we made an attempt to predict the bodyweights of lactating cows using images from various angles. Seventeen lactating cows from the University Livestock Farm and Fodder Research Station, Mannuthy, were selected randomly. Different body measurements of the animals were obtained manually and photographs of the lateral, rear, and dorsal views were taken using the demo version of the CAD-KAS measure-pictures 1.0 software. The surface area was estimated using the body length along the back on the midline from the withers to the croup and the maximum stomach width from the dorsal view photographs. A stepwise multiple linear regression model was used to predict the body weight of the animals. A regression equation fitted using the surface area and perpendicular length between the Tail Head above and the plane in level with the ventral line of the abdomen below yielded an R^2 of 90.5 percent. This study suggests that models built using measurements retrieved from digital image analysis techniques can be used as a promising tool for predicting the body weight of animals.

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Management of livestock largely depends on the Body weight (BW) of an animal, which is considered to be one of the most important indicators of its production potential, growth and health condition. It is a vital tool for developing suitable breeding programmes, calculating nutritional requirements, determining pharmaceutical doses of drugs and assessing feed conversion efficiency and carcass quality (Chacko and Mathen, 2003and Snehal*et al.,* 2021).However, increased input of labour, time, imminent strain for both the animal and people involved, limited availability of an appropriate weighing machine in the farm premises etc., make it challenging to weigh the animal. Estimation of weight using digital camera will help in automated cattle management systems improve accuracy. Photographs are commonly taken for insurance purposes and hence digital data on the weight of the insured animals could be an additional information pool. In certain veterinary emergencies where weighing is considered to be a difficult task due to the dis ably of the animal, the dose of the drug must be determined according to the body weight estimate. Thus there are various practical situations in which an estimate of animal weight is extremely useful.

Materials and methods

Study design and setting

A cross-sectional study was conducted by randomly selecting seventeen homogeneous lactating animals from the University Livestock Farm (ULF), Mannuthy. The live weights of lactating cows were accurately measured while standing on a weighing machine under a squeeze chute. The weights of lactating cows were calculated using the commonly used Schaeffer's formulae proposed by Sastry *et al.*(1983). According to Schaeffer's formula the body weight is measured using the Chest Girth (G) and Body Length (L) measured from the point of shoulder to the point of hip as given below.

$$BW = \frac{LG^2}{300} \qquad (1)$$

Where, L = Straight length measured from the point of shoulder to the hip bone (in inches) and G = Heart Girth or Chest Circumference (in inches)

To capture the photographs of dorsal, rear and lateral views at a time, a new device for fixing the cameras was designed and developed by the Department of Statistics, College of Veterinary and Animal Sciences, Mannuthy (Fig. 1 and Fig. 2). Fig. 2 shows the arrangement of the device at a constant distance from the weighing machine.

The rear and lateral view photographs (Fig.3 and Fig.4) of the animals at a perpendicular distance of 2.5m from the squeeze chute were taken using the digital camera Sony Cyber shot DSC-S930 placed at a distance of 1.20m above ground level. Photographs of the animals from the dorsal view (Fig. 5) were capturedusing a Tech-Com web camera with a wide lens placed above the squeeze chute at a height of 2.75m from ground level.

Enevoldsen and Kristensen (1997) developed a reliable model for estimating the body weight of very different dairy cows maintained in a wide range of environments using body condition scores, demographic information, and measurements of hip height and hip width. Morphological traits such as Curved Body Length (BL), measured along the back on the midline from the croup to the midpoint of the line joining the two horns, Straight Body Length (L) measured from the point of shoulder to the hip bone, Heart Girth or Chest Circumference (G) measured as body circumference just behind the forelimb, Hip Height (HH), Hip Width (HW) and Wither Height (WH) measured from the top of the shoulder from the mid-point of the shoulder blade of the animal to the ground in a perpendicular line were measured using a measuring tape. All body traits were measured before feeding time by the same person to avoid individual variations and decrease estimation errors.

Images of the lateral, dorsal and rear views of the animals were analysed using the demo version of the CAD-KAS measure-pictures 1.0 software. All photographs were taken while the cows were in a squeeze chute.

It was almost ensured that pictures were taken perpendicular to the cows.

Dorsal View measurements such as Shoulder Width from photograph, (SW_DV) measured at the widest point of the shoulder, Maximum width of the abdomen (2nd W), Hip Width from photograph (HW_DV), Body Length (BL_DV) measured along the back on the midline from the withers to the croup, Lateral View measurements such as Abdomen Depth (AD_LV), Length measured from the point of shoulder to the hip bone (L_LV) and the rear View measurement: perpendicular length

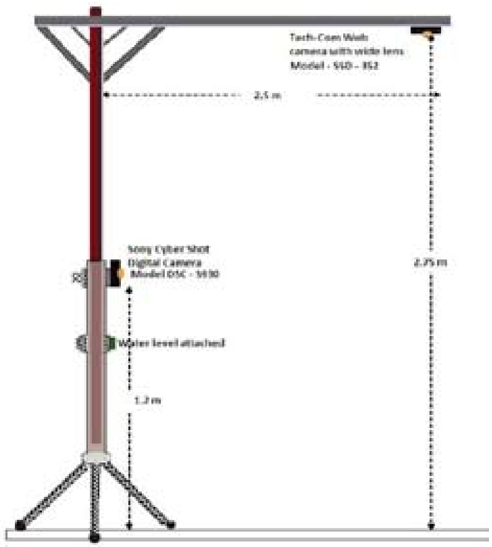

Fig.1. Device for fixing camera(s)


Fig. 2. Device and weighing machine


Fig. 3. Rear view

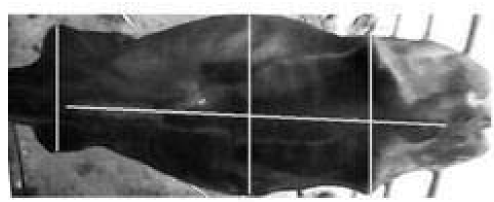
Fig. 4. Lateral View


Fig. 5. Dorsal view

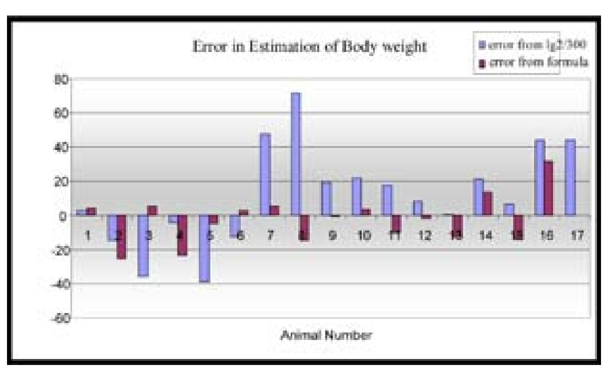

Fig. 6. Deviations from actual body weight

Table 1. Manual measurements of morphological traits of lactating cows (n=17)

Variable	Body Weight (kg)	G (cm)	BL (cm)	L (cm)	WH (cm)	HW (cm)	HH (cm)
Mean ± S.E	322.47 ± 10.96	164.59 ± 1.80	162.82 ± 2.70	105.88 ± 1.53	127.29 ± 1.27	43.59 ± 0.70	131.47 ± 1.60

Table 2. Morphological traits of lactating cows from the photographs (n=17)

Variable	BL_DV	SW_DV	2^{nd} W_DV	HW_DV	L _ LV	SD _LV	TP_RV
Mean ± S.E	101.77 ± 1.87	32.23 ± 0.76	47.68 ± 0.74	43.63 ± 0.79	103.72 ± 2.33	66.50 ± 1.35	69.99 ± 1.56

Live weight was regressed against various morphological traits and area obtained from image analysis and the following regression coefficients were estimated (Table 3.).

Table 3. Regression coefficients of the fitted model

Variables	Regression coefficients	S.E. of Regression coefficients	t-statistic	P- value
Intercept (Constant)	-105.69	41.58	2.54*	<0.001
SA	0.05	0.08	7.37*	<0.001
TH_VA_RV	2.54	0.68	3.74*	<0.001

**Statistically significant*

between the Tail Head above and the plane in level with the ventral line of abdomen below (TH_VA_RV) were estimated using the image analysis software. The total surface area of an animal provides a valuable aid for determining the necessary supply of daily dietary energy (Sreekumar and Nirmalan1990). Therefore, thesurface area (SA) estimated using BL_DV and the 2^{nd} W measurements from the dorsal view were also used to predict body weight.

Statistical analyses

All statistical analyses were performed using the SPSS software version 16.0. The continuous variables included in the study were found to be normally distributed and hence were summarized using the mean and standard error. The Kolmogorov-Smirnov test was used to check the normality of the data. The study used the method of stepwise linear regression analysis to establish the most appropriate equation to predict live weight of the lactating cows from body measurements obtained from image analysis. The multiple linear regression model used to explain the variability in the dependent variable using a set of several independent variables is given by

$$Y_i = \beta_o + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_k X_{ik} + e_i$$

Where,

$Y_i = Y_i =$ Body weight of the $i^{th} i^{th}$ animal; $i = 1,2,..n, i = 1,2,..n,$

$\beta_o = \beta_o = \beta_o$ intercept, $\beta_{j\,(j=1,2...k)}$ $\beta_{j\,(j=1,2...k)}$ $\beta_{j\,(j=1,2...k)} =$ Partial regression coefficients,

$X_{ij} = X_{ij} =$ digital measurement from $i^{th} i^{th}$ animal for $j^{th} j^{th}$ explanatory variable and

$e_i = e_i =$ error terms which are distributed normally with mean zero and constant variance

Results and discussion

The live weight and all other linear body measurements measured manually from the animals in cms are summarised as given in Table 1. Descriptive statistics of the measurements extracted from the photographs in pixels are presented in Table 2.

The fitted multiple linear regression model is as given below,

$$BW = -105.69 + 0.05 \times SA + 2.54 \times \mathrm{TH\_VA\_RV}$$

$$BW = -105.69 + 0.05 \times SA + 2.54 \times \mathrm{TH\_VA\_RV}$$

(2)

It was observed from the regression model that 90.5 % of the variability in BW was explained by SA and TH_VA_RV. Only measurements from the dorsal and rear-view images were found to be significant in predicting the body weight of the animals. Compared to the studies conducted by Bozkurt *et al.* (2007) and Ozkaya and Bozkur (2008),the current study provided a higher R square with fewer independent variables in the model. Due to various constraints in using more animals, the sample size was chosen in such a way as to obtain maximum homogeneity and thus reduce error. However, further validation of the above model may be attempted with a larger sample to ensure the predictability of the model.

The BW obtained using the Schaeffer's formula and predicted equation was compared to the actual weight. The deviations resulted from Schaeffer's formula was found to be very large when compared to those obtained from equation (2), (Fig. 6.).

Conclusion

The present study demonstrated that the live body weight of lactating cows can be predicted by regression equations using digital body measurements. From an economic and research point of view, the introduction of the newly developed model using the measurements obtained from image analysis without altering the behavior of the animals can result in a remarkable change in assessing the growth of the animal. The practical implications of this study are that the body weight of cows can be reasonably estimated using photographic measurements for selection purposes, feeding, and health and as a way of assessing market values in terms of the cost of animals. The cost, difficulty, staff requirements, danger, and stress problems during the manual measurement and weighing of animals would be solved using this new technique. However, this technique requires further validation under different field conditions and a larger sample size.However,this study can help researchers prioritize where to focus their efforts on obtaining more accurate measurements from image analysis. Similar studies can also be attempted in elephants to determine their body weight in order to estimate the amount of drug needs to be injected to them during the period of musth to reduce aggressiveness.

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Conflicts of interest

The authors declare no conflict of interests.

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