

Assessing diet quality of African ungulates from faecal analyses: the effect of forage quality, intake and herbivore species

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Faecal phosphorous and nitrogen can be used as indicators of the nutritive content of the veld. Dietary P concentrations can be predicted with reasonable accuracy from faecal P concentrations in faeces of caged impala rams using a simple linear regression model, $Y = 0.393X$ ($r^2 = 0.97$). This regression holds whether impala are grazing or browsing as well as for high and low levels of intake. The regression equation used in the prediction of dietary P in zebra, blue wildebeest and cattle, did not differ significantly from this simple regression and a combined regression equation could be formulated. A faecal P concentration of less than 2 g P/kg OM would appear to indicate a P deficiency in most species. The prediction of dietary N is influenced by the intake of phenolic compounds and different regression equations exist for grazers and browsers. For prediction of dietary N concentrations, both the concentration of N and P in the faeces should be taken into account. This multiple regression equation is applicable for grazing impala at all levels of intake. For impala utilising browse, a regression model with faecal Acid Detergent Insoluble Nitrogen (ADIN) and Acid Detergent Lignin (ADL) should be used to predict dietary N concentration. For grazers, a faecal N concentration of less than 14 g/kg DM would indicate a deficiency. Dietary digestibility can be predicted accurately in some species using faecal N, P and ADL concentrations. However, more work needs to be done to quantify their effects.

Key words: faecal analysis, dietary P prediction, dietary N prediction, browse, low intake, forage quality, dietary digestibility, zebra, impala, blue wildebeest, cattle.

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Introduction

Nutrition directly affects the survival and fertility of ungulates, thus the determination of nutritional status is of importance. Forage quality estimates have been used to determine nutritional status, but these estimates may not accurately reflect dietary quality (Cook *et al.* 1994), due to selection. Other methods used to determine nutritional status are fistulation and slaughtering of animals, which are both impractical and expensive

and may also be socially objectionable. An alternative could be to use a chemical characteristic of faeces that is related to the quality or quantity of ingested diets (Holechek *et al.* 1982b). Faecal samples are both inexpensive and easy to collect. Faecal nitrogen (N) has been found to be positively correlated with dietary protein (Holechek *et al.* 1982a; Mould & Robbins 1981, Wofford *et al.* 1985), intake (Arnold & Dudzinski 1963), dietary dry matter digestibility (Greenhalgh & Corbett 1960; Leslie & Starkey 1985) and

weight change in mature game species (Gates & Hudson 1981). These positive relationships permit the use of chemical composition of faeces as an index of the quality of available forage.

Researchers have used faecal nutrient levels to predict dietary nutrient levels in elk (Leslie & Starkey 1985, Mould & Robbins, 1981), black-tailed deer (Leslie & Starkey 1985), white-tailed deer (Jenks *et al.* 1989), moose (Leslie *et al.* 1989), duiker, eland, hartebeest, mule deer, Thomson's gazelle (Robbins 1983) and domestic livestock (Belonje 1980; Belonje & Van den Berg 1980; Grant 1989; Holechek *et al.* 1982; Moir 1960).

Monitoring and comparing faecal components for several herbivore species in different areas should give insight into their nutritional ecology and give an indication of marginal areas and critical times (Erasmus *et al.* 1978). This becomes important in the veld since, in certain areas and at certain times of the year shortages occur with N being the most limiting nutrient in winter (dry season) on natural pastures in Africa (Bell 1971) and phosphorous (P) the most limiting mineral (Du Toit *et al.* 1940). Phosphorous is claimed to be deficient in the whole of South Africa with the exception of the scrub bushveld (Bothma 1989). Where P deficiency occurs, growth and reproduction in large mammalian herbivores are hampered (Grassman & Hellgren 1993).

Moir (1960) and Belonje (1980) proved that faecal P correlates well with P intake. According to Grant *et al.* (1995), both faecal N and faecal P should be used in conjunction when predicting the nutritional status of wild herbivores because their excretions are linked (Grant 1989; Moir 1966). Both P and N were thus examined in this paper. A calibration study was undertaken with a combination of different P and N levels in the diets in order to predict dietary concentration from

P and N excretion. Factors which may affect this relationship were examined, e.g. the presence of tannins in browse which may increase faecal N excretions and so bias the prediction of dietary quality and level of intake (Mould & Robbins 1981; Read 1984), while individual differences in intake will affect faecal output and dietary digestibility. We examined the possibility of extrapolating these results, using faecal analyses to aid the nutritional management of game, and possibly cattle, on natural grazing. For this purpose results of faecal indices in predicting dietary intakes and digestibilities in blue wildebeest *Connochaetes taurinus*, impala *Aepyceros melampus*, zebra *Equus burchelli* and cattle were examined.

Methods

The effect of varying P and N concentrations in food on P and N in faeces

Four impala rams, caged separately, were used. Cages consisted of an enclosed interior area which contained the feeding troughs and an open exterior area which was used by the impala to defecate. Pelleted diets were formulated with different P and N levels (Table 1). For trial 1, four different diets were fed using a change-over design, with each animal receiving 1000 g of concentrate per day and lucerne or grass *ad lib* depending on the trial. The other trials were done with three animals. These diets were formulated to establish what effect different levels of P intake and different levels of N intake had on P and N excretion. The lucerne/hay intake was determined by weighing the hay supplied each day, and again weighing the remainder before the next feeding.

For the duration of the trial, faeces were collected every morning at the same time, after the impala were fed. Faecal samples were collected from a clean cement floor. Clean unbroken pellets, representing 10 % of the total faecal output, were collected and frozen at 40 °C. The rest of the faeces were weighed accurately to determine total faecal output for each day of the trial.

In order to determine the period that animals should be adapted to an experimental diet, animals were fed the same diet for one month, during which faecal

samples were collected every week. Faecal concentrations reflected the higher concentrations of a previous diet for one week only, therefore an adaptation period of one week was used in the experiment (Wrench 1996).

The effect of level of intake on P and N in faeces

To examine the effect of a restricted food intake, simulating drought or winter conditions, the amount of concentrate (Table 1) that the animals received was halved to 500 g and the lucerne intake was restricted to half of what each animal ate *ad lib*. Faeces were collected as described for trial 1.

The effect of the intake of browse on P and N in faeces

Browse intake has been reported to have an effect on the reliability of dietary N prediction from N concentrations in faeces, due to the protein-binding effect of tannins (Robbins *et al.* 1987). The bush species selected for this trial represented different levels of tannins (Furstenburg 1991). The bush with the lowest tannin (Furstenburg 1991) and the most palatable (Wentzel 1990), was buffalo thorn (*Ziziphus mucronata*) (0.905 %). Red bushwillow (*Combretum appiculatum*) and wild raisin (*Grewia*

spp) were fed to provide higher levels of tannins (17.26 % and 52.05 % respectively).

Browse was provided in the form of fresh shoots and leaves that were cut daily. The exact amount provided was determined each day. This was twice as much as the *ad lib* amount of lucerne eaten, to compensate for the fact that not all the browse that was provided would be eaten. This browse was supplemented with 1000 g of concentrate (diet no. 5). The overnight moisture loss was taken into account when the remaining browse was weighed back the following day.

The effect of low digestibility on P and N concentrations

To examine the effect of lower digestibility, animals were fed diets with a lower digestibility and comparable P and N concentrations (Table 1). Each animal received 1000 g concentrate and lucerne *ad lib*.

The effect of varying levels of P and N intake on P and N excretion in free ranging herbivores

P and N intakes and excretions were determined for blue wildebeest and zebra (Bodenstein unpublished) and for impala utilising browse and grazing (Meissner *et al.* 1995) on veld in camps in the Hans

Table 1
Experimental design and composition of diets fed

Composition	Diet number	P (g/kg OM)	N (g/kg DM)	Digestibility (DM)(%)	SD
Varying P, High N	1	2	20.8	67.7	2.55
	2	2.6	20.8	64.3	2.05
	3	3.2	20.8	61.5	3.57
	4	3.8	20.8	62.2	3.31
Low P, Medium N	5	1.4	13.3	62.9	2.89
Low P, Low N	7	1.5	10.2	61.3	5.04
High P, Medium N	6	3.1	13.6	64.3	4.79
Low P, Medium N	9	1.9	15.2	60.6	8.65
High P, Low N	8	2.5	11.8	60	5.07
Low intake	10	2.1	12	58.1	5.65
1/2 Pellets	11	2.6	13.6	54.5	4.85

Hoheisen Research Station in the Timbavati Nature Reserve bordering the Kruger National Park. This was compared to P and N excretion of cattle on natural grazing without supplementation in the mountain savanna area of Namibia (Grant 1989).

Preparation and analysis of samples

After the trial, faecal samples were unfrozen, mixed well, and 50 g was dried in an oven at 60 °C to constant weight. This was used to determine moisture content. The dried sample was milled in a Tecater mill using a 1mm sieve. Representative samples of the concentrates, hay, browse and lucerne were collected from the feed fed daily during each trial. These samples were dried in an oven at 60 °C to constant weight and then milled in a Tecater mill with a 1mm sieve.

Nitrogen was analysed according to the Kjeldahl method (AOAC 1984) and expressed on a dry matter (DM) basis. Phosphorus was determined by wet digestion according to Heckman (1968). A diluted sample was read against the following standards: 10, 30, 50, 80 and 100 mg/kg P in a spectrophotometer and expressed on an organic matter (OM) basis. ADF and ADL were determined by the Dosi Fibre method (Goering & Van Soest 1970).

ADIN was determined by doing an ADF analysis (Goering & Van Soest 1970) after which the remainder was submitted to the Kjeldahl method (AOAC 1984).

Statistical analyses

Simple and multiple regression analyses were used to set up regression models. Student's *t*-tests were used to test the difference between groups of samples. *T* tests adapted according to Zar (1974) were used to test for differences between slopes and intercepts of regression equations.

The distribution of points in data sets were tested with the Kolmogorov-Smirnov Two Sample test (Statgraphics Version 7.0).

Results

Prediction of dietary P

When P was fed at concentrations varying from deficient P to excess P, with varying N levels in the diet but with constant digestibili-

ty, dietary P concentration could be predicted by a simple linear regression equation using faecal P concentrations ($Y = 0.34X + 0.28$; $r^2 = 0.67$). Since, the intercept was not significantly different from zero, the regression could be simplified by forcing it through the origin ($Y = 0.39X$, $r^2 = 0.97$). When the effect of restricted intake on faecal P concentration was examined the prediction of dietary P concentration from faecal P concentration was weaker than before ($r^2 = 0.58$). The intercept and slope of this regression equation, however, were not significantly different from the intercept and slope of the original prediction model.

The data from trials where animals were fed browse was added to the original prediction model, the slope of the regression model did not change significantly nor did the standard error increase significantly. The intercept also did not differ significantly from zero. When data from the trials with lower digestibility were added to the original prediction model the r^2 of the regression weakened slightly ($r^2 = 0.65$) but did not change significantly. The prediction equation for P in the diet from P in faeces was not significantly changed when animals were fed diets

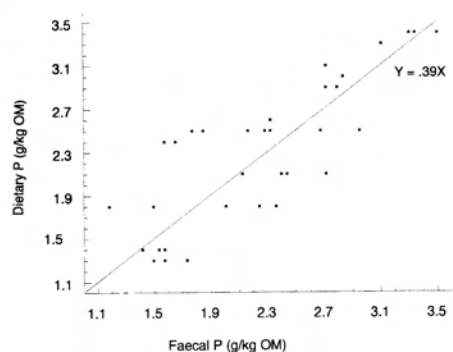


Fig. 1. Simple linear regression predicting dietary P concentration from faecal P concentration for varying N and P levels, browse data, restricted intake and low digestibility data, passing through the origin for the impala calibration trial.

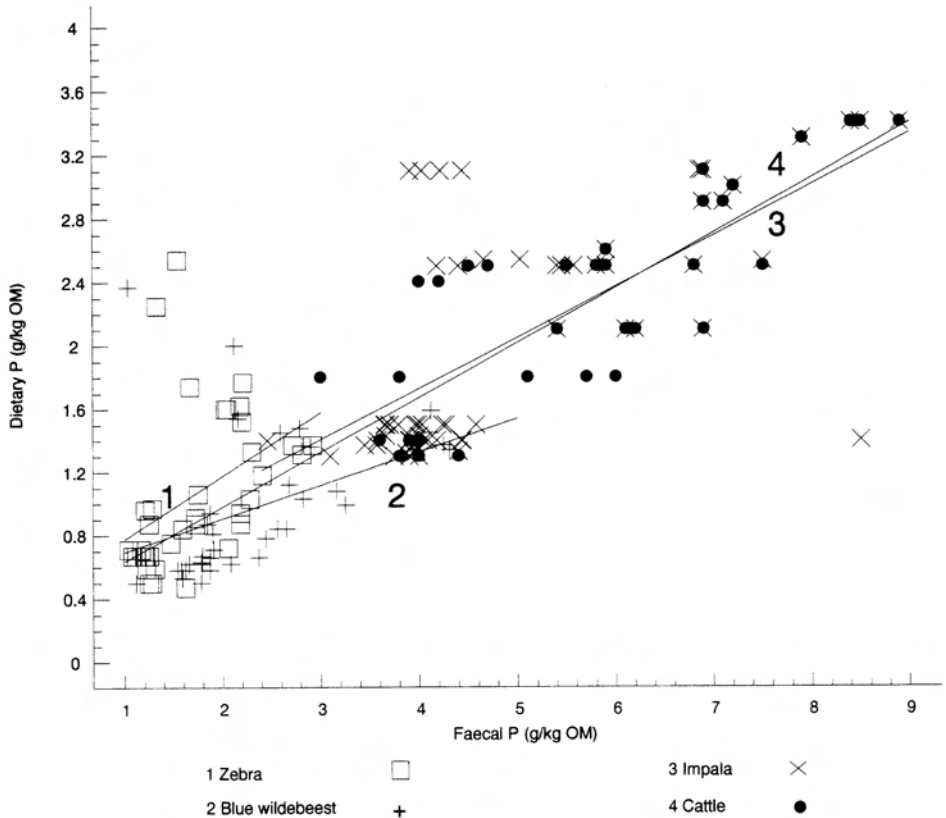


Fig. 2. Simple linear regressions predicting dietary P intake from faecal P for different species.

of low digestibility, diets with restricted intake and diets with high tannin levels therefore, one regression equation, $Y = 0.39X$ passing through the origin could be used to predict dietary P intake ($r^2 = 0.96$) (Fig. 1).

Prediction of dietary P for free ranging herbivores

The simple prediction models for impala, zebra, blue wildebeest and cattle are displayed in Table 2 and Fig. 2.

When the blue wildebeest model (Table 2) was compared to the impala model (Table 2), the slopes of the two models differed significantly ($P < 0.05$). However, as the range of

dietary P of the blue wildebeest was at the lower part of the graph compared to that of the impala, the Kolmogorov-Smirnov Two Sample test was used, which indicated that the distribution points of the two models did not differ significantly (Estimated overall statistic D.N.= 0.701). Therefore, the data from the blue wildebeest was added to the prediction model of the impala and the slope of this model did not differ significantly from the impala model. When the prediction model of the zebra data was compared to that of the impala model, no significant differences were found between either the slopes or the intercepts of the two models. The two data sets were therefore combined in one model without the slope of the regression

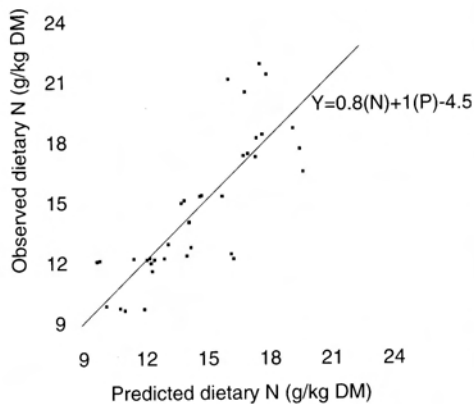


Fig. 3. Multiple regression predicting dietary N concentration from faecal N and P concentrations for the impala prediction model.

equation changing significantly. There was also no significant difference between the slopes and intercepts of the models of the cattle and the impala data. Adding the two sets of data did not alter the slope of the regression equation significantly. All data were subsequently combined into a single regression model $Y = 0.33X + 0.37$; $r^2 = 0.66$, of which the slope did not differ significantly from the impala model, indicating that when data for all four species were com-

ined into one prediction model this equation did not differ significantly from that of the individual species.

Prediction of dietary N

When diets were supplied which allowed high to low levels of P and N intake, 63 % of the variation in dietary N concentration could be explained by faecal N concentration ($Y = 1.27X - 7.93$). When P concentration in the faeces was also taken into account, dietary N could be predicted more accurately with an $r^2 = 0.71$. ($Y = 0.8(N) + 1(P) - 4.5$) (Fig. 3).

This was still true when the data from animals with restricted intakes was added rendering an r^2 of 0.6 ($Y = 0.75(N) + 0.74(P) - 5.01$). When the effect of browse on the prediction of dietary N from faecal N was examined, it was found that the regression had a significant negative slope and very high significant intercept ($Y = -0.56X + 28.37$; $r^2 = 0.27$). The slope and the intercept differed significantly from the original impala prediction model. This poor prediction could be explained by the fact that faecal N includes tannin-bound protein and

Table 2
Simple linear regression equations predicting dietary P(Y) (g/kg OM)
from faecal P (X) (g/kg OM) for different species

Species	r^2	b	c	SE of b	SE of c	n	SE	P	Dietary N range	Dietary P range
Impala calibration trial	0.67	0.34*	0.28	0.24	0.04	36	0.35	0.00	9.7-20	1.3-3.8
Blue wildebeest	0.14	0.21*	0.48*	0.08	0.21	36	0.41	0.02	4.3-12.6	0.45-2.37
Zebra	0.18	0.40*	0.37	0.14	0.37	36	0.45	0.01	4.6-12.5	0.5-2.54
Cattle	0.45	0.32*	0.44	0.04	0.23	65	0.54	0.00	9.6-20	1.3-3.4
All data	0.66	0.33*	0.37*	0.01	0.07	174	0.47	0.00	4.3-21.9	0.45-3.8

* significant difference from control ($P < 0.05$)

b = slope;

c = intercept;

SE = standard error

non-digested fiber-bound protein (Robbins *et al.* 1987). To address this problem faecal ADIN was used as a predictor of dietary N to represent the insoluble or non-digested N, and faecal ADL concentration was added as an indicator of lignin. This explained 64 % of the variation of dietary N ($Y = 0.036 (ADIN) + 0.05 (ADL) + 4.2$)

When the effect of the extremely high tannin levels (tannin levels ADL >210g/kg), were removed from the above prediction model, as in nature it is unlikely that the animals would eat such large amounts of low quality browse, the prediction of the model using faecal ADL and faecal ADIN concentrations as predictors of dietary N improved ($Y=0.1(ADIN) + 0.05 (ADL) + 0.1, R^2 = 0.83$)

Low digestibility affects the accuracy of the prediction of dietary N. Data from trials with lower digestibility added to the prediction model of the first three trials, resulted in a weaker prediction. In the multiple regression the effect of N decreased $Y = 0.67(N) + 0.92(P) - 2.8; R^2 = 0.47$.

The prediction of dietary N for free ranging herbivores

The results of the simple regression models for prediction of dietary N concentration from faecal N concentration are displayed in

Table 3 and Fig.4. For the field data of impala a simple model was used to predict dietary N concentration (Table 3). The slope and intercept of this regression differed significantly from that derived from the impala calibration trial. This is most likely due to the intake of browse during this study (Meissner *et al.* 1995).

The slope and intercept of the simple prediction model to predict dietary N from faecal N concentration in blue wildebeest and cattle differed significantly to that of the impala (Table 3). In the case of zebra, only the intercept differed significantly from the model predicting dietary N from faecal N for impala.

There was no significant difference between the prediction models of the blue wildebeest and the zebra and the intercept was not significant so the line was passed through the origin ($Y = 0.81X; r^2 = 0.92$) showing that faecal N explained 81 % of the variation in dietary N.

Digestibility prediction for free ranging herbivores

Faecal indices were tested in regression equations to determine whether some of the faecal indices could be used as predictors of dietary digestibility. Faecal N, P and ADL were tested. Faecal N has been reported to be

Table 3
Simple regression equations to predict dietary N (g/kg DM) from faecal N (g/kg DM) for different species

Species	r ²	b	c	SE of b	SE of c	n	SE	P	N range	P range
Calibration trial	0.63	1.24*	-6.9	0.16	2.99	36	2.33	0.00	9.7-20	1.3-3.8
Impala field data	0.34	0.83*	3.8	0.14	1.84	64	2.86	0.00	9.76-22	1.3-3.8
Blue wildebeest	0.45	0.84*	-0.97	0.15	1.59	36	2.1	0.00	4.3-12.5	0.45-2.37
Zebra	0.41	0.95*	-0.4	0.18	1.63	36	2.2	0.00	4.6-12.5	0.5-2.54
Cattle	0.46	0.9*	-1.6	0.12	2.08	64	2.67	0.00	9.6-20	1.3-3.4*

*Significant difference from control ($P < 0.05$).

b = slope; c = intercept; SE = standard error

a reliable indicator of dietary digestibility (Lancaster 1949; Greenhalgh & Corbett 1960; Holloway *et al.* 1981) whereas a relationship between dietary digestibility and lignin content was reported by Pietersen (1991). As faecal N and P excretions are linked we thought that faecal P might be able to predict dietary digestibility. Faecal N, P and ADL were tested. For the calibration trial with impala the best prediction was from the combination of faecal N, P and ADL concentrations ($r^2 = 0.41$). For blue wildebeest faecal N ($r^2 = 0.63$) as well as the combination of faecal N and ADL ($r^2 = 0.64$) gave satisfactory predictions. For zebra faecal N ($r^2 = 0.63$) as well as the combination

of faecal N, P and ADL ($r^2 = 0.72$) gave satisfactory predictions. Using faecal indices a fair indication of digestibility could be obtained (Table 4). As these equations are vastly different no overall prediction equation for digestibility can be offered from this study.

Discussion

From this study it appears that dietary P can be predicted with reasonable accuracy from faecal P under variable circumstances. This corresponds with the findings of Leslie & Starkey (1985) for free ranging elk and deer, Howery & Pfister (1990) for white-tailed

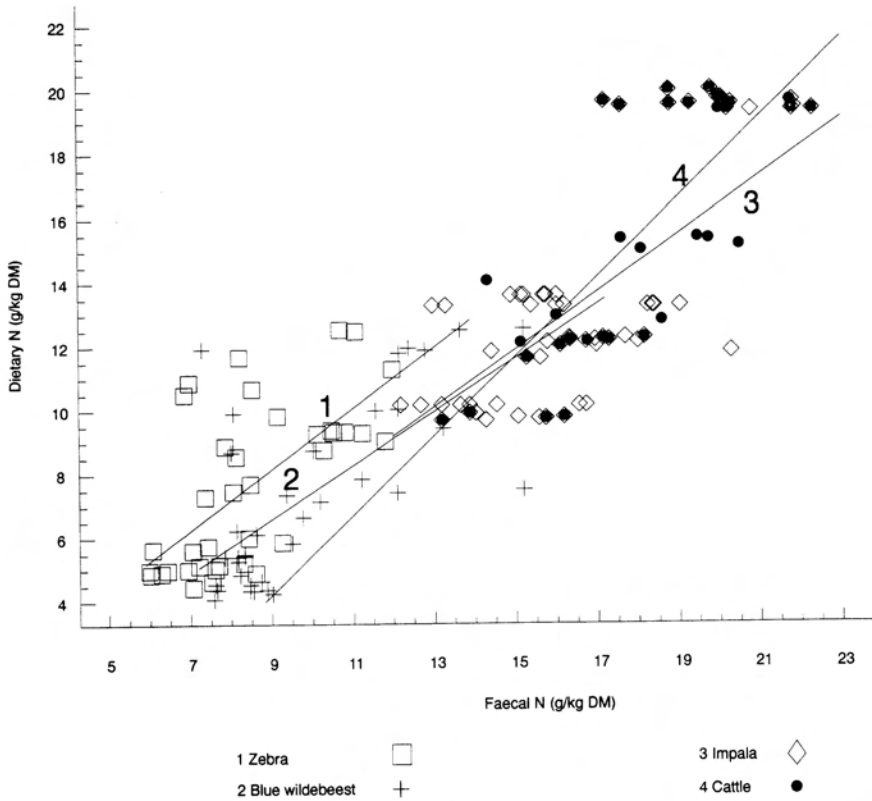


Fig. 4. Simple linear regressions predicting dietary N intake from faecal N for different species.

Table 4
Simple regression equations to predict dietary digestibility (g/kg DM) from faecal P (g/kg OM), N (g/kg DM) and ADL (g/kg DM)

Species	Indices	r ²	b	c	SE of b	SE of c	n	SE	P
Calibration trial	N	0.26	14.6	35.7	4.16	7.68	36	6.22	0.001
Calibration trial	P	0.06	11.1	55.1	7.04	4.02	36	7.01	0.12
Blue wildebeest	P	0.12	42.6*	33.1*	19.7	4.77	36	9.21	0.03
Blue wildebeest	N	0.63	34.3*	9.1	4.45	4.49	36	7.9	0.00
Blue wildebeest	ADL	0.12	-2.66*	81.2	1.19	17.2	36	9.17	0.03
Impala field samples	N	0.01	0.11	50	0.53	6.72	55	9.69	0.82
Zebra	N	0.63	41.1*	10.1*	5.27	4.5	36	5.49	0.00
Zebra	P	0.39	104*	27.0*	22.3	4.01	36	7.12	0.00
Zebra & blue wildebeest	N	0.54	31.2	15.3	3.68	3.45	72	6.58	0.00

* Significant difference from control ($P < 0.05$) b = slope; c = intercept; SE = standard error.

deer and in domestic ruminants by using either total faecal P output (g/day) or total faecal P concentration (percentage dry matter) (Belonje 1980; Belonje & Van den Berg 1980; Cohen 1974; Holechek *et al.* 1982a; Holechek *et al.* 1985; Moir 1960). In our study dietary P could be predicted using the simple regression equation of $Y = 0.33X + 0.37$.

Dietary N concentration may influence P excretion (Grant *et al.* 1995) when dietary N concentrations are very low. We, however, found that including faecal N concentrations did not improve the prediction of dietary P concentrations. Dietary digestibility did not influence the prediction of dietary P, neither did the tannins in browse effect the prediction of dietary P concentration, which corresponds with findings of Leslie & Starkey (1985). Contrary to the findings of Read (1984), a lower intake had no effect on the prediction of dietary P. It has been reported that faecal P levels lower than 2 g P/kg OM indicate a deficiency in most species (Grant *et al.* 1995). Using the above regression model for all species it can be calculated that for the recommended dietary P intake of 0.76 g P/kg DM (Cohen 1975), faecal P con-

centration should be 2.05 g P/kg OM with a SE of 0.4 g /kg OM. This is very similar to the result of 2 g/kg OM (SE = 0.47) when the impala calibration model is used.

Multivariate models were needed to predict dietary N concentration. This corresponds with findings of Holloway *et al.* (1981) and Grant *et al.* (1995). Dietary N concentration could be predicted satisfactorily from faecal N and P concentrations. Other researchers reported that for elk, deer, duiker, eland, har-tebeest and cattle only faecal N concentrations were needed to predict faecal N concentrations. However, in these studies neither faecal P nor other variables were considered. The accuracy of the prediction of dietary N concentration from faecal P and N concentration was poorer with low dietary digestibilities. The prediction of dietary N is also influenced by high levels of soluble phenolics such as tannins (Wofford *et al.* 1985) in the diet. Faecal N concentration is elevated whenever diets contain tannins (Cook *et al.* 1994; Hobbs 1987). In our study, when browse apparently containing high tannin levels were fed, we found faecal ADIN and ADL to be better predictors of dietary N than faecal N. Faecal ADL con-

centrations may be used as an indication of bush utilisation by impala as the lignin content of bush is higher than that of grass. When faecal ADL is above 160 g/kg, but below 210 g/kg, indicating browse utilisation, the regression equation using faecal ADL and ADIN should be used in the prediction of dietary N. However, with faecal ADL below 160 g/kg, indicating grass utilisation, faecal N and P concentration should be used. The slopes of the regression equations predicting dietary N concentration from faecal N concentration for blue wildebeest $Y = 0.84X - 0.97$, zebra $Y = 0.95X - 0.4$ and impala $Y = 0.83X + 3.87$ are similar to those found for elk and deer (Leslie & Starkey 1985) These equations however, differ widely from those predicting dietary N in duiker, eland, elk, hartebeest, mule deer, Thomson's gazelle and white-tailed deer (Robbins 1983).

It would therefore appear that different models should be used to predict dietary N for grazers and browsers and that in the case of browsers the slope of the model is smaller than for grazers. This would explain why the models for the browsers or selective feeders such as duiker, eland, elk, mule deer, Thomson's gazelle, white-tailed deer and browsing impala differ from those found in zebra, blue wildebeest, cattle and grazing impala. This higher faecal N excretion in browsers could be due to tannins in browse. This is confirmed by Mould and Robbins (1981) who found that when 100 % maple was fed to elk the prediction model of faecal N vs. dietary N departed from the model of faecal N and dietary N for low phenolic, grass/alfalfa rations. To predict dietary N for browsers, more than faecal N is needed to compensate for the tannins present in the browse.

Gates and Hudson (1981) reported that weight loss in elk was associated with faecal N levels below 1.6 %, while Minson (1967)

reported that 11-12 g N/kg DM in grass is required for microbial activity. From the regression for zebra and blue wildebeest, it can be seen that approximately 80 % of faecal N is from dietary N. To realise 1.6 % N in faeces dietary N would have to be 1.28 %. If 11 g N/kg is required, approximately 13.75 g N/kg should be excreted. Therefore, a faecal N concentration of less than 14 g N/kg would indicate a N deficiency in grazers. For browsers this is not as simple, since multiple factors affect the prediction.

Wehausen (1995) suggested that dietary digestibility was not directly correlated with faecal N because of tannins, and that a log transformation of faecal N should rather be used to linearise the relationship with digestibility. Faecal N has been reported to be a reliable indicator of dietary digestibility (Corbett 1960; Greenhalgh & Corbett 1960; Holloway *et al.* 1982; Lancaster 1949), whereas a relationship between dietary digestibility and lignin content was reported by Pietersen (1991). As faecal N and P excretions are linked there is reason to believe that faecal P might be a good predictor of dietary digestibility. In this study a combination of P, N and ADL gave the best predictions of digestibility in the case of blue wildebeest, zebra and impala.

Conclusion

From the above it can be seen that the prediction of faecal P is robust and one prediction can be used for all species and situations studied. An accurate estimate of dietary P can be made from faecal P alone. In southern Africa where P deficiency is one of the most common causes of poor fertility (Read *et al.* 1986), estimation of dietary P could be important to establish when P supplementation may be necessary. The prediction of dietary N is not as robust as that for dietary P as it is influenced by the intake of phenolic compounds. It appears that a different

prediction model should be established for browsers. The prediction for grazers is better calibrated and may be used to determine whether or not N deficiency exists in grazers. Anticipation of N deficiency allows timely management measures to be taken to avoid losses associated with such deficiencies.

Faecal indices are given that may be used to indicate dietary N (< 14 g/kg DM) and P (< 2 g/kg OM) deficiencies in grazers. Using these as indicators it could help to understand the differences resulting from nutrient availability in the habitats occupied by these species.

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