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Faecal NIRS to monitor the diet of Mediterranean goats

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Abstract

A method to establish the diet of goats in ligneous environments is needed. Twelve Damascus yearlings were subjected to 12 test periods in which days 1-7 were for adaptation, intake was recorded on days 8-10 and faeces were grab-sampled on days 9-10, resulting in 143 pairs of diets and faeces. Diets consisted of hay and concentrate given in different ratios (n = 60), or combinations of three species browsed by goats (*Pistacia lentiscus, Phyllirea latifolia,* and *Pinus Brutia)* and concentrate (n = 83). Faeces were scanned in the 1,100-2,500 nm range by aid of a Near Infrared Spectrometer. Chemical and botanical percentage (% of DM) and actual (g/d) intake values were then fitted to reflectance values. Values for R^2 and the standard error of cross validation (SECV), used as estimates of calibration quality for component percentages were: CP, 0.98, 0.5; NDF, 0.94, 1.5; *in vitro* DMD, 0.98, 2.0; PEG-binding tannin, 0.96, 1.0; hay, 0.99, 5.5; concentrate, 0.95, 4.5; total browse, 0.97, 6.1; *P. lentiscus*, 0.95, 7.1; *P. latifolia*, 0.94, 7.0; and *P. brutia*, 0.95, 6.5. Values for R^2 and SECV of intake (g/d) were: DM, 0.83, 126; CP, 0.75, 12; NDF, 0.79, 56; *in vitro* digestible DM, 0.74, 58; PEG-binding tannin, 0.92, 20; hay, 0.97, 67; concentrate, 0.95, 41; total browse, 0.87, 180; *P. lentiscus*, 0.93, 106; *P. latifolia*, 0.85, 194; and *P. brutia*, 0.85, 151. Chemical composition (% DM) can be predicted from faeces spectra as accurately as from direct analyses of feeds. Predictions of nutrient and botanical intake (g/d) are less accurate but still relevant for monitoring purposes.

Keywords: Ruminant nutrition, range management, near infrared, Mediterranean pasture, grazing
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Introduction

Goats are used for brush control and ecological management of Mediterranean scrubland (Perevolotsky & Seligman, 1998). Farmers are willing to co-operate with communities in this important role on condition that profitability is not impaired, i.e. the diets of goats are compatible with their production goals. They need a method to evaluate the daily intake of nutrients in order to supplement the animals, if needed. In heterogeneous environments, this information can be acquired by time-consuming observations and hand-clipped reconstituted diets (Kababya *et al*., 1998), but such technology is not applicable for farm conditions. In addition, it provides group and not individual data on goat nutrition. The n-alkane method can provide reliable information, provided that individual correction is made for alkane recovery in the faeces (Brosh *et al*., 2003), but analytical costs make it unsuiatble for farm studies.

The importance of faecal chemical composition in understanding nitrogen and energy status was demonstrated by Nunez-Hernandez *et al*. (1992). The chemical information concealed in faeces can provide information on the chemical (Leite & Stuth, 1995) and botanical (Walker *et al*., 2002) composition of intake in goats. The Near Infrared Spectrometry (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 oesophageal-fistulated goats, using NIR spectrometry of faeces, Leite & Stuth (1995) succeeded in explaining 94% and 93% of the variation in dietary crude protein (CP) and *in vitro* (Tilley & Terry, 1961) digestibility (% of dry matter, DM), with respective accuracies of 1.1 and 2.0%. A further step was achieved by Coates (2000) who developed prediction equations for the DM intake (DMI) and digestible DMI (DDMI) in terms of g/d/kg BW in penned cattle.

In the frame of a program aimed at establishing methodologies to monitor Mediterranean ecosystems, this study was a preliminary step to establish NIRS calibrations for dietary composition and intake in ranging goats.

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Materials and Methods

Twelve Damascus yearling goats (mean weight of 38.5 ± 0.7 kg) were used for this study that was conducted south of the Carmel ridge, Israel. The goat facility consisted of roofed individual dust-floor pens and of a roofed collective corral where animals were placed in between tests. Pen dimensions were 1.7 x 1.7 m, i.e. large enough to allow goats not to alter their daily patterns of intake or activity. Pens were close together in order to reduce the cage effect on behaviour. Each pen was outfitted with a 15 L water bucket and a trough divided into two compartments for concentrate and hay separation. A shelf was placed under each trough in order to facilitate residue collection.

Table 1 Composition of diets during the tests

Period	Dietary components	Dry matter (DM) intake (g/d)	Percentage of component in diet (% of DM)
1	Lucerne hay	746	79.5
	Concentrate	195	20.5
2	Lucerne hay	709	74.4
	Concentrate	243	26.5
3	Lucerne hay	423	57.2
	Concentrate	322	42.8
4	Lucerne hay	535	75.1
	Concentrate	177	24.9
5a	*P. lentiscus*	724	61.8
	Concentrate	442	38.2
5b	*P. latifolia*	589	56.2
	Concentrate	442	43.8
6a	*P. lentiscus*	560	55.2
	Concentrate	442	44.8
6b	*P. latifolia*	734	61.5
	Concentrate	442	38.5
7a	*P. lentiscus*	931	72.7
	Concentrate	348	27.3
7b	*P. latifolia*	1311	78.8
	Concentrate	348	21.2
8	*P. lentiscus*	246	19.7
	P. latifolia	646	52.2
	Concentrate	348	28.1
9	*P. brutia*	895	71.0
	Concentrate	364	29.0
10	Clover hay	406	57.8
	Concentrate	321	42.2
11	*P. brutia*	317	29.8
	P. lentiscus	466	44.1
	Concentrate	277	26.1
12	*P. brutia*	301	23.7
	P. lentiscus	233	18.7
	P. latifolia	429	35.0
	Concentrate	278	22.6

Diets consisted of hay and concentrate given in different ratios, or combinations of three species browsed by goats (*Pistacia lentiscus, Phyllirea latifolia,* and *Pinus Brutia)* and concentrate (Table 1). Browse branches were cut daily. Diets were weighed and distributed once every morning. The study consisted of twelve 10-day tests. On the morning of the day 6, pens were thoroughly cleaned of any residues before the distribution of rations. On days 7 to 10, residues were collected every morning before feeding and weighed. Feeds were weighed on a scale with ± 0.5 g accuracy. On days 9 to 10, faeces were grab-collected at three different times in the morning, midday and evening in order to reach better heterogeneity of

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digestion stages. Mean intake of days 6 to 9 was calculated as the daily intake value of each goat. This procedure resulted in 144 pairs of faeces and diet of which one had missing information on diet intake and was not used for calibration purposes. The calibration data consisted of 60 pairs resulting from hay-and-concentrate diets and 83 diets comprising browse species. All samples (feed and faeces) were air-dried at 60 °C during 48 hours in a ventilated oven and ground to pass a 1 mm sieve. Samples were re-dried at 60 °C for one hour and desiccated at ambient temperature for 1 hour before scanning. Crude protein, neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analysed in diets according to AOAC (1984). *In vitro* digestibility of dry matter (IVDMD) was according to Tilley & Terry (1961). PEG-binding tannins were assessed as described by Landau *et al*. (2004). All these attributes in percentages, botanical composition and intake values were used as reference values in the NIRS calibrations.

Faeces samples 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). The calibration of Log (1/R) against wavelengths was carried out, using the (1, 4, 4, 1) procedure, i.e., first derivative of transformed spectra, 4 nm gaps and 4 nm smoothening value, or the (2, 6, 6, 2) procedure, in order to overcome particle size and light scatter distortions (ISI, 1999). The (2,6,6,2) procedure was also used. Calibration equations were developed on the treated spectral data, using the Modified Partial Least-Squares using WinISI II software (ISI, 1999). Before data analysis was performed, outliers were identified and removed (ISI, 1999). In order to widen the range of attribute in calibrations, up to 20% "zero" samples were added in calibration sets, e.g. 12 samples of faeces from diets that did not contain hay were added to 60 samples from diets that did contain hay for calibration of hay percentage in diets.

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. The statistical measures of the calibration equation prediction ability and accuracy were the coefficient of determination (R^2) and the Standard Error of Cross Validation (SECV).

Results and Discussion

Table 2 Prediction of chemical dietary attributes in diets (% of DM) and intake (g/d) for the whole data set (n = 143). PEG-binding tannins have been calibrated for the browse data (n = 83) only. First[1] or second[2]-derivatized spectra were used for calibration

		Reference values			Calibration performance		
Constituent	Outliers	Mean	s.d.	Range	R^2	SEC	SECV
% of DM							
CP[2]	7	12.2	2.9	7.7-16.9	0.98	0.4	0.53
NDF[2]	5	37.9	5.6	28.5-50.1	0.94	1.4	1.53
DDM[2]	9	60	10.8	41.3-80	0.98	1.65	1.98
PEG-binding tannins[2]	2	6.15	4.5	0.29-15.6	0.96	0.85	1.07
g/d							
DM[2]	7	1031	249	552-1874	0.83	101.7	126.4
CP[2]	7	121	21.2	61-193	0.75	10.5	12.3
NDF[2]	4	386	96	179-690	0.79	44.3	55.8
DDM[2]	7	599	95.3	352-950	0.74	48.2	57.8
Tannin[1]	6	4	306	0.26-12.4	0.93	0.79	1

DDM – digestible dry matter

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The calibrations of dietary chemical attributes in percentages were of high linearity (all R^2 above 0.94, Table 2). Accuracy and linearity values for CP and DDM (%) are higher than those by Leite & Stuth (1995). This could be because the same animals provided diet estimates and faecal spectra in our study, whereas diets were obtained from fistulated animals while free-grazing non-fistulated counterparts 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 greater number of wavelengths (700) in the whole NIR region. Interestingly, the quality of the prediction of chemical composition is as good from faecal spectra as from feed spectra, as noted before by Lyons & Stuth (1992). Garcia-Ciudad *et al.* (1993) reported a R^2 value of 0.95 and SECV's of 1 and 2% for CP and NDF, respectively. We get similar accuracy in our lab for composite vegetation collected on pastures. Landau *et al*. (2004) reported accuracy of 1.6% in the prediction of PEG-binding directly assessed in browse, compared with 1.1% in this study when established from faecal spectra. In other words, our study corroborates the view that the assessment of dietary value from faeces is as accurate as from feed components, but feed components are unknown in ranging animals and faeces are always available.

Calibrations of the intake of nutrients were less linear and accurate than those of percentages (Table 2), as noted before by Coates (2000) in cattle. Expression of reference values on kg BW or kg $BW^{0.75}$ basis did not improve calibrations, compared with absolute daily (g/d) values. Even though prediction of intake values are relatively uncertain, two calibrations have special nutritional value. Dietary CP is the first limiting factor in ranging animals. In many situations prediction of CP intake with an accuracy of 12 g/d determines the decision whether to supplement goats or not. Similarly, the prediction of PEG-binding tannin at the accuracy of 1 g/d reflects the intake of browse, and can help to decide whether or not to supplement goats with PEG in order to alleviate the effects of tannin (Landau *et al*., 2000).

Table 3 Prediction of botanical components in diets (% of DM) and their intake (g/d) in the whole data set (n = 143). PEG-binding tannins have been calibrated for the browse data (n = 83) only. R^2 and the standard errors of calibration (SEC) and of cross-validation (SECV) serve as estimates of prediction quality. First[1]-or second[2]-derivatized spectra were used for calibration

Constituent			Reference values			Calibration performance		
Component	n	Outliers	Mean	S.D.	Range	R^2	SEC	SECV
% of DM								
Hay[2]	72	0	56.7	34.8	0-100	0.99	3.6	5.5
Concentrate[1]	143	5	31.1	17	0-76	0.95	3.7	4.5
Total browse[1]	100	3	58.6	27	0-83	0.97	4.6	6.1
Pistacia lentiscus[2]	65	0	32.7	23.9	0-76.5	0.95	5.4	7.1
Phylirea latifolia[2]	49	1	45.2	23.6	0-81.4	0.94	5.6	7.0
Pinus brutia[1]	43	1	35.5	25.5	0-78	0.95	5.7	6.5
g/d								
Hay[2]	72	0	460	298	0-989	0.97	47.6	67
Concentrate[1]	143	5	309	150	0-577	0.95	33.7	40.6
Total browse[2]	100	0	709	380	0-1526	0.87	137	180
Pistacia lentiscus[1]	65	1	376	289	0-1130	0.93	76.5	106
Philyrea latifolia[2]	49	0	573	379	0-1526	0.85	146	194
Pinus brutia[2]	43	0	422	340	0-1186	0.85	130	151

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The prediction of botanical percentages (Table 3) is of high linearity ($R^2 > 0.94$), but the accuracy of prediction is less than for chemical attributes in the diet (Table 2). The accuracy reached here is similar to that achieved by Walker *et al.* (2002) for the prediction of percent sagebrush (determination of one species, in mixtures of three) in sheep by faecal NIRS and by Brosh *et al.* (2003) with n-alkanes, after correction for alkane recovery. However, it must be remembered that the method proposed here requires no extraction, and no individual correction for marker recovery. Predictions of the intake of individual botanical species had unexpectedly relatively high R^2 values and accuracies high enough for monitoring purposes.

Conclusion

It seems that the faecal NIRS method may provide a "fast and clean" practical and accurate method for farm-use process for estimating diet attributes of diets consumed by goats. The prediction of botanical components by faecal NIRS is novel for goats. One of the major practical advantages of faecal NIRS is the ability to monitor individuals as well as the whole herd. By monitoring individual animals the farmer can obtain information about efficiency of the individual animal and consider this information in further management decisions. Even though the calibrations presented here can be considered a methodical breakthrough in our ability to reach dietary information in goats, their robustness has yet to be ascertained under field conditions.

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