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Faecal near infrared spectroscopy (FNIRS), a support tool to manage small ruminants

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Abstract. Faecal near infrared spectroscopy (FNIRS) can be a good technique to predict functional properties like intake or *in vivo* digestibility of forages by small ruminants. Data were collected from 108 different digestibility indoor and outdoor trials in Senegal and France carried out from 1993 to 2013 on sheep fed with a large variety of forage species. Faecal samples were scanned by a Foss NIRSystem 5000 monochromator. Calibrations were established on indoor trials samples and performed using the modified partial least square (mPLS) procedure to estimate dry or organic matter (DMI, OMI, g/kg metabolic weight, $BW^{0.75}$) intake, *in vivo* dry and organic matter (DMD, OMD, %) digestibility. The derived standard errors of calibration (SEC) and coefficients of determination (R^2cal) were 6.52 g/kg $BW^{0.75}$ and 0.81 for DMI, 5.17 g/kg $BW^{0.75}$ and 0.86 for OMI, 1.50% and 0.93 for DMD and 1.95% and 0.88 for OMD, respectively. These values confirm the interest of the use of FNIRS as a tool to manage small ruminants. The results obtained show a good accuracy with values similar to other published results for intake and digestibility. Validation on outdoor trials samples show the difficulty to extrapolate the prediction of intake with limited samples number and only one pasture quality.

Keywords. Near infrared spectroscopy – Faeces – Digestibility – Feed intake.

La spectroscopie proche infrarouge fécale (FNIRS), un outil de pilotage pour la gestion des petits ruminants

Résumé. *La spectroscopie proche infrarouge fécale (FNIRS) peut être une bonne technique pour prédire des propriétés fonctionnelles comme l'ingestion ou la digestibilité des fourrages par les petits ruminants. Les données proviennent de 108 essais de digestibilité différents en cage ou au pâturage réalisés au Sénégal et en France entre 1993 et 2013 sur des ovins incluant une grande variété d'espèces fourragères. Les échantillons de fèces ont été scannés avec un monochromateur Foss NIRSystem 5000. Les étalonnages ont été effectués avec la procédure des moindres carrés partiels modifiée (mPLS) avec les échantillons des essais en cages pour estimer l'ingestion de matière sèche ou de matière organique (DMI, OMI, g/kg^{0,75}), la digestibilité de la matière sèche ou de la matière organique (DMD, OMD, %). Les erreurs standard d'étalonnage (SEC) et les coefficients de détermination (R^2cal) étaient respectivement de 6,52 g/kg^{0,75} et 0,81 pour DMI, 5,17 g/kg^{0,75} et de 0,86 pour OMI, 1,50% et 0,93 pour DMD et 1,95% et 0,88 pour OMD. Ces valeurs confirment l'intérêt de la FNIRS comme outil de pilotage pour la gestion des petits ruminants. Les résultats obtenus montrent une bonne précision avec des valeurs similaires à celle rencontrées dans la bibliographie. Une validation sur les échantillons des essais au pâturage montre la difficulté d'extrapolation des étalonnages pour la prédiction de l'ingestion lorsque le nombre d'échantillons est limité et restreint à une seule situation.*

Mots-clés. *Spectroscopie proche infrarouge – Fèces – Digestibilité – Ingestion.*

I – Introduction

The understanding and management of ruminant husbandry require the measurement of functional properties such as intake or digestibility. These measurements require animal trials that are costly and time-consuming to implement either in the case of animals in metabolism cages or even more

in the case of animals in grazing conditions. The indirect measurement by faeces spectrum pioneered by Lyons and Stuth (1992) and well described by Stuth *et al.* (2003) makes it possible to obtain less-expensive information on the performance of animals in order to support livestock management. The use of a simple and fast technique such as near infrared spectroscopy (NIRS) to predict these functional properties is well established (Bastianelli *et al.*, 2018). Faecal NIRS is therefore an interesting alternative to tedious reference methods, particularly in some tropical countries where the technical and economic conditions are difficult to set up animal trials at experimental stations. In this work, we evaluate the capacity of our database collected during 20 years with various animal trials to contribute to support the management of small ruminants by predicting digestibility and intake.

II – Materials and methods

1. Samples and trials conditions

A total of 1321 samples of faeces were collected either at the rectal level or on total faeces collection during 108 different indoor (100) and outdoor (8) animal trials in Senegal (65) and France (43) from 1993 to 2013 on sheep. In Senegal, trials were conducted with individual metabolism crates only at the ISRA-LNERV Experimental Unit in Dakar. In France, trials were conducted at the Montpellier-Vauguières Experimental Unit (INRA-PHASE, UMR SELMET) in the south of France and at the La Fage experimental farm unit (INRA-GenPhyse) in a semi-mountainous area. The 8 outdoor trials were conducted at La Fage on about 0.5 ha rangeland paddocks (fertilized or not) with a stocking rate of 58 ewe lambs and suckling ewes per/ha. Sheep were equipped with a bag for collecting total faeces. Dry (DMD) and organic (OMD) matter digestibility were estimated with the *in vitro* pepsine cellulase method (Aufrère *et al.*, 2007) on hand clipped forages collected on the same paddocks. Dry (DMI) and organic (OMI) matter intake were calculated with total faeces and DMD and OMD respectively. One indoor trial was conducted with three groups of about 10 sheep fed in group for which DMI and OMI were measured. For other indoor trials, sheep were placed in individual metabolism crates. Several forage species were evaluated, either as a monoculture or multispecies meadows or dehydrated feed according to the trial. All faeces were dried (48h, 60°C) and ground through a 1-mm sieve before NIRS measurements.

According to the objectives of the different trials, DMI and OMI (g/kg metabolic weight, $BW^{0.75}$) were measured or estimated (outdoor trials) and *in vivo* DMD and OMD (%) were measured (indoor trials) and assembled into our database. The description of the database used for calibrations based on indoor trials only, is detailed in Table 1.

Table 1. Descriptive statistics of the faecal database used for calibrations (n = 1321)

Parameter	N	Min.	Max.	Mean	S.D.
DMI (g/kg $BW^{0.75}$)	677	25.00	112.00	73.40	16.04
OMI (g/kg $BW^{0.75}$)	659	30.00	104.00	69.51	14.19
DMD (%)	259	48.92	83.00	57.77	7.53
OMD (%)	109	52.65	79.60	63.50	6.04

N: number of observations; Min.: minimum value; Max.: maximum value; S.D.: standard deviation; DMI: dry matter intake; OMI: organic matter intake; DMD: *in vivo* dry matter digestibility; OMD: *in vivo* organic matter digestibility.

2. NIRS measurements

The samples of faeces were scanned on a Foss NIRSystem 5000 monochromator (Silver Spring, MD, USA). Measurement was done in reflectance mode in small circular cups (diameter: 50 mm) with quartz glass. Spectral data were collected every 2 nm from 1100 to 2500 nm as log 1/R. Samples were scanned in duplicate (two different cup fillings) and spectra were averaged. The NIRS calibration was performed using the modified partial least squares regression (mPLS procedure, WinISI software, Infrasoft Int., Port Matilda, PA, USA). Mathematical pre-processing was applied to spectra with detrending and normalization of data, and use of the second derivative calculated on five consecutive points with a smoothing also on a gap of five points (SNV-D 2,5,5). In order to evaluate the capacity of the models to be used on animals in grazing conditions, spectra from indoor trials were used as calibration set and spectra from outdoor trials as validation set. During the calibration process, prediction outliers (studentized residual T>2.5) were discarded. Cross-validation based on dividing the database into four groups of samples was used to select the optimum number of terms. Criteria for the evaluation of the prediction models are: SEC (standard error of calibration), SECV (standard error of cross-validation), which is an estimate of precision that can be expected in routine analysis, R^2cal (coefficient of determination of calibration) and R^2cv (coefficient of determination of cross-validation). Validation performance for the models was assessed by SEP (standard error of prediction) and R^2val (coefficient of determination of validation).

III – Results and discussion

The performances of the different calibrations obtained are presented in Table 2. For DMI, the SEC of 6.52 g/kg $BW^{0.75}$ and the SECV of 6.86 g/kg $BW^{0.75}$ or the R^2cal of 0.81 and the R^2cv of 0.79 are similar to the values reported by Andueza *et al*. (2017): 6.60 and 6.72 g/kg $BW^{0.75}$ or 0.65 and 0.64 respectively.

Table 2. Calibration and validation performances (outdoor measures) for faecal NIRS calibration equations developed from faeces samples of sheep

	Calibration set					Validation set		
Parameter	**N**	**SEC**	**R^2cal**	**SECV**	**R^2cv**	**N**	**SEP**	**R^2val**
DMI (g/kg $BW^{0.75}$)	622	6.52	0.81	6.86	0.79	36	8.38	0.01
OMI (g/kg $BW^{0.75}$)	615	5.17	0.86	6.21	0.80	36	8.20	0.09
DMD (%)	236	1.50	0.93	2.01	0.88	36	3.71	0.76
OMD (%)	104	1.95	0.88	2.41	0.82	21	2.26	0.82

N: number of observations; SEC: standard error of calibration; R^2cal: coefficient of determination of calibration; SECV: standard error of cross-validation; R^2cv: coefficient of determination of cross-validation; SEP: standard error of prediction; R^2val: coefficient of determination of validation; DMI: dry matter intake; OMI: organic matter intake; DMD: *in vivo* dry matter digestibility; OMD: *in vivo* organic matter digestibility.

For OMI the SEC (5.17 g/kg $BW^{0.75}$) and R^2cal (0.86) were similar to those reported by Decruyenaere *et al.* (2009) with values ranging from 3.46 to 5.15 g/kg $BW^{0.75}$ for SEC and 0.66 to 0.89 for R^2cal for sheep. These values were also in agreement with those reported by Boval *et al*. (2004) on cattle with values ranging from 3.40 to 9.60 g/kg $BW^{0.75}$ for SEC and 0.61 to 0.90 for R^2cal.

The calibration statistics obtained for DMD and OMD (SEC=1.50%; R^2cal=0.93 and SEC=1.95%; R^2cal=0.88 respectively) were consistent with the values reported by Dixon and Coates (2009). The values of SEC ranged from 1.70% to 3.20% for DMD and from 1.50% to 3.20% for OMD and the values of R^2cal reported ranged from 0.91 to 0.98 for DMD and 0.80 to 0.94 for OMD.

The results of the validation show that it is possible to extrapolate the prediction of digestibility of grazing animals using calibrations established with indoor trials. However, these results need to be confirmed with more outdoor trials samples. On the other hand, this extrapolation was not possible for DMI or OMI (SEP higher than SEC or SECV and very low R^2val). This result is certainly due to the low number of outdoors samples obtained on natural rangeland including hundred species.

IV – Conclusions

The results of this study confirm that our database aggregating 20 years of collect of faeces sample's during animal trials on sheep could contribute to support the management of small ruminants. However, in order to improve the robustness of these calibrations, future work will need to implement the database with more variability in term of diet and field conditions.

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