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Quantitative and qualitative monitoring of diet by analysis of NIR spectra of goat faeces: A preliminary study

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SUMMARY – The feasibility of using Near Infrared Reflectance Spectroscopy (NIRS) analyses from faecal samples, as a tool for the assessment of the quality of goat diets, was evaluated in twelve Damascus yearling goats fed diets containing different percentages of hay and concentrate. The determination coefficient (R^2) and Standard Error of Cross Validation (SECV, an estimator of accuracy) values for predictions of the percentage of hay, CP (%), Tilley and Terry IVDMD (%), NDF (%) and ADF (%) were: (0.99, 2.5), (0.96, 0.06), (0.98, 0.60), (0.98, 0.83) and (0.98, 0.81), respectively. The R^2 and SECV values for intake (g/day/kg BW $^{0.75}$) of hay, total DM, digestible Tilley and Terry DM, CP, NDF and ADF were: (0.88, 4.7), (0.69, 4.9), (0.66, 3.67), (0.57, 0.87), (0.72, 2.5) and (0.84, 1.78), respectively. These results indicate that NIRS technology may be a powerful tool for predicting the percentage of some constituents with high accuracy and to a lesser extent the absolute intake values of some diet constituents.

Keywords: Nutrition, feeding, NIRS, caprine.

RESUME – *"Contrôle quantitatif et qualitatif du régime par analyse des spectres de NIR des fèces de chèvre. Une étude préliminaire". La faisabilité de la prédiction de la qualité de rations pour les caprins par l'analyse des fèces par spectrométrie dans le domaine du proche infra-rouge (NIRS) a été étudiée chez douze chèvres Damascus, recevant des concentrés et du foin en pourcentage variable. Le coefficient de détermination (R^2) et l'écart-type de validation (SECV, un estimateur de la précision) de la prédiction du pourcentage de foin, la digestibilité d'après Tilley et Terry (%) et les contenus en MAT (%), NDF (%) et ADF (%) ont été de (0,99 ; 2,5), (0,98 ; 0,60), (0,96 ; 0,06), (0,98 ; 0,83) et (0,98 ; 0,81), respectivement. Les valeurs de R^2 et SECV de l'ingestion (g/jour/kg BW^{0,75}) de foin, MS totale, MS digestible (Tilley et Terry), MAT, NDF et ADF ont été de (0,88 ; 4,7), (0,69 ; 4,9), (0,66 ; 3,67), (0,57 ; 0,87), (0,72 ; 2,5) et (0,84 ; 1,78), respectivement. Ces résultats indiquent que le NIRS des fèces peut être un outil adéquat pour prédire la composition des rations, mais de moindre valeur pour établir l'ingestion absolue de leurs constituants.*

Mots-clés : *Nutrition, alimentation, NIRS, caprins.*

Introduction

Elucidating the diet of ranging goats is important for two reasons. First, goats are the most efficient animal in long-term strategies for brush control and ecological management of scrubland; and second, adequate nutrition is the key to productivity in goats. A most important step towards adequate nutrition is knowledge of their consumption. Such knowledge may be acquired by time-consuming observations and hand-clipped reconstituted diets (Kababya *et al*., 1998), but such methods are not relevant for farm conditions. In addition, they provide group, rather than individual data on goat nutrition.

The importance of faecal chemical composition in understanding nitrogen and energy status was demonstrated by Núñez-Hernández *et al*. (1992). The information concealed in faeces can provide information on the chemical (Leite and Stuth, 1995) and botanical (Walker *et al*., 2002) composition of intake in goats.

The NIRS methodology offers many advantages over standard methods used for dietary evaluation, and, in particular, low cost, chemical-free, rapid, and non-destructive analyses. In a pioneering study with esophageal fistulated goats, using NIR spectrometry of faeces, Leite and Stuth (1995) succeeded in obtaining NIRS predictive models explaining 94% of the variation in dietary CP (%), with an accuracy of 1.1%, and 93% of in vitro (Tilley and Terry, 1961) DM digestibility, with an

accuracy of 2.0%. However, it is unclear to what extent fistulated animals – from which diets were obtained – were representative of their free-grazing counterparts that contributed the faeces. In addition, the calibrations were based on a limited number of discrete wavelengths, whereas monochromators and chemometry software, such as that provided by ISI (1999), enable NIRS prediction equations based on a greater number of wavelengths in the whole NIR region.

In the framework of a project aimed at establishing methodologies to monitor Mediterranean ranging goat systems, the aim of this study was re-visiting the use of faecal NIRS to predict chemical diet attributes of goats.

Materials and methods

Location and facilities

This study was conducted during August – November 2002, in "Ramat-Hanadiv" park, south of the Carmel ridge, Israel. The animals used for this study are part of the "Ramat-Hanadiv" herd used for studies of grazing utilization by goats. The goat facility consisted of individual roofed dust-floor pens and a roofed collective corral, where animals were placed between trials. Pen dimensions were 1.7 x 1.7 m, i.e., large enough to allow for goats not to alter their daily patterns of intake or activity (Morand-Fehr *et al*., 1980). Pens were close together in order to reduce the cage effect on behaviour, as recommended by Meuret (1988). Each pen was outfitted with a 15-liter water bucket and a trough divided into two compartments for concentrate and hay separation. A shelf was placed under each trough to facilitate residue collection. Approximately 90% of hay residues fell onto the shelves. Pen sides were constructed of ½" metal bars with 10 cm spacing, so that animals could not access their counterparts' rations.

Animals and experimental design

The study consisted of four 10-day trials (8 adaptation days, 2 sampling days). Twelve Damascus yearling goats (mean weight of 38.5±0.7 kg) were penned separately during each trial. At each trial, goats were randomly divided into three groups. Each group received a diet featuring different hay-to-concentrate ratio (Table 1).

Table 1. Experimental design of the four trials (each group consists of 4 goats)

	Group	Percent of hay	Percent of concentrate	Diet weight (grams)
Trial 1	I	100	0	1100
	II	75	25	1100
	III	50	50	1100
Trial 2	I	100	0	1100
	II	75	25	1100
	III	50	50	1100
Trial 3	I	100	0	800
	II	50	50	800
	III	25	75	800
Trial 4	I	90	10	800
	II	60	40	800
	III	25	75	800

During all trials, goats were fed alfalfa hay and concentrate. Diets were weighed and distributed once daily each morning. On the morning of the sixth day, pens were thoroughly cleaned of any residue, before the distribution of rations. From the seventh day on, residue was collected every morning before feeding, and weighed. On the ninth and tenth days, faeces were grab-collected at

three different times, in the morning, midday and evening, in order to achieve better heterogeneity of digestion stages. Mean intake of days 6-9 was calculated as the daily intake value of each goat. Forty-six pairs of faeces and their relevant dietary information were used to obtain NIRS calibration models (two pair had missing information on diet intake and were not used for calibration purposes).

Reference data

Goats were weighed before every trial with a scale programmed to perform 100 weighs per second, on which the weight is read once the SE of weighing reaches a ±10 gram level. Feeds were weighed on a scale with ±0.5 gram accuracy. All samples (feed and faeces) were air dried at 60ºC for 48 hours in a ventilated oven and ground to pass through a 1 mm sieve. Samples were re-dried at 60°C for one hour and desiccated at ambient temperature for one hour before scanning. Crude protein (CP), neutral detergent fibre (NDF), and acid detergent fibre (ADF) were analysed according to AOAC (1984). In vitro digestibility of dry matter (IVDMD) was calculated according to Tilley and Terry (1961). The intake of hay, total dry-matter (DM), in vitro digestible DM, CP, NDF and ADF was calculated on a daily basis and expressed on live-weight and metabolic weight ($BW^{0.75}$) basis (g/day). All of these attributes were used as reference values in the NIRS calibrations (Table 2).

Table 2. Chemical composition of hay and concentrate fed to goats during trials

	Alfalfa hay	Concentrate
% DM	90.8	88.5
DM basis		
% CP	16.0	17.3
% ADF	36.9	7.1
% NDF	48.6	24.9
% IVDMD	65.0	85.0

NIRS analysis and statistics

All faeces samples (n = 46, 5 g DM) were packed into sample cells with a near-infrared transparent quartz cover glass and scanned between 1104-2492 nm in 2 nm increments using a Foss NIRSystems 5000 NIR reflectance (R) monochromator spectrometer (Foss, Tecator, Hoganas Sweden). Raw spectral data was transformed by using the standard normal variate (SNV) and detrend procedure against scattering distortion (Barnes *et al.,* 1989). Calibration equations were developed using the modified partial least-squares regression on the first derivative spectra (1,4,4,1), where the first digit is the number of the derivative, the second is the gap over which the derivative is calculated, the third is the number of data points in a running average or smoothing, and the fourth is the second smoothing (ISI, 1999). The ability of the calibration equation to predict external samples from the same population was assayed by cross-validation, using a rotating 1/6 of the samples for six times as an "internal" subset for the cross-validation procedure. Before data analysis was performed, outliers were identified and removed. Outliers were defined with cut-off values of 2.5 and 4 for "*T*" and "*H*" respectively (ISI, 1999). This resulted in the elimination of a maximum of two samples per calibration. The statistical measures of the calibration equation linearity and accuracy were the coefficient of determination (R^2) and the standard error of cross validation (SECV).

Results and discussion

The feasibility of the NIRS method was evaluated as a means of predicting the percentage or absolute values of some constituents and attributes of the diets served (Table 3). Values of R^2 and SECV for predictions of percentage of hay, CP, IVDMD, NDF, ADF were: (0.99, 2.5); (0.96, 0.06); (0.98,0.6); (0.98, 0.83); (0.98,0.81), respectively; and, for intake per kg metabolic BW ($g/kg^{0.75}$) of hay,

CP, digestible DM (DDMI), NDF, ADF and total DM: (0.88, 0.47); (0.57, 0.87); (0.66, 3.67); (0.72, 2.5); (0.84, ;1.78) and (0.69, ;4.9), respectively. Good correlations were found between predicted and actual values of constituent percentages, but good prediction was harder to obtain for absolute attributes (Table 4, Fig. 1). This agrees with results from cattle feedlot experiments conducted in Australia (Coates, 2000) where predictions of intake and DDMI (g/kgLW) were less accurate than for nitrogen (%) and IVDMD coefficient: (0.79,1.8) and (0.89, 1.03) vs (0.99, 0.087) and (0.97, 0.022), respectively. Similar results have been reported by Leite and Stuth (1995) for dietary percentage of CP for goats grazing small paddocks [R^2 = 0.93; SEV (corrected for bias) = 1.28)].

Table 3. Means, ranges and standard deviations of constituents and quality attributes of the diets

Constituent	Percent			Intake (g/kg $BW^{0.75}$)		
	Mean	SD	Range	Mean	SD	Range
Hay	70.6	23.6	25 -100	38.8	14.8	10.2-74.3
CP	16.36	0.32	15.7-16.9	8.9	1.5	6.7-11.9
IVDMD	70.9	4.7	65-79.9			
ADF	28.9	7.04	15.3-38.6	15.8	4.9	6.1-28.4
NDF	42.1	5.8	30.9-50.5	23.07	5.4	12.4-37.8
DDMI				38.6	6.84	27.3-54
Total DM				54.5	9.45	40.3-74.3

Table 4. Linearity (R^2) and accuracy (SECV) for the prediction of diet quality (percent) and intake of dietary constituents and quantity attributes

Constituent	Percent		Intake (g/kg $BW^{0.75}$)	
	R^2	SECV	R^2	SECV
Hay intake	0.99	2.5	0.88	4.7
CP	0.96	0.06	0.57	0.87
IVDMD	0.98	0.6		
ADF	0.98	0.81	0.84	1.78
NDF	0.98	0.83	0.72	2.5
DDMI			0.66	3.67
Total DM			0.69	4.9

Conclusions

The findings of the current study indicate that NIRS analyses of faecal samples method may provide a "quick and clean", practical and accurate methodology for farm use process for estimating attributes of diets consumed by goats at farm level. This study and others presented here indicates that NIRS is a very powerful tool for predicting the percentage of diet attributes, whereas it is harder to extract the information regarding absolute values of dietary attributes by this method and this aspect requires further investigation. One of the major practical advantages of faecal NIRS, is the ability to monitor individual animals, as well as the entire herd. By monitoring individual animals the farmer can obtain information about efficiency of the individual animal and consider this information in further management decisions. This study, as well as other previous studies, may help in establishing an adequate system of diet monitoring of grazing goats that will improve animal health and production management systems.

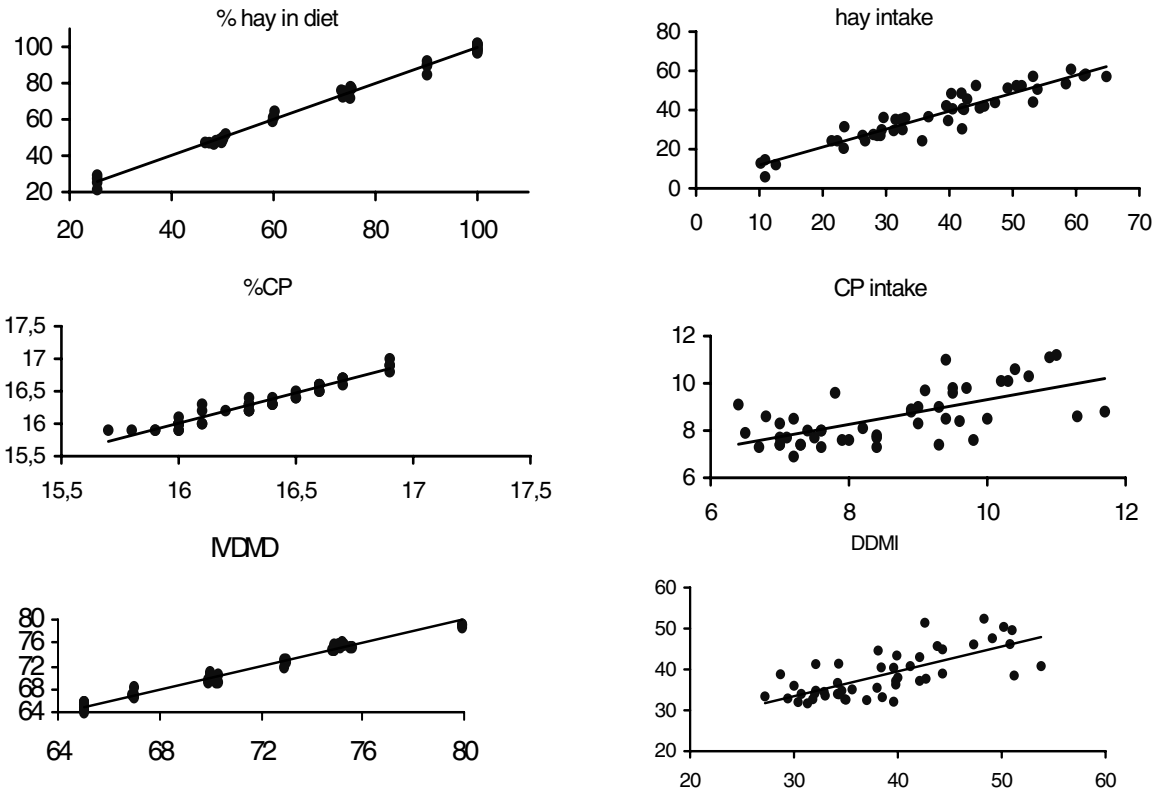

Fig. 1. Actual (x-axis) as compared to predicted (y-axis) constituents: the left and right columns represent percentages and intake (g/day/kg BW $^{0.75}$) of constituents, respectively.

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