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Comparison of different devices for predicting the lean meat percentage of pig carcasses

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ABSTRACT

Lean meat percentage (LMP) is the criterion for carcass classification and it must be measured on line objectively. The aim of this work was to compare the error of the prediction (RMSEP) of the LMP measured with the following different devices: Fat-O-Meat'er (FOM), UltraFOM (UFOM), AUTOFOM and VCS2000. For this reason the same 99 carcasses were measured using all 4 apparatuses and dissected according to the European Reference Method. Moreover a subsample of the carcasses ($n = 77$) were fully scanned with X-ray Computed Tomography equipment (CT). The RMSEP calculated with cross validation leave-one-out was lower for FOM and AUTOFOM (1.8% and 1.9%, respectively) and higher for UFOM and VCS2000 (2.3% for both devices). The error obtained with CT was the lowest (0.96%) in accordance with previous results, but CT cannot be used on line. It can be concluded that FOM and AUTOFOM had better accuracy than UFOM and VCS2000.

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1. Introduction

Lean meat percentage (LMP) is an important carcass quality characteristic because it is the criterion for carcass classification. It is measured objectively on line at slaughterhouses using different types of equipment. Depending on their degree of automation, these devices can be manual devices (for instance the Optical Probe), semiautomatic (for instance, Fat-O-Meat'er-FOM and Ultra-FOM-UFOM of Carometec A/S, Herlev, Denmark; Hennessy Grading Probe-HGP of Hennessy Grading System Ltd., Auckland, New Zealand; Capteur Grass-Maigre-CGM of Sydel Corporation, Lorient Cedex, France) or automatic (for instance: AUTOFOM and Classification Center-CC of Carometec A/S, Herlev, Denmark; VCS2000 of e + V Technology GmbH, Oranienburg, Germany; TOBEC of Meat Quality Inc., Springfield, Illinois, USA). Futhermore, depending on the methodology used to take the measurements the devices can use light reflectance (FOM, HGP, CC), ultrasound (UFOM, AUTOFOM), electromagnetism (TOBEC) or vision (VCS2000) (Pomar, Marcoux, Gispert, Font i Furnols, & Daumas, 2008). All devices are calibrated predicting the LMP. The estimation of calibration parameters are based on a trial conforming to the EU Regulation (Commission Regulation (EC) 1249/2008). In some non EU countries, the definition of lean content can be different from that in the EU (Marcoux, Pomar, Faucitano, & Brodeur, 2007). The dissection trial in the EU stipulates the dissection of at least 120 carcasses, which are representative of the country, following the reference method (Walstra & Merkus, 1995). For the approval of the calibration equation it is necessary to have an error of prediction (RMSEP) lower than 2.5% (Commission Regulation (EC) 1249/2008). So the RMSEP is a very important parameter for knowledge of the accuracy of the different devices. The RMSEP varies depending on the device and the country, and has values from 1.6% to 2.45% (Brøndum, Egebo, Agerskov, & Busk, 1998; Busk, Olsen, & BrØndum, 1999; Engel, Lambooij, Buist, Reimert, & Mateman, 2006; Font i Furnols, Engel, & Gispert, 2004).

Moreover, as a result of the European Project EUPIGCLASS (www.eupigclass.net), Computer Tomography (CT) and Magnetic Resonance Imaging have arisen as possible reference devices to calibrate the different types of equipment used on line for pig carcasses classification. The advantage of these apparatuses is that they can measure the entire carcasses and therefore it is unnecessary to cut and dissect them, which is hard, difficult and time consuming work. Furthermore, the RMSEP of these pieces of equipment is very low, varying from 0.6% to 1.7% (Judas, Höreth & Branscheid, 2007; Christensen & Borggaard, 2005; Font i Furnols, Teran, & Gispert, 2009), although the conditions for the measurements are not the same for all studies. In fact, in all cases it is smaller than the errors made by the butchers during the dissection trial, which is 2.0% (maximum difference between butchers) (Nissen et al., 2006) or 1.0% (average error between butchers) (Judas, 2009).

The aim of this paper was to compare the different devices used to estimate the lean meat percentage of pig carcasses.

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2. Materials and methods

2.1. Carcass sampling and dissection

A trial was carried out in Spain to obtain prediction formulas for the estimation of the lean meat percentage of pig carcasses with Fat-O-Meat'er (FOM), UltraFOM (UFOM), AUTOFOM and VCS2000 equipments, and to achieve authorization for them from the Management Committee of the Common Organisation of the Agricultural Markets. The selection of the carcasses ($n = 156$) was carried out at one slaughterhouse (Patel S.A.U.) following the fat thickness national distribution (Gispert & Font i Furnols, 2007). These carcasses were transported to IRTA-CENTA facilities in Monells (Girona) in refrigerated conditions and manually dissected according to the European Reference Method (Walstra, 1995), within 48 h *postmortem*. From the dissection the dissected lean meat percentage (LMP089) was calculated according to the Commission Regulation (EC) 1249/2008 as:

$$\mathrm{LMP089}\ (\%) = 0.89 \times \frac{\sum \mathrm{lean}\ (\mathrm{ham, loin, belly, shoulder}) + \mathrm{tenderloin}}{\sum \mathrm{weight}\ (\mathrm{ham, loin, belly, shoulder, tenderloin})} \times 100$$

A subsample of 99 of these carcasses was measured with the four pieces of equipment and was used for the following calculations. The rest of the carcasses had incorrect measurements for one or more than one of the pieces of equipment (i.e. device did not work, bad contact device-carcass, error with a camera, error with the images, etc.). The sample used in this work consisted of 12% of lean carcasses (fat thickness less than 12 mm), 63% of medium carcasses (fat thickness between 12 mm and 17 mm) and 25% of fat carcasses (fat thickness higher than 17 mm). Moreover, 20% were carcasses from castrates, 43% from females and 37% from entire males. The subsample used in the present work is representative of the Spanish pig population for fat thickness (16%, 64% and 16% for lean, medium and fat groups) and sex (20% castrates, 50% female and 30% entire) although this was not necessary for the comparison of the different devices.

2.2. Measurements on line

AUTOFOM was the first piece of equipment which completely automatically measured the carcasses. It was installed behind the dehairing machine and it scanned the entire body. The AUTOFOM measured 127 variables related to different fat and muscle thickness. Then the carcasses were eviscerated and split and in close proximity to the weighing point two trained operators measured them first with FOM and then with UFOM, thus avoiding that the pressure applied with UFOM to the carcass affecting the FOM measurement. FOM measured the fat depth and muscle thickness between the 3rd and 4th last ribs and at 6 cm of the midline because this is the point of measurement stipulated for this device by the Spanish official equation. The UFOM, following the equipment instructions, measured fat depth and muscle thickness between the 3rd and 4th last ribs and at 7 cm of the midline. Finally the VCS2000 equipment carried out the classification of the carcasses automatically. VCS2000 is a vision system that measure different fat depths, muscle thickness, areas and ratios between them (total 330 variables), in the interior part of the half carcass.

2.3. Scanning with the computed tomography equipment

A subsample of these carcasses ($n = 77$), distributed by fat thickness and sexes as in the previous one, were scanned with the computed tomography equipment (General Electric, HiSpeed Zx/I) located at IRTA-CENTA in Monells (Girona). The scanning parameters were 140 kV, 145 mA, matrix of 512×512, displayed field of view between 460 and 500 and reconstruction algorithm STD+. From the obtained DICOM images the volume associated to each Hounsfield attenuation value as explained in Font i Furnols et al. (2009) was calculated. The new legislation (Commission Regulation (EC) 1249/2008) allows the use of dissection with a CT apparatus, as well as the manual dissection methods. For the present work, some carcasses were scanned with CT in order to prepare the equipment to replace manual dissection in future studies.

2.4. Statistical analysis

For FOM and UFOM the multivariate regression was carried out with the REG procedure of SAS (SAS Institute Inc., Cary, NC, USA). The LMP089 was estimated by means of linear combinations of on line measurements (fat depth and muscle thickness). The root mean square error of prediction (RMSEP) obtained with leave-one-out procedure was calculated by means of the PRESS statistic as described in Causeur et al. (2003) and Engel et al. (2006).

For the AUTOFOM and VCS2000, since there are many highly correlated on line measurement used as prediction variables, a more robust parameter estimation is obtained using Partial Least Square Regression (PLS), a multivariate technique used on this kind of data (Brøndum et al., 1998; Engel et al., 2006). The PLS procedure of SAS was used. LMP089 was the dependent variable and the different variables of the equipment were used as prediction variables. Due to the large number of variables for both pieces of equipment (127 for AUTOFOM and 330 for VCS2000) a selection was carried out by means of a SAS macro (Judas & de Smet, 2008). To calculate the RMSEP with leave-one-out procedure another SAS macro was used (Causeur et al., 2003).

For the CT data the PLS procedure of SAS was used (Tobias, 1995). LMP089 was the dependent variable and the volume associated with attenuation Hounsfields values from -100 to +120 were used as independent variables because this range of variables provides good results as explained in Font i Furnols et al. (2009). The RMSEP with leave-one-out procedure was calculated with a SAS macro (Causeur et al., 2003).

When the PLS technique was used the number of extracted factors was presented because a low value of these factors is important in order to avoid over-fitting. Moreover, for each device the regression between the predicted and the dissected LMP089 was obtained and the correlation coefficient (R^2) was calculated.

3. Results and discussion

The present work compared four different classification devices which evaluated the same 99 carcasses.

Table 1 shows the RMSEP obtained from the different devices and other parameters related to the prediction equation. It could be seen that the smaller RMSEP corresponded to the LMP prediction with CT that also had the highest R^2. However, CT is a type of equipment that, for the moment, cannot be used on line. Nevertheless, due to the low CT prediction error, which has been reported previously (Font i Furnols et al., 2009; Judas et al., 2007;

Table 1
Characteristics of the prediction equation of the lean meat percentage as calculated by the different devices ($n = 99$).

Device	RMSEP (%)	Number of variables	Number of factors	R^2
FOM	1.8	2	–	0.77
UFOM	2.3	2	–	0.64
AUTOFOM	1.9	42	2	0.78
VCS2000	2.3	75	4	0.70
TC[a]	1.0	221	6	0.96

[a] $n = 77$.

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