

Handheld NIR spectrometers to evaluate grass silage quality A study of calibration performance evaluation

**Juan Antonio Fernández Pierna¹, Nicolas Chamberland¹,
Philippe Vermeulen¹, Virginie Decruyenaere², Eric
Froidmont³, Oliver Minet¹, Bernard Lecler¹, Vincent
Baeten¹**

E-mail: j.fernandez@cra.wallonie.be

¹Knowledge and valorization of agricultural products Department,
Quality and authentication of products Unit,

²Productions in agriculture Department, Animal production Unit,

³Sustainability, systems and perspectives Department, Agriculture and
sustainability Unit, Walloon Agricultural Research Centre (CRA-W),
5030 Gembloux, Belgium



Feed is the main variable load in dairy farming. A more efficient use of the **forage resources (EFR)** produced is one way to reduce production costs.

Improving EFR can start with a better assessment of the **dry matter content** and **nutritional value** of forages. Currently, the analysis time is often long and the analyses are not regular while the quality of the fodder changes over time. Being able to analyse forages directly on the farm would make it possible to adapt the animal diet according this variability in order to limit the feeding costs and improve the profitability of the farm.

To this end, and in the context of the EFFORT project, the idea is to offer **rapid analysis solutions, in situ, to better understand the composition of fodder in order to assess its feed value.**



The goal of this study is to **evaluate the performance of three recent developed spectroscopic handheld devices**, namely the Viavi Micronir 1700 (908-1676 nm), the OceanOptic Flame-NIR (936-1665 nm) and the ASD FieldSpec (350-2500 nm) to predict dry matter content and chemical composition of fresh and unground grass silage in the framework of precision feeding.

Viavi Micronir



908-1676 nm

OceanOptic
Flame-NIR



936-1665 nm

ASD FieldSpec

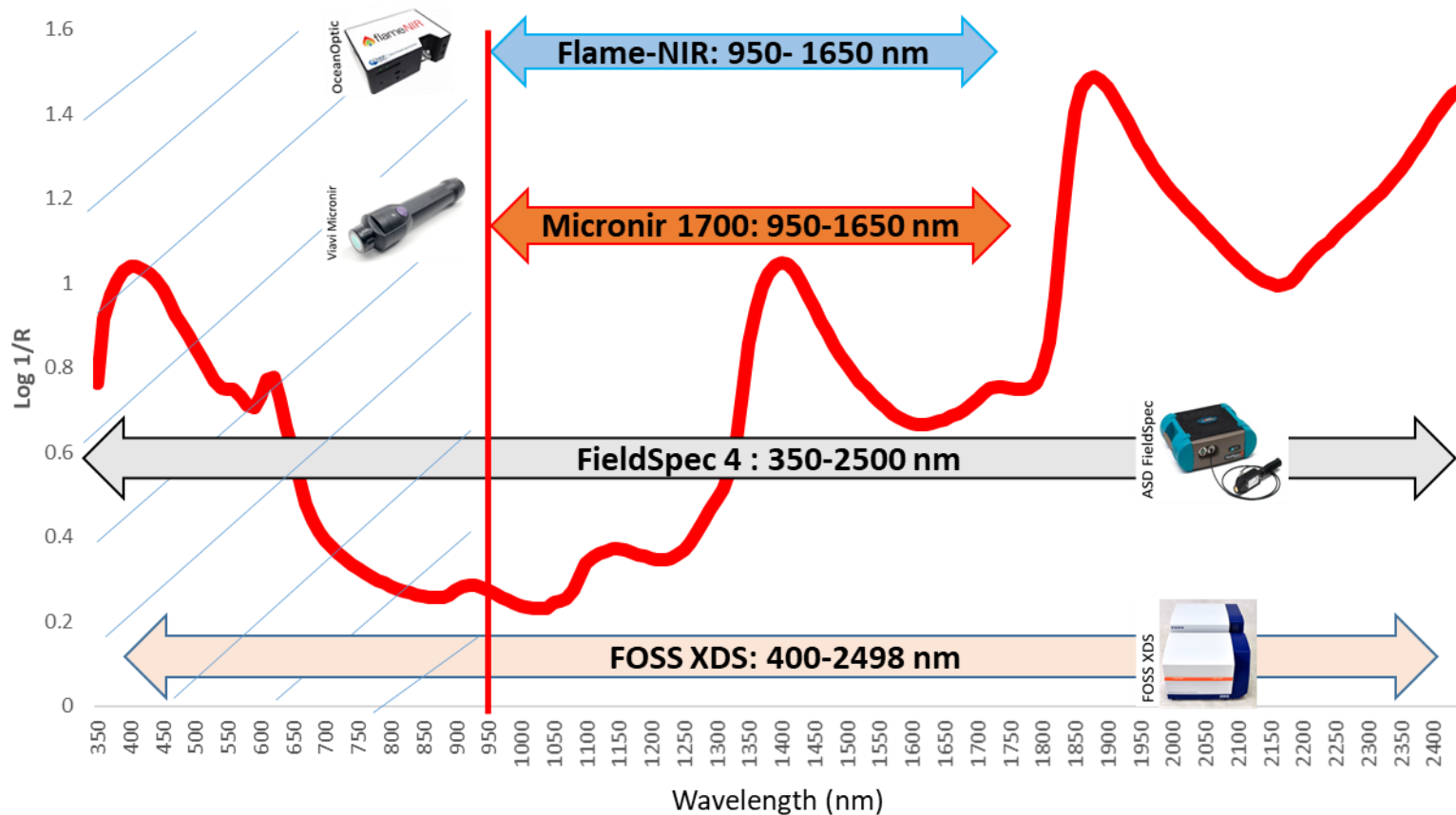


350-2500 nm



The novelty of this work is the fact that **fresh grass silage** is measured and **directly on the fields**. Moreover, a benchtop spectrometer, namely the FOSS XDS, is also used in this study. Spectral datasets for dry and ground samples are already available for that system, which can be used to have a first idea of the performances that can be reached.





For this study, **181 samples of grass silage** were collected between 2018 and 2020 at 60 different silage silo in Wallonia (Belgium).



Sampling and
measurement protocol

Samples were measured in fresh and unground. The spectral databases differ slightly as not all samples were measured on all handheld devices. However, these databases are quite similar in terms of their size and the characteristics of their parameters in terms of mean and standard deviation.



An alternative set of **19 validation samples** was also obtained from the same period and coming from different locations as in the calibration sets. This validation dataset is the same for all devices.

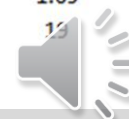
For all these datasets, reference values were obtained by prediction with a FOSS DS2500 on dried and ground samples for **protein (CP), total ash (ashes), crude fiber (CEL), acid and neutral detergent fiber (ADF and NDF) constituents**. Dry matter (DM) was obtained by drying samples at 60°C during 48 hours.



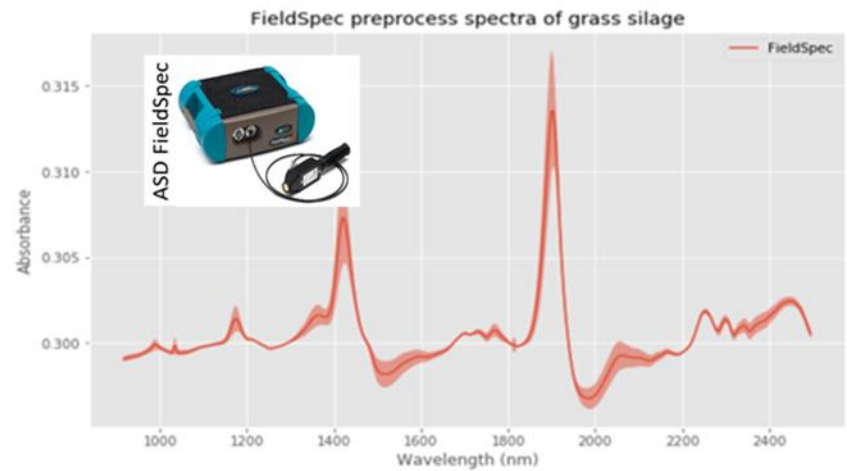
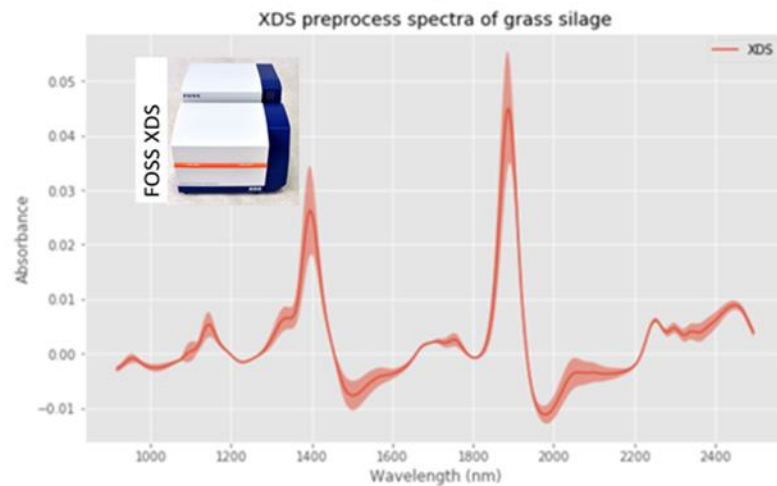
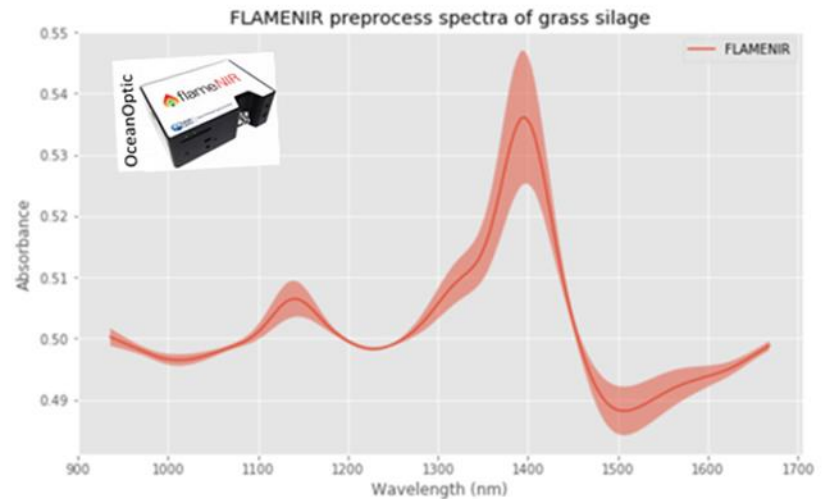
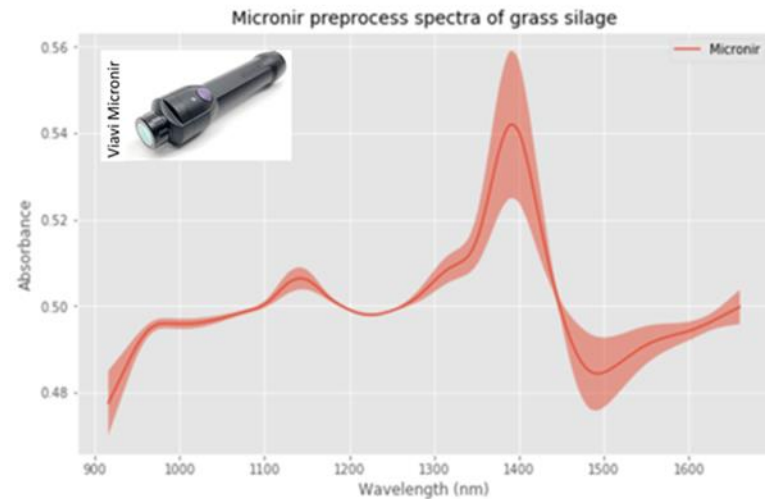
CALIBRATION SETS

	XDS					
	DM	CP	CEL	ashes	NDF	ADF
Min	27	10.6	19.54	7.71	33.52	20.14
Max	88.2	22.52	34.3	16.82	64.63	39.75
Mean	48.41	16.78	26.7	11.39	47.98	29.57
STD	12.74	2.57	2.68	1.72	6.29	3.25
N	139	141	141	141	141	141
	Micronir1700					
	DM	CP	CEL	ashes	NDF	ADF
Min	20.47	11.1	20.27	7.04	36.3	21.92
Max	78.82	22.52	37.76	16.78	74.62	44.15
Mean	47.35	16.54	27.52	11.23	49.31	30.49
STD	12.77	2.89	3.22	1.85	7.18	3.73
N	149	150	150	150	150	150
	Flamenir					
	DM	CP	CEL	ashes	NDF	ADF
Min	21.51	11.19	20.68	7.04	36.3	21.92
Max	77.3	22.52	37.76	16.82	74.62	44.15
Mean	44.24	16.76	27.23	11.4	48.73	29.86
STD	12.92	2.98	2.84	1.52	6.94	3.62
N	115	113	113	113	113	113
	Fieldspec					
	DM	CP	CEL	ashes	NDF	ADF
Min	24	10.6	19.54	7.01	33.52	20.14
Max	88.9	22.3	36.25	16.82	64.63	41.71
Mean	49.96	16.32	27.97	10.85	49.8	31.01
STD	13.4	2.61	3.18	1.85	6.47	3.92
N	150	151	151	151	151	151

VALIDATION SET	DM	CP	CEL	ashes	NDF	ADF
Min	28.1	13.1	21.6	7.5	41.3	23.9
Max	78.6	20.9	27.94	16.82	52.5	30.06
Mean	44.3	16.93	25.19	10.99	46.88	27.61
STD	12.59	1.65	1.82	1.95	3.6	1.69
N	19	19	19	19	19	19



Spectra - preprocessing

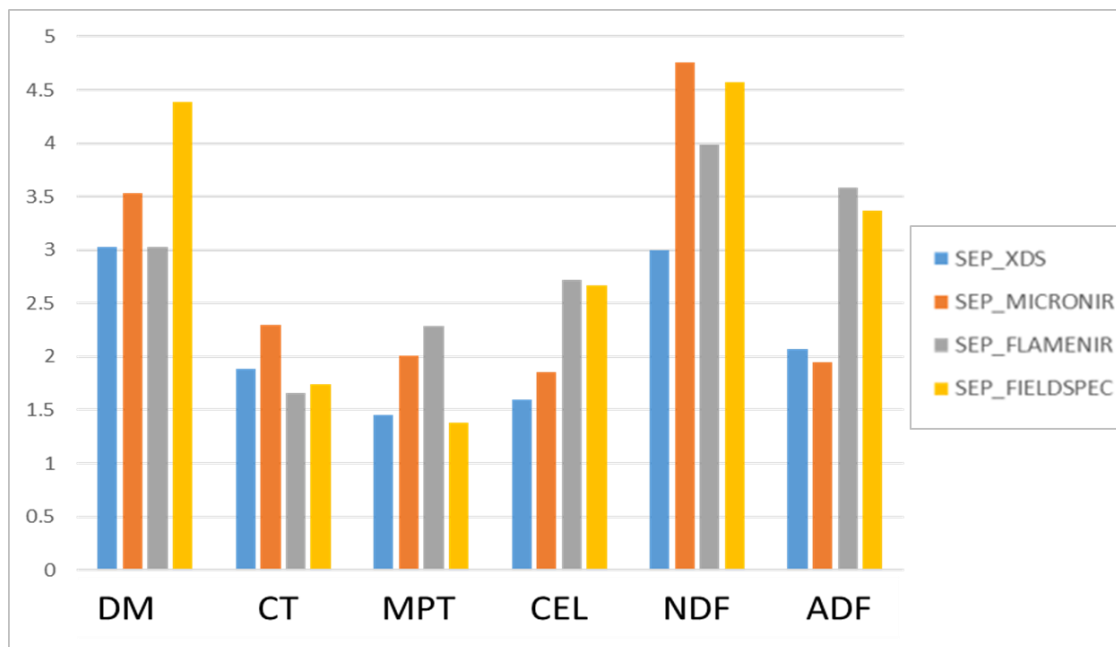


After SNV and first derivative

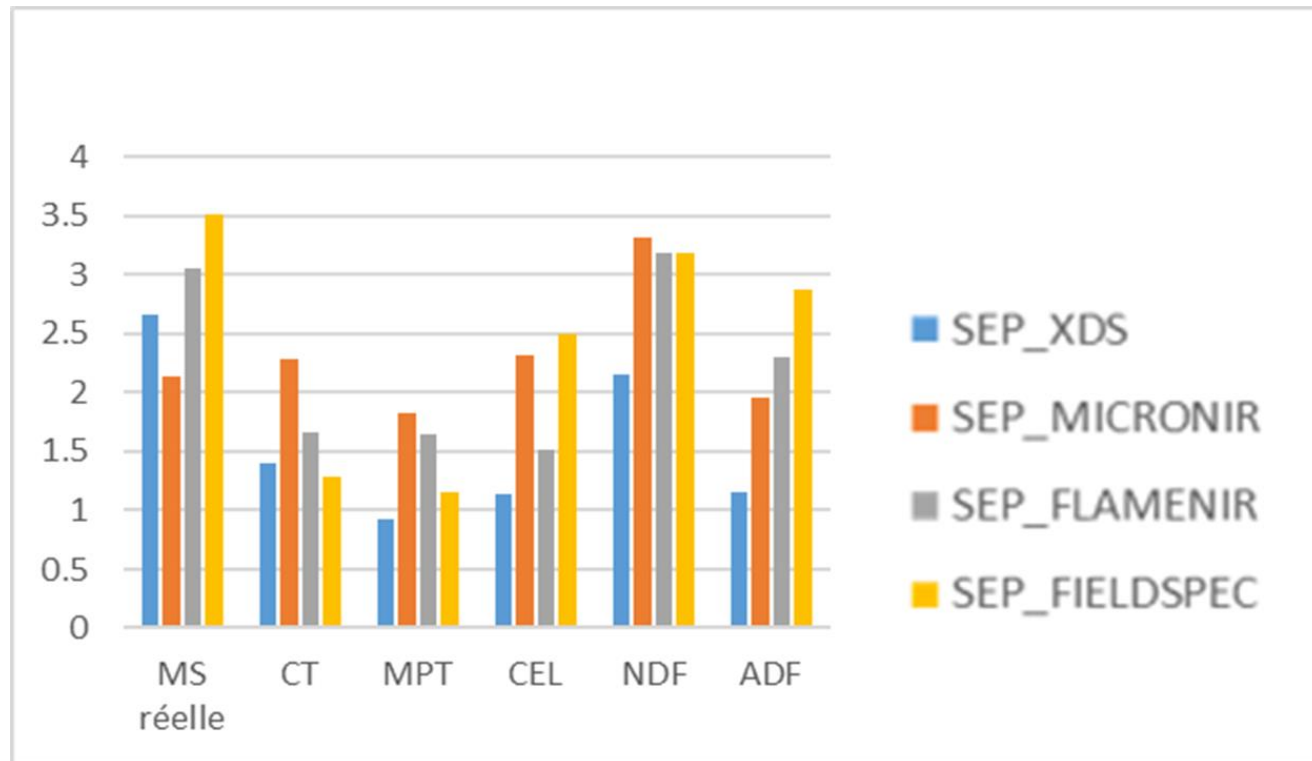


Chemometric tools comprised the building of calibration models using the classical **Partial Least Squares (PLS)** regression as well as the use of a **local based PLS algorithm**.

PLS



Local PLS



The best way to evaluate the performances is to compare the PLS prediction results for each device with the error obtained when working in the classical way, i.e. on dry and ground samples. The standard error in calibration (SECV) obtained for the dry samples measured with the XDS device gives us an idea of the performances obtained until now for grass silage.

In order to take into account the difference with this SECV and the laboratory error (SEL), a real SEP for each device is determined using the following equation:

$$SEP_{\text{actual}} = SEP_{\text{observed}} - (\text{SECV}_{\text{dry}}^2 - \text{SEL}^2)$$

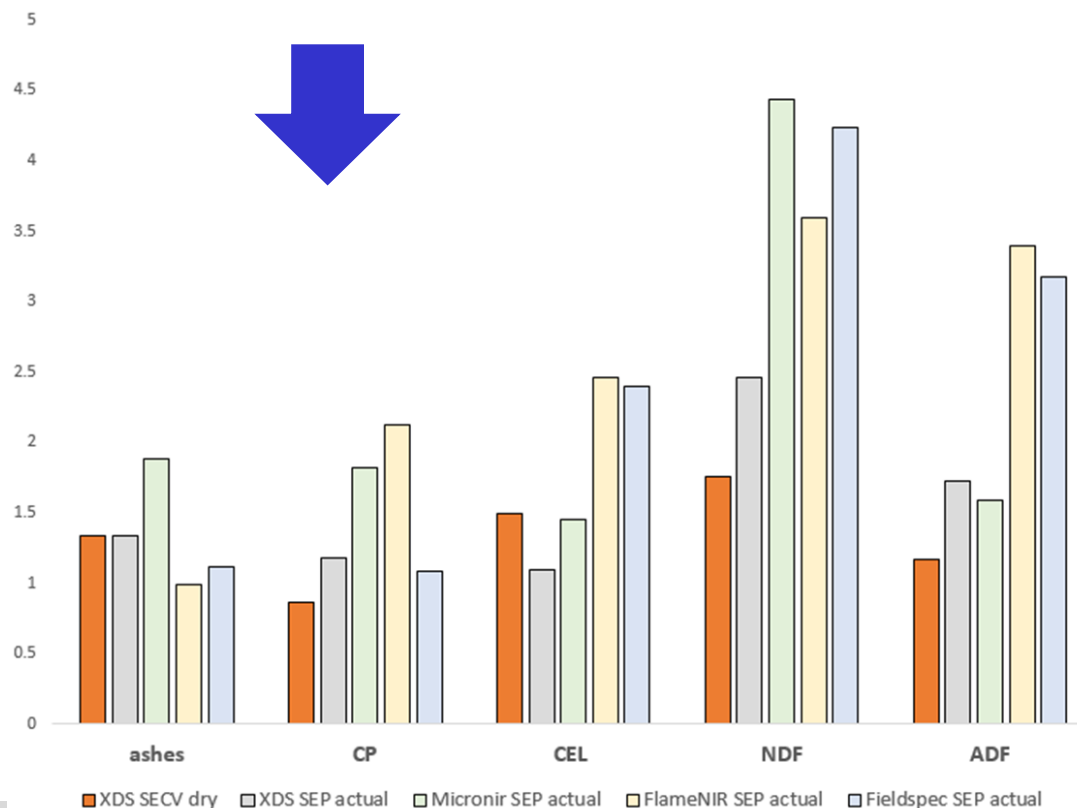
Where SEP: Standard Error of Prediction, SECV: Standard Error of Cross-Validation (estimated on the calibration set and dried samples) and SEL: Standard Error of Laboratory (reference analysis)

'Estimation of partial least squares regression (PLSR) prediction uncertainty when the reference values carry a sizeable measurement error'
J.A. Fernández Pierna, L. Jin, N. M. Faber, F. Wahl, D.L. Massart. Chemometrics and Intelligent Laboratory Systems 65 (2003) 281-291.



Results

Parameter ¹	SEL ²	XDS SECV dry	XDS SEP observed	XDS SEP actual	Micronir SEP observed	Micronir SEP actual	FlameNIR SEP observed	FlameNIR SEP actual	Fieldspec SEP observed	Fieldspec SEP actual
CT	0,15	1,34	1,89	1,34	2,30	1,88	1,66	0,99	1,74	1,12
MPT	0,20	0,87	1,45	1,18	2,01	1,82	2,29	2,13	1,38	1,09
CEL	0,95	1,50	1,60	1,10	1,86	1,45	2,72	2,46	2,67	2,40
NDF	0,40	1,76	3,00	2,46	4,76	4,44	3,99	3,60	4,57	4,24
ADF	0,30	1,17	2,07	1,73	1,95	1,59	3,58	3,40	3,37	3,17



As expected, in general, performances are lower when working with fresh and unground samples.

Parameters as ashes, CP and CEL, even if lower, they are still reasonably well predicted. Higher errors are obtained for NDF and ADF.

These performances can be probably improved by including more samples / spectra into the databases and by applying new validation sets covering a large majority of the variation present in the calibration sets for these parameters, which is not the case in the present study.





This study was realised in the framework of the Effort project funded by the CRA-W.

More information on <https://www.cra.wallonie.be/en/effort-2>

