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Use of *in vivo* video image analysis as a substitute for manual biometric measurements on the prediction of qualitative and quantitative carcass characteristics of hair sheep lambs

J.C. Araújo [a], H.A.S. Santos [a], E.S.C. Ribeiro [a], A.C.C. Trindade [a], M.A. Sousa [b], M.P.M. Nunes [a], A.C.S. Lima [c], L.C.C. Daher [a], A.G.M. Silva [b,*]

[a] *Federal Rural University of Amazonia (UFRA), Belém, Pará, Brazil*
[b] *Federal University of Pará(UFPA), Castanhal, Pará, Brazil*
[c] *Federal Institute of Science and Technology of Amapá, Amapá, Brazil*

A R T I C L E I N F O

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A B S T R A C T

The objective of this study was evaluate whether Video Image Analysis methodology can replace the biometric measurements *in loco*, made in live hair sheep lambs, and predict carcass weight, commercial cuts weight and qualitative characteristics of carcass. Information was obtained from 92 male lambs from the Santa Inês genetic group and Dorper x Santa Inês crossbred. Nine biometrics measurements were made *in loco* in dorsal view and 15 in side view using hypometer and measuring tape, the same measurements were made in 184 images obtained from live hair sheep lambs using the ImageJ version 1.52k program. The database using images and database using measurements *in loco* were evaluated with algorithm Elastic net to select the best database. The VIA using dorsal view showed best results for prediction of carcass (R^2 - 0.96; 0.95 for hot and cold carcass respectively) and commercial cuts weight (R^2 - 0.70 - shoulder and leg; 0.85 for rib). The use of VIA to obtain biometric measurements can replace the traditional method and allows the prediction of carcass weights and commercial cuts weights through images of live animal, however, it was not efficient to predict characteristics as rib eye area and subcutaneous fat thickness.

1. Introduction

Image processing is a technique widely used in the most diverse sectors such as the detection of defects in industrial manufacturing products, traffic control and animal production. The use of imaging techniques to collect information in the livestock is important, as it saves time and labor, thus allowing information to be obtained from a big number of animals, where the great interest is in their colors, textures and shapes and geometric traces, in herds, imaging can be used to identify and detect health problems, slaughter evaluation and determine weight (Tsai and Huang, 2014; Chung et al., 2015).

Biometric measurement has a high relationship with body characteristics such as live weight and these metrics can help in the prediction of weight in occasions when a scale is not available (Franco et al., 2017). However, these techniques still spend a lot of time, becoming unfeasible in properties with large number of animals.

Thus, new ways to obtains biometric mesurements weight have been tested, including the use of images as a tool to predict information on live weight and carcass weight from images of the live animal. The use of image capture equipments such as 2D digital cameras, thermographic cameras or those that capture 3D images, are alternatives for capturing biometric measurements as they help to reduce the stress caused by the handling performed when trying to obtain the biometric measurements directly on the live animal (Wang et al., 2021).

The objective of this study was evaluate whether Video Image Analysis (VIA) methodology can replace the biometric measurements *in loco*, made in live hair sheep lambs, and predict carcass weight, commercial cuts weight and qualitative characteristics of carcass.

* Correspondence to: Federal University of Pará (UFPA), Campus Castanhal, Av. dos Universitários S/N, Castanhal, Pará, 68746-630, Brazil.
E-mail addresses: jonas.carneiro123@hotmail.com (J.C. Araújo), hugosanto03@gmail.com (H.A.S. Santos), anazootec16@gmail.com (E.S.C. Ribeiro), zoosyanne@gmail.com (A.C.C. Trindade), sousa.map@gmail.com (M.A. Sousa), manuella.paula@hotmail.com (M.P.M. Nunes), alynecslima@gmail.com (A.C.S. Lima), luciaracelichaves@yahoo.com.br (L.C.C. Daher), andregms@ufpa.br (A.G.M. Silva).

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2. Material and methods

The experimental procedures were approved by the Federal University of Para's Committee of Ethics on Animal (CEUA/UFPA protocol no. 97-2015) and animal care followed the guidelines of the National Council of Animal Experimentation Control (CONCEA, 2015).

2.1. *Obtaining information in vivo*

Information was obtained from 92 hair sheep lambs, castrated males, from commercial herds in the state of Pará - Brazil, which were finished in confinement and slaughter in a range of weight from 21 to 49 kg. Weighing took place within a period of 14 days to obtain body weight (BW) from the beginning of the experiment.

2.2. *Manual biometric measurements*

The biometric evaluation was performed as proposed by Cezar and Sousa (2007), using a measuring hypometer and measuring tape, both with an accuracy of 1 mm and scale of 1 cm, where animal was kept on station for correct postural position. Nine measurements were taken in dorsal view and 15 measurements in side view (Fig. 1).

2.3. *Obtaining the images*

The lambs were contained in a containment and positioning box, aiming to preserve upright posture and standardization of adjustments proportions of photographs. Furthermore, containment environment for capturing was added with a black non-slip floor which in the 2D dorsal imaging became the background of dorsal view; a green vinyl canvas was attached to the back wall of side view, which in side image became the side background.

The images were captured every 14 days. To capture these images, a 16 MP camera (Canon PowerShot SX160 IS® Canon, Tokyo, Japan) was used, which was placed on a capture support positioned at 2.5 m in height in middle of containment structure to obtain images from dorsal view and at 0.5 m high in relation to the floor and 2.5 m away from containment structure of animals to obtain images from side view. In the test, a stick marker ink was used to delimit anatomical reference points for measuring biometric measurements directly in the animals, in both dorsal and lateral imaging planes.

2.4. *Ultrasound*

Ultrasonography was performed one day before each slaughter using a linear transducer, with aid of gel, which was arranged perpendicular to *longissimus lumborum* muscle, using ultrasound equipment CHISON D600VET with frequency adjusted to 5.0 MHz. The ultrasound was performed in region comprising between the 12th and 13th thoracic vertebrae on animal's right side, area being previously shaved, to obtain images and measurements of *longissimus lumborum* muscle.

Thus, with the acquisition of the ultrasound image generated on the monitor, manually and with aid of the equipment configuration, measurement tool was used to measure following metrics in *longissimus lumborum* muscle: depth of the longissimus muscle (DLM mm), width of the longissimus muscle (WLM mm) and subcutaneous fat thickness (SFT mm). Then, as proposed by Souza et al. (2013) calculated the rib eye area (REA cm2) using the equation: REA= [(DLM/2 *WLM/2)* π].

2.5. *Slaughter, obtaining carcasses and commercial cuts*

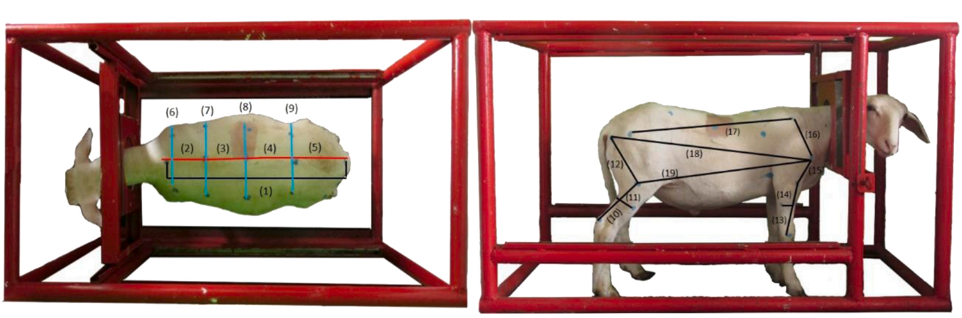
Before slaughter, the animals were fasted for a period of 12 h and after this period they were slaughtered in an experimental slaughterhouse following rules of the Regulation of the Industrial and Sanitary Inspection of Products of Animal Origin – RIISPOA (BRASIL, 2000). After slaughter, carcasses were weighed to obtain hot carcass weight (HCW) and then placed in a cooling chamber for refrigeration for a period of 24 h at a temperature of 4 °C, then carcasses were weighed to obtain cold carcass weight (CCW).

In cold carcass, commercial cuts of shoulder, leg, rib and loin were performed (Lage et al., 2014), which were weighed and dissected.

2.6. *Image processing*

To compare biometric measurements taken directly on animal and from photographic images, 92 images obtained from dorsal view and 92 from side view were used for processing using ImageJ as a tool (Schneider et al., 2012), in which it is possible to make delimitations within images and thus obtain information on delimited sizes. Markings performed on anatomical points of animals were used to define areas obtained by program, which needed to be performed manually on images. This information is provided in pixels which have been converted to centimeters to carry out statistical analyses.

In ImageJ software, a cross grid with an area of 1000 pixels/quadrant was first superimposed over images, to standardize images and facilitate process of delimiting distances and spatial relationships, considering that the grid enables measurement more precisely, as boundary remains straight. Soon after this process, biometric measurements were obtained in both views, considering points of intersection of reference grid. Twenty-four biometric measurements were considered: 9 metric in dorsal view (Fig. 1a) and 15 metric in side view (Fig. 1b), these being the same measurements obtained using a caliper and measuring tape in live animal (Fig. 1).



(a) (b)

Fig. 1. – Arrangement of animals in containment box and positioning of hair sheep lambs for imaging of animal's dorsal view (a) and side view (b) to obtain biometric measurements measured *in vivo* and by VIA. 1 – Body lenght; 2 – Distance from the withers to the 5th vertebra; 3 – Distance from the 5th thoracic vertebra to the 13th thoracic vertebra; 4 – Distance from the 13th thoracic vertebra to 1st sacral vertebra; 5 – Distance 1st sacral vertebra to tail insertion; 6 – Distance between the spines of the scapula; 7 – Chest width; 8 – Loin width; 9 – Rump width; 10 – Leg lenght; 11 – Leg width; 12 - Thigh lenght; 13 – Forearm lenght; 14 – Forearm width; 15 –Arm lenght; 16 – Scapula Lenght; 17 – Distance between the spine of the scapula-ileum; 18 – Distance between the scapula-humeral and ischium joint; 19 – Distance between scapula-humeral joint and femur-tibia joint; 20 – Height of withers; 21 – Chest height; 22 – Loin height; 23 – Croup height; 24 – Rump height.

2.7. Statistical analysis

Descriptive statistics were performed, obtaining mean, standard deviation, minimum, maximum and coefficient of variation using Microsoft Excel® (2016). The data normality test was performed using Shapiro Wilk test at a 5 % significance level. Two databases were structured for the data obtained through biometric measurements obtained *in loco* and biometric measurements obtained through VIA, composing two views (dorsal and side) using biometric measurements performed in a conventional way (*in loco*) and two views (dorsal and side) using biometric measurements obtained through the use of images. Then, using the R version 3.5.1 software, was used the elastic net machine learning algorithm, regularization for prediction of characteristics. This statistical methodology randomly divides the database into cross-validation and testing through stratified random sampling (type 2), thus segregating the databases into 70 % in cross-validation and 30 % in testing using the set seed 06 command. The combination of the k-fold cross-validation technique, adopting 5-fold cross-validation through the repeatedcv method with 5 repetitions, from the caret package of the R version 3.5.1 software (R Core Team, 2019) was performed in order to evaluate performance and stability of regression models, in addition to testing, validating equations in the cross-validation database and minimizing prediction error.

The model's performance was evaluated through results of cross-validation (cv) which consists of separating sample in cross-validation and test. This performance was evaluated using metrics: coefficient of determination (R2), root mean square error (RMSE), mean absolute error (MAE) and bias (BIAS), which is a mechanism for evaluating model's predictive accuracy error by absence of a better fit (Chai and Draxler, 2014). The model fit was evaluated considering as an underestimated (BIAS <1) or overestimated (BIAS > 1), $0 \leq R2 \leq 1$, with values tending to 0 for poor performance and tending to 1 for strong predictive performance, when the RMSE is similar to MAE with ideal value tending to 0 (Bennett et al., 2013; Rauschenberger et al., 2020). Body weight was used together with the two databases for improve the adjustment of the equations obtained.

3. Results

The results of descriptive statistics of characteristics of live animal (BW, REA and SFT), of carcass (weight of commercial cuts) as well as of means obtained in live animal and through VIA are represented for dorsal and lateral views (Supplementary Table 1).

Both techniques used to obtain morphometric data were not effective in predicting REA and SFT characteristics (Table 1) obtained through use of ultrasound, stated that weight and total volume of loin is difficult to assess and extract information from side view images.

The metrics that were generated for variables for both dorsal and side views are presented in Supplementary Table 2, however, as dorsal view presented better results for prediction of weights and needs a smaller number of variables, only regression equations for dorsal view by VIA is showed (Table 1).

The results of RMSE, R^2, MAE and Bias were better adjusted (lower values of RMSE, MAE and BIAS and higher R^2) for dorsal view using VIA with inclusion of BW.

The equations supports the importance of BW to obtain a better prediction of characteristics mainly related to weight which presented high values of R^2 (HCW = 0.96; CCW = 0.95) and lower values of RMSE (HCW = 0.72 %; CCW = 0.81 %, percentage of the mean of variable) and MAE (HCW = 0.59 %; CCW = 0.66 %, percentage of the mean of variable).

For biometric measurements, distances measured between the vertebrae, body length and widths of the chest and loin were included, demonstrating that these were more important than widths taken in scapula and croup region, which despite being regions of great deposition of muscle and fat are less representative for prediction of HCW and CCW than measurements taken throughout animal, because these measurements can better represent animal's length and, associated with width of the chest and loin, demonstrate depth characteristics, thus enabling a better prediction of body weight and carcass of lambs.

Table 1
Regression equations for dorsal VIA database to predict the characteristics of slaughter weight, carcass weight and commercial cuts of hair sheep lambs using VIA.

Variables	Equations	RMSE (%)	R^2	MAE (%)	BIAS
HCW	Y= 16.93 + 3.30 *BW + 0.04 *D5TV_13TV + 0.10 *D1SV_TI	0.72	0.96	0.59	0.08
CCW	Y= 16.49 + 3.42 *BW + 0.04 *BL + 0.04 *D5TV_13TV	0.81	0.95	0.66	0.11
Shoulder	Y= 2.82 + 0.32 *BW + 0.04 *BL + 0.05 *DW_5TV + 0.09 *D5TV_13TV + 0.04 *DSS + 0.002 *RWD	0.31	0.70	0.24	0.01
Leg	Y= 5.19 + 0.65 *BW + 0.17 *BL	0.67	0.70	0.46	-0.06
Loin	Y= 1.13 + 0.10 *BW + 0.04 *BL - 0.01 *DCW5_TV + 0.02 *D5TV_13TV + 0.01 *D13TV_1SV + 0.05 *D1SV_TI + 0.01 *DSS − 0.01 *CWD − 0.04 *LWD + 0.02 *RWD	0.34	0.38	0.24	0.01
Rib	Y= 5.82 + 1.14 *BW + 0.18 *BL+ 0.07 *D5TV_13TV + 0.03 *D1SV_TI + 0.08 *RWD	0.65	0.82	0.50	0.12
REA	Y= 9.46 + 1.59 *BW − 0.41 *BL + 0.78 *DW5_TV + 0.68 *D5TV_13TV + 0.09 *D13TV_1SV + 0.42 *D1SV_TI + 0.55 *DSS − 1.13 *CWD − 0.59 *LWD + 0.26 *RWD	2.21	0.49	1.76	0.97
SFT	Y= 2.43 + 0.23 *BW − 0.01 *DCW5_TV + 0.15 *D13TV_1SV − 0.29 *D1SV_TI − 0.04 *DSS + 0.008 *CWD + 1.25 *LWD − 0.11 *RWD	1.43	0.43	1.1	-0.38

Body weight (BW); hot carcass weight (HCW); cold carcass weight (CCW); rib eye area (REA); Subcutaneous fat thickness (SFT); body lenght (BL); Distance from the withers to the 5th thoracic vertebra (DW_5VT); Distance 1st sacral vertebra to tail insertion (D1S_VTI); Loin width (LWD); Chest width (CWD); Distance from the 5th thoracic vertebra to the 13th thoracic vertebra (D5TV_13TV); Distance between the spines of the scapula (DSS); Rump width (RWD); Distance from the 13th thoracic vertebra to 1st sacral vertebra (D13TV_1SV). coefficient of determination (R2), root mean square error (RMSE), mean absolute error (MAE). The bases for the percentages in RMSE and MAE are the means of the predicted variable.

The equations that make up shoulder, loin and rib meat cuts also presented biometric measures related to distances measured between vertebras and added the croup width to composition of equation, croup width is associated with the animals' weight gain, being an indicator of muscle gain, so this measure is related to size of rib, loin, shoulder and leg, however for prediction of leg, only two variables were needed BW and body length, which are characteristics that present greatest relationship with weights of meat cuts.

The prediction for loin showed low values of RMSE (0.34 %, percentage of the mean of variable), MAE (0.24 %, percentage of the mean of variable) and low values of R^2 (0.38), this is due to size of cut which, being smaller than others, makes it difficult to predict by means other than use of ultrasound.

Similar to the loin results, REA and SFT variables were also difficult to predict, either through VIA or biometrics, which is associated with this information being obtained in the loin muscle, which, as already mentioned, is difficult to measure in the animal alive without use of ultrasonography.

4. Discussion

When evaluating dorsal and side views, some characteristics such as HCW and CCW, dorsal view presented better results than side view (lesser errors and higher R^2 values). This is associated with the fact that in dorsal region, is possible to use measurements that represents a large part of carcass, such as body length, and widths of the scapula, thorax and rump that are performed in regions of carcass that have large deposition of musculature and adipose tissue, in addition, animals that have a larger chest width are deeper and have greater deposition of musculature and fat (Ferreira et al., 2016; Araújo et al., 2020). Dorsal measurements tend to suffer less distortion when measured along the animal when compared to measurements obtained from side view, thus not being so subject to positioning of the animals.

Due to positioning of loin, which is located along dorsal region, this view was better for predicting weight characteristic than side view. This can be explained by the biotype of lambs that are meat type, which have a barrel-shaped body development, so back region tends to develop and accumulate more muscle and fat, leading the animal to have a greater back size (Gusmão Filho et al., 2009; Ferreira et al., 2016; Lima et al., 2017).

Comparing techniques used, biometric measurements obtained through VIA presented similar results with measurements obtained directly from animal and was able to predict information from live animal, such as HCW and CCW and it was able to predict weight of commercial cuts for shoulder, ribs and leg, thus proving to be an important tool for animal production that is increasingly looking for new techniques that facilitate handling and increase speed within farm.

The use of the VIA technique with the BW improved the prediction of characteristics as carcass weight and meat cuts weight through dorsal view, demonstrating that using a single view and a single image is possible to predict carcass weights and cuts. Dorsal view of animals can be easily obtained through a camera positioned above the containment trunk, thus enabling image capture and obtaining information in the handling of animal weighing, which it would facilitate the collection of data and contribute to reducing the stress of animals that would not need to be handled to obtain biometric measurements. Furthermore, cameras have been increasingly used to reduce human and animal interaction in order to mitigate stress of animals (Wang et al., 2021).

The use of VIA has already been used to obtain carcass characteristics such as HCW and CCW as well as information on commercial cuts (Gomes et al., 2016; Lorenzo et al., 2017; Araújo et al., 2020) and in live animals (Miller et al., 2019; Weber et al., 2020) thus demonstrating that the use of VIA is increasingly present within rural property.

The use of VIA to obtain biometric measurements allows for greater speed in relation to these measurements, in addition to being a more accurate technique with fewer human error during measurements, allowing to monitor body development of animals in a better and faster way and with fewer people to perform the service. Measurements are a way to monitor animal development and, as demonstrated in this study, enables prediction of important carcass characteristics, such as hot carcass weight, which is directly linked to amount paid for animal, and information about commercials cuts. However, these measurements are often left out and are not carried out in large commercial herds due to the amount of time and labor it would require to obtain all of them. Thus making the use of measurements obtained through images in an automated way is a faster and more accurate way.

Obtaining these measurements through images allows to know information regarding the animal's carcass before slaughter, thus allowing choose between keeping the animal on the property, aiming at greater weight gain for a given market that will pay for this termination, or slaughter the animal at right time, thus allowing the animal to spend less time on the property. The use of morphometric measurements associated with hair sheep lambs made it difficult for the methodology used to present high results of determination coefficient, hair sheep lambs tend to have a lower capacity for external fat deposition and greater internal deposition which makes it difficult to measure the amount of fat in the carcass only using linear measures.

5. Conclusion

The use of VIA to obtain biometric measurements can replace the traditional method and allows the prediction of carcass weights and commercial cuts weights through images of live animal, thus being a tool for predicting these characteristics before slaughter, however, it was not efficient to predict characteristics as rib eye area and subcutaneous fat thickness.

Conflicts of interest

The authors wish to confirm that there are no know conflicts of interest associated with publication video image analysis for prediction of lamb carcass characteristics through biometric measurements obtained in vivo and there has no significant financial support for this work that could have influenced its outcome.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.smallrumres.2022.106779.

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