P-07-19

Vis-NIR spectrophotometry to predict Intramuscular fat (IMF) and pH in beef under contact and non-contact modes in a meat processing pilot plant (#391)

Yash Dixit[1], Sam Hitchman[1], Talia Hicks[2], Cameron Craigie[3], Marlon Reis[1]

[1] Agresearch Grasslands, Meat Quality, Food and Bio-based products, Palmerston North, New Zealand; [2] Agresearch Ruakura, Meat Quality, Food and Bio-based products, Hamilton, New Zealand; [3] Agresearch Lincoln, Meat Quality, Food and Bio-based products, Christchurch, New Zealand

Introduction

IMF (Intramuscular fat) refers to the fat deposits within a muscle between muscle fibers and muscle fiber bundles playing a critical role in the beef eating experience. Equally important, pH is also assessed during grading and used to define the quality of carcass, where carcasses with pH below 5.7 are downgraded. Thus, there is a growing interest in the use of non-invasive/non-contact devices that can be easily used within processing plants to assess IMF and pH. Vis-NIR spectroscopy is an extensively researched non-invasive technology with regard to meat quality characteristics such as IMF and pH. However, most of the previous studies have been laboratory-based and utilized contact probes. Also, a lot of these studies used homogeneous samples (minced beef) which hinders the transfer of technology to the industry (Dixit et al., 2017; Porep et al., 2015). The current study envisages developing the Vis-NIR spectroscopy for industrial application. Two spectrophotometers were used; One spectrophotometer performed measurements using a contact probe. In contrast, the other spectrophotometer performed measurements at a stand-off distance of 180 mm. The chemometric technique of PLSR was used for developing prediction models. The study demonstrated the ability of Vis-NIR spectroscopy as a potentially robust and rapid technique to predict IMF and pH in beef in a meat processing plant under both contact and non-contact modes.

Methods

A total of 181 beef samples were measured 24 hr post slaughter in a meat processing pilot plant at AgResearch, Ruakura campus. Samples were cut into a rectangular shape and intermuscular fat was removed. Two Vis-NIR spectrophotometers (Labspec5000 & Labspec4, ASD Inc., Boulder, CO, USA), working in a wavelength range of 350-2500 nm were used in the reflectance mode. Spectrophotometer used for contact measurements had a spectral resolution of 3nm @700nm; 10nm@1400/2100nm and used a contact probe; where six measurements were taken at different regions covering the sample surface. The other spectrophotometer (non-contact) had a spectral resolution of 3nm @700nm; 6nm @ 1400/2100nm which performed a single scan over the entire sample surface at a stand-off distance of 180 mm where the sample was illuminated using a halogen light source. A total of 40 sub-scans were collected for each spectrum.

Data analysis was performed in R language (Team, 2018). Initially, the six scans obtained using contact spectrophotometer for each sample were averaged into one spectrum thus obtaining single spectrum per sample for both spectrophotometers. Spectral data in the wavelength range of 389-2149 nm was used in order to remove regions with a low signal-to-noise ratio (SNR). Raw spectral data from both spectrophotometers were pre-processed using standard normal variate (SNV) transformation in order to remove any baseline effects and enhance SNR. Pre-processed spectral data along with chemical reference data were subjected to partial least square regression to develop prediction models for IMF and pH.

Results

IMF content for all the beef samples (n=181) was obtained in the range of 0.67-19.36 % using an AOAC approved method (Method 996.06); the pH values were determined using a pH meter which ranged from 5.32-6.91. Table 1 shows a summary of PLSR models. The models showed a good fit, yielding high coefficients of determination (R^2) with low standard errors of cross-validation (SECV) for both IMF and pH in contact and non-contact modes. The models also showed good prediction ability, yielding high R^2 for prediction with low standard errors of prediction (SEP). Similarly, the pH model also yielded high prediction and low SEPs in both modes (Fig.1). It can be observed that variable importance in projection (VIP) scores plot captures the relevant region related to fat peak at about 1215 nm (ElMasry et al., 2013) in both modes. Similarly, relevant VIP scores were observed for pH (Fig.2).

Conclusion

Overall results showed that Vis-NIR spectroscopy has the ability to predict IMF and pH in a meat plant environment in both contact and non-contact modes. Both modes showed good and comparable prediction ability. However, non-contact mode provides certain advantages over contact mode such as less scan time (1 vs 6) and minimal sample intervention.

References

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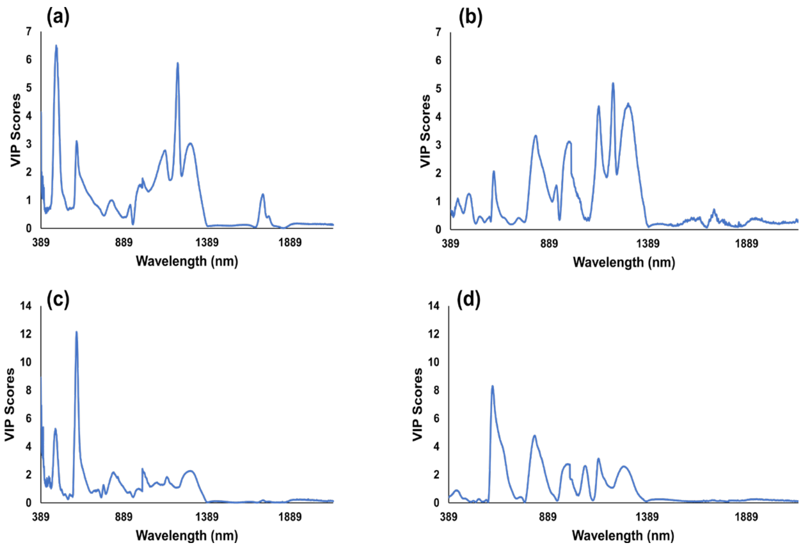

Figure 2 VIP scores plots (a) NIR contact: IMF, (b) NIR non-contact: IMF, (c) NIR contact: pH and (d) NIR non-contact: pH

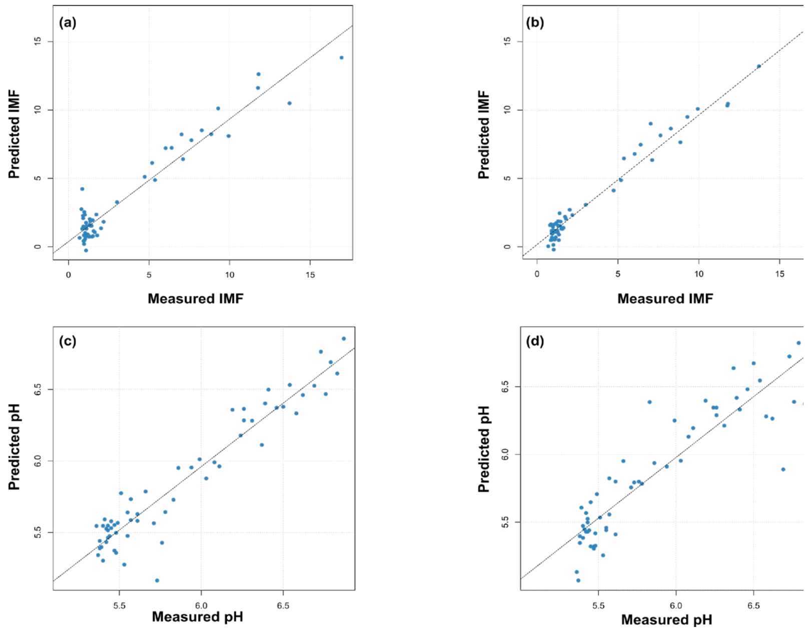

Figure 1 Prediction plots (a) NIR contact: IMF, (b) NIR non-contact: IMF, (c) NIR contact: pH and (d) NIR non-contact: pH. Number of validation samples for IMF (n_{IMF})= 59 and Number of validation samples for pH (n_{pH})= 60

Instrument	Attribute	Calibration and cross-validation						Validation		
		n	LV	R2C	SEC	R2CV	SECV	n	R2P	SEP
NIR (contact-probe)	IMF	122	9	0.95	0.90	0.91	1.16	59	0.92	1.04
	pH	121	9	0.92	0.14	0.87	0.18	60	0.87	0.16
NIR (non-contact)	IMF	122	9	0.97	0.68	0.95	0.91	59	0.95	0.80
	pH	121	5	0.86	0.18	0.81	0.21	60	0.82	0.21

Summary of PLSR models

Notes