ESTIMATION OF MEAT TENDERNESS USING VISIBLE-NEAR-INFRARED SPECTROSCOPY

Tharcilla I.R.C. Alvarenga[1*], Mario Palendeng[2], David L. Hopkins[3], Stephanie M Fowler[3], Peter McGilchrist[1] and Suresh Thennadil[2]

[1]University of New England, Armidale, NSW 2351, Australia;
[2]Charles Darwin University, Darwin, NT 0815, Australia
[3]NSW Department of Primary Industries, Centre for Red Meat and Sheep Development Cowra, NSW 2794, Australia
*Corresponding author email: tharcilla.alvarenga@une.edu.au

I. INTRODUCTION

Determining animal maturity is crucial to the red meat industry as it has high impact on meat eating quality [1]. Currently the meat industry estimates animal age and maturity by counting the number of permanent incisors – dentition, and scoring the changes in cartilage around the spine – ossification score. However ossification and dentition are strongly affected by several factors such as nutrition, breed, hormone status and animal health. Preliminary studies have shown the potential of using a fiber-optic based visible-near-infrared system (Vis-NIR) to predict cattle age by scanning the hides. Thus, the current study examines whether Vis-NIR reflectance measurements can be used to accurately estimate meat tenderness by scanning the *longissimus* and *semitendinosus* muscles.

II. MATERIALS AND METHODS

Longissimus lumborum and *semitendinosus* muscles were removed at 1 day postmortem (pm) from eighty Angus carcases of animals in an age range from 26 to 142 months old for objective measurement of meat quality. The average shear force (mean ± SD) of *longissimus* muscle at 2, 14 and 28 days pm was 50.80 ± 13.75, 37.51 ± 8.35 and 36.75 ± 8.49, respectively. The average shear force (mean ± SD) of *semitendinosus* muscle at 2, 14 and 28 days pm was 59.22 ± 8.94, 56.29 ± 6.49 and 56.14 ± 7.11, respectively. The Vis-NIR scans of the muscles were taken using a spatially resolved spectroscopy (SRS) system. At 2 days pm, *longissimus* and *semitendinosus* were portioned into 3 parts per muscle. The portions were randomly allocated to three ageing periods, 2, 14 and 28 days pm and held at 2-4 °C. Once the ageing period was completed, blocks of meat with at least 3 cm of thickness were scanned using Vis-NIR system at 2, 14 and 28 days pm. Vis-NIR measurements were taken with the instrument probe placed parallel to the meat fiber orientation. The SRS probe consists of a source fibre at the centre and 5 rings of detection fibres surrounding it with rings 1-5 placed at increasing radial distances from the source fibre. Data analysis in this study considered only reflectance measurements from ring 5, which consists of fibres placed at a radial source-detector distance of 2.5 mm. The three scans on each location were done automatically by utilizing the internal settings of the device. The scanning time for the 3 replicate measurements was around 1 minute per location.

Further sections of meat (200 – 250 g) at each ageing period were vacuum packed and frozen at – 20 °C for subsequent shear force analysis. Shear force samples were thawed and then cooked in a plastic bag submerged in a 70 °C water bath (Model: BTC 9090) for 1 h. Shear force analysis were performed using a Lloyd Instruments LRX Materials Testing Machine fitted with a 500 N load cell. Six subsamples with a rectangular cross section of 15 mm wide by 6.66 mm deep (1 cm^2) were cut from each sample, with the fiber orientation parallel to the long axis, and at right angles to the shearing blade. The mean peak force required to shear through the clamped subsamples with a straight 0.64 mm thick blade pulled upward at a speed of 100 mm/min was recorded.

Calibration models for predicting tenderness using ring 5 were built using Partial Least Squares (PLS) regression. Spectra were pre-processed using an Automatic Whittaker Filter baseline correction and mean centred. As part of the calibration step, wavelength selection using a genetic algorithm was applied. Leave-one-out cross-validation was used and root mean-square error of cross-validation (RMSECV) and the coefficient of determination of cross-validation R^2_{cv} were used to compare performance of models. R^2 was obtained from CV by using R^2_{cv}. All calculations were carried out using MATLAB (64-bit (win64)) [2] and the PLS Toolbox [3].

III. RESULTS AND DISCUSSION

By scanning the *longissimus* muscles at 2 days pm the calibration model was able to predict shear force at 2 days pm with an RMSECV value of 10.31 N and R^2_{cv} = 0.43 For the *semitendinosus* muscle the model was able to predict the shear force values at 2 days by using the spectra data scanned at 2 days pm with an RMSECV value of 5.7 N and R^2_{cv} = 0.58. Muscles of locomotion, such as the *semitendinosus* muscle, are tougher as a consequence of their higher amount of connective tissue. Thus, it's hypothesized that the prediction of shear force values is an indirect measurement of the prediction of connective tissue in the muscle. This may explains the better ability to predict shear force values from spectra collected on the *semitendinosus* muscle compared to *longissimus* muscle.

When the spectral data for *longissimus* muscles at 2, 14 and 28 days were used to predict shear force at 14 and 28 days, a poor predictability was observed. Given that the ability to predict shear force values declined as the muscle aged, it is plausible that the structural degradation of the myofibril affected the accuracy and precision of the models as the noise and quality of the spectra may have declined with ageing as more light is able to pass through the sample.

Table 1 Performance of the models to predict shear force of the *longissimus* and *semitendinosus* using muscle spectra data scanned at 2, 14 and 28 days pm against shear force at 2, 14 and 28 days pm.

Spectral scan (days pm)	Shear force (days pm)	*Longissimus*			*Semitendinosus*		
		RMSECV	Latent variable	R^2_{cv}	RMSECV	Latent variable	R^2_{cv}
2	2	10.31	7	0.43	5.70	7	0.58
2	14	8.47	1	0.02	5.88	6	0.23
2	28	8.69	2	0.04	5.50	4	0.28
14	14	7.54	4	0.20	7.35	4	0.32
28	28	8.51	1	0.00	5.83	7	0.57

IV. CONCLUSION

This study demonstrated that spectra data collected from the *semitendinosus* muscles at 2 days pm shows a better prediction of shear force values than spectra collected from the *longissimus* muscle. Given that the *semitendinosus* muscle is a locomotive muscle this indicates that the prediction of meat tenderness may be an indirect prediction of connective tissue in the muscle. However, further work is required to examine the repeatability and robustness of these models including data from an independent validation set and determine the mechanisms which are behind this prediction.

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