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 apparatus and dissected according to the European Reference Method. Moreover a subsample of the carcasses (n=77) were fully scanned with a 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 presented better accuracy than UFOM and VCS2000.

Keywords: pig carcass classification, lean meat percentage, classification devices, X-ray computed tomography, prediction error, calibration

1. Introduction

Lean meat percentage (LMP) is an important carcass quality characteristic because it is the criteria for carcass classification. It is measured objectively on line at slaughterhoses using different types of equipment. Depending on their degree of automation, these devices can be manual devices (for instance Optical Probe), semiautomatic (for instance, Fat-O-Meat'er -FOM and UltraFOM -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 measures 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; Font i Furnols, Engel & Gispert, 2004; Engel, Lambooij, Buist, Reimert & Mateman, 2006).

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 of the measurements are not the same for all studies. In fact, in all the 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 carcass.

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 slaughterhose (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 Simplified Reference Method (Walstra & Merkus, 1995), within 48 h *post mortem*. From the dissection the dissected lean meat percentage (LMP089) was calculated according to the Commission Regulation (EC) 1249/2008 as:

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

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 measure 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 affected 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 computer 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 512x512, 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 method. 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 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 in this kind of data (Brøndum, Egebo, Agerskov & Busk, 1998; Engel et al., 2006). 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 amount 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 to 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 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 presented 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; Picouet, Teran, Gispert & Font i Furnols, submitted for publication) this equipment can be used as a reference method. In fact, recent changes in legislation allow using CT as a reference method (Commission Regulation (EC) 1249/2008).

It is important to compare the different devices that can be used on line at the slaughterhouses for the classification of pig carcasses because there are important differences between them in terms of prediction error, although all of them fulfil the EU legislation (prediction error lower than 2.5%). Even though FOM is not fully automatic and only measures one fat depth and one muscle thickness, its RMSEP (1.8%) is smaller than the others. AUTOFOM also presented a low prediction error (1.9%), measuring 127 variables (42 of them used in the prediction equation). The highest prediction error corresponded to the VCS2000 (75 out of 330 variables included in the prediction equation) and UFOM (2 variables, one fat depth and one muscle thickness) devices (2.3% for both devices). When the R^2 was studied it could be seen that FOM and AUTOFOM presented the highest values (0.77 and 0.78, respectively), UFOM the lowest value (0.64) and VCS2000 an intermediate value (0.70).

FOM prediction error found in this work was higher than those obtained by Gispert and Diestre (1994) (1.6%) but lower than the error found by Allen and McGeehin (2001) (2.2%), Brøndum, Egebo, Agerskov and Busk (1998) at a study in Germany and the USA (2.0% and 2.4%, respectively), Font i Furnols et al. (2004) (between 2.2% and 2.3%) and Fortin, Jones and Haworth (1984) (between 2.3% and 2.1%). However, some errors are difficult to compare because in some studies the RMSE was calculated instead of the RMSEP, and RMSE presents lower values than RMSEP (Engel et al., 2006). Moreover the lean meat percentage definition, pig population characteristics, butchers' skills, etc. were not the same in all the studies and could have been affected the prediction error. For the calculation of the Spanish official prediction equation (LMP= 66.91-0.895*fat thickness + 0.144*muscle depth; Commission Regulation (EC) 11/2009) the number of carcasses used for the calibration was 150 (the 99 used in this work plus 51 more carcasses), and the RMSEP and the R^2 were almost the same (1.8% and 0.75, respectively).

UFOM prediction error of the present work is similar to those reported by Piechocki, Borzuta and Grzeskowiak (1994) in a study carried out in Poland (2.3% *vs.* 2.4%). However, Fortin, Tong and Robertson (2004), when predicting the saleable meat yield with UFOM found a RMSE of 1.7%, which is much smaller than those found in the present work. This equipment is based on ultrasound measurements and for accurate measurements it is very important to have not only a good contact between device and carcass but also a warm moist carcass surface (Pomar et al., 2009). This can create an error in the measurements because sometimes carcasses could be insufficiently moist and this is possibly one of the reasons why the error in this equipment is higher than the error found with FOM, as both devices use one fat depth and one muscle thickness to predict the LMP. The Spanish official prediction equation of the LMP with the UFOM (LMP=69.22-1.023*fat thickness + 0.116*muscle depth; Commission Regulation (EC) 11/2009) was obtained by means of 145 dissections (the 99 used in this study plus 46 more). The RMSEP was lower (2.1%) and the R^2 higher (0.70) than those obtained from the present work with the subsample.

The prediction error obtained with AUTOFOM (1.9%) is somewhat lower than those reported by Strzelecki, Jomender, Borzuta and Lisiak (1998) and by Gispert, Font i Furnols, Batallé & Diestre (2002) which was 2.0% in both studies. However it is somewhat higher that those reported by Fortin et al. (2004) which was 1.7 for the prediction of the saleable meat yield and by Brøndum et al. (1998) which was 1.6% in a trial carried out in Germany, 1.7% in USA and 1.8% in Denmark. To obtain the Spanish official prediction equation of the LMP with the AUTOFOM, the number of carcasses used for the calibration were 135 (the 99 of the present work plus 36 more), and the RMSEP and R^2 were slightly higher (2.0% and 0.81%, respectively).

VCS2000 presented a higher prediction error than AUTOFOM and FOM. In disaccordance with our results, Branscheid, Höreth, Baulain, Tholen and Dobrowolski (2004) did not find important differences in the prediction error between AUTOFOM and VCS2000. VCS2000 is influenced by the splitting of the carcass because it measures the interior part of half a carcass. However, for the present trial, only well split carcasses were used. Engel, Lambooij, Buist, Reimert and Mateman (2006) found a RMSEP of 2.2% for the VCS2000 equipment when 115 variables were measured and all of them were included in the equation. The error of prediction found in the present work was somewhat higher (2.3%) and the number of variables used in the prediction equation, lower (75). The RMSEP decreased a little to 2.2%, and the R^2 was the same (0.70) when 135 carcasses (the 99 of this work plus 36 more) were used for the calibration, in order to obtain the Spanish official prediction equation of the LMP.

4. Conclusions

The error of prediction of the lean meat percentage depends on the device used for taking the measurements: FOM and AUTOFOM presented lower prediction error than UFOM and VCS2000. CT is the most precise equipment but it cannot be used on line. However it is good equipment which can be used as a reference method for the calibration of the on-line devices as it is allowed by the EU legislation.

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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 *	1.0	221	6	0.96

* n=77