AUTOMATIC ASSESSMENT OF MEAT MARBLING AND TENDERNESS

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Introduction

Overall quality of meat is determined by a combination of many factors including intramuscular fat, marbling, water absorption and pH. These factors also influence the quality of meat such as tenderness, juiciness and flavor at the time of eating (palatability) (AMSA, 2001). Marbling, which is defined as the intramuscular fat intermingled with lean within a muscle, has great influence on acceptability and palatability of the meat by the consumer. In the meat industry, marbling is evaluated and graded into different levels to meet the various requirements of different markets. Degree of marbling is a primary parameter for determination of meat quality grade. The Canadian/US beef marbling standards differentiate marbling into nine levels namely Trace, Slight, Small, Modest, Moderate, Slightly Abundant, Moderately Abundant, Abundant, and Very Abundant. The National Pork Producers Council (NPPC) pork marbling standards (NPB, USA 2002) depict seven grades of pork in terms of marbling from 1.0 (devoid) to 6.0 and 10.0 (abundant). In practice, marbling is currently assessed in the meat industry by subjective methods. Visual and subjective measurements of quality are typically difficult to implement reliably as they show poor repeatability of results although the use of experienced assessors can improve results.

Tenderness is one of the most important palatability characteristics that influence consumers' satisfaction with meat. It describes the consumers' perception of how easily the teeth can sink into a piece of steak or how long it takes to chew the meat before eating. Tenderness can be assessed by trained sensory panels or by consumer tests. There are also a number of objective methods that are used to measure tenderness. One of the commonly used objective methods is the Warner-Bratzler shear force (WBSF). This method measures the amount of force required to shear through a sample of cooked meat using an Instron machine. It is destructive and time-consuming and thereby not practical for commercial fresh-meat grading. The cooking step plays a very important role in WBSF measurement. There is a relationship between increased degree of doneness and shear force and/or decreased tenderness (Jeremiah, Dugan et al., 2003), which partly explains why WBSF results are not completely correlated with trained sensory panel judgments.

Effective meat quality assessment is increasingly vital for the meat industry due to globalization and segmentation of markets. Currently, assessments of meat marbling and tenderness are conducted off-line, and they are time-consuming, inconsistent, and destructive. These disadvantages make the conventional methods not suitable for a fast-paced online process. Thus there is an urgent need for appropriate and efficient technologies to assess meat quality levels (Qiao et al., 2007). An automatic meat marbling and tenderness assessment system that is able to operate in a rapid, accurate and non-destructive mode would be an asset for the meat industry.

Technologies for Non Destructive Assessment of Meat Quality

One potential solution to rapid non-destructive assessment of meat marbling and tenderness from fresh-meat characteristics is computer vision. Imaging technique is capable of providing superior spatial information. Image processing can quantitatively and consistently characterize complex colour, geometric and textural properties. The combination of simplicity, speediness, and little or no sample preparation makes computer vision one of the most popular methods for food quality control. The technique has been applied for objective assessment of marbling and tenderness of beef (Shiranita et al., 2000; Tan, 2004; Toraichi et al., 2002; Yoshikawa et al., 2000; Jackman et al., 2009; Tan and Shatadal, 2001) and pork (Faucitano et al., 2005; Qiao et al., 2007; Huang et al., 2012). Typical imaging technique is lmited by its difficulty to assess chemical and internal components of products.

Another widely used technique in food quality control is the NIR spectroscopic technique. NIR spectroscopy is recognized as a rapid, non-destructive, and quantitative method for multi-parametric analysis of chemical compositions (such as fat, protein, and water content), physical properties (such as color), and textural properties (such as hardness and tenderness) of food products based on their light transmittance or reflectance characteristics (Park et al., 2001). The most common constituents (carbohydrates, proteins, fats and water) in food products have specific spectral "fingerprints" in both visible and NIR wavebands that can be used as indicators of their presence and quantity (Silverstein and Webster, 1998). The fingerprints are due to absorptions in spectral regions that arise from overtones and combinations of fundamental vibrations of molecules including O-H, N-H and CH bonds (Osborne and Fearn, 1986). The NIR region of electromagnetic waves enables high penetration that leads to good capacity for probing deep and collecting internal characteristics of the object (Alishahi et al., 2010; Bellon et al., 1994). NIR spectroscopy has been successfully applied to determine the concentration of meat constituents such as intramuscular fat content and moisture (Barlocco et al., 2006; Prevolnik et al., 2005; Prieto et al., 2009). However, spectroscopic technique is not able to provide spatial information of detected object due to its limited spatial field of view. This limitation makes it not suitable for applications related to heterogeneous material such as intact meat cuts.

Recent research efforts have shown high potential for the application of hyperspectral imaging in the development of on-line systems for assessing food quality. Hyperspectral imaging is an emerging, cutting-edge and non-contact analytical technology that combines spectroscopy and digital imagery to simultaneously acquire both spectral and spatial information from an object. A hyperspectral image, also called '*hypercube*', is a three-dimensional image with two spatial dimensions and one spectral dimension (Qiao et al., 2007), which contains enormous information about the analyzed object. The combination of spectral and spatial information makes hyperspectral imaging able to ascertain minor and/or subtle physical and chemical properties in an object. With respect to meat and meat products, hyperspectral imaging has been successfully applied for detection of fecal and tumour in chicken carcass (Kong et al., 2004; Park et al., 2006), assessment of beef tenderness (Cluff et al., 2008; Naganathan et al., 2008), discrimination of lamb muscles (Kamruzzaman et al., 2010), classification of cooked turkey ham quality (ElMasry et al., 2011), and prediction and differentiation of pork quality (Qiao et al., 2007; Liu et al., 2010, 2012; Huang et al., 2012, 2013, 2014).

Assessment of Marbling

The hyperspectral imaging laboratory at McGill University has developed different technologies to measure pork marbling scores (Qiao *et al.*, 2007; Liu *et al.*, 2012; Huang et al., 2012, 2014). Different image features and image texture characteristics were simultaneously detected by hyperspectral imaging and formulated for assessment of marbling scores. Figure 1 shows the marbling detection results of NPPC pork marbling standards using a line pattern recognition method (Liu et al., 2012). Multiple linear models were used to differentiate the marbling levels over the entire range of NPPC standards. The adjusted coefficient of determination (R^2) of the model was 1.0 and the root mean square error of leave-one-out cross-validation (RMSECV) was 0.1 showing the very high accuracy of the method (Liu et al., 2012). High correlation coefficients of calibration and validation ($Rc=0.94, Rv=0.94$) of prediction models were also obtained for assessment of marbling scores of fresh pork loin chops (Huang et al., 2012).

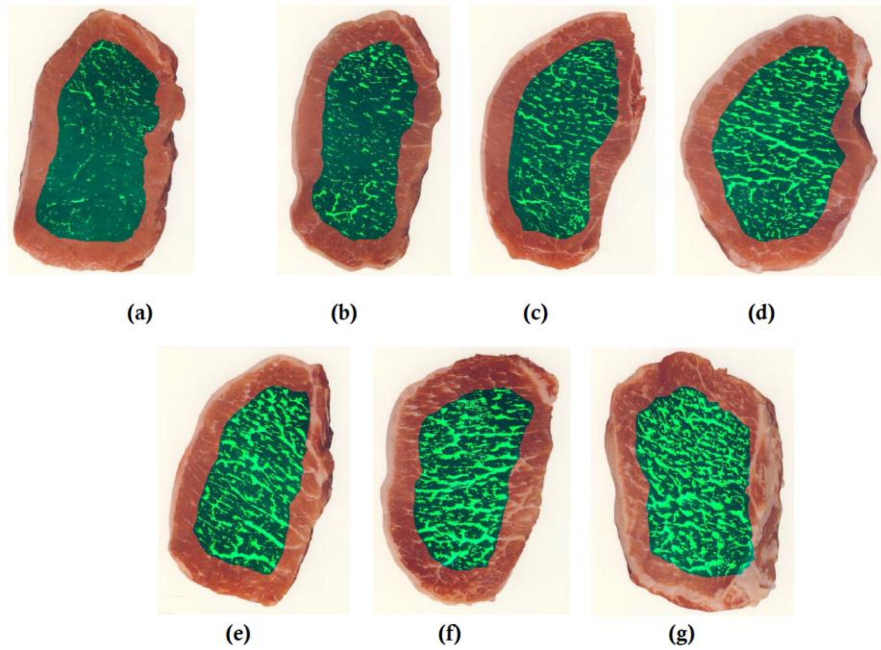

Figure 1 (a)-(g). Automatic detection and representation of NPPC pork marbling standards corresponding to NPPC marbling scores of 1-6, 10; respectively. The detected marbling is displayed in green.

Assessment of Tenderness

Hyperspectral imaging technique and prediction models have also been successfully developed to measure tenderness of beef. The technology has been tested on cuts from 4 different muscles. Effective wavebands were selected using the stepwise regression approach and the image spectral features were extracted at the selected wavebands. Multiple linear regressions (MLR) were employed to establish the prediction models based on the preprocessed image spectral features. The prediction accuracies, i.e. the correlation coefficients (*R*) between the measured and predicted WBSF values, were all above 0.8 for 4 muscles types. The measured and predicted values of tenderness (WBSF) for the 4 different muscles are shown in Figure 2.

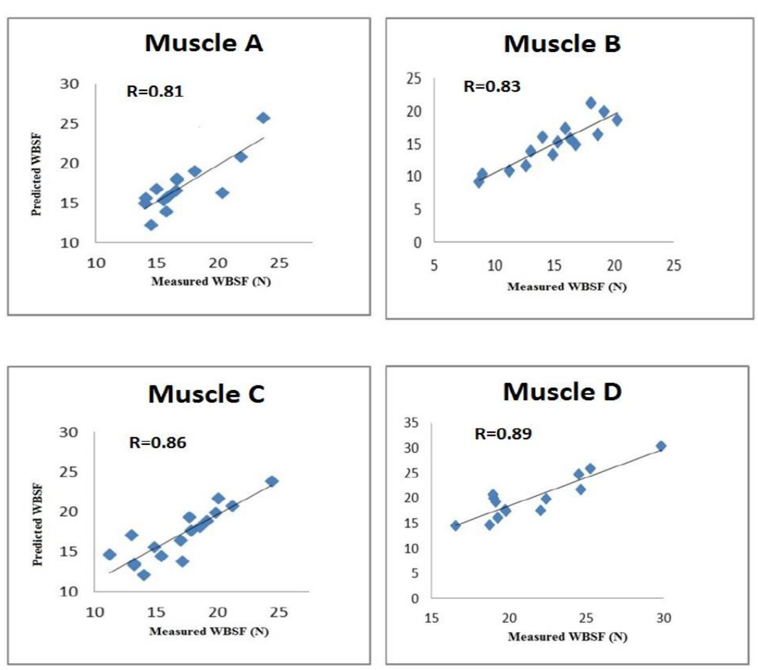

Figure 2. Measured vs. predicted WBSF for different muscles.

Development of Prototype for Automatic Meat Quality Assessment

In spite of the enormous progress that has been made on rapid techniques for evaluation of meat quality, the technologies are still at the laboratory stages and they are not readily available in the industry. This is largely due to the difficulty of synchronizing data collection and analysis in order to implement true online or real time analysis. There is also the issue of data storage arising from the typically large data sets. The team at McGill University has made progress on developing a prototype for automatic assessment of meat marbling and tenderness that is capable of objective, rapid, accurate and non-destructive measurements. The system operates on selected optimized spectral channels to rapidly collect both spectral and spatial data simultaneously. Analysis of the data and presentation of results are performed using custom software developed based on techniques that the team has developed in the past years. The system is a standalone system with user control interface and integrated lighting assembly. It can be connected to a computer via USB connection to improve user portability. It is hoped that the prototype will soon be available for wide testing and industrial adoption.

Reference

Alishahi, A., Farahmand, H., Prieto, N. and Cozzolino, D. (2010). Identification of transgenic foods using NIR spectroscopy: A review. Spectrochimica Acta Part A. 75: 1-7.

AMSA, American Meat Science Assosiation, National Cattlemen's Beef Association, & National Pork Producers Council. (2001). Meat evaluation handbook: Amer Meat Science Assn.

Barlocco, N., Vadell, A., Ballesteros, F., Galietta, G. and Cozzolino, D. (2006). Predicting intramuscular fat, moisture and Warner–Bratzler shear force in pork muscle using near infrared reflectance spectroscopy. Animal Science, 82: 111-116.

Bellon, V., Vigneau, J.L. and Scvila, F. (1994). Infrared and near infrared technology for the food industry and agricultural users: on-line applications. Food Control. 5: 2-27.

Bratzler, L.J. (1932). Measuring the tenderness of meat by means of a mechanical shear. Master's thesis, Kansas State College.

Cluff, K., Naganathan G.K., Subbiah J., Lu R., Calkins C.R. and Samal A. (2008). Optical scattering in beef steak to predict tenderness using hyperspectral imaging in the VIS-NIR region. Sensing and Instrumentation for Food Quliaty and Safety, 2: 189-196.

ElMasry, G., Iqbal, A., Sun, D.W., Allen, P. and Ward, P. (2011). Quality classification of cooked, sliced turkey hams using NIR hyperspectral imaging system. Journal of Food Engineering, 103: 333- 344.

Faucitano L., Huff P., Teuscher F., Gariepy C. and Wegner J. (2005). Application of computer image analysis to measure pork marbling characteristics. Meat Science, 69, 537-543.

Huang, H., Liu, L., Ngadi, M.O. and Gariepy, C. (2012). Prediction of pork marbling scores using pattern analysis techniques. Food Control, 31(1), 224-229.

Huang, H., Liu, L., Ngadi, M.O. and Gariepy, C. (2013). Rapid and non-invasive quantification of intramuscular fat content of intact pork cuts. Talanta, 119, 385-395.

Huang, H., Liu, L., Ngadi, M.O. and Gariepy, C. (2014). Near-Infrared spectral image analysis for pork marbling based on Gabor filter and wide line detector techniques. Applied Spectroscopy, 68(3).

Jackman, P., Sun, D.W., Du, C.J. and Allen, P. (2009). Prediction of beef eating qualities form colour, marbling and wavelet surface texture features using homogenous carcass treatment. Pattern Recognition, 42(5), 751-763.

Jeremiah, L.E., Dugan, M.E.R., Aalhus, J.L., & Gibson, L.L. (2003). Assessment of the relationship between chemical components and palatability of major beef muscles and muscle groups. Meat Science, 65, 1013-1019.

Kamruzzaman, M., ElMasry G., Sun, D.W. and Allen, P. (2010). Application of NIR hyperspectral imaging for discrimination of lamb muscles. Journal of Food Engineering, 104: 332-340.

Liu, L., Ngadi, M.O., Prasher, S.O. and Gariépy, C. (2010). Categorization of pork quality using Gabor filter-based hyperspectral imaging technology. Journal of Food Engineering, 99(3), 284-293.

Liu, L., Ngadi, M.O., Prasher, S.O. and Gariépy, C. (2012). Objective determination of pork marbling scores using the wide line detector. Journal of Food Engineering, 110 (3), 497-504.

Naganathan, G.K., Grimes I.M., Subbiah J., Calkins C.R., Samal A. and Meyer G.E. (2008). Visible/near- infrared hyperspectral imaging for beef tenderness prediction. Computers and Electronics in Agriculture, 64: 225-233.

NPB (National pork board). (2002). Pork quality standards. Des Moines, IA USA.

Osborne, B.G. and Fearn, T. (1986). Near-Infrared Spectroscopy in Food Analysis. UK: Longman Scientific and Technical, London.

Prevolnik, M., Candek-Potokar, M., Škorjanc, D., Velikonja-Bolta, Š., Škrlep, M., Znidaršic, T. and Babnik, D. (2005). Predicting intramuscular fat content in pork and beef by near infrared spectroscopy. Journal of Near Infrared Spectroscopy. 13: 77-86.

Prieto, N., Roehe, R., Lavín, P., Batten, G. and Andrés, S. (2009). Application of near infrared reflectance spectroscopy to predict meat and meat products quality: A review. Meat Science, 83(2): 175- 186.

Qiao, J., Ngadi, M.O., Wang, N., Gariépy, C. and Prasher, S.O. (2007). Pork quality and marbling level assessment using a hyperspectral imaging system. Journal of Food Engineering, 83(1), 10-16.

Shiranita, K., Hayashi, K., Otsubo, A., Miyajima, T. and Takiyama, R. (2000). Grading meat quality by image processing. Pattern Recognition, 33, 97-104.

Tan, J. (2004). Meat quality evaluation by computer vision. Journal of Food Engineering, 61, 27-35.

Tan, J.L. and Shatadal, P. (2001). Classification of tough and tender beef by image texture analysis. Meat Science, 57, 341-346.

Toraichi, K., Kwan, P.W.H., Katagishi, K., Sugiyama, T., Wada, K., Mitsumoto, M., et al. (2002). On a fluency image coding system for beef marbling evaluation. Pattern Recognition Letters, 23, 1277-1291.

Yoshikawa, F., Toraichi, K., Wada, K., Ostu, N., Nakai, H., Mitsumoto, M., et al. (2000). On a grading system for beef marbling. Pattern Recognition Letters, 21, 1037-1050.