Prediction of beef quality attributes from early post mortem near infrared reflectance spectra

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Introduction

The quality of red meat offered for sale in many countries is highly variable. Tenderness is the single most important quality parameter for consumer acceptance and studies have shown that customers are willing to pay a higher price for beef with guaranteed tenderness.[1,2] A method that could predict tenderness of beef at the time of consumption, at the slaughter line, would be beneficial for both consumers and industry. Those carcasses that do not tenderise to an acceptable level after ageing could then be identified and used for other purposes. Near infrared (NIR) spectroscopy has been used for assessment of fat, moisture and protein in emulsified or ground meat.[3–5] In recent years, new applications of NIR spectroscopy for estimation of textural and sensory characteristics in intact beef cuts have emerged.[6–10] Most of these studies report results regarding correlations between NIR spectra and textural and sensory analysis that were sampled at the same point in time. However, Byrne *et al*.[9] used NIR spectra (750–1098 nm), which were recorded one, two and seven days after slaughter to predict tenderness, as measured 14 days *post mortem*. An early detection of carcasses that will not age well is highly desirable. No studies have been identified in the literature where NIR spectra of beef have been recorded *pre rigor* or earlier than 24 hours *post mortem*. The aim of this study was therefore to examine if NIR reflectance spectra (1100–2500 nm), could be used to predict final tenderness earlier than 24 hours *post mortem*.

Materials and methods

Altogether 127 *M. longissimus dorsi* muscle samples from the Norwegian Red breed were included in two separate studies. Study 1 included 79 loins, collected in five subsets over a one-year period. The remaining 48 samples were collected during three consecutive days. 12 and 24 carcasses from Study 1 and 2, respectively, were electrically stimulated immediately after bleeding (90 V, 12.5 Hz, 40 s). The muscle samples were excised from the bones approximately 45 minutes after stunning, packed in polyethylene bags and conditioned for one day at 15°C. The samples were further aged at 4°C for up to 7 days after slaughter. Continuous NIR reflectance spectra in the 1100–2500 nm range at 4 nm intervals were recorded transversally to the muscle fibres on freshly cut samples 2–30 hours *post mortem* with an InfraAlyzer 500 spectrophotometer (Bran+Luebbe GmbH, Norderstedt, Germany). The quality measurements were performed after two and seven days ageing on samples which were heat-treated in a water bath at 70°C for 50 min, frozen and thawed before the texture analyses. Ten parallels were sheared at right angles to the fibre direction on samples with a cross-sectional area of 1×1 cm^2 with a WB shear-press device in an Instron Materials Testing Machine (Model 4202, Instron Engineering Corporation, High Wycombe, UK). Data were analysed using the Unscrambler software package (Version 6.11b, Camo A.S, Trondheim, Norway). Partial least squares regression

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Table 1. Range of properties for the bovine *M. Longissimus dorsi* samples.

	Constituent/Property	Unit	Range	Mean	*n*
Bulls	Carcass weight	kg	227–477	308	61
	Fat content of loins	%	0.8–5.9	2.0	61
	WB shear press (2 days)	kg cm^{-2}	4.3–11.2	7.3	61
	WB shear press (7 days)	kg cm^{-2}	2.9–9.7	5.5	61
Cows	Carcass weight	kg	155–341	253	66
	Fat content of loins	%	1.0–14.8	4.1	66
	WB shear press (2 days)	kg cm^{-2}	2.7–9.1	6.0	66
	WB shear press (7 days)	kg cm^{-2}	2.6–8.0	4.9	66

(PLS) was used in predicting textural properties from NIR spectra and full cross-validation was used in the validation method.

Results and discussion

The ranges of some quality parameters are shown in Table 1. The mean weight was significantly higher for bulls than for cows, but cows had higher fat content compared with bulls. The average WB shear forces were also significantly higher for bulls than cows at both two and seven days in Study 1, but not in Study 2.

Figure 1 shows the average NIR spectra recorded four and 26 hours *post mortem* in Study 1. Study 2 had similar spectra with only minor changes due to different recording times after slaughter. In the wavelength region between 1100 and 1900 nm *post rigor* spectra had lower absorbance compared with *pre rigor* spectra. During *rigor mortis*, shortening of myofibrils give a more compact structure in the muscle, which shortens the penetration length of light into the muscle. The myofibril contraction could also lead to displacement of water, which may result in light scattering in the tissue.

Table 2 shows the prediction results for WB shear force from early *post mortem* NIR spectra. Predictive models were generated by both partial least square (PLS) regression and principal component regression (PCR), but the correlation coefficients were relatively low. PLS seemed to give better correlation coefficients, even though these models needed more factors. However, there was significant correlation between NIR and WB for all models, $p < 0.01$. *RMSEP* was in the range 1.5–1.8 kg cm^{-2} for

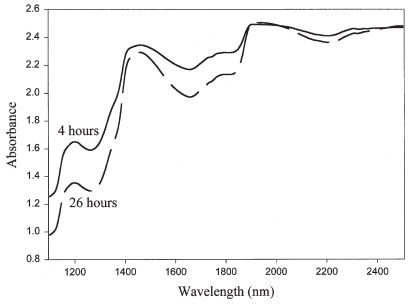

Figure 1. Average NIR spectra measured four and 26 hours *post mortem*.

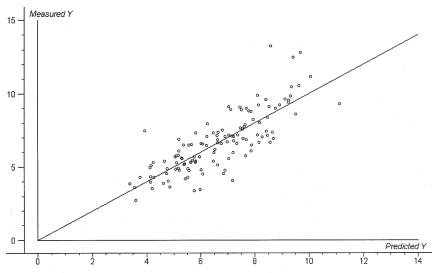

Figure 2 Predicted v. measured WB shear force values for the PLS regression between NIR spectra *post rigor* and WB seven days after slaughter.

Table 2. Prediction of quality attributes from NIR reflectance spectra of beef samples, full cross-validation.

n	*X*-matrix	*Y*-matrix	Corr. coef.	*RMSEP*	Oprtimal no. of factors
PLS					
127	NIR *pre rigor*	WB 2 days	0.47	1.81	5
127	NIR *pre rigor*	WB 7 days	0.51	1.53	11
127	NIR *post rigor*	WB 2 days	0.55	1.75	11
127	NIR *post rigor*	WB 7 days	0.54	1.49	14
PCR					
127	NIR *pre rigor*	WB 2 days	0.48	1.79	5
127	NIR *pre rigor*	WB 7 days	0.37	1.59	5
127	NIR *post rigor*	WB 2 days	0.45	1.83	7
127	NIR *post rigor*	WB 7 days	0.44	1.56	12

these models, which must be regarded as high. Predicted v. measured WB shear force values for the regression between NIR spectra *post rigor* and WB seven days after slaughter are shown in Figure 2. Multiplicative scatter correction (MSC) of the spectra did not improve the prediction results. Regressions between NIR difference spectra and tenderness after seven days or the difference between WB shear force at two and seven days did not yield models with predictive power. This showed that the NIR difference spectra did not contain essential information about final tenderness of the aged samples. Thus NIR spectral changes during *rigor mortis* were not related to the ageing potential of the individual loin samples.

Considerable variations in corresponding correlation coefficients were also reported by Byrne *et al*.[9] Their coefficients seem to be higher than the values reported in this paper. They used NIR spectra in the range 750–1098 nm but the overtones in this area has the same origin as the absorbance in the 1100–2500 nm area. A more likely explanation for their better results could be that they used a more homogenous animal material, i.e. heifers of similar age, size and grade. In our study, the random sampling from a regular slaughter line included animals of a wide range of age from both genders. The gender's influence on the prediction results was examined by making separate models for cows and bulls. Although prediction of WB shear press from MSC spectra recorded after 26 hours from separate bull or cow sample sets gave models with correlation coefficients up to 0.68, no systematic difference in prediction of tenderness between genders was observed.

Figure 3 shows the four hours NIR spectra for the averages of the ten most tender and ten toughest carcass samples, compared to the average NIR spectrum of all carcasses in Study 1. WB shear force on Day 2 was used as the criteria for this classification. On average, the tender samples had lower absorbance than the tough samples over the whole spectral region. The same picture was observed when the 26 hours NIR spectra or WB shear force after seven days was

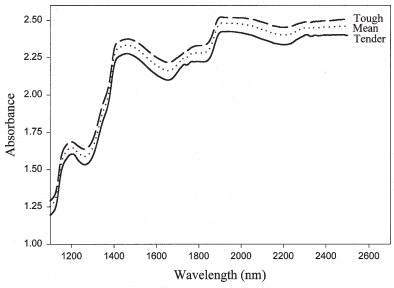

Figure 3 Average NIR spectra measured four hours *post mortem* for the averages of ten most tender and ten toughest samples compared to the average of all samples in Study 1.

used for classification. However, in Study 2 there were no differences between tough and tender samples.

Conclusion

NIR spectra recorded *pre rigor* had overall higher absorbance compared with NIR spectra recorded *post rigor* in bovine *M. longissimus dorsi* muscles from 127 carcasses. Prediction of tenderness from NIR spectra recorded *pre* or *post rigor* gave multivariate correlation coefficients up to 0.68 when WB measurements were used as a response variable. Results obtained in this study provide only limited support that early *post mortem* NIR spectroscopy can be used as a predictor of final tenderness. However, only wavelengths between 1100 and 2500 nm were used in this study. By including wavelengths from 750 to 2500 nm it might be possible to improve the prediction models.

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