THE POSSIBILITIES OF DETERMINING THE NUTRITIONAL VALUE OF PRESERVED SORGHUM SILAGE USING NIRS TECHNOLOGY

Menšík, L.[1], Nerušil, P.[1], Mrkvicová, E.[2], Jambor, V.[3], Křížová, L.[4] *et al*.

[1]Czech Agrifood Research Center (CARC), Drnovská 507/73, 161 00 Praha 6 – Ruzyně, Czech Republic
[2]Mendel University in Brno, Zemědělská 1665/1, 613 00 Brno, Czech Republic
[3]NutriVet Ltd., Vídeňská 1023, 691 23 Pohořelice, Czech Republic
[4]Masaryk University, Kamenice 5, 625 00 Brno, Czech Republic

ABSTRACT

The aim of the paper is to present newly verified progressive methods for evaluating the nutritional value of dry feed (standard ground sample, particle size <1 mm) of preserved two-coloured sorghum silage (*Sorghum bicolor* (L.) Moench.) in terms of the following parameters: CP, fibre, fat, ash, ADF, NDF, cellulose, ADL, DMD and OMD, using near-infrared spectroscopy (NIRS). The parameters of the sorghum silage were determined using classical laboratory methods and measured simultaneously using NIRS. Calibration equations were developed using multidimensional regression methods (PLSR, MPLSR). The values of the coefficient of determination (R^2) of the calibration (validation) ranged from 0.83 to 0.96 (0.77 to 0.97) for the nutritional value parameters. Only a small amount of sample material (approx. 5–10 g) is required for analysis using NIRS. Not only is the measurement very fast (sample determination takes approx. 2–5 minutes), it is also sufficiently accurate.

Keywords: sorghum silage, NIRS

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench.) is a promising crop for producing bulk feed, particularly silage for ruminants, in areas with low precipitation (arid to semi-arid regions). It thrives under such environmental conditions as well as in areas with lower soil fertility, such as hilly regions (Li *et al*., 2020; Mrkvicová *et al*., 2025). Due to its high water-soluble carbohydrate (WSC) content, sorghum is well-suited for preservation as silage (Rodrigues *et al*., 2020), which enhances its ensilability by promoting lactic acid formation. Sorghum silage can help stabilize fluctuations in roughage supplies, compensating for variations in corn silage yields and preserved forage from grasslands. Furthermore, it serves to maintain sufficient feed supplies in the event of roughage shortages (Nazlı and Polat, 2024). Regarding the analysis of sorghum silage quality using NIR spectroscopy, there is still limited information in the global scientific literature concerning calibration models for predicting quality and determining key parameters, such as crude protein (CP), fiber, acid detergent fiber (ADF), and neutral detergent fiber (NDF) (Eguchi *et al*., 2013; Kański *et al*., 2013). When formulating feed rations, understanding the nutritional value of roughage components is crucial; however, conventional laboratory analyses are often time-consuming and costly (Menšík *et al*., 2025). Within the framework of precision livestock feeding, near-infrared spectroscopy (NIRS) plays a key role, enabling the immediate quantification of nutritional parameters and forming the basis for the dynamic adjustment of feed rations (Liu *et al*., 2023).

MATERIALS AND METHODS

The basis for developing calibration equations to determine the nutritional value of sorghum silage consisted of microsilage samples from two sorghum varieties ('Latte' and 'Pampa Triunfo') harvested in 2022–2023. These were grown on experimental plots at Mendel University in Brno (Žabčice site). The sorghum varieties were cultivated in both fertilized and unfertilized plots under a one-cut regime per year. The crops were harvested using a cutter, and the material was ensiled in experimental microsilos (microtubes) containing various additives (microbial and chemical additives based on acids, acid salts, and urea), as well as untreated control variants. A total of 170 microsilage samples were obtained. Following four months of fermentation, samples were collected, dried at 60 °C, and ground to a particle size of less than 1 mm using a laboratory grinder. Laboratory analyses were used to determine dry matter (DM) content and basic silage quality parameters: crude protein (CP), fiber, fat, ash, acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose, acid detergent lignin (ADL), dry matter digestibility (DMD), and organic matter digestibility (OMD). Identical forage samples were scanned using a FOSS NIRSystems 6500 dispersion spectrometer (NIRSystems, Inc., Silver Spring, USA) located at the CARC Prague, Research Station in Jevíčko. Measurements were performed in duplicate using small ring cups. Scanning was conducted in reflectance mode across the 400–2500 nm range (visible and near-infrared regions) with a scanning step of 2 nm. WinISI II software (version 1.50; Infrasoft International, Inc., USA) was used to develop the calibration and validation equations, including graphical outputs. Partial Least Squares Regression (PLSR; Næsset *et al*., 2005) and Modified PLS (MPLSR; Nawar *et al*., 2023) methods were applied.

RESULTS AND DISCUSSION

The dataset of sorghum silage samples, comprising 170 reference values, was divided into a calibration set (n = 154; for DMD and OMD n = 56–57) and a validation set (n = 13–16; for DMD and OMD n = 6–7). The validation set was created by selecting every 10th sample from the original collection. This independent validation set exhibited forage quality parameters similar to the calibration set and was used to verify prediction accuracy. The results, verified using independent validation datasets with comparable characteristics, confirm a high degree of agreement between conventional laboratory methods and NIRS analysis. Validation of the developed calibration equations yielded coefficients of determination (R2) ranging from 0.77 to 0.97 across individual parameters (see Table 1).

CP - crude protein, ADF – acid detergent fiber, NDF – neutral detergent fiber, ADL – acid detergent lignin, DMD – dry matter digestibility, OMD – organic matter digestibility; n – number of validation samples, SEP – standard deviation of prediction, SEP (C) – standard deviation of the prediction corrected by the calibration curve constant (BIAS), BIAS – calibration curve constant, SLOPE – calibration curve slope, R2 – koeficient of determination; RPD – Ratio of Performance to Deviation

Based on the achieved coefficients of determination, the performance of the calibration models was excellent for most evaluated parameters ($R^2 \geq 0.90$), making them suitable for routine agricultural practice and monitoring the quality of plant products (Dvořáček *et al*., 2014). The Ratio of Performance to Deviation (RPD) ranged from 2.0 to 5.0. RPD values above 2.0 or 2.5 are considered applicable for standard agricultural practice and environmental quality monitoring (Pasquini, 2018; Samadi *et al*., 2020).

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Tab. 1: Validation of quality parameters of sorghum silage using NIRS technique

Parameter (%)	Validation						
	n	SEP	SEP (C)	BIAS	SLOPE	R2	RPD
CP	16	0.401	0.411	-0.045	0.887	0.94	4.0
Fibre	15	0.772	0.662	-0.431	0.881	0.77	2.4
Fat	13	0.469	0.474	-0.109	0.768	0.80	2.1
Ash	16	0.182	0.181	-0.049	0.920	0.86	3.2
ADF	14	0.874	0.888	0.176	1.235	0.89	2.0
NDF	14	1.203	0.755	0.957	0.906	0.92	3.8
Cellulose	14	0.463	0.479	0.028	1.108	0.90	3.1
ADL	15	0.345	0.346	-0.009	0.909	0.88	2.7
DMD	6	1.612	0.888	1.622	1.106	0.97	5.0
OMD	7	2.481	2.127	1.510	1.106	0.89	2.4

CP – crude protein, ADF – acid detergent fiber, NDF – neutral detergent fiber, ADL – acid detergent lignin, DMD – dry matter digestibility, OMD – organic matter digestibility; n – number of validation samples, SEP – standard deviation of prediction, SEP (C) – standard deviation of the prediction corrected by the calibration curve constant (BIAS), BIAS – calibration curve constant, SLOPE – calibration curve slope, R2 – koeficient of determination; RPD – Ratio of Performance to Deviation

CONCLUSIONS

Calibration equations were developed using near-infrared reflectance spectroscopy (NIRS) to evaluate the quality of sorghum silage across various parameters (e.g., CP, fiber, fat, ash, ADF, and NDF). Based on silage (microsilage) samples, these equations demonstrated a high degree of agreement between laboratory methods and NIRS determination (calibration set, $R^2 = 0.83–0.96$; validation set, $R^2 = 0.77–0.97$). The highest prediction accuracies were achieved for CP, DMD, ADL, ADF, and NDF content ($R^2 = 0.88–0.96$). For most evaluated parameters, the RPD values indicate that these models are suitable for routine agricultural practice and environmental quality monitoring. Key advantages of NIRS include enhanced operator safety and environmental sustainability, since the process consumes no reagents and generates no chemical waste. Furthermore, the process is rapid (taking approximately 2–5 minutes, depending on the instrument settings), accurate, and has no negative environmental impact.

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Contact Information

Ladislav Menšík: e-mail: ladislav.mensik@carc.cz