ESTIMATION OF THE WEIGHT OF CARCASS TISSUES OF GROWING PIGS USING COMPUTED TOMOGRAPHY

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Abstract – The aim of the present work is to estimate carcass composition of live growing pigs with computed tomography images. For this purpose 20 pigs (Pietrain x (Landrace x Large White)) were enrolled, scanned and slaughtered at 30, 70, 100 and 120 kg target weight (n=5 per target weight). Scanning was performed with a General Electric Hi Speed Zx/I computed tomographic scanner (CT). Fat, muscle and bone total volumes were calculated as the sum of voxel volumes ranging respectively between -149 and -1, 0 and +140 and +141 and +1400 Hounsfield (HU). After scanning, pigs were slaughtered, and left half carcasses were cut and dissected. Dissected lean, fat and bone weights of the main cuts were obtained and related with the respective radiodensity volumes. These relationships were established using linear, quadratic and allometric regressions. From these results it was concluded that lean, fat and bone can be estimated using live pigs CT images and this without removing the viscera.

I. INTRODUCTION

Estimating carcasses composition would allow the meat industry to optimize processes, to increase benefits and to satisfy consumer demands. The knowledge of pig carcass composition in live pigs during growth would help breeding and nutritional companies to produce the desired product. Carcass characteristics depend on several factors such as genetics, gender, feeding or management [1,2].

Computed tomography (CT) is a non invasive technology based on X-rays that allows visualizing and quantifying tissues of live animals and carcasses. The X-rays are attenuated in their way through the body. The degree of the attenuation depends on the density of the tissues and it is measured in Hounsfield units (HU). Because lean, fat and bone have different densities, HU values allow to differentiate between tissues. CT has been applied to estimate carcass composition of live animals and carcasses [3,4,5].

The aim of the present study was to estimate carcass composition in live growing pigs using computed tomography images.

II. MATERIALS AND METHODS

Animals and CT scanning procedure

A total of 20 pigs (Pietrain × (Landrace × Large White)) were used in the present study. Pigs were reared in the experimental farm of IRTA (Monells, Girona, Spain) and fed *ad libitum* in a two-phase feeding program. Five pigs were CT fully scanned at each of the following live weights: 31.4 ± 2.2 kg, 67.7 ± 1.8 kg, 100.5 ± 1.5 kg and 123.1 ± 3.8 kg live weight.

The scans were performed with a General Electric HiSpeed Zx/I CT. Pigs were previously anaesthetized and placed in a specific PVC cradle for easy transportation to the device installations (Figure 1). Acquisition conditions were: axial, matrix 512x512, 140 kV, 145 mA, 7 mm-thick at the lowest weight and 10 mm-thick at the rest of weights, and displayed field of view between 300 and 460 mm, depending on the volume of the animal.

Figure 1. Scanning of a live pig with a computed tomography device.

Carcass cutting and dissection

After the scans the pigs were slaughtered following the standard procedures. At 24 h *post mortem* left half carcasses were cut following Walstra and Merkus [8] procedure. Then, lean, fat and bones of the main cuts (loin, ham, belly and shoulder) were separated by a trained butcher and weighed. The entire tenderloin was also added to the amount of lean)

Image treatment

The distribution of voxels, based on the Hounsfield (HU) scale, was obtained from all the CT images of each pig, without the cradle and with viscera, and analyzed with the VisualPork software [6,7]. Frequency of voxels was transformed to volume by means of the displayed field of view, slice thickness and matrix. Volume between -149 and -1 HU values were classified as fat, values between 0 and 140 HU as lean and values between 141 and 1400 HU as bone. These volumes were used as predictors in the statistical analysis. Distribution of volume depending on HU values for the lean and fat area is presented in Figure 2.

Statistical analysis

Three different types of regression equations were performed to estimate the amount of lean, fat and bone weight of the four main cuts (tenderloin was added to the lean): (1) linear regression ($y=a+b\cdot x$), (2) quadratic regression ($y=a+b_1\cdot x+b_2\cdot x^2$), and (3) allometric regression ($y=a\ x^b$, linearized as $\log y= \log a + b\cdot \log x$). Predictors were the volume of lean for the lean weight, the volume of fat for the fat weight and the volume of bone for the bone weight.
Data analysis was performed with the REG procedure of SAS software (version 9.2; SAS Institute Inc., Cary, NC, USA). Dependent variables were weighed by the inverse of the standard deviation of the residuals at each target weight. To validate the models the mean of the residuals, the residual standard deviation and the correlation between predicted variables and residuals were studied. Moreover the root mean square error (RMSE) was calculated as:

$$RMSE = \sqrt{\frac{\Sigma(y_i - \hat{y}_i)^2}{n}}$$

where y_i is the dissected value, $\hat{y}_i$ the predicted value and n the number of observations.
The RMSE of prediction was obtained by cross validation leave-one-out (RMSEPCV) by means of a SAS macro adapted from those of Caseur et al. (2003).

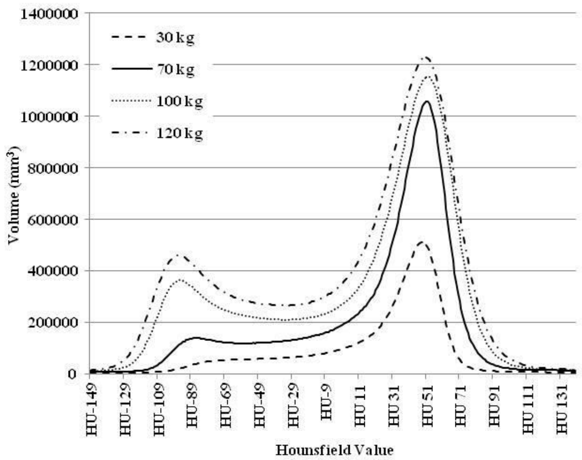

Figure 2. Volume distribution depending on Hounsfield values and target weight of the scanned live pigs.

III. RESULTS AND DISCUSSION

Averaged lean content was 14532 g, the averaged fat content was 5488 g and the averaged bone content was 1922. Thus, the mean of the residuals and the residual standard deviation were used to evaluate the goodness of fit of the equations and they were particularly low (Table 1). Furthermore, the correlations between residuals and predicted values were always close to zero indicating the lack of prediction biases. Figures 3, 4 and 5 show the relationship between the volumes and the weight of the different tissues. All the RMSE and RMSEP were quite similar. But the lowest RMSEP (in absolute value) for the prediction of the bone weight was obtained with the linear approach. Nevertheless, although it seems linear, it is possible to see that for lean weight, quadratic and allometric approaches gave the lowest RMSE and the lowest RMSEP, respectively. For the weight of the fat, quadratic approach produced the lowest RMSE and RMSEP. However, the magnitude of the errors between the different approaches was not very high.

Table 1 Goodness of fit for the different statistical approaches.

	Mean[a]	r.s.d.[b]	r[c]	RMSE	RMSEP
Lineal					
Lean	-22.6	399.4	0.07	389.9	410.8
Fat	-8.3	288.6	-0.08	281.4	312.7
Bones	-4.3	89.0	0.04	86.9	94.3
Quadratic					
Lean	-7.1	382.5	-0.01	372.9	414.5
Fat	6.8	270.4	0.00	263.6	305.8
Bones	-3.3	88.4	0.00	86.2	102.7
Allometric					
Lean	13.7	386.3	-0.05	376.7	396.8
Fat	-29.2	301.3	-0.21	295.1	328.2
Bones	-2.7	90.1	0.08	87.9	95.2

[a] Mean of the residuals; [b] standard deviation of the residuals; [c] Coefficient of correlation between r.s.d. and predicted variables; RMSE: root mean square error; RMSEP: RMSE of prediction by cross-validation leave-one-out.

IV. CONCLUSION

It is concluded that the amount of different tissues such as lean, fat and bone can be estimated using CT images of live pigs, without the necessity of removing the viscera.

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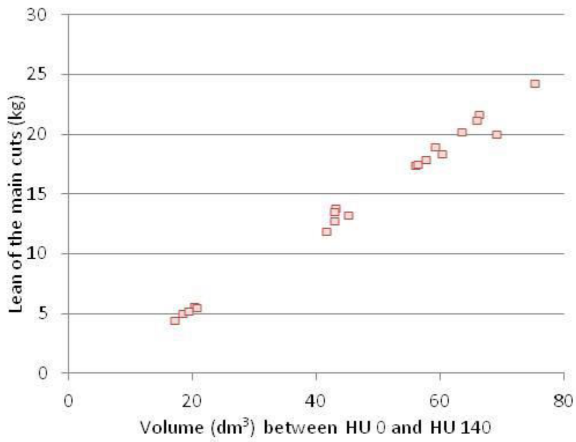

Figure 3. Relationship between the weight of lean of the main cuts from dissection and the volume of lean from CT images of live pigs.

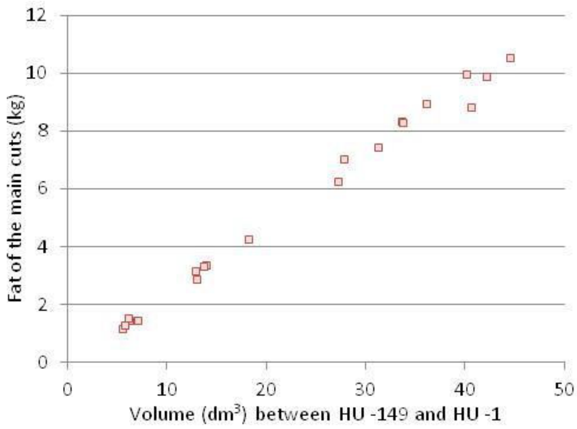

Figure 4. Relationship between the weight of fat of the main cuts from dissection and the volume of fat from CT images of live pigs.

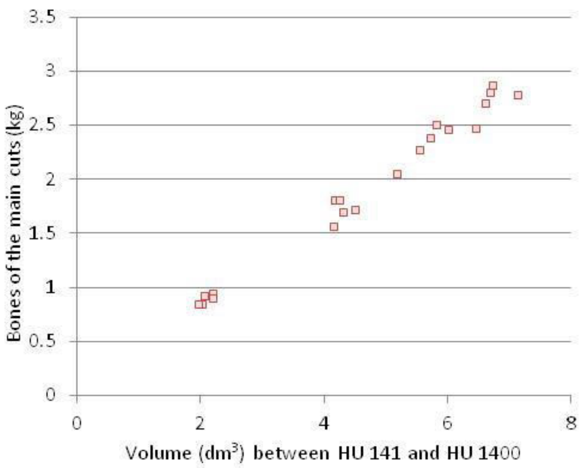

Figure 5. Relationship between the weight of bones of the main cuts from dissection and the volume of bones from CT images of live pigs.

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