ASSESSMENT OF FAT AND LEAN CONTENT IN ITALIAN HEAVY GREEN HAMS BY MEANS OF ON-LINE NON-INVASIVE TECHNIQUES

N. Simoncini[1], R. Virgili[1], C. Schivazappa[1], A. Pinna[1], A. Rossi[2], J. Álvarez[3]and J. M. Rodriguez[3]

[1]Stazione Sperimentale per l'Industria delle Conserve Alimentari (SSICA), V. le Tanara, 31/A Parma, Italy; Centro Ricerche Produzioni Animali (CRPA), Corso Garibaldi, 42, Reggio Emilia, Italy; [3]Centre de Recerca i Innovació de Catalunya (CRIC), S.A C/ Víctor Pradera 45, Cornellà de Llobregat, Barcelona, Spain

Abstract – The commercially available AutoFom and the prototype Lenz Fat Analyzer™ have been tested for their capability to predict fat and lean content in Italian heavy hams before being processed into typical dry-cured hams. Both equipments operate in a non-invasive way: the former is based on carcass response to ultrasound, the latter on the different response of lean and fat tissues to a frequency dependent electromagnetic field. In the case of AutoFom, 40 selected carcasses of Italian heavy pigs were scanned after slaughtering to achieve the ultrasonic Image Parameters used to predict fat content of the corresponding hams. In the case of Ham Scanner, 20 heavy green hams were scanned to achieve a signal related to the lean content of the ham. In both cases, green hams were dissected after scanning to quantify the lean and the fat content. PLS and multiple linear regression were applied to ultrasonic and electromagnetic parameters generated by AutoFom and Lenz Fat Analyzer™ respectively. Though a larger number of samples is needed to achieve fully validated models, two regression models, promising to classify heavy green hams at an industrial level, were obtained.

Key Words – AutoFom, Ham classification, Lenz Fat Analyzer™, Non-invasive techniques, Regression models.

I. INTRODUCTION

In Italy the subcutaneous fat thickness of domestic heavy green hams to be processed into typical dry-cured hams is defined by tutelary regulations establishing a minimum value corresponding to 20 mm. Currently, green hams allowed to be processed into typical dry-cured hams, i.e. Parma and San Daniele to mention the most known brands, are those labeled as U, R, and O according to the EUROP grid.

The development of non-destructive technologies for prediction of fat and lean content of green hams could be a positive step for dry-cured ham processors, providing them with a tool for classifying green ham suitability for dry-curing with reference to weight loss and absorbed salt [1-6]. Two on-line non-destructive technologies have been tested for fat and lean prediction in green hams: the ultrasound scanner AutoFom and the Lenz Fat Analyzer™ system based on electromagnetic induction.

The aim of the study was to investigate the capability of the tested systems to give quantitative information concerning fat and lean amount in heavy green hams (12-15 kg).

II. MATERIALS AND METHODS

AutoFom scanning of carcasses

A sample of 145 carcasses of Italian heavy pigs were scanned by means of ultrasound scanner AutoFom (Carometec A/S, Herlev, Denmark): 48 ultrasonic image parameters (IPs) were extracted from each scanned carcass. The same carcasses underwent traditional Fat-o Meter (FOM) to be classified on EUROP grid according to estimated lean meat percentage. Carcasses were hot sectioned and hams taken from each carcass were labelled to keep a link with the corresponding carcass. After refrigeration, during ham trimming, the thickness of subcutaneous fat under *caput femoris* bone was manually measured. A subsample of 40 hams (randomly right or left), representative of an adequate variability in subcutaneous fat thickness and weight, were selected to assess AutoFom capability of predicting fat content of green hams. From each green ham subcutaneous fat, bone, rind, and lean with inter and intramuscular fat were separated and weighted. Lean with fat (inter and intramuscular) were minced and analysed for fat content according to AOAC 960.39 official method [7]. Ham total fat was calculated by adding subcutaneous fat (weight data) to intra and intermuscular fat (analytical data).

Lenz Fat-Analyzer™ scanning of green hams

A Lenz Fat-Anlayzer™ system (Lenz Instruments, S.L., Barcelona, Spain*)* was used to predict the lean and fat content of a selected batch of green heavy hams. The measurement principle of this low cost instrument relies on the different response of ham lean and fat tissues to an externally applied time dependent electromagnetic field [8]. The system measures the complex dielectric permittivity of each individual ham, which is correlated with their respective fat content. The device is equipped with an automatically controlled conveyor belt to enable scanning hams in a simple and reproducible way. By using electromagnetic antennas rather than contactless electrodes, the dielectric properties of meat parts can be analyzed reliably and without contact. This measurement procedure is absolutely non-invasive, and requires just a few seconds for each analysis. In addition, the system includes also a 3D vision camera, which allows obtaining morphological data of meat parts. Though not used in the present study, this information can be introduced in the correlation model to increase the accuracy of the instrument.

A sample of 20 heavy green hams with a representative variability in fat thickness (18 to 43 mm) and weight (12.5 to 15 kg) were selected to assess Lenz Fat-Analyzer™ capability for predicting fat and lean content in heavy green hams. Green hams were refrigerated at 3°C prior to their analysis, to avoid possible temperature induced errors. Scanned hams were dissected to determine fat and lean content, following the same procedure as described earlier for AutoFom.

Data Analysis

The IPs given by AutoFom were statistically handled by means of PLS analysis (Unscrambler ver. 9.7, CAMO Software AS, Norway). The procedures Correlation and Multiple Linear Regression of SPSS ver. 13.5 statistical package were used to relate fat and lean content of green hams to Lenz Fat Analyzer™ signals. In this study, morphological data has not been taken into account, and only two independent correlation variables have been considered (weight and output voltage value related to the ham permittivity).

III. RESULTS AND DISCUSSION

AutoFom measurements

The physical principle of AutoFom is based on ultrasound energy that is fired into carcass, travels through different tissues and comes back as echo signal influenced by fat/meat barrier and tissue depth [9].

Lean and fat data are reported for carcasses and hams used for AutoFom testing (Table 1): fat and lean content of hams varied in the range 13-33 % and 53-72 % respectively. Fat thickness below *caput femoris* bone ranged from 18 to 49 mm.

Estimated lean content of the carcasses was found to be positively related ($P < 0.01$) to lean and fat ($R^2 = 0.41$) content of the corresponding hams. In this respect, carcass classification on the EUROP grid proved to be scarcely predictive of corresponding ham lean content.

Table 1 Summary data of carcasses and hams used for AutoFom testing

Item (*n* = 40)	Mean ± std. dev
Carcass weight (kg)	136 ± 8
%, Estimated lean of carcass	51.0 ± 4.9
Ham weight (kg)	17.3 ± 0.82
Trimmed ham weight (kg)	14.6 ± 0.68
%, Ham lean	64.5 ± 4.45
%, Ham fat	21.3 ± 4.56

The scanned carcasses allowed a preliminary model to be calculated, to test AutoFom capability to predict fat content of green hams. The IPs of the 40 carcasses given by AutoFom ultrasonic image were used to predict the fat content (%) of the corresponding green hams by means of PLS analysis and a calibration/prediction model was achieved. In Fig. 1 is displayed the regression between ham fat content predicted by the PLS model and the ham fat content given by ham dissection.

The model is based on two PLS factors and the variance explained is 83.7% and 89.2% for X- and Y-data set respectively (calibration model). Comparing traditional FOM information and AutoFom prediction of ham fatness, AutoFom model is more effective for an adequate green ham classification according to fat content.

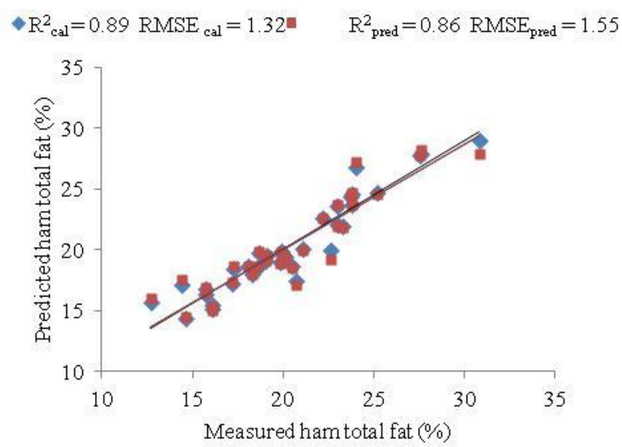

Figure 1. AutoFom prediction of ham fat content

Even if a higher number of carcasses and dissected hams are needed to achieve a fully validated model, AutoFom is promising for classifying heavy green hams in different groups according to fat content in order to assign them to the most appropriate salting and maturing treatments during dry-curing process.

Lenz Fat-Analyzer™ measurements

Fat and lean amount given by dissected green hams were related to signal values generated during ham scanning. The output voltage signal related to the ham permittivity given by the Lenz Fat-Analyzer™ varied from 1.17 to 1.77. A simple linear correlation model can be used to predict percentage of fat (F %) in the hams, according to the following equation, in which $\bar{S}$ is the output signal of the instrument normalized to the weight of the ham, and α_F and β_F are fitting parameters.

$$F\% = \alpha_F \cdot \bar{S} + \beta_F$$

Applying this model to the experimental dataset, the adjusted coefficient of determination achieved was [*adj.-R^2*] = 0.806, with a Root Mean Square Error of calibration of [$RMSE_{cal}$] = 1.5%. Fig. 2 shows the predicted and actual values, as determined by the dissection method.

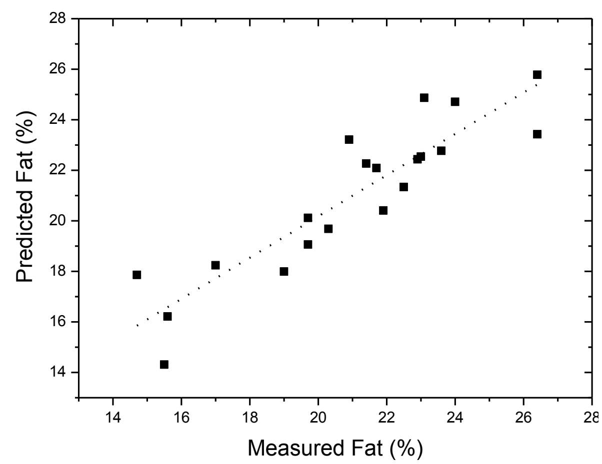

Figure 2. Lenz Fat-Analyzer™: regression between measured and predicted ham fat content

Likewise, a similar simple prediction model can be used to predict the total lean content in the ham (L), which is found to be linearly correlated with the output signal of the instrument (S), and the total weight of the ham (W):

$$L = \gamma_L \cdot W + \alpha \cdot S_L + \beta_L$$

In this case, the prediction error obtained was *[$RSME_{cal}$]* = 0.23 (kg), with *[adj. R^2]* = 0.900. Calibration results for the prediction of lean are shown in Fig. 3.

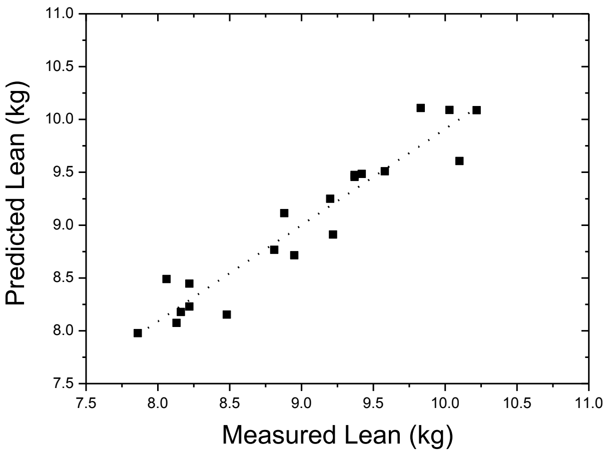

Figure 3. Lenz Fat-Analyzer™: regression between measured and predicted ham lean content

IV. CONCLUSION

Both AutoFom and Lenz Fat-Analyzer™ proved to be suitable tools for predicting fat and lean content of heavy Italian green hams. Due to the limited number of scanned and dissected samples (n = 40 for AutoFom and n = 20 for Lenz Fat-Analyzer™) the prediction models are regarded as preliminary but promising to classify ham on-line at industrial level. The equipments are targeted for different applications, i.e carcass grading at slaughterhouse, and grading of primal cuts at both slaughterhouse and dry-curing plants, respectively. In both cases, the possibility of measuring fat and lean content in green hams before processing could be an important development for the sector in the perspective of lowering salt content and variability in dry-cured hams.

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