ESTIMATION OF VISIBLE FAT CONTENT IN BEEF *M. LONGISSIMUS* USING NEAR INFRARED SPECTROSCOPY

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Introduction

Near infrared (NIR) spectroscopy is a non-destructive measurement method that analyses the light reflected from a sample in order to infer information about the sample composition and structure. It has been shown that NIR spectroscopy can be correlated with the tenderness of lean meat (McGlone *et al.*, 2005). However, when assessing the NIR spectra of meat, it would be useful to objectively estimate the spectral contribution of substance that is not lean. Additionally, estimation of the visible fat content of meat may have potential for automated grading purposes.

Materials and Methods

Four pairs of beef *m. longissimus et lumborum* (LL) were removed 30 minutes after slaughter from steers shot with a captive bolt and not electrically stimulated. The LLs were wrapped in polyethylene cling film to prevent shortening (Devine *et al.*, 1999) and were held at 15°C to enter rigor mortis and aged at this temperature for 24 hours. Each of the wrapped muscles, with an approximate circular cross section, was positioned in a holder and a 14mm thick slice was removed from the rump end of the muscle and discarded.

To estimate the visible fat content across the face of the muscle an image was taken using a JAI machine vision colour camera. Then, forty-nine NIR readings were made on the face of the muscle in a grid arrangement with a 14 mm spacing. The NIR readings at each grid position were taken using a fibre optic probe (with diameter of approximately 16 mm) attached to a diode array spectrophotometer from KES Analysis (NY, USA). The instrument covered the spectral range from 400 to 1700 nm. At grid positions where there was no muscle, readings were omitted from the data analysis. After the forty-nine readings on the face of the muscle were taken, another 14 mm slice was removed from the rump end of the LL and the process was repeated. After approximately 20 slices, the whole LL was examined along its length using digital imaging and NIR measurements. This process was carried out for all eight LLs.

Digital colour imaging and image processing methods (Gonzalez and Woods, 2002) were used on the collected camera images to estimate the lean and fat content of meat at each grid position. To locate the grid positions, a simple colour difference technique was used. To analyse the visible fat content at each position, a colour-based principal component analysis (PCA) was employed to determine the maximum variation in colour, followed by a threshold to find candidate fat objects and finally an object filter to improve the specificity of fat object detection.

Data from three animals were used to analyse the relationship between the NIR spectra and the visible fat content in the camera images. Data from the fourth animal was kept exclusively for independent validation of the prediction method. To relate the NIR spectra to the visible fat content, Partial Least Squares (PLS) regression was used (de Jong, 1993). PLS works by finding and utilising the covariance between data and response. In the context of this work it obtained and utilised spectral information indicative of the interaction of NIR light with fat. Predominantly, this information was due to light interaction with water, hydrocarbon chains and the higher absorption of light by lean than by fat. The model was validated by cross-validation, *i.e.* a PLS model was built in turn on data from two animals and tested on the third (per animal hold out subset evaluation). Examination of spectra per animal increases independence of cross-validation test sets, simulating behaviour of a separate validation dataset (but does not reduce the importance of validation on an independent test data set).

Results and Discussion

Figure 1A shows two typical examples of NIR spectra from meat demarcated as being entirely lean and almost entirely fat by the image analysis. Due to the NIR probe window size no spectrum was entirely fat, so greater than 85% fat was chosen. Figure 1B shows the visible fat content from the image analysis against the PLS prediction result from the NIR spectra using per animal cross-validation training and testing with 95% confidence intervals computed via the root mean square error of prediction.

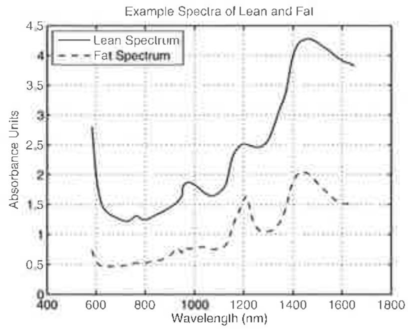

Figure 1A: Example NIR spectra of lean and fat samples.

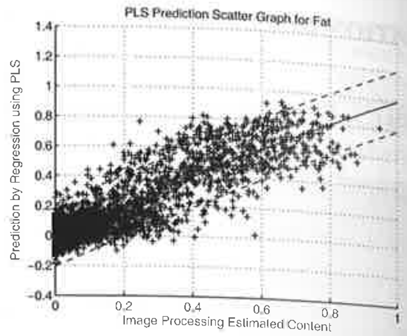

Figure 1B: Scatter plot of visible fat predicted by NIR using PLS.
(95% prediction intervals are shown as dashed lines).

The spectral shapes of fat and lean in Figure 1A are very similar; however, several important differences are apparent. Most apparent is that the absorbance of light by fat is less than by lean. Examples of other useful variations are the overlapping water/hydrocarbon peaks around 1200nm and 1450nm and the peak in the lean spectrum at 970nm that is not in the fat spectrum. Figure 1B shows that an approximately linear relationship was found between the visible fat content and NIR measurements using PLS. The coefficient of correlation (R) between visible fat content and prediction of fat content using PLS on the NIR data was 0.90. The Root Mean Square Error of Prediction (RMSEP) was 0.103. Despite the strong correlation, the 95% confidence interval in prediction is 0.206, or approximately 21% of the maximum value.

Conclusions

Calibration of NIR data against visible fat content gave a correlation of 0.90 and an RMSEP of prediction of 0.103. Future work may include PLS and other standard NIR analysis of lean and connective tissue and investigations into non-linear mathematical techniques. In addition, consideration will be given to the problem of classifying a spectrum as lean or not lean.

References

de Jong, S. (1993). SIMPLS: An alternative approach to partial least squares regression. *Chemometrics and Intelligent Laboratory Systems* 18, 251-263.

Devine, C.E., Wahlgren, N.M., and Tornberg, E. (1999). Effect of rigor temperature on muscle shortening and tenderisation of restrained and unrestrained beef *m. longissimus thoracis et lumborum*. *Meat Science* 51, 61-72.

Gonzalez, R.C. and Woods, R.E. (2002). *Digital Image Processing*, 2nd ed., Prentice Hall, Upper Saddle River, NJ.

McGlone, V.A., Devine, C.E., and Wells, R.W. (2005). Detection of tenderness, post rigor age and water status changes in sheep using near infrared spectroscopy. *Journal of Near Infrared Spectroscopy* 13, 277-285.