# APPLICATION OF NIR TECHNIQUE FOR RAW MEAT COMPOSITION CONTROL

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## Summary

Rapid instrumental water, fat and protein analysis in raw pork and beef has been developed based on NIR technique for in plant production control of standard composition of sausage products. Diffuse reflection spectra of the homogenized samples were measured in near infrared with an INFRAPID-61 type instrument and different predicting equations were constructed by multiple linear regression methods describing the composition of unknown meat samples as multivariable functions of spectral data. The method was checked by control sample population and the accuracy was characterized by statistical accuracy parameters. 1.4 mass % standard error and 0.1 mass % mean difference for moisture control in 20–75 mass % range, 3.2 mass % standard error and 0.2 mass % mean difference for fat control in 0–75 mass % range and 1.2 mass % standard error and 0.3 mass % mean difference for protein control in 6–24 mass % range were found by predicting composition of unknown samples. The calibrated instrument was installed in Debrecen Meat Factory and operates properly in practice.

## Introduction

During the last decade a new method (NIR = Near Infrared Reflection) was introduced mainly for quality control of agricultural and food products used for rapid instrumental determination of main components based on diffuse reflectance (or reflectometer) values of the homogeneous samples measured at different wavelengths. In our Institute research has been going on for years on developing and application of this technique also on the field of composition (water, fat, protein content) measurement of raw meat. Earlier publications reported the preliminary experiments mainly about the disturbing factors [1], the comments and proposals about the methodology [2] and about investigation of different predicting equations [3] constructed with a Research Composition Analyzer instrument (type NEOTEC 6450). Recent report deals with practical application experiments in cooperation with the Debrecen Meat Factory installing a Labor MIM made INFRAPID-61 instrument for composition measurement of pork and beef raw materials in the course of sausage production control.

## Materials and methods

The meat samples were collected and prepared at the Debrecen Meat Factory. As also our earlier expriences showed that common calibration can be used for pork and beef, both the calibrating and control populations consisted of pork (that of I to V quality classes) and beef (that of I to IV quality classes) samples. The samples were homogenised by a rotating knife chopper blender (type KERIPAR) and transported cooled in closed glass jars to our Institute for analytical and spectral measurements.

The composition of the samples was analyzed by standard laboratory reference methods in three replicates for all the components. The water content was measured by gravimetric method (by the Hungarian Standard MSZ 5874/4-72, the fat content by Soxhlet method MSZ 8874/2-79) and the protein content by a KJELFOSS 16200 type automatic analyzer.

The diffuse reflection spectra of the samples were measured by INFRAPID-61 scanning instrument in 2 nm steps over the 1300–2400 nm wavelength range. The collected "basic spectra" consisted of reflectometer values ($R'$) related to a diffuse gold surface standard. These spectra together with the analytical data were sent to a floppy disc of a NEOTEC 6450 RCA system for data processing.

The aim of the calibration data processing is construction of mathematical equations between the optical characteristics (spectral data at different wavelengths) and the compositional characteristics based on the spectral and analytical data of the calibration samples. Applying these predicting equations the composition of unknown samples can be calculated as functions of the fast measured spectral data. For every compositional characteristics, different kinds of predicting equations can be constructed even based on the data of the same calibrating population. These predicting equations can differ in the form of the equations, in the spectral variables of the equations and in the "characteristic wavelength" values where the spectral variables are taken to form the concrete independent variables of the equations. (The spectral variables can be formed by different transformations applied to the basic spectra e.g. log $(1/R')$, derivatives, etc.)

The different predicting equations can be compared (or selected) by different statistical accuracy—parameters calculated on the data base of the calibrating and control sample populations (control samples were not used for calibration procedure). Relating to the calculation and interpretation of these statistical parameters (e.g. SEC: standard error of calibration, SEP: standard error of prediction, DSEP: the earlier one calculated by Demming regression, BIAS: mean difference, r: multiple correlation coefficient) we refer to the literature, among others to our earlier publications [2].

## Results

The next different types of predicting equations were constructed for all the three components on the data base of 125 mixed pork and beef calibration samples and first tested by 55 control samples:

Type I $$Q = K_0 + \sum_{i=1}^{p} K_i V(\lambda_i)$$

Type II $$Q = K_0 + \sum_{i=1}^{p} K_i V'(\lambda_i)$$

Type III $$Q = K_0 + \sum_{i=1}^{3} K_i [V(\lambda_{1i}) - V(\lambda_{2i})]$$

where

— $Q$ represents the compositional characteristics (water, fat or protein content in mass % respectively),

— the spectral variable of the type I equation is the logarithm of the reciprocal reflectometer value: $V = \log(1/R')$,

— the spectral variable of the II type equation is the first derivative of this $V$ variable: $V' = \partial V / \partial \lambda$

— the spectral variable the III type equation is the difference of the $V$ taken at two different wavelengths.

The type I equation was constructed step by step. First, two optimal ($\lambda_1$ and $\lambda_2$) wavelengths were chosen by a two variable searching computer programme—checking all the possible wavelength combinations—where highest correlation was found for the calibration samples between the $Q$ values analyzed by standard laboratory method and computed by the equation I. Than a third $\lambda_3$ wavelength was searched to the first two where maximal correlation could be found again. This way the number of variables ($p$) was increased until the DSEP residual deviation calculated for the control samples was decreasing.

Constructing the type II predicting equations the same procedure was followed using the $V'$ first derivative spectral data: $V' = \partial V / \partial \lambda$.

In the type III equation the variables are differences of the $V = \log(1/R')$ taken at two wavelengths. The first such "wavelength pair" was optimized chosen at the maximal correlation between the "LABOR" moisture data and "NIR" moisture data calculated by the equation. The second wavelength pair was optimized similarly for fat and the third for protein content. Then these three pairs were prescribed for variables of all the three component equations and the coefficients $K_0 \ldots K_3$ were calculated by least square method of multiple regression.

The results are summarized in the next table. W: water, F: fat, P: protein are the components; $p$ is the optimal number of variables found for type I and II

**Table 1**

| Component | Equation type | $p$ | Calibration with 125 samples | | Control with 55 samples | | | |
|---|---|---|---|---|---|---|---|---|
| | | | SEC | $r$ | SEP | DSEP | BIAS | $r$ |
| W | I | 1 | 1.10 | 0.997 | 1.62 | 1.52 | 0.28 | 0.990 |
| W | II | 2 | 1.19 | 0.996 | 1.51 | 1.41 | 0.06 | 0.991 |
| W | III | 3 | 1.00 | 0.997 | 1.38 | 1.27 | 0.00 | 0.993 |
| F | I | 4 | 1.26 | 0.997 | 3.28 | 3.12 | −0.13 | 0.977 |
| F | II | 4 | 1.13 | 0.998 | 3.36 | 3.19 | −0.34 | 0.976 |
| F | III | 3 | 1.28 | 0.997 | 3.36 | 3.14 | 0.18 | 0.977 |
| P | I | 3 | 0.72 | 0.984 | 1.21 | 1.15 | −0.23 | 0.940 |
| P | II | 4 | 0.63 | 0.988 | 1.21 | 1.15 | −0.31 | 0.943 |
| P | III | 3 | 0.76 | 0.982 | 1.24 | 1.16 | −0.07 | 0.949 |

equations (at minimal DSEP) that was decided to be 3 at type III. The table gives the statistical parameters characterizing the accuracy: SEC and r for calibrating sample population containing 125 pork and beef sample elements and SEP, DSEP, BIAS and r for the control population of 55 elements.

To demonstrate the spread of the LABOR-NIR composition data points around a control regression line three control diagrammes are shown on the Figs 1–3 each representing one line chosen from the table (line 2 for water content, line 4 for fat content and line 7 for protein content respectively).

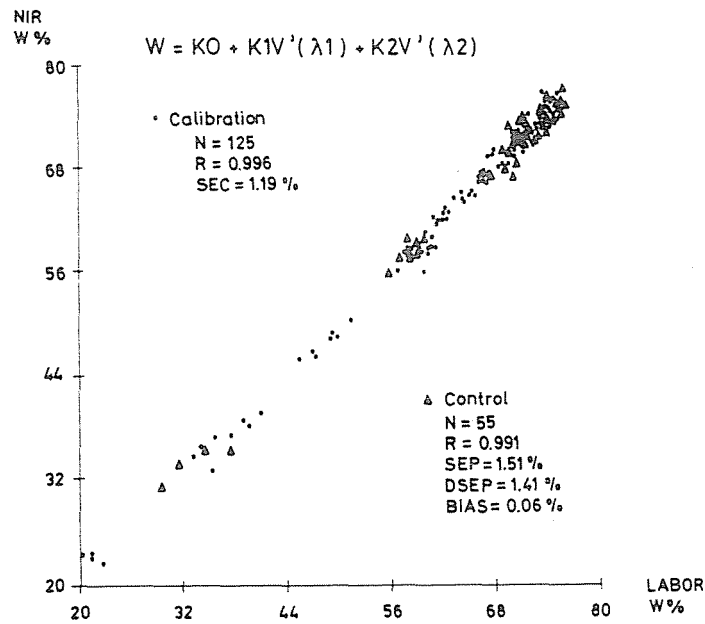


*Fig. 1.* Pork and beef water content

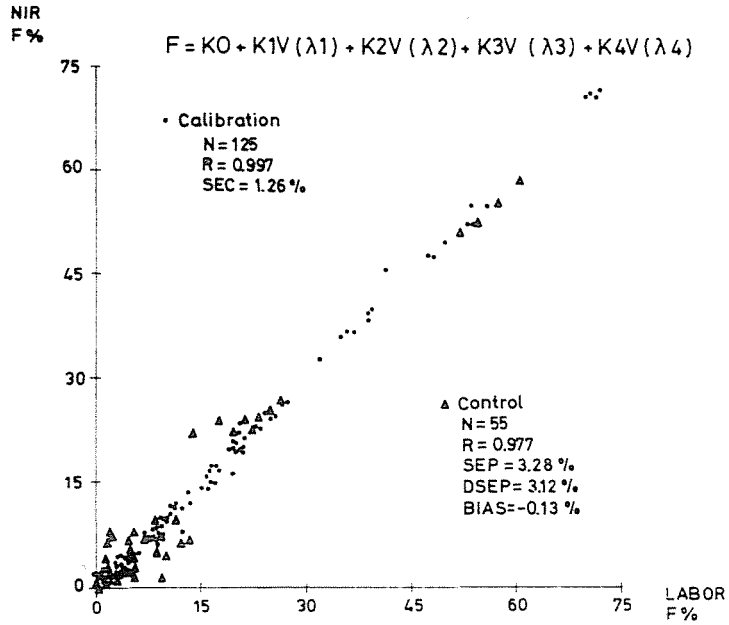


*Fig. 2.* Pork and beef fat content

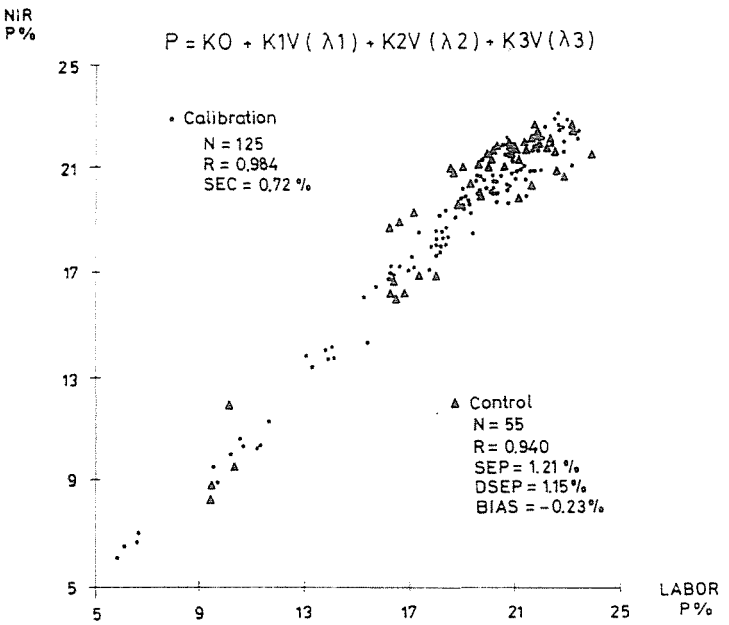


*Fig. 3.* Pork and beef protein content

The data of the table show that with a chosen NIR instrument using the data of the same sample population, different spectral transformations, variables and predicting equations finally give practically equal accuracy for NIR composition control. We have already published similar conclusions [3] with another type of NIR instrument (NEOTEC model 6450 Research Composition Analyzer).

An INFRAPID-61 NIR instrument programmed by the predicting equations of the table above has been working satisfactorily in practical quality control at the sausage plant of the Debrecen Meat Factory for a year.

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