DETERMINATION OF PORK QUALITY CHARACTERISTICS USING VIS/NIR SPECTROSCOPY

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Introduction

Rapid screening techniques to determine quality characteristics of meat are of great interest to the industry. In this respect, near-infrared spectroscopy (NIRS) is one of the most promising techniques (Monin, 1998). In recent years, the usefulness of NIRS has been investigated for a number of quality aspects of pork. Amongst these are the fatty acid composition of pork fat (García-Olmo et al., 2001; González-Martín et al., 2002), on-line determination of fat, water and protein content of ground pork (Togersen et al., 1999), measurement of pH (Andersen et al., 1999), measurement of intramuscular fat (Brøndum et al., 2000; Schwörer et al., 2000) prediction of drip loss (Brøndum et al., 2000; Forrest et al., 2000; Geesink et al., 2003), prediction of tenderness (Geesink et al., 2003), and determination of the RN- phenotype (Josell et al., 2001; Josell et al., 2000). Most of these applications were moderately successful to successful, with the exception of prediction of tenderness. Prediction models for drip loss were moderately successful with correlation coefficients and prediction errors of 0.64 and 2.43% (Brøndum et al., 2000) and 0.74 and 1.1% (Geesink et al., 2003) when spectra were recorded post rigor, and a correlation coefficient and prediction error of 0.84 and 1.8% when spectra were recorded pre rigor (Forrest et al., 2000). In all of these studies the models were validated by full cross validation (leave one out). Thus, these models have not been tested on an independent data set.

Objectives

The purpose of the present study was to further investigate the usefulness of NIRS to predict water-holding capacity. In addition, the predictive power of NIRS for intramuscular fat, color characteristics and pH was tested further.

Methodology

Animals and slaughter

Visible/near-infrared spectra and meat quality characteristics of the longissimus muscle were collected from three batches of pigs, slaughtered at different days. Pigs in the first batch (n = 38) were boars and gilts from crossbreed Dutch landrace x Finnish

landrace (sow) and Yorkshire (boar). Pigs in the second (n = 87) and third batch (n = 82) were barrows and gilts from crossbreed Yorkshire (sow) and Pietrain (boar). Pigs were slaughtered at a live weight of about 105 kg at a commercial slaughter plant. Pigs were electrically stunned and killed by exsanguination. Further processing of the carcasses was according to routine procedures of the slaughter plant.

Meat quality traits

One day after slaughter ca. 25 cm of the longissimus muscle of the right carcass side, starting at the 4th lumbar vertebra, was collected and transported to CCL Research and stored at 4°C. The following day the muscles were divided in 1.8 cm slices starting at the rostral end of the muscles. Slices 2, 4, 6, and 8 were used for determination of drip loss. The 3rd slice was used for visible/near infrared spectroscopy, pH determination, and determination of intramuscular fat. The 5th slice was used for color measurements. For determination of drip loss, two circular samples with a diameter of 4 cm were removed from the slices using a cork borer. The samples, 8 per muscle, were weighed, placed on display trays, covered with foil and stored for 5 days at 4°C. After storage, the samples were patted dry with paper towel, and drip loss (%) was determined by reweighing the samples. Color was determined, after blooming for 30 minutes, by measurement of L*-, a*-, and b* values using a Minolta Chromameter CR-210 (Minolta Co., Osaka, Japan). A Radiometer PHM85 Precision pH meter equipped with a Radiometer PHC 2431 glass electrode (Radiometer, Brønshøj, Denmark) was used to determine the pH of the muscles. Intramuscular fat content was determined by a commercial laboratory (Nutricontrol, Veghel, The Netherlands) according to ISO/IEC 17025:2000.

Visible/Near Infrared Spectroscopy and chemometric analyses

Reflectance spectra of meat were recorded between 400 and 2500 nm using a NIRSystem 6500 scanning spectrophotometer (Foss NIRSystems, Silversprings, MD, USA) with a transport module. Samples were place in a sample holder (5 x 6 cm) with a quartz window. Twenty five spectra per sample with a resolution of 2 nm were recorded. Spectrophotometer control and preliminary spectral file management were performed using WINISI software (version 1.50; Infrasoft International, Port Matilda, MD, USA). Exploratory data analysis, calibration, and validation were performed using WINISI.

Calibrations were developed for each meat quality trait testing a number of wavelength ranges (400-800 nm, 400-1100 nm, 800-1100 nm, 800-2500, 1100-2500, and 400-2500), derivative orders (0-2), and by using or not using scatter correction (SNV and Detrend). The remaining settings were the defaults of the software package. Regression equations, using modified partial least squares (MPLS), were first developed for the complete data set. Based on the standard error of cross validation (SECV) and coefficient of determination, the wavelength range and mathematical treatments of the most promising models were used to develop calibration models based on the data of two batches of pigs. The resulting models were validated using the data from the remaining batch. All batch combinations were tested this way to test the stability of the NIR calibrations.

Results & Discussion

Summary statistics of the meat quality attributes are given in Table 1. In all measured parameters, the standard deviation (SD) was 18 - 20% of the difference between the maximum and minimum values of that parameter. This indicates that the data set contained a sufficiently large variation to allow for a meaningful calibration.

Characteristics of the predictive models are given in Table 2. The ratio between the standard error of calibration (SEC) and the standard error of cross-validation within the calibrated data set (SECV) varied between 1.02 and 1.53, indicating a sufficiently robust calibration. The ratio between the standard error of prediction (SEP) and the SEC ranged from 0.84 to 2.15 (1.27 on average). Assuming the SEC is approximately equal to the standard error of the laboratory (SEL), this ratio is very acceptable with regard to the accuracy of the calibration.

Among the 207 samples in the validation data set, 54.1, and 86.5% of the samples were predicted within 1 and 2% of the observed drip loss. On an arbitrary basis samples with a drip loss < 6% can be classified as superior water-holding capacity and > 8% as inferior water-holding capacity (Figure 1). Of all samples 34 were predicted to be superior and 33 inferior. Of the samples classified as superior, 50% exhibited a drip loss < 6%, whereas 6% exhibited a drip loss > 8%. Of the samples classified as inferior, 64% exhibited a drip loss > 8% and none had a drip loss < 6%. This example shows that the model is not robust enough to correctly classify each individual sample, but it may be used to select batches of meat with an on average superior or inferior water-holding capacity.

For the color parameters 80.2% of the samples were predicted within 2 units of the actual L*-value, and 85% and 95.7% within 1 unit of the actual a*- and b*-value, respectively. Given that both the Minolta Chromameter and the NIRSystem measure light reflectance in the visual spectrum a stronger correlation between both measurements could have been expected (Table 2). However, considerable variation in color exists within the porcine longissimus (Van Oeckel and Warnants, 2003). Since both measurements were not performed on the same muscle slice, color variation within the muscle may explain the relatively moderate correlation between both measurements.

In accordance with the results of Andersen et al. (1999), pH could be predicted relatively well despite the narrow pH range of the samples (Tables 1 & 2). Of all samples, 84% were predicted within 0.1 pH unit of the measured value. Given that measurements with a pH probe are relatively slow and, in our opinion, do not offer good precision during routine use under processing conditions, NIRS may be a suitable alternative to measurement with pH probes.

Intramuscular fat was predicted with good accuracy (Table 2). Of all samples, 83.9% and 97.6% were predicted within 0.5% and 1%, respectively, of the measured amount.

This experiment assessed the potential use of NIRS for measuring meat quality traits by doing a proper validation of successful calibrations described in other studies. When calibrating, the robustness and accuracy are usually judged by using cross-validation methods. However, this judgement is of limited value unless it holds true for independent samples as well. This study showed that calibrations for pH, intramuscular fat, drip loss, and L*, a*, and b* color values in the porcine longissimus muscle can be used on samples from an independent batch of pigs with about 1.27 times the accuracy of the

calibration itself. The batches of pigs used consisted of different crossbreeds. Combinations of different batches of pigs were used for calibration, but the similarity of the results implies that breed, at least for modern commercial type pigs, does not affect the accuracy of the calibration.

The potential for use of NIRS depends on the parameter to be predicted. Intramuscular fat can be determined with good accuracy. Muscle pH and color values are reasonably well predicted with NIRS. It can be expected that predictions for color can be improved if both Minolta and NIRS measurements are done on the same slice of meat. These measurements are sufficiently accurate to use either quantitatively of for classification of quality categories of pieces of meat. Drip loss can not be determined with sufficient accuracy using NIRS, but classification of quality groups is possible. The average drip loss between groups will be different if selected on the basis of NIRS. For use in practice, a validation should be made for an industrial type NIRS apparatus.

Conclusions

After validation with sets of independent samples, NIRS has the potential to become a valuable rapid screening method for the meat industry. Intramuscular fat, pH and color values may be predicted quantitatively or be classified. Drip loss may be used for selecting quality subgroups. NIRS calibrations appear breed independent and thus allow use of this technique in most slaughter houses.

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Tables and Figures

Table 1. Meat quality traits (mean, range, and standard deviation) of three batches of pigs, slaughtered on different days.

	Batch 1 (n = 38)			Batch 2 (n = 87)			Batch 3 (n = 82)		
Trait	Mean	Range	S.D.	Mean	Range	S.D	Mean	Range	S.D.
Drip loss (%)	8.0	5.6-10.9	1.2	6.7	2.9-11.3	1.8	6.9	2.5-11.6	1.7
L*-value	53.5	48.4-59.5	2.7	51.0	45.2-58.4	2.6	50.1	43.7-58.0	2.5
a*-value	14.7	13.0-17.6	1.0	15.1	13.5-17.5	0.9	15.4	13.1-17.0	0.8
b*-value	6.5	4.8-8.0	0.7	6.0	4.3-8.1	0.7	5.9	4.6-8.0	0.7
Muscle pH	5.39	5.25-5.53	0.06	5.46	5.31-5.66	0.08	5.46	5.27-5.71	0.09
I.M. Fat (%)	1.2	0.4-2.3	0.4	1.1	0.1-3.6	0.6	1.1	0.2-4.3	0.5

Table 2. Correlation coefficients (r), standard error of calibration (SEC), and standard error of prediction in the PLSR models for meat quality attributes.

				Calibration				Validation	
Item	Wavelength	Treatment	Model	N	SEC	SECV	r	SEP	r
Drip (%)	400-800	None	Exp. 1 + 2	123	1.11	1.24	0.74	1.41	0.58
			Exp. 1 + 3	117	1.27	1.35	0.56	1.42	0.59
			Exp. 2 + 3	165	1.19	1.35	0.70	1.14	0.56
L*-value	400-800	None	Exp. 1 + 2	124	1.28	1.57	0.89	1.42	0.83
			Exp. 1 + 3	119	1.57	1.65	0.85	1.64	0.79
			Exp. 2 + 3	165	1.27	1.39	0.87	1.25	0.89
a*-value	400-1100	1st deriv.	Exp. 1 + 2	122	0.46	0.57	0.88	0.67	0.66
		SNV +	Exp. 1 + 3	116	0.51	0.59	0.83	0.67	0.72
		Detrend	Exp. 2 + 3	165	0.57	0.58	0.76	0.74	0.68
b*-value	400-800	None	Exp. 1 + 2	123	0.44	0.46	0.81	0.52	0.67
			Exp. 1 + 3	117	0.44	0.49	0.81	0.51	0.71
			Exp. 2 + 3	168	0.50	0.52	0.68	0.42	0.84
I.m. fat (%)	800-2500	2nd deriv.	Exp. 1 + 2	122	0.33	0.36	0.70	0.39	0.69
			Exp. 1 + 3	115	0.20	0.26	0.86	0.37	0.76
			Exp. 2 + 3	164	0.28	0.33	0.83	0.40	0.63
pH	400-1100	2nd deriv.	Exp. 1 + 2	123	0.033	0.045	0.91	0.071	0.66
			Exp. 1 + 3	117	0.047	0.060	0.85	0.070	0.63
			Exp. 2 + 3	166	0.049	0.063	0.83	0.047	0.84

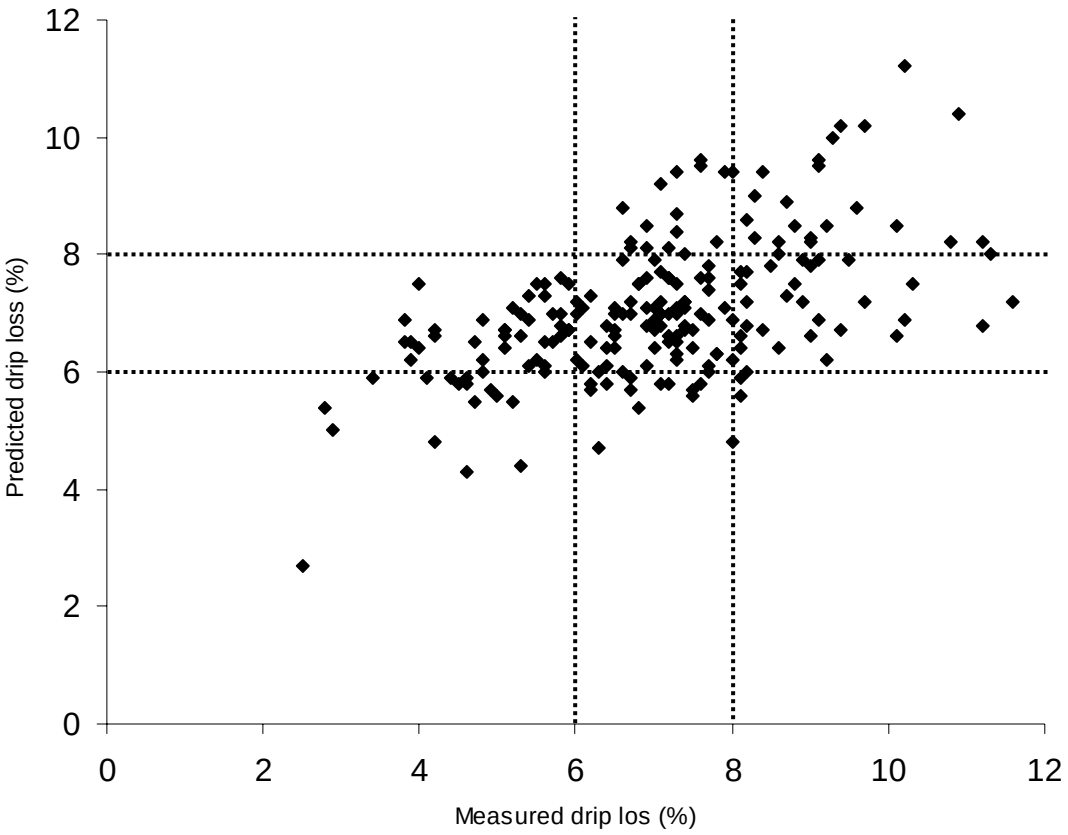

Figure 1. Predicted versus measured drip loss in 207 loin samples as assessed by NIRS