A New Technique for Non-Destructive Measurement of Marbling in Beef Meat Using Visible and Near-Infrared Imaging

Ziadi A. [1], Maldague X. [1] and Saucier L. [2]

[1] Department of Electrical and Computer Engineering, Université Laval, Quebec City, Canada
[2] Department of Animal Science, Université Laval Quebec City, Canada

Abstract— **Quantitative evaluation of marbling (intramuscular fat) in beef meat is an important attribute with respect to quality. The chemical analysis, which is a destructive method, is the gold standard to evaluate the quantity of marbling in meat. It is a destructive and tedious method which does not give any information of marbling distribution in tissues. In this paper, an operational and flexible new method for a non-destructive measurement of the marbling quantity and distribution in beef meat is proposed. Based on the absorption and reflection properties of the fat when exposed to near infrared (NIR) light (940 nm), it is possible to show and evaluate the marbling under the surface, which is not accessible by visual methods commonly proposed in computer vision using visible (VIS) image. The results obtained by the proposed method (non-destructive) were compared with results obtained by chemical analysis (Soxhlet) of the muscle fat content. Preliminary results indicate that it is possible to evaluate the composition and the distribution of marbling in lean beef muscle.**

Keywords— **Marbling, Non-Destructive, Visible and Near-Infrared Imaging.**

I. INTRODUCTION

Visual evaluation of the marbling (fat within the muscle fibres) in beef meat is the easiest but also the most subjective method to evaluate intramuscular fat [1-4]. Also it limits the measurement to the visible fat at the surface of the meat. This means that this is a measure of the amount of external fat which does not provide any indication about the marbling with no indication of the variation inside the meat sample. In order to objectively evaluate the amount of marbling in meat samples, chemical analysis of the fat content is currently the "gold standard" method [5-6]. It is a destructive method, expensive, tedious and time consuming, and does not give any information about the marbling distribution in the lean tissue.

In response to these disadvantages, several research groups have proposed alternative methods to the chemical method. Newcom et al. [7], studied an ultrasound method to predict the percentage of intramuscular fat in swine meat. In this method, the marbling evaluation was conducted on Regions Of Interest (ROIs) of 100x100 pixels in the Ultrasound image. It is then, a localised measurement to predict an overall estimate of marbling in pork. Avila et al. [8], proposed a 3D reconstruction method to estimate the amount of marbling in a sample of pork meat. The approach proposed in this method is based on a technique of digital reconstruction of 3D surface images from Magnetic Resonance (MR) of a series of thin slices (2 mm) of meat. It is a complex method of approximation and limited to thin meat samples. In a commercial context, the FOSS company [9], has developed an analyzer called ''FoodScan'', which uses near-infrared technology to measure several parameters of meat composition such as moisture, protein and fat. To predict the composition of the meat, the sample must first be grinded. Thus, this method does not qualify as a non-destructive one.

With respect to non-destructive methods, visual imaging has been investigated to some extend [7, 8]. However, to best of our knowledge, no publication describing a similar method as the one presented in this work was found. Here, results of our method demonstrate that using NIR light in transmission mode, allows the detection of not only the visible fat on the meat surface but also underneath the surface. Hence, by modeling the geometric shape of the observed marbling regions, it is possible to estimate the volumetric proportion of the marbling in a meat sample.

II. MATERIAL AND METHODS

Fig.1a illustrates the experimental setup for the proposed system. It is composed of four elements: 1) a Phoenix CCD camera (MuTech Corporation company) with a resolution of 1280x1024 pixels; 2) two sheets of plexiglas (transparent to NIR radiation)to keep the meat sample in front of the camera. The plate below acts as a holder for the meat sample while the top one is positioned to press the meat and to keep the surface of the sample parallel to the CCD of the camera in order to maximize the amount of light reflected from the meat surface; 3) a light diffuser; and 4) a NIR light source. Hence, during the experiments, two types of light sources were used. For VIS images acquisition (reflection mode), fluorescent lighting mounted on the ceiling of the laboratory was used. However, for the NIR acquisition (transmission mode), a NIR light projector (940 nm wavelength) was used. Fig.1b is a schematic image of a meat sample, it illustrates how NIR light is reflected or deviated by the fat particles through the meat sample before eventually reaching the opposite side of the meat sample. Fig.1c shows NIR images obtained using the proposed acquisition system presented in Fig.1a. Experiments were performed on Angus beef meat. The meat was obtained from a specialized butcher shop and sliced in samples of 5 to 7 mm thickness.

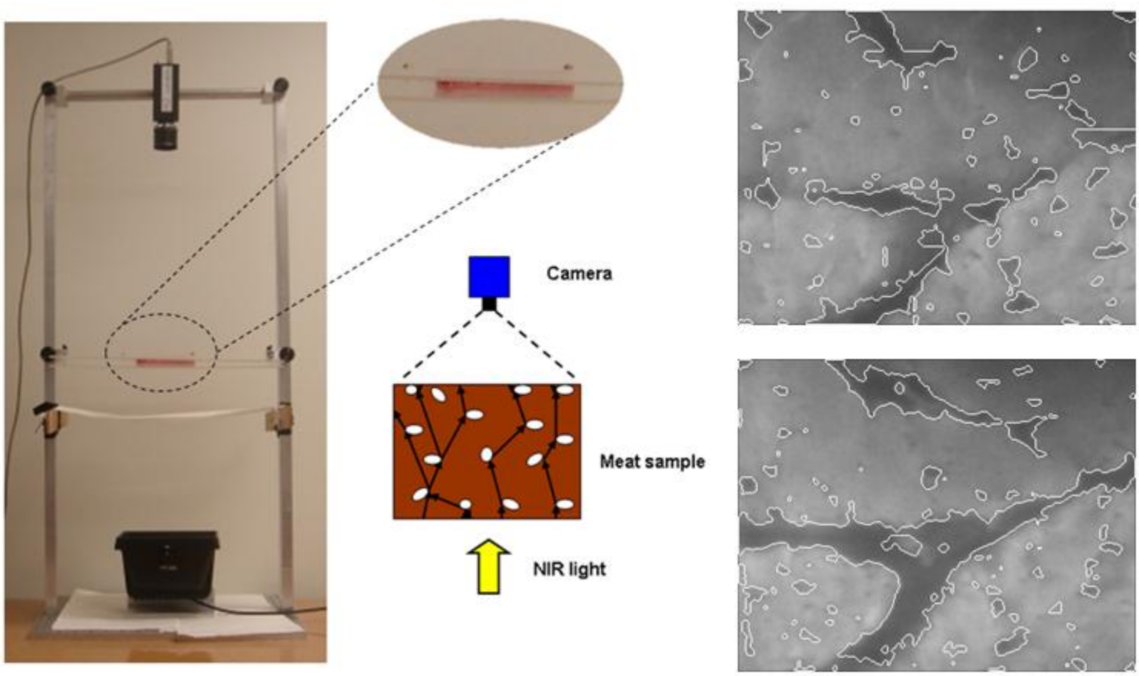

Fig. 1 Proposed technique for the volumetric marbling estimation in beef meat : (a) experimental setup; (b) schematic image to show NIR light transflectance mechanism through the meat; (c) real acquisition images of top and bottom faces of the meat sample.

A. Marbling isolation

Marbling isolation (or detection) in meat samples is an important stage of the intramuscular fat volumetric estimation process. This step consists in the segmentation of the fat particles observed in the VIS and NIR images. Hence, it is a critical step and the global performance of the volumetric estimation method of marbling could not be guaranteed without the performance of a proper segmentation stage. In this paper, we use our own image segmentation method which was developed specifically for this application [10, 11]. Fig.1c shows NIR images segmented to isolate the marbling. We compared the proposed method to the chemical method [5].

B. *Shape modelling of marbling and proposed method*

In a previous study [12], we demonstrated that NIR images of meat samples are rich in information regarding the intrinsic composition of meat such as water, proteins and fat. Based on the geometric shapes of the marbling regions, it is possible to establish the relationship of the distribution and connectivity of the marbling at different depth levels of the meat sample. The process leading to the completion of this task is a process of pattern recognition that is in itself a large computer vision research field [13].

To our knowledge, there is no report published so far that describe the geometric shape or pattern of fat deposition that leads to marbling of the lean muscle. Specifically, there is no scientific literature describing if the fat deposit follows a particular geometric shape, i.e: conical, cylindrical or otherwise. On the other hand, based on our observations and experimental research [14, 15], fat particle shapes leading to marbling regions are rather formed at random: spherical, conical, ellipsoid or any other complex shape. Nevertheless, according to our observations, the shape of marbling could be classified in two categories: 1) small isolated regions and; 2) in the form of solid areas connected between the two sides of the meat. Based on this categorization, volumetric marbling in meat sample is calculated: the first category is modeled as spheroid shape. The second category is modeled as a cylindrical or conical shape, as illustrated in Fig.2.

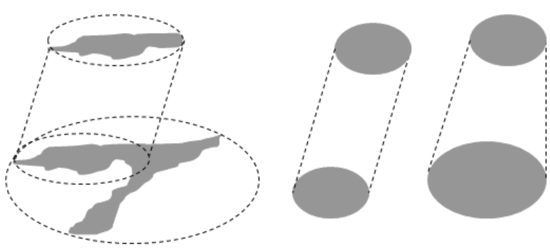

Fig. 2 Model of two matched regions: (a), (b) and (c) cylindrical and conical shapes.

The proposed method for volumetric marbling assessment of the meat sample can be summarized as follows:

a) Isolate the marbling observed in VIS and NIR images using image segmentation (an example is shown in Fig.1c). At this stage, marbling regions in the meat are identified for all images.

b) From the results obtained in a), classify the identified marbling regions according to their categories (Fig.2) and calculate the volumetric marbling of all regions according to their categories.

c) From the results obtained in b) and using the volume of the meat sample, calculate the volumetric proportion of the marbling in the meat sample.

III. RESULTS AND DISCUSSION

The proposed method was successfully tested on a total of 22 samples (sirloin, filet mignon, steak and Longissimus dorsi muscle of Angus beef). These samples were taken over a two month period from the shelves of specialty stores in butchery. These stores obtain their supplies from several cattle farms in different Canadian regions. These farms do not necessarily have the same breeds or use the same farming system. These factors affect the quality of marbling deposited between muscles [15].

The correlation between both methods, namely the calculation of the Pearson correlation coefficient is illustrated in Fig.3 and the linear regression (r) calculated from the 22 samples is 0.7. Hence the results show a reasonable trend between the results obtained from both methods. This demonstrates the viability of the proposed method.

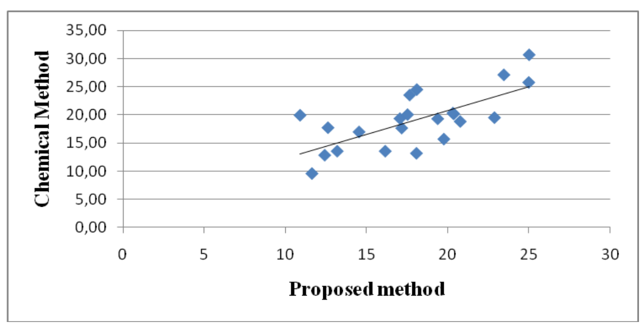

Fig. 3 Fat content correlation between the proposed method versus the chemical method

IV. CONCLUSIONS

In this paper, a flexible new non-destructive method using computer vision is proposed to predict the volumetric intramuscular fat in beef meat. It is demonstrated that using NIR light in transmission mode, it is possible to detect not only the visible fat on the meat surface but also underneath the surface. Hence, segmented marbling regions are modeled according to their shapes, and finally, the volumetric proportion of the marbling in the meat sample is calculated. Results obtained using the proposed method in NIR are correlated (r = 0.7) with the results obtained using the chemical method, which is the gold standard for marbling determination. The proposed method is non-destructive, flexible, faster and effective, which make it a potential attractive alternative method to the cumbersome traditional chemical (destructive) method.

ACKNOWLEDGMENT

This research was sponsored by grant from the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Canada Research Chair. The authors are thankful to Drs Anthony Guernec and Luigi Faucitano for their precious advice.

REFERENCES

1. ACGB. (2010) at http://www.beefgradingagency.ca, (consulted in April, 2010)
2. Yoshikawa F, Toraichi K, Wada K, Ostu N, Nakai H, Mitsumoto M, Katagishi K. (2000) On a grading system for beef marbling. Pattern Recognition Letters. 21:1037-1050
3. Lu J, Tan J, Shatadal P, Gerrard D.E. (2000) Evaluation of pork color by using computer vision Meat Sci 56:57-60
4. Tan J. (2006) Meat quality evaluation by computer vision. J Food Engineering 61:27-35
5. AOAC Official Method 991.36. (2006) Fat (Crude) in Meat and Meat Products, Solvent Extraction (Submersion) Method. Journal of AOAC international.
6. AOAC 960.39. (2006) Fat (Crude) or Ether extract in Meat, Journal of AOAC international
7. Newcom D.W, Baas T.J and Lampe J.F. (2002) Prediction of intramuscular fat percentage in live swine using real-time ultrasound. J Anim Sci 80:3046-3052
8. Avila M.M, Durán M.L, Antequera T, Palacios R, and Luquero M. (2007) 3D Reconstruction on MRI to Analyse Marbling and Fat Level in Iberian Loin. Pattern Recognition and Image Analysis: Lecture Notes in Computer Science 4477:145-152
9. Anderson S, Determination of Fat. (2007) Moisture, and Protein in Meat and Meat Products by Using the FOSS FoodScan™ Near-Infrared Spectrophotometer with FOSS Artificial Neural Network Calibration Model and Associated Database: Collaborative Study. Journal of AOAC international 90:1073-1083
10. Ziadi A, Maldague X, Saucier L. (2011) Extraction of homogeneous gray-level regions using the “First Class Extraction” algorithm. J of Machine Vision and Applications (accepted paper)
11. Ziadi A. (2011) Analyse d’images visible et proche infrarouges : contributions à l’évaluation non-destructive du persillage dans la viande de bœuf. P.h.D thesis, Université Laval
12. Ziadi A, Maldague X, Saucier L. (2009) Near-Infrared Light Transmission in Beef Meat and Qualitative Marbling Evaluation Using Image Analysis, ICGST International Journal on Graphics. Vision and Image Processing 9:7-12
13. Huang L, Wang M. (1996). Efficient shape matching through model-based shape recognition. Pattern Recognition 29:207-215
14. Yang X. J, Albrecht E, Ender K, Zhao R. Q and Wegner J. (2006) Computer image analysis of intramuscular adipocytes and marbling in the longissimus. Journal of Animal Science 84:3251-3258
15. Lebret B, Lefaucheur L, Mourot J. (1999) La qualité de la viande de porc, Influence des facteurs d’élevage non génétiques sur les caractéristiques du tissu musculaire. INRA Prod Anim 12:11-28