ASSESSMENT OF MEAT EATING QUALITY CHARACTERISTICS OF BEEF *M. longissimus thoracis et lumborum* BY WAY OF RAMAN SPECTROSCOPY

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I. INTRODUCTION

Eating satisfaction, sensory characteristics and nutritional content are key factors that influence consumers with regard to purchasing fresh meat [1]. Measurement of beef texture and percentage intramuscular fat (% IMF) using laboratory reference methods such as Warner-Bratzler Shear Force (WBSF), Smart-Trac and Soxhlet extraction are time consuming, expensive and destructive of sample [2]. Raman spectroscopy is a non-invasive vibrational spectroscopic technique that has been proposed as a method of prediction for beef quality traits, with advantages such as rapid measurements, simple preparation of sample and non-destructive analysis [3][4]. Therefore, the objectives of this study were: 1) to investigate the use of Raman spectroscopy and chemometrics on meat collected on day 2 post-mortem for the prediction of WBSF and % IMF values of beef *M. longissimus thoracis et lumborum* (*LTL*), and 2) to assess the effect of different mathematical spectral pre-treatments upon chemometric models used.

II. MATERIALS AND METHODS

Crossbred beef bulls and steers (18±4 month old, n = 119) finished under controlled feeding and environmental conditions were slaughtered in 8 batches in the same commercial plant by electrical stunning followed by exsanguination. Twelve steaks with a thickness of 2.54cm were removed from the *LTL* at 48 h *post-mortem*, vacuum packaged, aged for either 2 (% IMF, Raman) or 14 days (WBSF) at 4°C then frozen at -20°C. The 2nd, 4th and 12th steak on each loin was selected for %IMF, WBSF and Raman spectroscopy. WBSF analysis was conducted according to AMSA (1995) guidelines using the Instron 4464 Universal testing machine (Instron Ltd., Buckinghamshire, UK). Percentage IMF was determined using the Smart System-5 microwave drying oven and NMR Smart-Trac rapid fat analyser (CEM Corporation, USA) using AOAC Official Methods 985.14 & 985.26, 1990. Raman spectra were collected on intact defrosted *LTL* using a DXR SmartRaman spectrometer (ThermoFisher Scientific UK Ltd., Loughborough, UK), with six spectra (three per side) recorded. Raman intensity counts per second were recorded over the 250-3381 cm^{-1} wavelength range using 1 cm^{-1} intervals. Prediction models for WBSF and % IMF were developed using partial least squares (PLS) regression with cross validation and variable importance in projection (VIP) for variable selection. Furthermore, several pre-processing techniques such as standard normal variate (SNV), extended multiplicative scatter correction (EMSC) and Savitzky-Golay (SG) with 1st and 2nd derivatives were evaluated together with the raw spectra. Spectral pre-processing and data analysis were performed in R (R Core Team, 2014).

III. RESULTS AND DISCUSSION

Ranges, means, standard deviations (SD) and coefficients of variation (CV) of three beef eating quality traits are presented in Table 1.

Table 1. Descriptive statistics of beef *LTL* eating quality traits (n = 119)

Attribute	Min	Max	Range	Mean	Median	SD	CV
WBSF (N)	22.55	64.53	41.98	40.87	40.64	7.98	19.64
% IMF	0.16	4.63	4.48	1.77	1.44	1.02	59.65

Both WBSF and % IMF datasets had a large range and variability, in particular % IMF which had a CV of 59.65 %. Variability was not as abundant for WBSF, which had a CV of 19.64 %.

PLS models for WBSF and % IMF were built using raw and preprocessed data covering the region from 700-1800 cm^{-1}, since this range comprises most of the Raman peaks/bands associated to meat quality traits [5]. A summary of the best performances is shown in Table 2.

Table 2. Best fitting predictive models of WBSF and % IMF on beef samples using Raman spectroscopy

Attribute	Range (cm-1)	Pre-processing	Var	n	L	R^2c	R^2cv	RMSEC	RMSECV
WBSF	1800-700	Raw	326	114	6	0.44	0.21	5.93	7.06
WBSF	1800-700	EMSC	407	114	4	0.42	0.26	6.04	6.85
% IMF	1800-700	SG (1d,5p,7w)	346	111	3	0.76	0.26	0.50	0.87
% IMF	1800-700	SG (2d,2p,9w)	356	111	3	0.67	0.26	0.58	0.87

Var, number of spectral variables retained; EMSC, extended multiplicative scatter correction; SG, Savitzky-Golay; d, derivative; p, polynomial order; w, smoothing window; n, number of samples; L, number of PLS loadings; R2c, coefficient of determination of calibration; R2cv, coefficient of determination of cross validation; RMSEC, root mean square error of calibration; RMSECV, root mean square error of cross validation.

The best model for WBSF (R^2c 0.42 and RMSECV 6.85 %) was obtained when undesired spectral variation was removed/reduced via EMSC; while for % IMF (R^2c 0.76 and RMSECV 0.87 %), best results were obtained when using SG 1st derivative. In the frame of calibration, WBSF models provided modest values of R^2; whereas IMF models presented notable performance. These results may be due to the fact that the WBSF parameter depends on multiple physic-chemical factors. Furthermore, Raman spectra are complex, where the signal of a group vibration may be attributed to different compounds [5]. Consequently, resulting prediction models may take into account spectral responses which simultaneously contain WBSF related and non-related information. With regard to the cross validation, both models showed modest R^2cv yet considerably low values of RMSECV indicating promising predictive ability.

IV. CONCLUSION

Raman spectroscopy has the potential to predict important beef eating quality traits, in particular percentage IMF. Useful prediction calibrations were also developed for WBSF. This technology has potential to be utilised by breeding societies to facilitate improvement of beef eating quality by genetic selection.

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