ACCURACY OF THE PREDICTION OF THE FEED VALUE OF UNDRIED GRASS AND MAIZE SILAGES BY A HANDHELD NIRS DEVICE

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ABSTRACT

Mobile NIRS devices are increasingly available for various applications. Their use for prompt feed ration adaptation seems attractive. Thus one model was tested for its reliability in terms of the prediction of feed value parameters of moist silages. Dry matter content turned out to be the best predictable parameter.

Keywords: predictive quality, on-farm tool, near-infrared spectroscopy, forages

INTRODUCTION

Efficient livestock production depends on diets that accurately matches animal nutrient requirements. However, the nutritional composition of forages and compound feeds can vary considerably due to differences in harvest timing, storage conditions, processing and environmental factors. Conventional wet-chemistry analyses provide reliable compositional data but are labour-intensive and time-consuming, limiting their suitability for rapid on-farm decision making (Williams & Norris, 2001). Near-infrared spectroscopy (NIRS) offers a rapid, non-destructive and cost-effective alternative for estimating key feed quality parameters such as dry matter (DM), crude protein (CP) and fibre fractions (Reeves, 1999; Cozzolino & Labandera, 2002). Recent technological advances have enabled the miniaturisation of NIR sensors into portable handheld devices that allow farmers and nutritionists to assess forage quality directly on the farm (Cherney *et al.*, 2021; Zhu *et al.*, 2022). However, handheld instruments generally operate over a narrower spectral range and measure fresh, untreated samples, which can reduce prediction accuracy compared with laboratory spectrometers (Fernández Pierna *et al.*, 2022; Rukundo *et al.*, 2021). Factors such as moisture content, particle size and sample heterogeneity may therefore influence calibration performance and model reliability. Despite the growing availability of portable NIR sensors, independent evaluations under practical farm conditions remain limited. The present study evaluates the performance of the PAL One (Trinamix GmbH, Ludwigshafen, Germany) handheld NIRS device for estimating feed value parameters in grass silage, maize silage and cereal grain samples and compares device predictions with laboratory NIRS analyses.

MATERIAL AND METHODS

Two sampling campaigns were conducted in August and September 2024. In total, 195 samples were analysed, including approximately 100 grass silages, 40 maize silages and 55 cereal grain samples (wheat, barley, rye). The first campaign was carried out at the LKS Lichtenwalde laboratory, where freshly delivered samples from farmers were scanned using a PAL One handheld NIRS device immediately after registration and sample splitting. The second campaign was conducted at the Lehr- und Versuchsgut Köllitsch in September 2024, where samples were collected directly from silos and feed stocks. All samples were analysed in their fresh state without drying or grinding.

For each sample, one portion was sent to the LKS laboratory for reference analysis, while the remaining portion was analysed with the PAL One device. The handheld spectrometer operates in reflectance mode within approximately 1400–2400 nm and transfers spectral data to a cloud-based application where chemometric models generate predicted nutrient values. To reduce sample heterogeneity, the sensor was moved across several areas of the sample surface during scanning and replicate spectra were averaged.

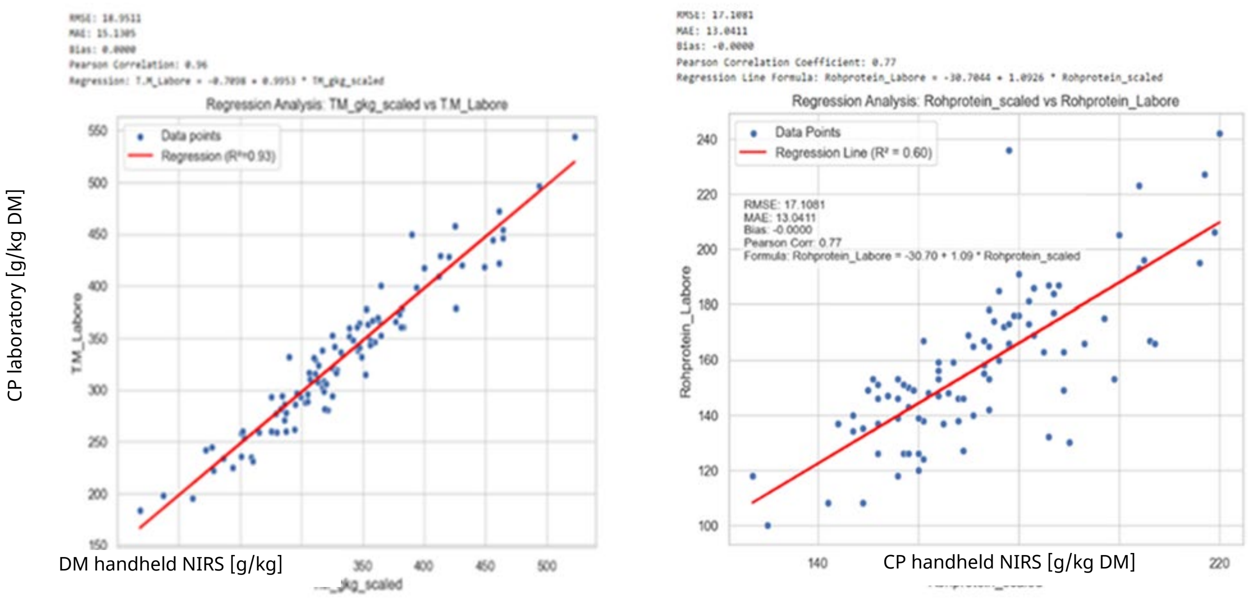

Fig. 1: Regression between handheld NIRS predictions for DM (left) and CP (right) in grass silage

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Tab. 1: Regression performance between handheld NIRS predictions and laboratory reference values

Feed type	Metric	DM	CP	ADF	NDF	ELOS	Sugar	Ash
Grass silage	R^2	0.93	0.60	0.41	0.29	0.28	0.16	0.07
Grass silage	RMSE	18.9	17.31	20.88	36.64	48.58	39.85	17.87
Maize silage	R^2	0.52	0.00	0.04	—	0.01	—	0.00
Maize silage	RMSE	20.88	5.67	19.19	—	26.16	—	2.46
Cereal grain	R^2	0.00	0.16	—	—	—	—	0.30
Cereal grain	RMSE	12.77	15.42	—	—	—	—	1.62

Reference analyses

Laboratory reference analyses were conducted at the LKS mbH feed testing laboratory using a FOSS XDS Rapid Content Analyzer (400–2500 nm). Prior to analysis, samples were dried at ≤60 °C to constant mass and milled to 1 mm particle size. DM was determined in two stages with a final drying at 103 °C for 4 h in a forced air drying oven. Spectral measurements were processed using ISIScan software, and nutrient concentrations were predicted using WinISI calibrations based on VDLUFA wet-chemistry reference methods (VDLUFA 1976). Additional measurements were performed at a second laboratory (Betriebsgesellschaft für Umwelt und Landwirtschaft) using a FOSS NIRS 5000 spectrometer (1100–2500 nm) equipped with an autocup sampler. Both laboratories operate according to ISO 12099:2018 standards for NIRS calibration and validation.

Statistical analysis

All statistical analyses were conducted in Python using pandas, scikit-learn, and SciPy. Data were first inspected with heat maps and scatterplots, and obvious errors or outliers were removed. For NDF, values reported below the detection limit (“<”) were replaced with the stated limit. Descriptive statistics were calculated for DM, CP, NDF, ADF, sugar, ash, and ELOS. Agreement between handheld and laboratory measurements was assessed by linear regression using R^2, RMSE, MAE, and bias. Correlation matrices were used to examine relationships among variables. Depending on normality, paired t-tests or Wilcoxon signed-rank tests were applied to compare handheld and laboratory results. Bland–Altman plots were used to evaluate agreement, while residual plots, Q–Q plots, and histograms were used to check regression assumptions.

RESULTS AND DISCUSSION

Regression results varied substantially depending on feed type and parameter (Table 1). The strongest relationship between handheld NIRS predictions and laboratory reference values was observed for dry matter in grass silage ($R^2 = 0.93$; RMSE = 18.9 g/kg), while crude protein showed a moderate correlation ($R^2 = 0.60$; RMSE = 17.31 g/kg) (Fig. 1).

In contrast, other parameters in grass silage, such as ADF, NDF, ELOS, sugar and ash, showed considerably lower predictive accuracy. For maize silage, only dry matter exhibited moderate agreement between device and laboratory measurements ($R^2 = 0.52$), whereas the remaining parameters showed weak relationships. In cereal grain, prediction performance was generally low, with the highest correlation observed for ash ($R^2 = 0.30$) (Table 1).

CONCLUSION

The handheld NIRS device showed high predictive accuracy for dry matter in grass silage and moderate performance for crude protein. The results indicate that the predictive performance strongly depends on the analysed parameter. Handheld NIRS technology can therefore serve as a rapid screening tool for limited on-farm forage evaluation, while laboratory analysis remains necessary for precise nutrient determination.

REFERENCES

Cherney, J. H., Digman, M. F., Cherney, D. J. R. 2021. Handheld NIRS for forage evaluation. *Computers and Electronics in Agriculture*. 190, 106469. https://doi.org/10.1016/j.compag.2021.106469

Cozzolino, D., Labandera, M. 2002. Determination of dry matter and crude protein contents of undried forages by near-infrared reflectance spectroscopy. *Journal of the Science of Food and Agriculture*. 82(4), 380–384. https://doi.org/10.1002/jsfa.1050

Fernández Pierna, J. A., Vermeulen, P., Chamberland, N., Decruyenaere, V., Froidmont, E., Minet, O., Lecler, B., Baeten, V. 2022. Performance of three handheld NIR spectrometers for predicting grass silage quality. *Biotechnology, Agronomy, Society and Environment*. 26(Special Issue), 1–10. https://doi.org/10.25518/1780-4507.19918

Reeves, J. B. 1999. Mid- versus near-infrared spectroscopic analysis of diversely treated feedstuffs. *Journal of Near Infrared Spectroscopy*. 7(2), 89–100. https://doi.org/10.1255/jnirs.240

Rukundo, I. R., Danao, M.-G. C., Macdonald, J. C., Wehling, R. L., Weller, C. L. 2021. Performance of two handheld NIR spectrometers to quantify crude protein of composite animal forage and feedstuff. *AIMS Agriculture and Food*. 6(2), 463–478. https://doi.org/10.3934/agrfood.2021027

Williams, P., Norris, K. 2001. *Near-infrared technology in the agricultural and food industries*. 2nd Edition. American Association of Cereal Chemists, St. Paul, MN.

VDLUFA. 1976. *Methodenbuch Band III: Die chemische Untersuchung von Futtermitteln* [*The chemical analysis of feedstuff*]. Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten, Darmstadt.

Zhu, C., Fu, X., Zhang, J., Zhang, J., Qin, K., Wu, C., Wu, C. 2022. Review of portable near infrared spectrometers: Current status and new techniques. *Journal of Near Infrared Spectroscopy*. 30(2), 51–66. https://opg.optica.org/jnirs/abstract.cfm?URI=jnirs-30-2-5

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