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Development of near infrared reflectance spectroscopy to predict chemical composition with a wide range of variability in beef

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A total of 182 beef samples were minced and divided into calibration set (n = 140) and independent validation set (n = 42). Calibration models of NIRS (1000–1800 nm) were built using partial least squares regression (**PLSR**) on the calibration set of samples. Both the coefficient of determination in calibration ($\mathbf{R^2_C}$) and the coefficient of determination in prediction ($\mathbf{R^2_P}$) were over 0.98 for all chemical compositions. The ratio performance deviation (**RPD**) was 17.37, 5.12 and 10.43 for fat, protein and moisture, respectively. The results of the present study indicate the outstanding ability of NIRS to predict chemical composition in beef.

1. Introduction

In the past few decades the meat industry has vastly flourished and with the growth of economy, and demands for superior quality meat are increasing in China (Zhou, Zhang, & Xu, 2012). To fulfill consumer's satisfaction it is very important to accurately assess meat quality characteristics (Troy & Kerry, 2010). Chemical composition is considered very important for the nutritional value, technological and sensory quality of meat. Conventional chemical procedures are time consuming, expensive and potentially hazardous to human health and environment. In recent years, the near infrared reflectance spectroscopy (**NIRS**) has been proved to be a favorable technique for the analyses of quality attributes to meat and meat products (Prieto, Roehe, Lavín, Batten, & Andrés, 2009). Compared to conventional methods NIRS is a sensitive, fast, non-destructive and relatively inexpensive analytical technique with simplicity in sample preparation and possibility to determine numerous meat quality parameters simultaneously (Osborne, Fearn, & Hindle, 1993; Prieto et al., 2009). Hence, the NIRS technique would be especially useful and interesting where analyses on large scale are needed or an alternative of conventional methods which are harmful to health or environment.

Many studies indicate that NIRS has the ability to predict the meat chemical components such as fat, protein and moisture in beef (De Marchi, Berzaghi, Boukha, Mirisola, & Gallo, 2007; Prevolnik et al., 2005; Prieto, Andrés, Giráldez, Mantecón, & Lavín, 2006; Tøgersen et al., 2003), mutton (Viljoen, Hoffman, & Brand, 2007), chicken meat (Berzaghi, Dalle Zotte, Jansson, & Andrighetto, 2005; Cozzolino & Murray, 2002; McDevitt, Gavin, Andrés, & Murray, 2005) and even in pork sausages (Gaitán-Jurado, Ortiz-Somovilla, España-España, Pérez-Aparicio, & De Pedro-Sanz, 2008; Ortiz-Somovilla, España-España, Gaitán-Jurado, Pérez-Aparicio, & De Pedro-Sanz, 2007). It has to be noted that the success of this method partially relies on the variability present in the samples analyzed. However, other authors showed high levels of error for the prediction of chemical composition in beef, lamb, pork or poultry meat (Alomar, Gallo, Castañeda, & Fuchslocher, 2003; Andrés et al., 2007; Brøndum et al., 2000; Cozzolino, De Mattos, & Martins, 2002; Liao, Fan, & Cheng, 2010; Ripoll, Albertí, Panea, Olleta, & Sañudo, 2008; Savenije, Geesink, van der Palen, & Hemke, 2006). These differences can be partially explained by the narrow range of variability in the reference data, which negatively affect NIRS predictability in these studies.

Although published results vary considerably, Prieto et al. (2009) suggest that NIRS is a suitable alternative to analytical methods to predict the chemical composition of meat and meat products. In particular, under commercial conditions where simultaneous measurements of different chemical components are required, NIRS is expected to be the method of choice. Additionally, in the commercial market of China, the

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Table 1
Reference values of chemical parameters in beef samples measured by traditional methods.

Statistics	Calibration set (%)			Validation set (%)		
	Fat	Protein	Moisture	Fat	Protein	Moisture
n	140	139	140	42	41	42
Mean	10.04	19.42	69.92	9.59	19.34	70.42
Minimum	0.20	1.98	12.85	0.51	3.07	16.18
Maximum	86.45	23.28	78.53	84.29	23.41	79.25
Range	86.25	21.30	65.68	83.78	20.34	63.07
SD	16.20	3.60	12.48	17.13	3.82	13.00

SD, standard deviation.

beef meat quality varies widely due to diverse cattle breeds combined with different feeding operations. With the purpose of more extensive applications of NIRS in the field of beef quality control, more robust calibrations should be developed by using larger sample sets with wide ranges for given parameters. Therefore, the objective of this study was to maximize the predictability of the main chemical composition (fat, protein, moisture) of beef by NIRS models. To guarantee the reliability and applicability of the models, calibration and independent validation samples were specifically selected from four different cattle breeds with different feeding operations to ensure a wide range of reference values.

2. Materials and methods

2.1. Preparation of beef samples

A total of 66 beef cattle from four different breeds (Simmental [n = 20, 10 bulls and 10 cows, 18 months of age], Qinchuan cattle (n = 14, adult steers, 18 months of age), Angus × Qinchuan cattle [n = 16, steers, 27 months of age] and Japanese black × Fuzhou cattle [n = 16, adult steers, 25 months of age]) were slaughtered at a commercial slaughterhouse. At 48 h post-mortem, four muscles (*Musculus longissimus dorsi* [**LD**], *Musculus semitendinosus* [**ST**], *Musculus psoas major* [**PM**] and *Musculus deltoideus* [**DT**]) were dissected from each carcass of Simmental and Qinchuan cattle, while at 7 d post-mortem only LD were dissected from carcass of Angus × Qinchuan cattle and Japanese black × Fuzhou cattle. The Angus × Qinchuan cattle and Japanese black × Fuzhou cattle were fattened by special feeding techniques to produce wonderful marbling and high percentage of fat (n = 32, mean fat content = 17.19%, ranged from 6.03% to 36.85%, SD = 8.92). The muscles were labeled and vacuum-packed in polyethylene bags and then transported in ice boxes to laboratories for analysis. In order to create large variation ranges of chemical composition, additional 14 samples were artificially mixed with high proportion of fat tissue (mean fat content = 60.33%, ranged from 41.75% to 86.45%, SD = 16.02). Finally, a total of 182 beef samples were used for NIRS modeling process in this study.

Table 2
Coefficients of correlation (Pearson) among the chemical parameters in beef samples.

	Fat	Protein	Moisture
Fat	1.000		
Protein	−0.933**	1.000	
Moisture	−0.993**	0.901**	1.000

** $P < 0.01$

2.2. Spectra collection and chemical analyses

Intact muscles were trimmed to eliminate connective tissue and fat tissue, and subsequently minced and homogenized in a blender. Immediately after homogenization, both NIRS and chemical analyses were performed as described below.

The meat paste was then loaded in a ring quartz cup with an internal diameter of 70 mm and a depth of 10 mm. Reflectance spectra were scanned and collected using SupNIR-1500 Near-Infrared Analyzer (Focused Photonics Inc., Hangzhou, China). Each sample was scanned three times and the spectra were averaged prior to statistical analysis. The spectrophotometer interpolated the data obtaining spectra with wavelengths between 1000 and 1800 nm at 1 nm intervals. The absorbance data were stored as log (1/R), where R represented reflectance.

After the spectra collection, chemical analyses were performed on the minced samples. Determination of fat content was carried out according to ISO International Standard Organization, 1443-1973 (Soxhlet extraction with hydrolysis) using a Soxtec™ 2050 Auto Fat Extraction System (Foss Analytical, Hileroed, Denmark). Protein content was determined according to ISO International Standard Organization, 937-1978 using Kjeltec™ 2300 Analyzer Unit (Foss Analytical, Hileroed, Denmark). Moisture content was measured in accordance with the ISO International Standard Organization, 1442-1997. Fat and protein contents were expressed as a percentage on a fresh weight basis. All determinations were carried out in duplicate and averaged prior to statistical analysis as the reference value. Basic statistics of fat, protein and moisture content for calibration and validation sample sets are presented in Table 1.

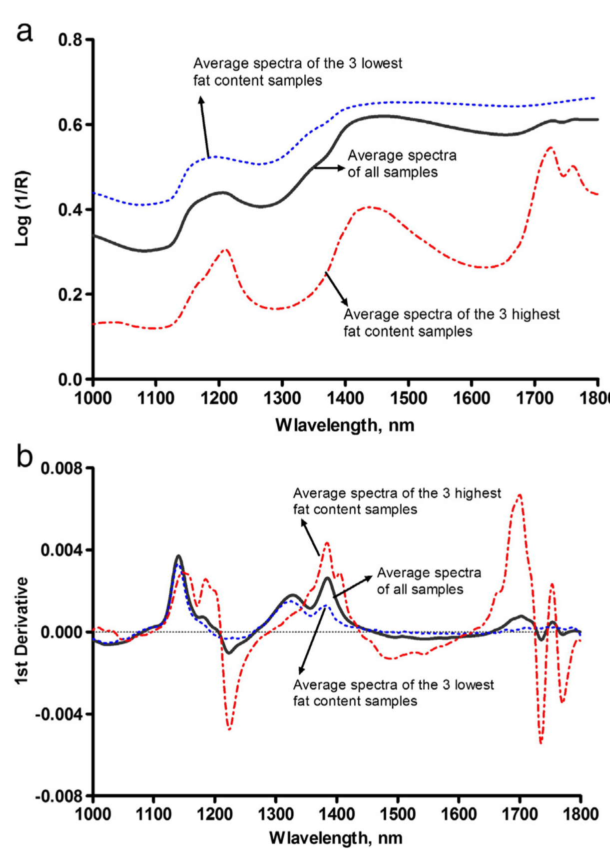

Fig. 1. Average NIRS raw absorbance spectra (a) and the 1st derivative spectra (b) of minced beef samples.