THE USE OF NEAR INFRARED SPECTROSCOPY TO DETERMINE FAT CONTENT AND FATTY ACID COMPOSITION IN BEEF MEAT

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Background

The fat content in meat is a helpful information since its content influences the organoleptic characteristics. Furthermore, the fatty acid composition is extremely important in terms of nutritional quality and consumer's health. The measurement of meat composition is generally destructive, time consuming, expensive and polluting. A fast and non destructive technique would allow a measurement directly on carcasses or meat cuts in slaughterhouses and cutting plants. Near infrared (NIR) spectroscopy is an adapted technique for chemical analysis and is widely used in chemical, petrochemical, pharmaceutic and food industries. A similar approach could also be explored for meat fat analysis (Mitsumoto et al., 1991 ; Sindic et al., 1993 ; Oh and Groβklaus, 1995).

Objectives

The aim of the current study was to evaluate the Fourier Transform NIR spectroscopy as a potential technique for beef fat content determination and specifically also for fatty acid composition analyses. Through this study, determinations of the spectral acquisition mode - reflection or transmission - for the best prediction quality were performed. The accuracy and precision of the predictive models obtained from spectra taken on fresh and freeze-dried meat samples were also compared in reflection mode.

Methods

Muscle *Longissimus thoracis* (7-8-9 ribs) was removed from 48 cows (mean age = 68 months) and 67 bulls (mean age = 21 months) at 48 hours *post mortem*. On the basis of the European S.E.U.R.O.P. carcass classification, 35 % of cows belonged to the S3 class and 31% to the E3. For the bulls, 78% were classified in the S2 class, 10% in the E2 and 10% in the U3 class. The muscles were always sliced on day 2 in order to dispose of samples processed in similar conditions. Cuts were used for both NIR or chemical analyses. Samples for chemical analyses were then minced, stored at −18°C and subsequently freeze-dried. Fat content was determined by ether extraction according to Soxhlet method. The gas-chromatography technique was used to determine the fatty acid composition (Sukhija and Palmquist, 1988).

The spectral data were acquired with a MB 160 D FT-spectrometer from Bomem which provides NIR spectra in the 800-2500 nm wavelength range. The fiber-optic Axiom probe FDR-320 was used for the spectral acquisition in reflection mode, 2 and 8 days *post mortem*. The transmission mode was performed also at days 2 and 8 by using the Bag SamplIR accessory on 3 mm thick cuts. In reflection mode, spectra were also taken on freeze-dried meat samples.

The data treatments were carried out by means of the Grams/32 (Galactic) software. The databases were first searched for outliers using the Principal Component Analysis (PCA). Several mathematical pretreatments were chosen on the basis of correlation analysis. The Partial Least Square (PLS) regression analysis was used for predicting beef meat composition from corrected spectra. The cross-validation technique was performed to determine the number of PLS terms for overfitting prevention. Among the different equations, the model with the lowest Standard Error of Cross-Validation (SECV) value was retained for each parameter in each database.

Results and discussion

Table 1 shows the results for the predictive models of ether extract content and fatty acid composition. The prediction values were always more accurate from spectra obtained from freeze-dried meat. For example, the models accuracy for ether extract was characterized by a SECV of 0.53 % and a Determination Coefficent of Cross-Validation (R^2cv) of 0.46 on fresh meat (figure 1 : reflection at day 8) and a SECV of 0.74 % and a R^2cv of 0.94 on freeze-dried meat (figure 2).

On fresh meat, the transmission mode was generally more performant (SECV of 0.49 % and R^2cv of 0.64 for ether extract at day 2) than the reflection mode (SECV = 0.60 % ; R^2cv = 0.48). The models from spectra recorded 8 days *post mortem* were often more accurate (SECV of 0.29 % and R^2cv of 0.70 for total fatty acids in transmission mode) than those obtained on day 2 samples (SECV = 0.35 % ; R^2cv = 0.61). By comparison, Mitsumoto et al. (1991) obtained with a broader range of fat contents (2.6 to 22.4 %) than in the present study (0.2 to 3.7 %) a Standard Error of Calibration (SEC) of 1.37 % and a Determination Coefficient of Calibration (R^2c) of 0.93 in transmission mode and SEC of 1.34 % and R^2c of 0.93 in reflection mode.

The predictions of SFA (Saturated Fatty Acids), UFA (Unsaturated Fatty Acids) and MUFA (Mono-Unsaturated Fatty Acids) contents were extremely accurate on freeze-dried meat samples ($R^2cv > 0.96$). This had interesting implications and raised the important questions as to whether the NIR spectroscopy estimated the content of each fatty acid or was the fatty acid composition predicted indirectly by the high correlation (figure 3) between content of each fatty acid and total fat content ? For example, it could be argued that the PUFA concentration was not well predicted by the model on freeze-dried meat and moreover that the correlation between PUFA and total fat contents was weak (figure 3). But this lower level of the predictive model accuracy could also be explained by the low variation of PUFA contents in the samples of the present database.

Table 1 shows the results of the prediction for each fatty acid (myristic, palmitic, palmitoleic, stearic and oleic acids) on freeze-dried meat. These models give a good prediction ($R^2cv > 0.88$), but the questions raised above can also be addressed in the present case.

Conclusions

The experiments showed that the the Fourier Transform NIR spectroscopy can give a fast and good estimate of fat and fatty acid contents on freeze-dried meat, except for the PUFA. When applied to fresh meat cuts, the transmission mode seemed more suitable for the determination of fat content and fatty acid composition. The quality of predictive models could be improved by increasing the fat content range and by mincing the meat samples before the spectral measurements in order to reduce heterogeneity.

Pertinent literature

Mitsumoto, M., Maeda, S., Mitsuhashi, T. and Ozawa S., 1991. Near-infrared spectroscopy determination of physical and chemical characteristics in beef cuts. *Journal of Food Science*, **56**, 1493-1496.

Oh, E.K. and Groβklaus, D., 1995. Measurement of the Components in Meat Patties by Near Infrared Reflectance Spectroscopy. *Meat Science*, **41**, 157-162.

Sindic, M., Chevalier, O., Dardenne P. and Deroanne, C., 1993. Analyse de la viande de poulet par spectroscopie infrarouge proche. *Viandes et produits carnés*, **14**, 95-98.

Sukhija, P.S. and Palmquist, D.L., 1988. Rapid method for determination of total fatty acid content and composition of feedstuffs and feces. *Journal of Agricultural and Food Chemistry*, **36**, 1202-1206.

Acknowledgments

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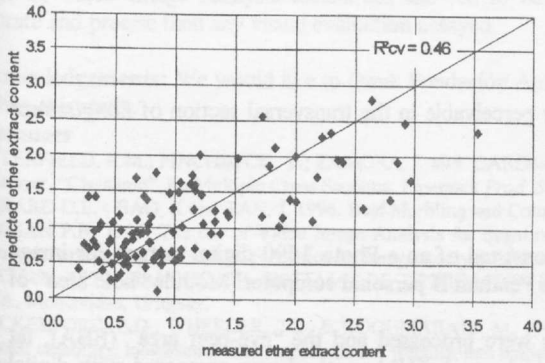

Figure 1 : Predicted *vs* measured ether extract content (reflection mode, day 8, on fresh meat).

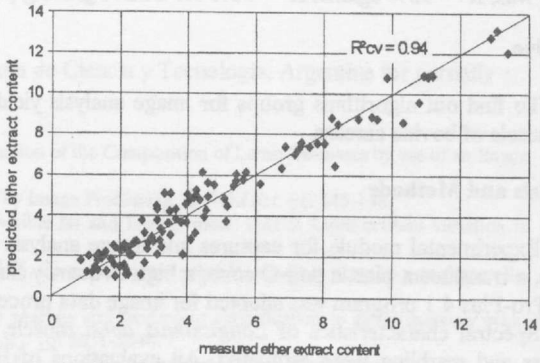

Figure 2 : Predicted *vs* measured ether extract content (reflection mode, on freeze-dried meat).

Table 1 : Accuracy and precision of models from fresh meat in transmission and reflection modes and from freeze-dried matter in reflection – Mean ; SD (Standard Deviation) ; SECV ; R²cv.

Items (%)	Freeze-dried meat				Fresh meat									
	Reference method		Reflection		Reference method		Reflection Day 2		Transmission Day 2		Reflection Day 8		Transmission Day 8	
	Mean	SD	SECV	R²cv	Mean	SD	SECV	R²cv	SECV	R²cv	SECV	R²cv	SECV	R²cv
Ether Extract	4.83	3.19	0.74	0.94	1.21	0.85	0.60	0.48	0.49	0.64	0.53	0.46	0.47	0.63
Total Fatty Acids	3.93	2.11	0.36	0.97	0.98	0.56	0.32	0.49	0.35	0.61	0.35	0.50	0.29	0.70
SFA	1.70	0.98	0.20	0.96	0.43	0.26	0.18	0.39	0.17	0.56	0.16	0.51	0.13	0.67
UFA	2.23	1.14	0.21	0.97	0.56	0.31	0.22	0.31	0.18	0.65	0.19	0.51	0.16	0.69
MUFA	1.64	1.18	0.22	0.96	0.41	0.31	0.22	0.33	0.19	0.63	0.19	0.53	0.16	0.68
PUFA	0.59	0.10	0.08	0.30										
C14:0 myristic acid	0.08	0.06	0.02	0.88										
C16:0 palmitic acid	0.93	0.60	0.13	0.95										
C16:1 palmitoleic acid	0.11	0.09	0.03	0.91										
C18:0 stearic acid	0.70	0.33	0.09	0.92										
C18:1 oleic acid	1.53	1.09	0.21	0.97										

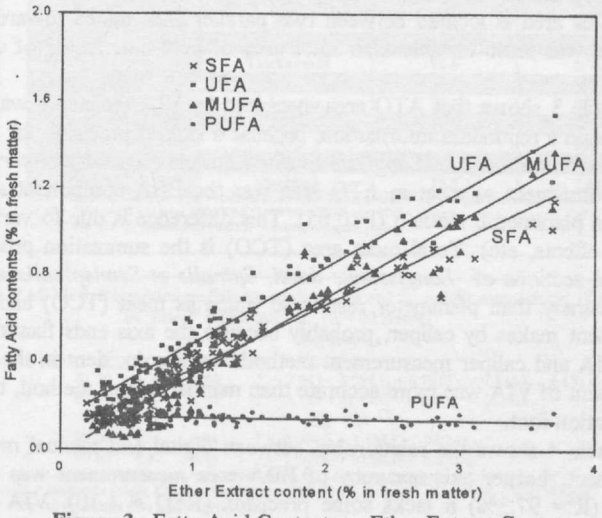

Figure 3 : Fatty Acid Contents *vs* Ether Extract Content