Reflectance measurements in the visible and near infrared range for the determination of different beef meat qualities

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SUMMARY

Reflectance spectroscopy in the visible and near infrared (NIR) range was used to measure intramuscular fat (IMF) and color (L^*-values) of raw beef meat. Reflectance data were collected directly from the surface of fresh meat samples and from homogenized specimens. A NIRSystems Analyser Model 6500 with an remote reflectance probe attached to the instrument via a fiber optic bundle was used. Calibration of this system was accomplished using samples of long. dorsi muscles obtained from 20 young bulls and 20 heifers with known IMF compositions and known L^* values. The study group consisted of 39 unknown muscles samples, spectroscopic values were determined and subsequently for validation IMF and L^*-values were obtained.

Results showed high correlations between NIR-values and the IMF-lab values for both homogenized (r = 0.99, standard error of prediction, SEP = 0.28%) and fresh cut surface samples (r = 0.90, SEP = 0.90%). Similarly, there was a high correlation between the NIRSystems and the Minolta values for color (r = 0.93, SEP = 1.0).

These results indicate, that the easy to obtain NIR measurements can replace costly and time consuming chemical analysis with high accuracy for both homogenized and fresh cut samples. Hence, with this method we can instantly classify beef according to IMF content (i.e. marbling degrees) and color.

INTRODUCTION

Instantaneous measurements of quality criteria would be a prerequisite for an efficient and reproducible classification of meat quality. This would provide desired information for not only the meat customers but also for meat processers to determine necessary technological treatments (e.g. conditioning). Important criteria for top quality beef are meat color and IMF content (DIKEMAN, 1990; BAUSCHMID et al., 1982). Unfortunately, most analytical methods currently available for accuratly determinating IMF content are extremely time consuming. Therefore, these methods are not suitable for routine analysis. Recently, an alternative has been identified, that is the use of near infrared (NIR) reflectance spectroscopy. This technique allows for a rapid and non destructive quantification of major food components (OSBORNE and FEARN, 1986). For example, fat content has been estimated by near infrared techniques in homogenized beef (MASSIE, 1974; LANZA, 1983; O'KEEFEE, 1987). However, important information on this technique is lacking, such as measurements on the meat surface directly and in samples where IMF levels may be below 10%. Hence, it was the aim of this study to determine if this technique could be used on fresh cut samples and in those with low IMF contents. In addition, we determined the accuracy of using this same instrument to measure meat color.

MATERIALS AND METHODS

Muscle samples (m. long. dorsi) for the reflectance measurements were removed 1 day post mortem at the height of the 7th rib from beef carcasses at a commercial slaughterhouse.

The NIR measurements were obtained with a NIRSystems Analyser Model 6500 (NIRSystems, Silver Spring, USA) equipped with a remote reflectance module attached via a fibre optic bundle. This instrument has a single-beam scanning monochromator that scans the 400 - 2500 nm spectrum. The first set of reflection measurements were of the intact meat specimens (freshly cut). Three locations were scanned per specimen. Next, the samples were homogenized for 10 s and subsequently these preparations were scanned (four times per sample).

Samples were frozen and latter chemical analysis of IMF were obtained on thawed samples by chloroform/methanol extraction (reference method) according the procedure of BLIGHT and DYER (1959). The L^*-values for meat color were obtained with a Minolta reflectance photometer Model Chroma-meter CR 200 (Minolta, Japan) directly from the fresh cut of the muscle samples (reference method).

For the calibration of the NIRSystems instrument, samples with known IMF and L^*-values from 20 young bulls and 20 heifers were used. In order to eliminate baseline shifts and other spectroscopic errors, the calibration for IMF was made with the second derivative transformation of the absorbance spectra. The calibration for the L^*-values was performed directly with the reflectance-values of the NIRSystems instrument. No outlier values were needed to be eliminated.

The study group consisted of 39 muscle samples with unknown IMF and unknown L^*-values, spectroscopic values were determined and subsequently for validation the reference IMF and L^*-values were obtained. The standard error of calibration (SEC) and the standard error of prediction (SEP) are estimates for the accuracy of the instrument relative to the calibration samples and the unknown validation samples.

RESULTS AND DISCUSSION

Chemical extraction values for IMF of the calibration samples ranged from 1 to 11%, the Minolta color values (L^*-values) ranged from 32-44. Validation data from the unknown samples provided similar values (Tab. 1). The chemical extraction values and the color values were highly reproducible (as indicated by standard deviation for differences, Tab. 1).

Shown in Fig. 1 are NIR-spectra obtained from homogenated samples, one with a low IMF (1.56%) and the other with a high IMF (9.88%) content. Included in this figure are the second derivates of the curves which are used for calibration of IMF. The most prominent peaks at 970, 1450 and 1940 nm are absorption maxima for water. The smaller peaks at about 1720 and 2310 nm are specific for CH_2 bonds which are indicative of intramuscular fat. In addition, a further absorption maximum for CH_2 bonds occurs at about 1210 nm, which only can be visualized using the second derivatives.

Table 1 - Statistics of the calibration and validation data

Sample set (n)	Parameter	Mean	Range	SDD[a]
Calibration set (40)	IMF %	4.28	1.17 - 11.06	0.18
	L^*-value	37.36	32.03 - 44.44	1.15
Validation set (39)	IMF %	4.27	1.15 - 9.75	0.22
	L^*-value	37.17	31.70 - 43.08	1.35

[a] Standard deviation for differences between duplicate reference measurements

For the unknown homogenized samples we observed a high correlation between NIR IMF values and for those subsequently obtained with chemical extraction (r = 0.99) (Tab.2). Similarly, for the intact meat preparations, there was a high correlation between IMF values obtained by either method (r = 0.90). However, it should be noted that there is a difference between the coefficients of correlation between the homogenized and the freshly cut samples due to compartmentalization of fat. There is no difference in the accuracy of measuring IMF content between the chemical extraction method and the NIR technique using homogenized samples (SDD = 0.22 compared to an SEP of 0.28). Values obtained from intact meat samples were not as precise.

Fig. 1 - Absorbance spectra (logl/R) of two homogenized samples, one with a low IMF (upper line) and the other with a high IMF (lower line) and their 2nd derivatives

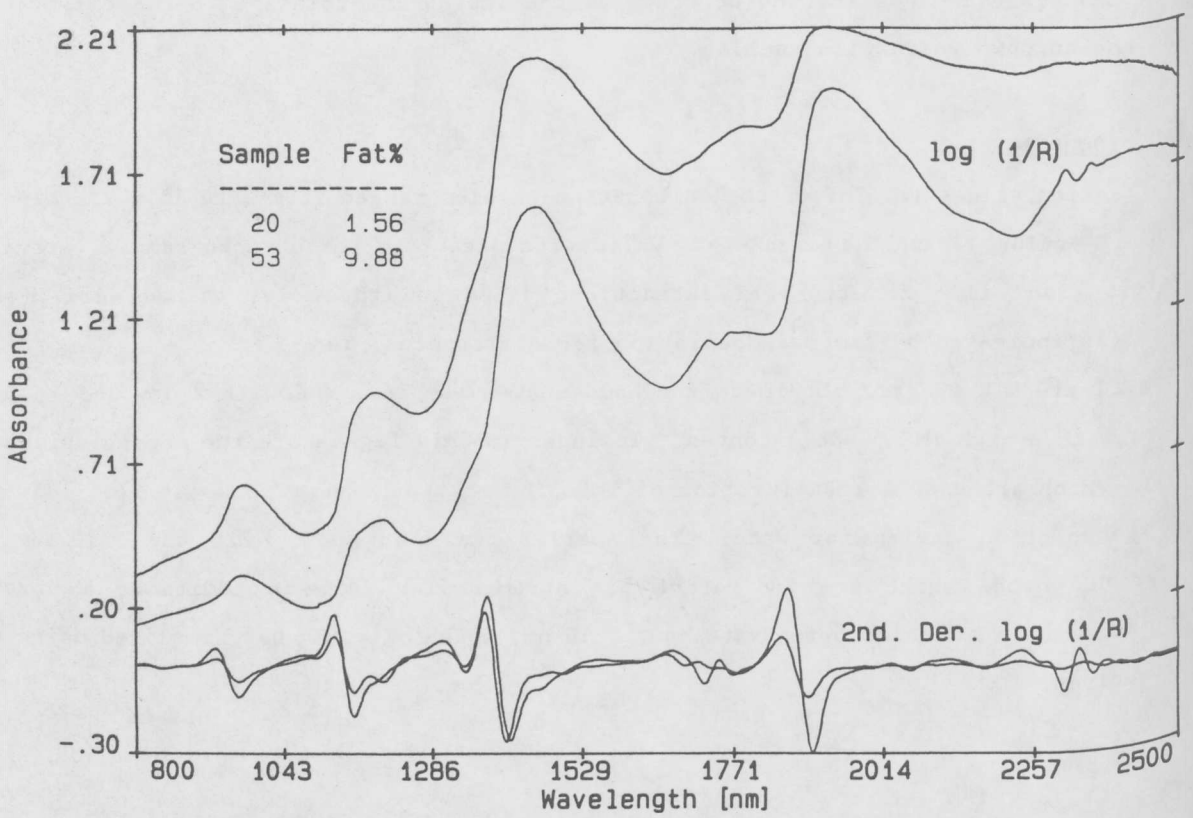

Table 2 - Calibration and validation statistics for the reflectance determination of intramuscular fat (IMF) and color (L^*-value) of beef

Parameter	Sample preparation	Wavelenght[a] (nm)	Calibration set		Validation set	
			R^b	SEC	r^c	SEP
IMF %	homogenized samples	970 1720 2308	0.99	0.31	0.99	0.28
	fresh cut surface	1210 1310	0.92	1.03	0.90	0.90
L^*-value	fresh cut surface	700	0.89	1.06	0.93	1.04

[a] wavelenghts used for calibration
[b] multiple correlation coefficient [c] correlation coefficient

but adequate to make estimates of marbling degrees (SEP = 0.90%). In addition, for the intact samples we observed that the color estimates were the same when detected by either the NIRSystems or the Minolta instrument (r = 0.93, SEP = 1.0) (Tab. 2).

Hence, this spectra can be used to instantaneously and accurately assess meat quality with minimal effort and no chemical waste.

CONCLUSIONS

We believe that NIR measurements are an exciting technology that equals chemical analysis in accuracy, its major advantages are that the method is instantaneous and does not produce chemical waste. Measurements on intact samples are reliable enough to establish an objective meat classification which include IMF and meat color.

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