MULTISCALE IMAGE ANALYSIS APPROACH FOR MEAT TENDERNESS PREDICTION

M. El Jabri[1*], S. Abouelkaram[2], J-L. Damez[2], A. Listrat[3]

[1]ADRIA Développement, Créac'h Gwen, F-29196 Quimper, France

[2]INRA, UR370 Qualité des Produits Animaux, F-63122 Saint Genès Champanelle, France

[3]INRA, UR1213 Unité de Recherche sur les Herbivores, F-63122 Saint Genès Champanelle, France

[*]Corresponding author (phone: +33-2-98-10-18-43; fax: +33-2-98-10-18-08 ; e-mail: mohammed.eljabri@adria.tm.fr)

***Abstract*— Image processing approach based on multiscale analysis was developed to predict beef tenderness. The study was carried out on the *semimenbranosus* muscle (SM). Images of SM slices, cut perpendiculary to the main muscle fiber axis, were acquired under polarized visible lighting. Statistical method was applied in order to relate Intramuscular Connective Tissue (IMCT) features, characterized by image analysis, to sensory tenderness evaluated by a trained panel. Using Principal Components Regression (PCR) analysis, IMCT image parameters were found to be good indicators of meat tenderness (R^2=0.92).**

***Index Terms*— Meat tenderness, Multiscale analysis, Principal Components Regression, Universal threshold.**

I. INTRODUCTION

Among organoleptic propreties which contribute to meat quality, tenderness remains the most important quality attribute for consumers. Generally meat tenderness is affected by two main structural components of the muscle: Intramuscular Connective Tissue (IMCT) and myofibres. Compared to that myofibres, the contribution of IMCT to the toughness of meat becomes predominant when the postslaughter handling procedure of the carcass allows a complete development of the post-mortem myofibrillar tenderization process (Sifre-Maunier, Taylor, Berge, Culioli & Bonny, 2006). For that reason, IMCT represents so-called "Background toughness" of meat.

Image analysis has been recognized as a highly promising approach to objectively assess the on-line quality control of meat products (Dun & Sun, 2004). Meat Quality prediction based on image analysis were studied by several authors.

Li, Tan, Martz and Heymann (1999) showed that the addition of image texture features to color and marbling parameters improved the accuracy of tenderness prediction compared to the use of color and marbling features only (R^2=0.70). Li, Tan, Martz and Shatadal (2001) used wavelet-based decomposition to classify steaks into tough and tender groups. They obtained a 83.3% corrected classification rate in cross-validation. Naganathan, Grimes, Subbiah, Callkins, Samal and Meyer (2008) developed and tested a visible/near-infrared hyperspectral imaging system to predict beef tenderness at 14-day post-mortem. This study based on image texture allowed a prediction of three beef categories, namely tender, intermediate and tough, with a 94.6% accuracy.

Other authors have focused on the amount and distribution of IMCT, using image analysis, to predict meat tenderness (Abouelkaram, El Jabri, Damez, Roux & Picard , 2006), collagen content (Abouelkaram, Berge, Hocquette, Culioli & Listrat, 2003) and recently tenderness, collagen content and lipids content (El Jabri, Abouelkaram, Damez & Berge, 2010). These studies yielded good results in terms of predicting tenderness and composition (R^2 values above 0.8). However these results can be improved by using more powerfull segmentation algorithms in order to optimize the information extraction of muscle structure and its components (El Jabri et al. 2010).

This paper presents a new automated prediction tool of meat tenderness, based on multiscale image analysis aproach. A multiscale analysis allows to extract the relevant information considered for IMCT. Compared to our previous researchs, the information obtained on the IMCT in this study allowed an improvement in the prediction of meat tenderness.

II. MATERIALS AND METHODS

A. Animals and Tenderness evaluation

Two groups of Salers and Holstein cull cows of similar age (6-7-year old) were used in this study. The assays were performed on 20 samples of *semimenbranosus* (SM) muscle excised from carcasses immediately after slaughter. After 14 days of ageing, the meat tendreness was evaluated by a panel of 12 trained persons. The experimental design was described in Jurie et al. (2007).

B. Imaging system

Muscle samples (n=20) were cut into a 5.0 x 4.5 x 2 cm^3 cube with a largest face being perpendicular to the main muscle fiber axis. Images of meat were acquired using a photographic measurement bench equipped with a black and white CCD camera (model MACC77, Sony), two white light lamps with polarized filters and an ultraviolet lamp (Fig. 1). More details of the imaging equipment are given in El Jabri et al. (2010).

One face of each sample was analyzed using polarized white light only. This led to a set of twenty images (i.e. 20 samples x 1 face x 1 light type). The digitized images had a dynamic of 256 grey levels.

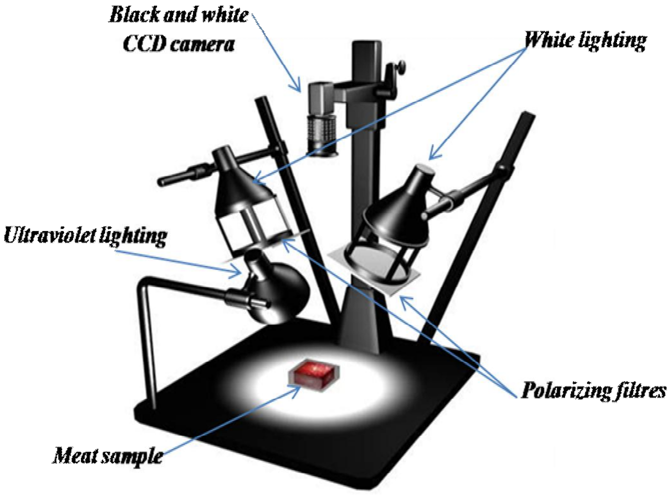

Fig. 1- Imaging bench

C. Image processing

The images, of which size was 512 x 512 pixels, were processed using a multiscale approach. The segmentation method used to detect significant structres of IMCT is based on the ”à trous” algorithm, which is a discrete wavelet decomposition algorithm developed initially by Holdschneider, Kroland-Martinet, Morlet and Tchamitchian (1989). The wavelet planes resulting from this decomposition was determined using the filter $h_{2D} = h' \times h$, with $h = \{1,4,6,4,1\}/16$, associated to the B-spline scaling function, h' is the vector transpose of h. In order to segragate significant structures of IMCT, the universal threshold (Donoho & Johnston, 1995) was applied to the wavelet plane images allowing to detect at each scale the significant structures. These selected objetcs were then superimposed on a single image called multiresolution support. The multiresolution support was defined in detail in Starck, Murtagh and Bijaoui (1995).

D. Image features extraction

A wavelet-based segmentation algorithm developed in this study allowed the surface extraction and labeling of significant objects considered for connective tissue network. The image features extracted represent the distribution of objects surfaces. It was calculated from binary images, issued from multiresolution support, after logarithmic transformation applied to the raw data. A classification of object sizes was obtained according to arithmetic progression as class limits method, and Huntsberger formula to determine the number of classes (El Jabri, 2008). This method allowed us to extract 13 parameters per image which were used in the statistical prediction model.

E. Statistical analysis

The prediction model of tenderness built in this study was determined by Principal Component Regression (PCR) using the SAS REG procedure (SAS version 9). The stage of parameters selection was performed in order to keep the most relevant components of the PCR. The final model retained for tenderness prediction is determined according to the Mallow’s CP criterion which is generally used when a best subset regression analysis is being performed. The appropriate subset is the one which corresponds to the minimum of Mallow’s CP statistic (Besse, 2003).

III. RESULTS AND DISCUSSION

Fig. 2 shows an example of meat image acquired whith polarized white light (a), and its first three wavelet planes (images (b), (c) and (d)) resulting from the ”à trous” algorithm. These three wavelet planes show structures of different sizes which correspond to several IMCT levels including intramuscular fat. Indeed, in the first wavelet plane (b) the small structures of IMCT begin to appear including noise, while in the third one (d) larger structures are highlighted. The number of scales was set to 3 in order to bring out only the connective tissue structure. Arrows were added on the figure 2 indicating some IMCT details.

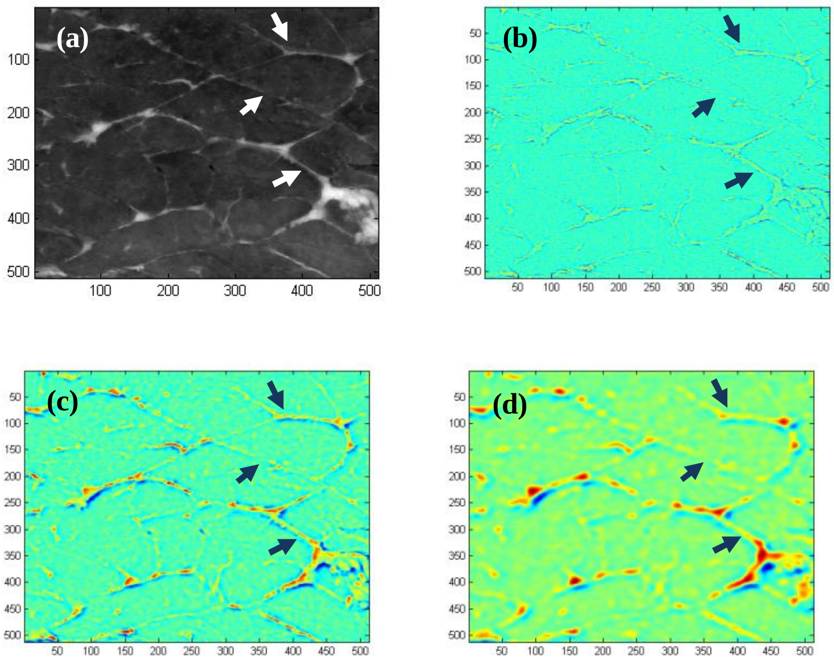

Fig. 2- Example of meat image acquired with visible lighting (a), and its first three wavelet transform obtained with “à trous” algorithm

The multiresolution support representing the result of the segmented image is given in Fig. 3. It shows the significant objetcs detected from wavelet planes (images (b), (c) and (d)) which were superimposed to visualise the connective tissue network rebuild with segmented objects.

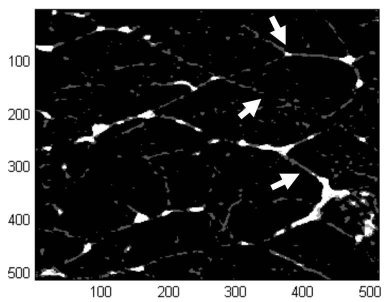

Fig. 3- Multiresolution support

Fig. 4 shows the evolution of Mallow’s CP criterion in accordance with number of principal components of image parameters. The best regression model according to this criterion corresponds to the one which has minimum Mallow’s CP. In our case, this minimum was obtained with the first 6 (among 13) principal components (Fig.4).

As shown in figure 4, there is no significant difference between models with 6 and 5 principal components in term of prediction. That’s why we chose a model with the first five principal components, pointed by an arrow in the figure 4. These principal components correspond to the parsimonious set of predictors that explain the most variation of tenderness. The prediction scores obtained by the PCR model were compared to the observed scores. This model allows a good prediction of tenderness with a high R^2 value of 0.92 (Fig. 5).

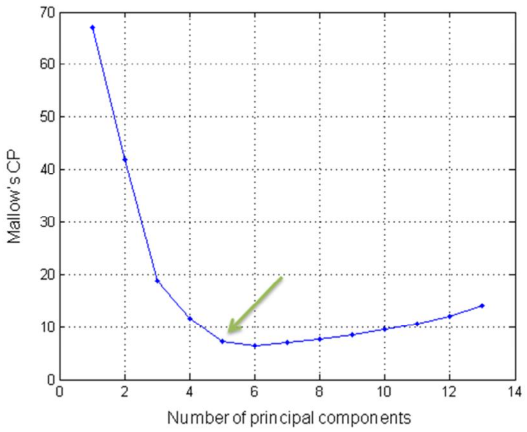

Fig. 4- Evolution of Mallow's CP according to the number of principal components

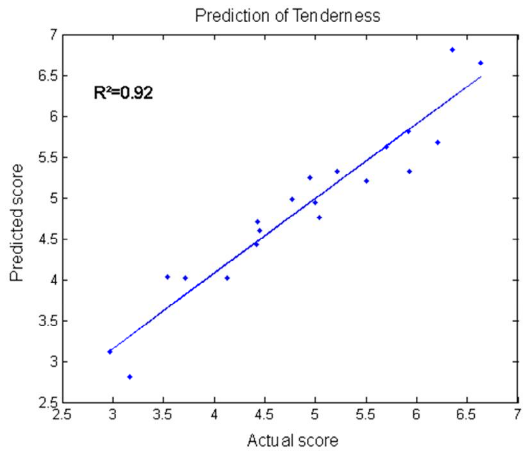

Fig. 5- Comparison of observed tenderness scores with tenderness scores predicted by PCR model.

IV. CONCLUSION

We reported in this study the development of a new segmentation method for meat images acquired with visible lighting system. The result obtained with this technique reveals the effectiveness of the proposed treatment. This solution has the advantage of being fast and allowed, from a B&W image type, to estimate optimally the significant structures of IMCT. Indeed, starting from a simple white light polarized image, three wavelet planes were generated in order to highlight different IMCT levels which include intramuscular components. The information extracted from segmented images represents the distribution of significant objects surfaces considered for IMCT. The prediction model developed using PCR method and Mallow's CP criterion allowed to select the most relevant parameters for the prediction of beef tenderness.

Multiscale image analysis study presented in this work may be regarded as a promising technique for the prediction of sensory data such as tenderness.

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