Determination of meat quality by near-infrared spectroscopy

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Abstract

The aim was to determine total protein, pure protein, non-collagen muscle protein, dry matter and moisture (water) in pork meat using Fourier transform near-infrared reflectance spectroscopy (FT-NIRS). The spectra of samples (n = 54) were measured on an integrating sphere in the reflectance mode with a compression cell in a range of 10 000 to 4 000 cm^{-1} and 100 scans on average. The evaluation was carried out using the method of partial least squares (PLS). The method of cross-validation was applied for verification. The best models were developed for dry matter and moisture (water). FT-NIR spectroscopy is a suitable technique for a quick analysis of the basic components of pork.

Dry matter, meat, moisture, near-infrared spectroscopy, protein

Introduction

Unlike conventional methods used to determine the physical and chemical composition of meat, near-infrared spectroscopy (NIRS) is a sensitive, expedient, simple, safe and non-destructive method for the simultaneous determination of several parameters (Tao et al. 2013). The use of NIRS for determining the quality of meat is usually associated with the determination of basic components – proteins, fat, water (moisture) and dry matter, as well as sensory properties (Alomar et al. 2003; Ripoll et al. 2008; Kapper et al. 2012).

The successful definition of calibration methods depends on the variability of the analysed samples. If the range of reference values for the definition of calibration models is too narrow, this may have a negative impact on the predictive value of this method (Su et al. 2014). In addition to quantitative analysis, NIRS is also used for the determination of quality, e.g. to assess the ripening, freshness and spoilage of meat. Many studies have been published over the last 40 years whose results demonstrate the exceptional potential of NIRS in the meat industry and other industries (Procházková and Králová 2013).

The aim of this study was to define calibration models for selected chemical parameters of pork using the method of Fourier transformation near-infrared spectroscopy (FT-NIRS).

Materials and Methods

Samples of pork meat (n = 54) were obtained from the University of Veterinary and Pharmaceutical Sciences Brno slaughterhouse. The following were determined in the samples: total protein (Kjeltec System 2300, Tecator, Switzerland), pure protein after distillation of non-protein N-substances with a hot solution of tannin and the subsequent transfer of organic nitrogen (Kjeltec System 2300, Tecator, Switzerland), non-collagen muscle protein (pure proteins – collagen), dry matter (CSN 576021 1999) and water (100 – dry matter). Following grinding and homogenisation, the samples were checked on a Nicolet Antaris NIR spectrometer (Thermo Electron Corporation, USA) in a spectral range from 10 000 to 4 000 cm^{-1} with a spectral resolution of 8 and 100 scans. The time of one spectrum sensing was around 1.5 min. (Růžičková and Šustová 2006). The spectra (Fig. 1) were measured at the integrating sphere in the reflectance mode with a compression cell and with the use of a spinner.

The measured data were processed by TQ Analyst version 6.2.1.509 (Thermo Electron Corporation, USA) using the partial least squares method (PLS). For all calibration models, the spectrum was used without any mathematical adjustment. Statistical analysis was performed using the STAT Plus statistical and graphical software (Matoušková et al. 1992).

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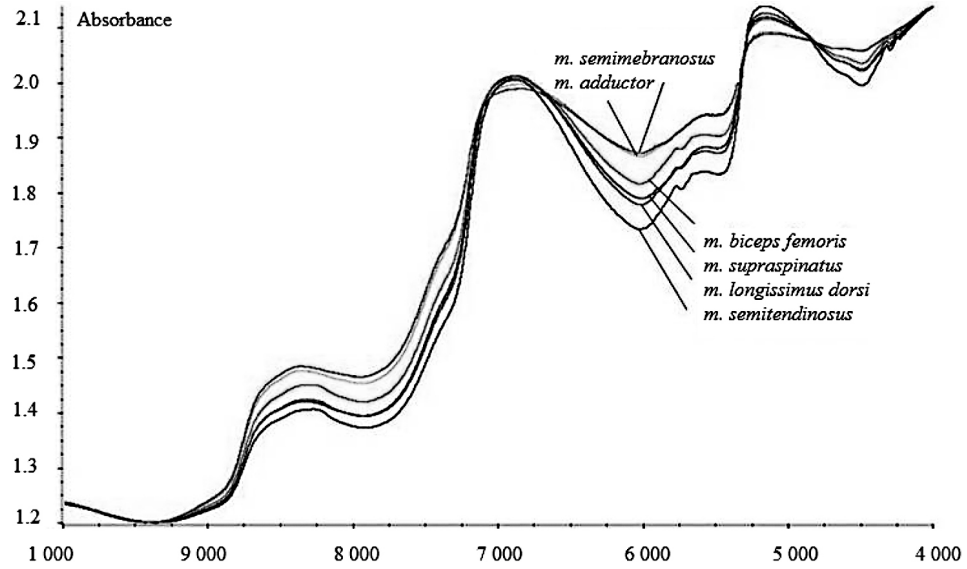

Fig. 1. Example of pork meat spectra

Results and Discussion

The range of reference values for the parameters in question is shown as a standard error in relation to the mean value (Table 1). The use of the diagnostic tools Spectrum Outlier and Leverage enabled the elimination of irrelevant standards in which the reference value was determined inaccurately or where there was a spectral error in the measured spectrum. The number of samples used for calibration after the elimination of irrelevant standards is shown in Table 2.

Table 1. Reference values measured in 54 samples

Parameter [%]	Min	Max	x	s
Total protein	18.36	24.76	21.83	1.72
Pure protein	16.42	21.28	19.07	1.28
Non-collagen muscle protein	15.78	21.17	18.60	1.35
Dry matter	14.29	30.57	26.06	2.40
Water	69.43	85.71	73.95	2.40

During calibration using the PLS method, all important concentration and spectral information on the analysed area or areas of calibration standards are condensed into a set of new variables known as factors (Table 2). Each factor represents an independent source of variability in the calibration data. PRESS values (Predicted Residues Error Sum of Squares) are indicators of errors in the PLS calibration method. The same set of samples that was used for calibration was also used to create validation models using the cross validation method. This diagnostic is one of the main indicators of model quality. The cross validation method quantifies each calibration standard as if it were a validation

Table 2. Calibration and validation results

Parameters [%]	n	F	Calibration				Validation			
			R	R^2	SEC	CCV [%]	R	R^2	SECV	PCV [%]
Total protein	51	5	0.80	0.63	1.03	4.7	0.71	0.51	1.2	5.5
Pure protein	52	4	0.75	0.56	0.85	4.5	0.66	0.43	0.97	5.1
Non-collagen muscle protein	51	4	0.75	0.56	0.88	4.7	0.68	0.46	0.98	5.3
Dry matter	53	5	0.88	0.77	0.85	3.2	0.83	0.70	0.97	3.7
Water	51	5	0.81	0.65	1.02	1.4	0.75	0.56	1.15	1.6

n – number of samples after the elimination of irrelevant standards; F – PLS factors (PRESS); R – correlation coefficient; R^2 – determination coefficient; SEC – standard error of calibration; SECV – standard error of validation; CCV – calibration coefficient of variation; PCV – prediction coefficient of variation

standard and calculates several parameters that describe the calibration model in question (Nicolet 2011).

The calibration coefficient of variation (CCV) and prediction coefficient of variation (PCV) are important criteria for determining the applicability of calibrations in NIR spectroscopy. If reliable calibration is to be achieved, these coefficients should not exceed values of 5% for CCV and 10% for PCV (Albanell et al. 1999).

The recommended values were not exceeded in terms of the parameters in question (Table 2). The best results were obtained for the calibration and validation models of dry matter and water (Fig. 2 and 3). When the pair T-test was applied, no statistically important differences ($p < 0.05$) were identified between the reference and predicted values.

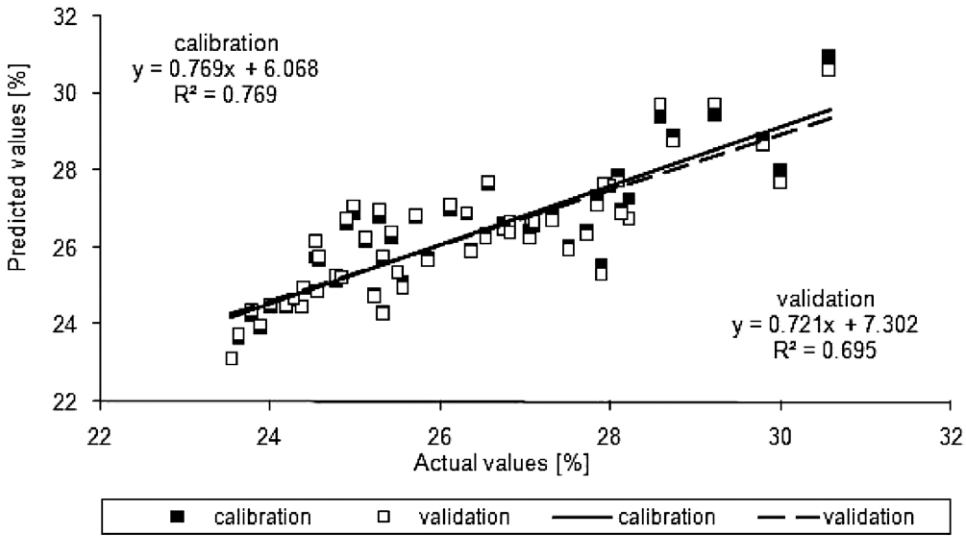

Fig. 2. Calibration and validation models for dry matter

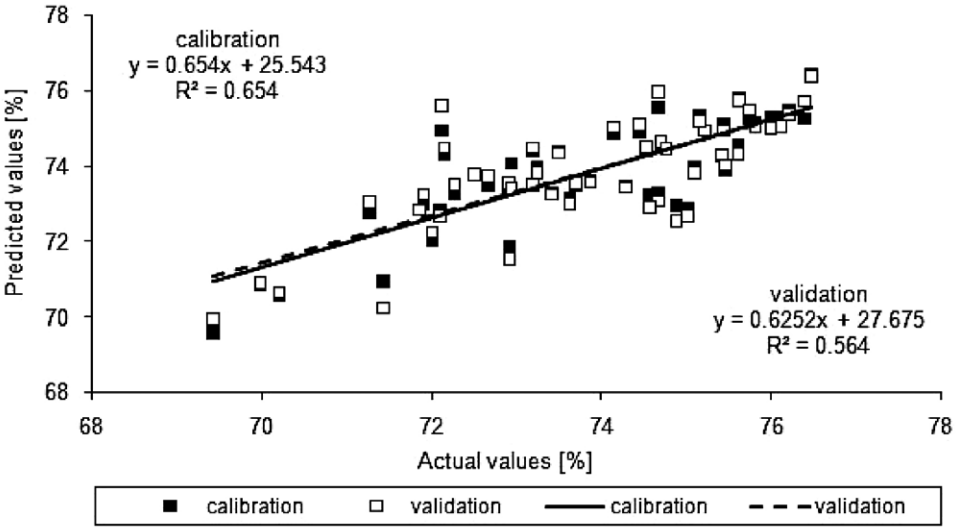

Fig. 3. Calibration and validation models for water

As the obtained results were compared with the available literature, Table 2 shows both the values of correlation coefficients and the coefficients of determination. Many authors have investigated the definition of the chemical parameters of meat using NIR spectroscopy (Tao et al. 2013). Prieto et al. (2009) show NIRS prediction in a number of chemical parameters in various kinds of meat and meat products. This review provides ranges of the determination coefficient of calibration for total protein $R^2 = 0.11$ to 0.99, dry matter $R^2 = 0.52$ to 0.98 and moisture $R^2 = 0.21$ to 0.98. Barbin et al. (2013) used the PLS method in combination with cross-validation to determine total protein and moisture in homogenised pork. For total protein, they recorded $R^2 = 0.95$ / SEC = 0.27 in calibration and $R^2 = 0.89$ / SECV = 0.42 in validation. For moisture, they determined coefficients of determination $R^2 = 0.91$ / SEC = 0.63 and validation $R^2 = 0.86$ / SECV = 0.82. The papers indicate that defining calibration models is highly dependent on the number of tested samples and their preparation prior to measurement of the spectrum on NIR spectroscopes (Barbin et al. 2013).

Conclusions

The NIR spectroscopy is a suitable method for determining the chemical parameters of meat. The proper use of NIR spectroscopy depends on many factors, such as the quality of the instrument, though also on the number of samples, the optimal preparation of the samples and the calibration method applied. The results are evaluated on the basis of correlation between the reference and predicted values from the calibration / validation equations and standard errors. Highly reliable calibration models were defined following the determined values of coefficients of variation for selected chemical parameters of pork meat.

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