ANALYSIS OF GROUND BEEF, ON-LINE, AT A MEAT GRINDER

G. Tøgersen, B.N. Nilsen, K.I. Hildrum, R.P.Hammond*, T. Isaksson

MATFORSK, Norwegian Food Research Institute, Osloveien 1, N-1430 ÅS, N.

* Infrared Engineering Limited, Galliford Road, Maldon, Essex, CM9 7XD, UK.

KEYWORDS: Near Infrared, NIR, on-line, non-invasive, ground beef, minced beef, grinder, fat, moisture, water, protein.

BACKGROUND

The world production of beef and veal in 1990 was about $5.1*10^{10}$ kg (FAO, 1990). It is estimated that in some countries, up to 50% of such meat was further processed by grinding using plates with 4 to 25 mm hole diameters (Meat Facts, 1989). The contents of fat, water and protein in ground beef are very important for the nutritional, technological and sensory quality of meat and meat products. The market price of ground beef is typically set on the basis of the fat content. Consequently, there is a strong need in the meat processing industry to determine these constituents efficiently, for recipe optimalisation and for price setting.

OBJECTIVE

The aim of the present work was to study the performance of an on-line, non-invasive, diffuse reflectance, near infrared instrument, when it was used to determine fat, moisture and protein contents of ground beef.

MATERIALS AND METHODS

A set of 48 commersial graded batches of beef trimmings from Norwegian Red Cattle, each of 20kg, were thawed over night at 4°C, prior to the grinding. The experiment was designed to cover an even distribution over the range 6-22 % fat. Each batch was first run through a grinder (Type:0250-1T-70, Wolfking, Slagelse Denmark) equipped with a single knife with 8 blades and a single plate with holes of 19 mm diameter. Each of the 19 mm ground batches were then ground at the same grinder equipped with a 13 mm plate. The ground beef batches were divided in two equal sub-sample lines. One of the sub-sample lines was ground (Type: SR 130/2, Modell und Maschinenfabrik Meissner & Co, Biedenkopf-Wallay, Germany) with a single knife with 4 blades and a single 8 mm hole diameter plate. The other parallel line was ground in the same grinder equipped with a 4 mm hole diameter plate. A ground sample of about 1 kg, from each sample and each line, was taken for chemical analysis. The temperatures of the ground beef out of the grinder varied from 0 to 6°C.
The NIR gauge (MM55, Infrared Engineering Limited, Maldon, Essex, United Kingdom) was mounted on a separate stand, and measurements were done directly at the grinder outlet. The distance from the gauge to the ground beef stream was from 200 to 300 mm. The illumination circle area, and consequently the analysis area, on the ground beef stream was about 40 mm in diameter. The gauge, or sensing head, was connected to a remote data processing control unit .
The five interference filters used were normally distributed in profile, and had centre wavelength specifications of 1441, 1510, 1655, 1728 and 1810 nm, each with a bandwith of about 25 nm. The selection of the 5 filters was done by analysis of a previous data set (Isaksson et al. 1992), and were selected to cover the C-H stretch overtone bands dedicated for fat (1728 nm), O-H stretch overtone bands dedicated for water (1441 nm and 1510 nm) and references with low absorbances (1655 nm and 1810 nm).
Output data were collected at maximum rate of 5 s^{-1}. For each sample/grinding size, the PSD (phase sensitive detector) spectra were collected for 3 periods of 5 s each, and the average, calculated for the total sampling period of 15 s, was used in subsequent calculations. The PSD values are relative reflectance measurements. The $\log_{10}$ of each of the PSD values were calculated and the 1810 nm log-PSD values were subtracted from the four remaining log-PSD values. The four calculated NIR-variables can be considered as absorbance differenses, i.e. differenses between absorbance at 1810 and absorbance at the four wavelengths; 1441, 1510, 1655 and 1728 nm.
Analysis for fat (Fosslet, Foss Electric, Hillerød, Denmark), moisture (105°C at 18 h) and protein (Kjeltec Auto 1030, Tecator AB, Höganäs, Sweden) were done in duplicate for each sample in the two parallel sample lines, ground at 4 or 8 mm hole diameters, and the averages were calculated. For the beef batches ground at 13 or 19 mm hole diameters, the average from both corresponding parallel sample lines were calculated, and used in the calibrations. All calculations were done using % wet weight as units. Multilinear regression was used as the calibration method. The calibration models were validated, by full cross validation, by calculating the prediction error, expressed as root mean square error of cross validation (RMSECV), defined as:

$$RMSECV = \left[I^{-1} \sum_{i=1}^{I} (y_i - \hat{y}_i)^2 \right]^{1/2}$$

where i [1,2,...,I] denotes the number of samples, y_i and $\hat{y}_i$ denotes the reference method values and the NIR predicted values, respectively. The root of the average variance between the duplicate analysis divided by the number of replicates, i.e. 2 for the samples ground with 4 and 8 mm hole diameters, and 4 for the samples ground with 13 or 19 mm hole diameters, are presented as standard error of the reference method (SREF).

RESULTS AND DISCUSSION

A survey over the chemical variations in the data set is given in Table 1. The reference method errors (SREF) were considered to be low, but did increase with grinder plate diameters. The main variations in chemical values were found in fat and moisture contents, while protein content were relatively stable.

Table 1: Chemical ranges and standard deviation (SD) of the beef data sample sets, for samples ground with 8 mm hole diameter plate (the other sample sets were similar). Reference method errors calculated for each grinding and each constituent, presented as SREF. All units are in % (of wet weight).

	RANGE 8 mm	SD 8 mm	SREF 4 mm	SREF 8 mm	SREF 13/19 mm
FAT	6.2-21.7	4.3	0.12	0.19	0.24
MOISTURE	59.6-72.9	3.5	0.12	0.11	0.25
PROTEIN	18.1-20.7	0.71	0.07	0.10	0.09

Table 2: Prediction error results expressed as root mean square errors of cross validation (RMSECV) for beef samples ground with grinder plates with different hole diameters. Each single diameter set contains 48 samples, except the 19 mm set where two outliers were removed. The correlation coeffisient (R) for NIR determined versus the chemical measured fat, moisture and protein are also presented. RMSECV units are in % (of wet weight).

	FAT		MOISTURE		PROTEIN	
	RMSECV	R	RMSECV	R	RMSECV	R
4 mm	0.73	0.98	0.75	0.98	0.23	0.93
8 mm	0.88	0.98	0.81	0.97	0.27	0.93
13 mm	1.14	0.96	1.05	0.95	0.32	0.88
19 mm	1.39	0.94	1.25	0.93	0.27	0.91

The prediction errors, expressed as RMSECV, with corresponding correlation coeffisients, R, for the different datasets and constituents, are presented i Table 2. In the set of samples ground at 19 mm hole diameter, two outliers had large prediction residuals, and were removed as suspected outliers. The reason for their deviating behaviour was not known.
All the calibrations were estimated by using all the four variables in the MLR model. Variable no.4, at 1728 nm, did contribute most to lower the RMSECV for fat and moisture.
The prediction error, RMSECV, increased with increasing hole diameter of the grinder plate. The correlation coeffisient (R) for NIR determined versus the chemical measured fat and moisture exceeded 0.93 for all sample sets, which was considered to be high.
The NIR prediction results, from calibrations for samples ground at 4 mm and 19 mm hole diameters, for NIR determined fat versus the chemical fat measurements, are presented in Figure 1. Figure 1 illustrates the increase in prediction error (Table 2) as the hole diameter in the grinder plates inscreases. This may be explained by the higher heterogenity in samples ground with larger hole diameters compared to samples ground with more narrow hole diameters.
Single NIR measurements on very coarse ground samples could, by random variation, be recorded on more extreme fatty or extreme lean samples. The NIR sampling could for this reason be substantially different from the sampling that was chemically analysed. Large hole diameter samples will consequently give a relatively larger sampling error (and RMSECV) compared to more narrow hole diameter samples.
Under the assumption that sampling and instrument errors are random, the total error (RMSECV) will decrease on increasing the number of measurements. For this reason it is expected that the overall prediction error for a larger batch will be much smaller by measuring continuosly at the grinder outlet.

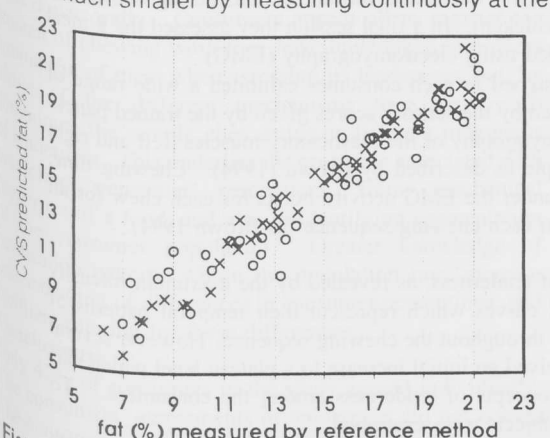

Figure 1: *NIR predicted fat vs fat measured by Fosslet as reference, for sample set grinded at 4mm (x) and 19 mm (o) hole diameter grinder plates.*

CONCLUSIONS

Non-invasive, on-line, NIR measurements gave prediction results for fat and moisture in beef ground with 4 mm or 8 mm grinder plates that were acceptable for industrial use.
Promising results were also obtained for beef ground with 13 mm and 19 mm diameter hole plates.
By measuring continuously on a batch, we believe that all the presented calibrations could be used and would be of substantial value for the meat processing industry.

REFERENCES

FAO yearbook, Production, Vol. **44**, (1990).
Isaksson, T., Miller, C.E. & Næs, T. (1992).
Nondestructive NIR and NIT determination of protein, fat and water in plastic-wrapped, homogenised meat.
Appl. Spectrosc. **46** 1685-1694.
Isaksson, T., Nilsen, B.N., Tøgersen, G., Hammond, R.P.,Hildrum, K.I.
On-line, proximate, analysis of ground beef directly at a meat grinder outlet.
Meat Science, (in press).
Meat Facts (1989). Edition. American Meat Institute, Washington, DC, USA.