ON-LINE PREDICTION OF TECHNOLOGICAL AND ORGANOLEPTIC PROPERTIES OF BEEF BY NEAR INFRARED SPECTROSCOPY

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Background

The organoleptic and technological parameters of beef such as tenderness, color and preservation ability -pH and water holding capacity (WHC)-, are determinant factors in meat quality. Nevertheless, the reference techniques to determine these parameters are extremely time consuming, expensive and destructive, and then inapplicable at production level (on-line).

Near infrared (NIR) spectroscopy with fibre optic probe has mainly been applied to processed meat or beef homogenates for the determination of fat and protein contents (Hildrum *et al.*, 1995a), of sensory qualities such as textures, flavour and tenderness (Hildrum *et al.*,1995b; Byrne *et al.*, 1998), or the differentiation of pork, mutton, beef and poultry meat (Thyholt *et al.*, 1997). The work carried out on beef addressed the on-line determination of fat, water and protein in ground meat (Togersen *et al.*, 1999). However, no experiment was performed for organoleptic and technological parameters by NIR analysis on beef carcasses in slaughterhouse.

Objectives

The aim of this study was to investigate the use of the NIR spectroscopy for on-line prediction of technological and organoleptic properties of beef in slaughterhouse. In this work, two different fibre optic probes - transmission and reflection - were compared.

Methods

A total of hundred Belgian Blue bulls, heifers and cows carcasses were used in the present experiment. The NIR spectra were directly taken on carcasses 48 hours *post-mortem* by inserting the transmission or reflection probes in the *Longissimus thoracis* muscle immediatly after cross-section of the half carcass into front and hind quarters.

Spectra were acquired with the Fourier Transform spectrometer Bomem MB 160D in the 4000 to 12000 cm^{-1}spectral range at 16 cm^{-1} intervals. The spectral acquisition in reflection mode was performed with the fibre optic Axiom probe FDR-320. A fibre optic probe was developed for an application in the transmission mode was also used. For each mode, spectra were obtained in five different locations of the same sample and the average spectrum was calculated and used in the data analysis.

For the calibration, the mathematical treatments were performed with the Grams/32 (Galactic) software. A PCA (Principal Component analysis) was first used to detect outliers. To optimize the calibration accuracy, several scattering corrections and mathematical treatments were tested (standard normal variate, SNV; multiplicative scatter corrections, MSC; normalisation, norm.; first and second derivatives). The best one was selected for each parameter on the basis of the lowest standard error of cross validation (SECV). The predictive models were calculated with the partial least squares (PLS) regression and the number of terms determined by cross-validation by using groups of five samples. The criteria of model quality is expressed by the SECV and the determination coefficient of cross-validation (R^2cv)

After NIR spectra acquisition, the corresponding samples were removed from the carcasses and transported to the laboratory for reference analysis. Two 2.5 cm thick cuts of the *Longissimus thoracis* were used to measure technological (pH and WHC) and organoleptic (color and tenderness) qualities at day 2 *post mortem* by instrumental reference methods. The pH was measured on intact cuts by use of an inserting combined pH electrode (Ingold) on a Knick 751 pH-meter. The Labscan II device (Hunterlab) was used to objectively measure CIE L* (brightness), a* and b* (color) parameters. The WHC was estimated by drip loss and cooking loss determination. Drip loss was assessed as the percentage weight loss after 6 days storage in a plastic bag at 2°C ; cooking loss was measured as the percentage weight loss after cooking in an open plastic bag in a waterbath during 60 min at 75°C. Warner-Bratzler peak shear force (WBPSF) was determined with a Lloyd LR5K universal testing machine perpendicular to the muscle fibre direction on ten 1.25 cm diameter cores obtained from the heated cuts.

Results and discussion

The best calibration results obtained by PLS regression both in the reflection and in the transmission modes are given in Tables 1 and 2.. These tables also show results from reference analysis which were used in the calibration set.

The prediction of color parameters (CIE L*, a*, b*) in reflection mode was more precise than that achieved in transmission mode, with the SECV equal to 1.31 %, 0.77, 0.87 and 1.69 %, 1.43, 1.00 respectively. This was probably due to the reference technique associated with colour parameters which were performed also in reflection mode in the visible range. In reflection mode, the coefficient of determination was higher for CIE a* parameter ($R^2cv = 0.82$) than for CIE L* and b* parameters ($R^2cv = 0.75$ and $R^2cv = 0.78$ respectively). By contrast, in transmission mode, the CIE L* and b* parameters were predicted to a better extend than CIE a* parameter since the coefficient of determination were respectively 0.57, 0.67 and 0.28. These results which were obtained on-line, were similar in transmission mode to those previously observed in the laboratory by Leroy *et al.* (2000) in NIR spectral range and Byrne *et al.* (1997) between 750-1100 nm.

For the drip loss, the fibre optic probe in transmission mode showed a higher correlation than that one in reflection. The coefficient of determination (R^2cv) was 0.54 in transmission and 0.38 in reflection and the SECV was 0.8 and 0.9 % respectively. Furthermore, the quality of the on-line prediction can be considered of high level since Leroy *et al.* (2000) reported SECV of 1.1 % and R^2cv of 0.32 for the prediction of drip loss in transmission mode and SECV of 1.0 % with R^2cv of 0.35 in reflection mode measured in the laboratory on samples removed from the carcasses.

The other WHC parameter, the cooking loss, was difficult to predict in both modes, the R^2cv being below to 0.11. The model quality obtained in previous researches, showed better results since the coefficient of determination was 0.55 in transmission mode (Leroy *et al.*, 2000; Mitsumoto *et al.*, 1991).

The pH values was weakly predicted by NIR since the best R^2cv was 0.30 obtained in transmission mode. No model was obtained for prediction of WBPSF in both modes.

Conclusions

It can be concluded from this experiment when applied on-line that when applied on-line the NIR spectroscopy prediction of several meat quality parameters can be at less equal to those obtained directly on meat samples in the laboratory. Nevertheless, the performances varied according to the acquisition mode: the reflection and the transmission showing potentialities for prediction of colour and drip loss respectively.

Before direct application on slaughterline for early meat quality prediction, the technique needs further adaptations in order to reduce the time of spectra acquisition and treatment.

Pertinent literature

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Table 1 : Accuracy of on-line prediction of meat quality parameters by NIR spectroscopy with a reflectance fibre optic probe – Mean ; SD (Standard Deviation) ; SECV ; R^2cv

Items	n	Min	Max	Mean	S.D.	Math*	Optimal factors	SECV	R^2cv
pH	100	5.35	5.98	5.49	0.10	0,0,5 none	2	0.08	0.16
CIE L* (%)	86	29.4	41.1	34.4	2.6	0,0,5 none	5	1.31	0.75
CIE a*	90	16.6	26.4	21.5	1.8	0,0,5 norm	8	0.77	0.82
CIE b*	90	11.9	20.1	16.1	1.9	0,0,5 none	5	0.87	0.78
Drip loss (%)	81	1.1	5.8	3.8	1.1	0,0,5 none	2	0.9	0.38
Cooking loss (%)	no model								
WBPSF (N)	no model								

*Mathematical treatment of the spectra : derivative, gap, smoothing segment and pretreatments.

Table 2 : Accuracy of on-line prediction of meat quality parameters by NIR spectroscopy with a transmittance fibre optic probe – Mean ; SD (Standard Deviation) ; SECV ; R^2cv

Items	n	Min	Max	Mean	SD	Math*	Optimal factors	SECV	R^2cv
pH	99	5.32	5.98	5.49	0.09	0,0,5 none	5	0.07	0.30
CIE L* (%)	90	29.4	41.1	34.5	2.5	0,0,5 none	9	1.69	0.57
CIE a*	92	16.9	24.8	21.6	1.7	0,0,5 norm	3	1.43	0.28
CIE b*	89	11.9	19.6	16.1	1.7	0,0,5 none	9	1.00	0.67
Drip loss (%)	78	1.0	6.7	3.8	1.2	0,0,5 norm	7	0.8	0.54
Cooking loss (%)	91	28.0	35.1	31.2	1.8	0,0,5 none	2	1.7	0.11
WBPSF (N)	no model								

*Mathematical treatment of the spectra : derivative, gap, smoothing segment and pretreatments.