3D MAPPING OF BEEF M. LONGISSIMUS USING NEAR INFRARED SPECTROSCOPY CHANGES AND MAHALONOBIS DISTANCE

P.W. Hansen*[1] L. Streeter[2,3], R. Burling-Claridge[2], M. North[2] and C.E. Devine[4]

[1] EquatioNZ, Lyngby Hovedgade 11B, 2. th., DK-2800 Kongens Lyngby, Denmark, [2] Meat Quality, AgResearch, PB 3123 Hamilton, New Zealand, [3] University of Waikato, Private Bag 3105, Hamilton, New Zealand, [4] Bioengineering and Biosensors, HortResearch, PB 3123 Hamilton, New Zealand. Email: PWH@equationz.dk

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Introduction

Ageing is the term given to the process of meat tenderisation. It occurs over the period following rigor mortis and is measured destructively by shear force measurements after cooking. We have shown that non-destructive measurements such as near infrared (NIR) spectroscopy can be correlated with tenderness although the correlation may not be sufficiently accurate and the question arises as to whether this is due to inherent variability of the meat itself, and if so, how is this variability characterised? (McGlone *et al.*, 2006). The theory of sampling (Petersen *et al.*, 2005) needs to be invoked in order to determine and understand the variability inherent in meat, and determine the appropriate measurement sites for calibration against NIR.

With meat it is clear that one cannot keep subdividing it into lots or fragments or consider the variation as it moves past a measurement device as the measurements are destructive. However it is possible to consider the variation of a muscle along its length and across its width, i.e. 3D mapping, by measuring NIR spectral changes using a combination of Principal Component Analysis (PCA) and Mahalanobis distance (D) (Mahalanobis, 1936). It is suggested to use D as a measure of how representative a given location inside a meat sample is for the whole meat sample. This study complements physical measurements on beef (Janz *et al.*, 2006) and pork (Hansen *et al.*, 2004) that show shear force gradients both across and along the muscles.

The Mahalanobis distance is a distance measure that takes the variability along the axis of the data set into account. In practical terms it fits an N-dimensional hyper ellipsoid around the data set and measures the distance using that as a ruler. This is different from the normal Euclidean distance where all directions have the same influence, independent of their variance. The advantage of D is that it allows even minor variations in the N-dimensional space to contribute to the distance. This is very useful when combining with PCA, which derives the principal components (PCs) according to their covariance.

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, were positioned in a holder and a 14mm thick slice was removed from the rump end of the muscle and discarded. Forty-two NIR readings were then made on the face of the muscle in a grid arrangement with a spacing of 14mm. The readings at each grid position were taken using a fibre optic probe (with diameter of approximately 16mm) 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-two readings on the face of the muscle were taken, another 14mm 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. This process was carried out for all eight LLs.

A PCA model incorporating all good NIR spectral data was developed. Standard Normal Variate (SNV) pre-processing was applied to reduce scatter effects. The optimal number of PCs was defined as the point when the loadings started to look "noisy" and this happened after 11 PCs, which were finally used to calculate D. For each animal, each 2D position appears up to 40 times (20 slices x 2 sides), so the averaging of D was carried out over 40 data points.

Results and Discussion

The average D values (D mean) for four animals were made and the regions correspond to low values of D mean, i.e. positions that resemble the average meat sample most. The central positions that are dark in colour (Figure 1) showed least variation. On average, positions 17, 18, 19, and 26 appear to be the least variable on the face of the muscle. For one animal the inner portions showed greatest variation due to the meat being rolled the wrong way during wrapping so that the fat seam was at the centre and this muscle was therefore removed from calculations.

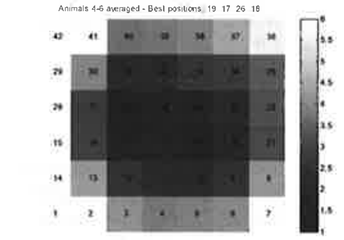

Figure 1A: A mean density pattern generated for the cross section

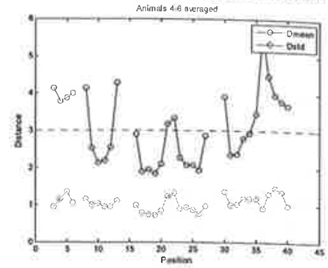

Figure 1B: D_{mean} (average of D) and D_{std} (standard deviation of D) over all slices from all three animals.The variation along the length of the muscle (i.e. the variability between slices) was determined with the resulting D_{mean} averaged over positions 17, 18, 19, and 26 for three animals shown in Figure 2A. The average and standard deviations for all three animals are shown in Figure 2B. Variation (D_{mean}) is lowest between slice numbers 8 and 20 (closer to the head end).

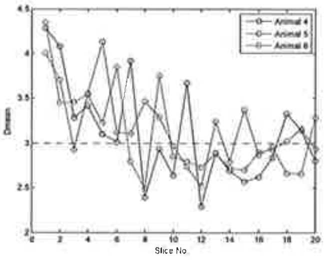

Figure 2A: Individual density values generated along the length for three animals.

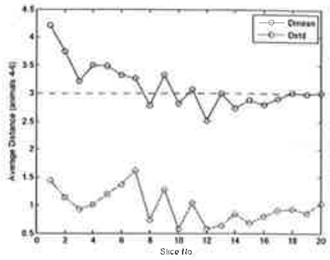

Figure 2B: The average and standard deviation for the three animals.

Conclusions

The results suggest that many shear force measurements are required to characterise a piece of meat and that the most representative results are obtained in the central regions of the LL, closer to the head end. These should be the best regions to use when developing NIR calibrations for meat tenderness.

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