Nutritive quality of maize silage by near infrared spectroscopy

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Introduction

The use of maize (*Zea mays*, L) silages in Galician dairy farms has been highly increased during the last years. The nutritive value of maize forage and its silages is considered fairly constant but their digestibility and energy content may vary due to growth conditions (location, year) and genotype.[1,2]

Various chemical and biochemical parameters have been studied as predictors for *in vivo* organic matter digestibility of forage maize[3] and maize silages.[4–6] It has also been shown that near infrared reflectance spectroscopy, NIR, is a suitable technique to analyse maize[7] and maize silages[8] including the prediction of *in vivo* digestibility.

In a previous work, NIR calibrations were developed to determine organic matter (OM), crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), starch (STA) and crude fibre (CF) on samples from dairy farms. At the same time, a first approach to *in vivo* organic matter digestibility (OMD) prediction was made using 31 maize silages.[9]

The aim of the present work was to improve those calibrations by adding new silage samples of known *in vivo* digestibility.

Materials and methods

Spectra of oven dried (80°C for 16 h) and ground (to pass 1 mm) samples received for analysis from dairy farms were recorded on a NIRystem 6500 Spectrophotometer (Foss NIRystem, Silver Spring, Washington, USA) equipped with WinISI 1.5 software (InfraSoft International, Port Matilda, PA, USA). Samples to be added to the calibration set were selected by the SELECT algorithm (WinISI 1.5). Silages to be evaluated *in vivo* were chosen from the selected samples taking into account their geoclimatic conditions and their NIR digestibility values, to cover a wide range of variability, up to 65 samples.

Sheep *in vivo* evaluation of chosen silages was performed in the animal feed unit[10] and *in vivo* organic matter digestibility values (OMD, g 100^{-1} OM) were the reference data for NIR analysis.

Reference methods to determine chemical parameters were carried out on oven dried selected samples. Residual water and organic matter (OM) were determined by a two-steps method (100°C and 475°C) in a LECO Mac 500 Proximate Analyzer (LECO Corporation, Michigan, USA). Crude protein (CP) was calculated as total organic nitrogen × 6.25 from a microKjeldahl digestion[11] followed by colorimetric ammonia determination with Bran+Luebbe AutoAnalyzer III, Method Nº G-188-97 Rev. 2 (Bran+Luebbe, Analyser Division, Norderstedt, Germany). The Van Soest detergent system[12] was the reference method to determine ADF and NDF (acid and neutral detergent fibres). Finally, starch (STA) was determined by polarimetry.[13] All laboratory determinations were repeated two or three times in duplicate and the mean data (g/100 g DM) were the reference values for NIR analysis.

The effect of light scattering was corrected by SNV on D-trended spectra[14] and calibration equations were developed by modified partial least squares (MPLS) regression of the 1st and 2nd derivatives of spectra (1100-2500 nm) on reference values.

Chemical composition and *in vivo* values of maize silages are summarised in Table 1

Table 1. Chemical composition and *in vivo* OMD values of maize silages

Component (g/100 g DM)	*N*	Minimum	Maximum	Mean	*SD*
Organic matter, OM	65	92.28	97.09	95.97	0.85
Crude protein, CP	65	3.89	13.38	6.81	1.61
Acid detergent fibre, ADF	65	21.09	45.94	27.75	5.22
Neutral detergent fibre, NDF	65	38.15	70.60	48.47	7.72
Starch, STA	65	0.00	36.15	24.08	9.77
In vivo OM digestibility; OMD	65	58.73	74.77	67.00	3.12

SD= standard deviation   *N* = number of samples

Results

Mathematical treatment (Math), determination coefficients *(RSQ)* and standard errors of calibration (*SEC*) and cross-validation (*SECV*) and outlier treatments of NIR equations are summarised in Table 2.

Table 2. NIR calibrations to analyse maize silages

Component (g 100^{-1} DM)	*N*	*RSQ*	*SEC*	*SECV*	Math	Outliers
Organic matter	65	0.906	0.271	0.453	2, 8, 4, 1	Downwheight
Crude protein	65	0.988	0.174	0.352	2, 8, 4, 1	Downwheight
Acid detergent fibre	65	0.830	2.15	2.37	2, 8, 4, 1	Downwheight
Neutral detergent fibre	65	0.902	2.41	3.47	2, 8, 4, 1	Downwheight
Starch	65	0.964	1.86	3.09	2, 8, 4, 1	Downwheight
In vivo OM digestibility	65	0.471	2.27	2.44	2, 8, 4, 1	Downwheight

N = number of samples; *RSQ* = determination coefficient; *SEC* and *SECV* = standard errors of calibration and cross validation; Math= mathematical treatment

Figures 1 and 2 show the calibration and cross-validation regression on reference data for *in vivo* organic matter digestibility and crude protein, respectively.
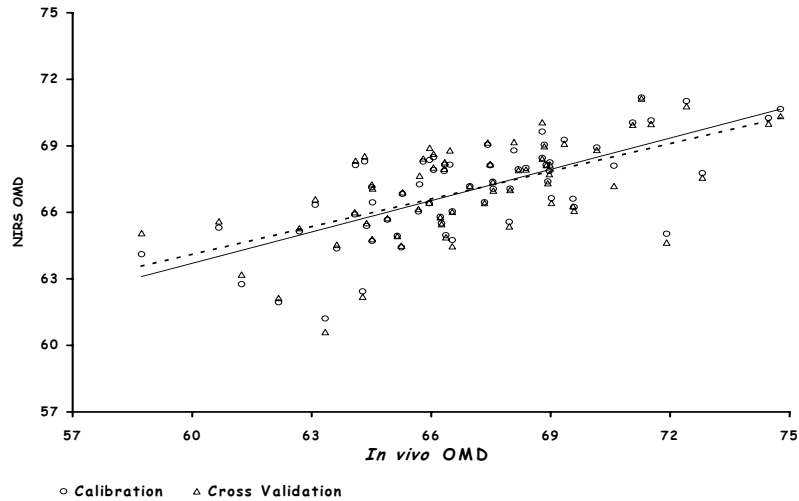
Figure 1. Determination of *In Vivo* Organic Matter Digestibility (OMD) by NIR
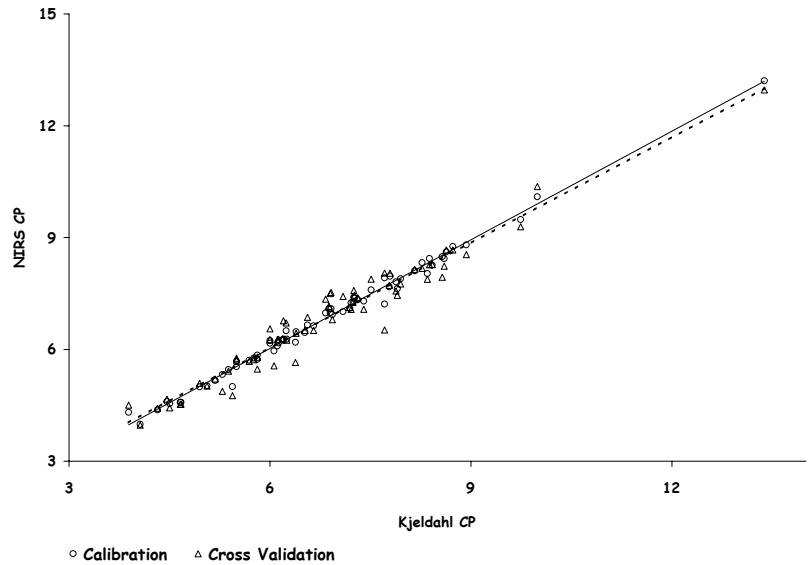

Figure 2. Determination of crude protein (CP) by NIR

Discussion

Standard errors of calibration (*SEC*) and cross-validation (*SECV*) were lower when using the 2nd derivative of spectra than those obtained when using the 1st derivative.