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Prediction of the nutritive value of maize silage using *in vitro* and near infrared reflectance spectroscopy (NIRS) techniques

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RIASSUNTO – Stima del valore nutritivo dell'insilato di mais mediante tecniche *in vitro* e con la spettroscopia nel vicino infrarosso (NIRS). *Scopo del lavoro è stato valutare la validità della tecnica NIRS per la previsione del valore nutritivo determinato in vitro del silomais e caratterizzare quelli prodotti in Lombardia e analizzati negli anni 2001-2004 dal laboratorio dell'ARAL. Su 100 campioni di silomais sono state fatte analisi chimiche e biologiche (gas test e digeribilità in vitro) i cui risultati sono stati utilizzati per la calibrazione dell'analizzatore NIR e la successiva stima di tali parametri su tutti i 2443 campioni di silomais a disposizione. La digeribilità (IVTD) media della SS è risultata pari al 77,7%, mentre quella dell'NDF è risultata solo del 49%. La calibrazione del NIRS per la produzione di gas (GP) ha fornito coefficienti di determinazione elevati (0,90 e 0,85 per la GP a 8 e 24 h), mentre l'R^2 per la digeribilità dell'NDF è risultato insoddisfacente (0,25). La tecnica NIRS conferma la sua potenzialità per la previsione del valore nutritivo dell'insilato di mais.*

Key words: maize silage, gas production, IVTD, NIRS.

INTRODUCTION – Maize silage is by far the most used forage in the diets for dairy cows and beef cattle in a large part of the Po plain, Italy. However, its chemical composition and its nutritive value range widely according to the genotype and to the climatic and agronomic conditions, particularly with regards to the plant maturity at harvest. Therefore, there is the need for an evaluation not only of the chemical composition but also of the biological parameters to predict the nutritive value of this forage that sometimes represents up to half of the dry matter intake.
On the other hand NIRS has shown great potential to predict chemical composition and digestibility of maize silage (De Boever *et al.*, 1997, Schwab *et al.*, 2003; Lovett *et al.*, 2004) and permits to obtain accurate information rapidly and at a low cost.
Aim of the present work was to confirm the potential of NIRS to predict the biological parameters and the nutritive value of maize silage and to characterize more accurately the maize silages produced in Lombardy and analysed in one of the main lab of this region in the years 2001-2004.

MATERIAL AND METHODS – 100 samples of maize silage were selected from the sample set (564 samples) analyzed with NIRS by the laboratory of the Associazione Regionale Allevatori of the Lombardy (ARAL) in the year 2001 and in the first quarter of 2002. The selection was made in order to obtain a wide range of NDF and starch contents. On these samples, chemical analyses were performed for DM, ash, CP, EE, NDF, ADF, ADL, NDFIP, ADFIP, starch (by polarimeter). On 56 samples the fermentative profile was also determined (pH, organic acids, ethanol, and ammonia). On all hundred samples gas production (GP) at 8, 24 and 48 h was determined by the Menke and Steingass (1988) procedure using the rumen fluid of 3 dry cows fed a diet with hay: concentrate ratio equal to 60:40. Net energy value (NE_l) was predicted using the equation proposed by these authors:

NE_l (MJ/kg DM) = 0.54 + 0.0959 GP 24h + 0.0038 CP + 0.0001733 EE^2

where GP=ml/200 mg DM; CP and EE=g/kg DM.

The *in vitro* true digestibility (IVTD) was also measured by the ANKOM DAISY[II] incubator for DM and NDF. 0.25 mg samples were incubated for 48 h in a buffered cow rumen fluid following the ANKOM procedures. All the chemical and biological parameters determined on the 100 samples were used to make regressions of the values measured against the spectral profile determined by NIRSystem 5000 monochromator (Foss). The accuracy of the calibrations was assessed based on the standard error of calibration (SEC) and the coefficient of determination. On the basis of these regression equations all the 2443 samples of maize silage analysed by ARAL lab in the years 2001-2004 were evaluated again to give updated data on the chemical/biological composition and the nutritive value. Data were statistically analysed by GLM procedure of SAS (2000).

RESULTS AND CONCLUSIONS – Table 1 shows that, on average, the 100 samples analysed were well representative of the whole population considered. Particularly, the first, second and third quartiles of NDF and starch contents of the 2443 maize silages were 40.0, 42.6, 45.4% and 29.2, 33.2, 36.7%, respectively. Starch, as expected, accounted for approximately ¾ of the non fibrous carbohydrates (NFC). The fermentative profile appeared good, with 3.87 pH, 4.87, 1.57, 0.30, 0.14% on DM for lactic, acetic, propionic and butyric acids, 6.2% of total N as NH_3-N, and 0.72% ethanol, on DM.

Table 1. Chemical composition and fermentative parameters of the two sample sets of maize silage.

		Determined			NIRS		
		No.	Mean	SD	No.	Mean	SD
DM	(%)	100	34.8	5.7	2443	34.8	4.8
Ash	(% on DM)	100	5.2	0.8	2443	4.9	0.8
CP	"	100	8.0	0.7	2443	8.0	0.7
EE	"	100	2.7	0.3	2443	2.7	0.3
NDF	"	100	43.5	6.2	2443	42.9	4.2
ADF	"	100	23.2	4.1	2443	22.8	3.0
ADL	"	100	2.9	1.1	2443	2.6	0.5
NDFIP	"	100	1.3	0.7	2443	1.2	0.5
ADFIP	"	100	0.5	0.4	2443	0.4	0.1
NFC	"	100	41.7	6.0	2443	42.8	4.3
Starch	"	100	31.4	8.6	2443	32.7	5.9

The *in vitro* true DM and NDF digestibility (table 2) indicate that the high DM digestibility is due mainly to the NFC, since NDF is digested to a limited extent, as reported by Givens and Deaville (2001) for the most recent genotypes of maize silage.
NDF true digestibility determined on the 100 samples was, on average, 10.9 percentage units lower than that calculated with the equation proposed by NRC 2001 based on NDF-N free and lignin contents. The DE calculated from digested NDF (dNDF) accounted on average for 28.4% of total DE of the maize silage computed with the equations proposed by NRC 2001 at maintenance level.

Table 2. *In vitro* true digestibility, gas production and net energy for lactation of the two sample sets of maize silage.

		Determined			NIRS		
		No.	Mean	SD	No.	Mean	SD
IVTD-DM	(%)	100	75.3	4.2	2443	77.7	3.1
IVTD-NDF	(%)	100	46.3	7.1	2443	49.0	4.1
GP-8 h	(ml/200mg DM)	100	32.8	4.8	2443	33.9	3.7
GP-24 h	(ml/200mg DM)	100	57.1	4.4	2443	58.2	3.2
GP-48 h	(ml/200mg DM)	100	68.2	4.3	2443	68.8	2.4
NE_l	(MJ/kg DM)	100	6.43	0.39	2443	6.55	0.31

Figure 1 shows the contribution of the DE attributable to dNDF to total DE, in function of the starch concentration in maize silage.

Concerning the gas production, nearly half of it was produced in the first 8 hours of incubation, due to the high content of rapidly fermentable carbohydrates; in fact we observed a positive relationship between the GP-8 h and the NFC content of the silages (R^2=0.77). Furthermore, the amount of gas produced in the last 24 hours, expressed as percentage of GP-48 h, was positively influenced by the ADF concentration of the sample (R^2=0.56). On the contrary, in the regression among the NE_l predicted with the equation previously reported and the chemical and biological parameters performed with the stepwise method, ADF had a negative influence and represented the first variable selected:

NE_l (MJ/kg DM) = 8.52–0.089*ADF (% DM); (n=100, R^2=0.72, P<0.001)

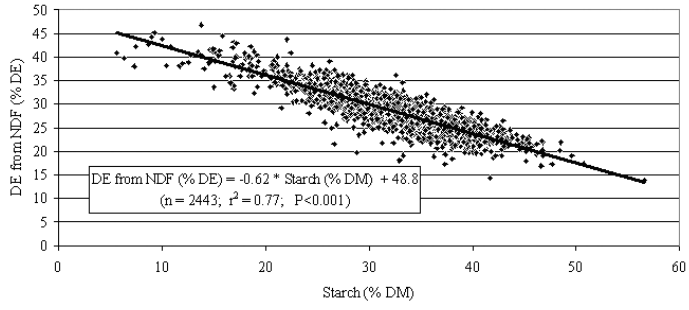
A refinement of the coefficient of determination was obtained considering the IVTD-NDF:

NE_l (MJ/kg DM) = 7.89–0.091*ADF (% DM)+0.014*IVTDNDF (%); (n=100, R^2=0.77, P<0.001)

The potential of NIRS to predict the biological parameters determined and the NE_l predicted, resulted to be high for the GP at 8 and 24 h (R^2=0.90, SEC=1.57; R^2=0.85, SEC=1.61, respectively) and for NE_l (R^2=0.85, SEC=0.15), moderate for the GP at 48 h (R^2=0.69, SEC=2.12) and for IVTD-DM (R^2=0.67, SEC=2.46), and poor for IVTD-NDF (R^2=0.25, SEC=6.31).

In conclusion, NIRS technique confirms its potential to predict some biological parameters of maize silage, allowing to estimate the nutritive value of this forage.

Figure1. Contribution of NDF to digestible energy at different starch contents in maize silage.



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