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THE USE OF FAECAL ANALYSIS TO PREDICT DIETARY COMPOSITION OF WILD HERBIVORES

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THE USE OF FAECAL ANALYSIS TO PREDICT DIETARY COMPOSITION OF WILD HERBIVORES

by

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THE USE OF FAECAL ANALYSIS TO PREDICT DIETARY COMPOSITION OF WILD HERBIVORES

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ABSTRACT

Faecal samples have been proven to be valuable in determining dietary composition of wild herbivores. Results indicate that samples should only be collected from dung pads that are still wet and that show no signs of dung beetle activity or have been exposed to rain. Samples can be air dried in a ventilated room or oven dried at 60°C but care must be taken to avoid fungal growth. Dried samples can be kept in paper bags for up to 1 year before analysing .

Faecal phosphorous and nitrogen can be used as indicators of the nutritive content of the veld. Faecal P concentrations can be used to predict dietary P concentrations satisfactorily, using a simple linear regression, Y= 0.32X +0.27 (r^2 =0.66). This regression holds when impala are grazing or browsing as well as for high and low levels of intake. This equation can also be used for predicting dietary P concentrations in zebra, blue wildebeest and cattle. For prediction of dietary N concentration, both concentrations of N and P in the faeces should be taken into account. A multiple regression equation can be used for grazing impala at all levels of intake. In browsers tannins apparently elevate N excretion, therefore dietary N prediction may be skewed. Therefore, a regression equation using faecal Acid Detergent Insoluble Nitrogen (ADIN) and Acid Detergent Lignin (ADL) should be used to predict dietary N concentration when impala browse or for other browsers. There are different regression equations predicting dietary N concentration for grazers and browsers.
Key words: faecal analysis, environmental factors, dietary P prediction, dietary N prediction, bush, low intake, impala, zebra, cattle, blue wildebeest.

SAMEVATTING

Daar is al bewyse dat mis monsters belangrik is om nutrient samestelling van wilde herbivore te bepaal. Resultate toon dat monsters slegs van nat mis versamel moet word met geen tekens van miskruier aktiwiteit, en wat nie blootgestel was aan reën nie. Mis monsters kan in 'n geventileerde kamer of in 'n oond by 60° C gedroog word, waar swamme nie op die monsters kan groei nie. Gedroogde monsters kan tot een jaar op 'n droë plek gebêre word voor hulle geanaliseer word.

Mis fosfaat (P) en stikstof (N) kan gebruik word as indikators van die veld se nutrient inhoud. Deur van die liniêre regressie Y = 0.32X +0.27 (Waar x= misP)gebruik te maak, kan die inhoud van die dieët voorspel word met r^2 = 66%. Hierdie regressie kan gebruik word wanneer rooibokke gras of bos vreet en by hoë en lae innames. Hierdie regressie kan ook gebruik word om P in die dieët van zebra's, blouwildebeeste en beeste te voorspel. Om dieët N te bepaal moet beide mis N en P in aanmerking geneem word. 'n Meervoudige regressie kan gebruik word onder alle omstandighede vir rooibokke wat gras vreet . Wanneer bos egter ingeneem word, verhoog die tanniene wat so ingeneem word die uitskeiding van N in mis en die voorspelling van N inname van die dieët is nie meer so akuraat nie. Deur die konsentrasie van mis ADIN en ADL in aanmerking te neem kan akkuraat voorspel word wanneer bos ingeneem word.

Sleutelwoorde : mis analise, omgewingsfaktore, dieët P voorspelling, dieët N voorspelling, bos. lae innames, rooibokke, zebra, beeste, blouwildebeeste.

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CHAPTER 1

1. 1 INTRODUCTION

The principle of experimental management should be a basic concern in our understanding of ecosystem processes (Murray, 1995). The composition of a plant community is unlikely to remain stable over an extended period of time as external factors perturb the herbivore-vegetation system. Management should be able to recognise the potential for fluctuations in species composition and attempt to monitor and model the system in such a way that the outcome of future pertuberations can be predicted (Jarman and Sinclair, 1979). For this a technique needs to be developed that will record long term nutritional changes, record the rate of change to try and explain the reason for declines in rare specie numbers and to act as an early warning system.

Effective management of wild herbivores and their habitat depends on a knowledge of the plants selected and the composition of their diet during each season. Nutrition directly affects the survival and fertility of ungulates, thus the determination of nutritional status is of importance. Nutritional research concerning grazing herbivores and the ability to monitor trends in the nutritional status of range animals have been limited by high labour demands and low precision of methodology. Development of techniques which would allow quick and easy sampling would be beneficial to researchers, land managers and livestock producers.

Such a technique could be to use a chemical characteristic of faeces that is related to the quality or quantity of ingested diets (Holechek , Vavra and Pieper, 1982(b)). Faecal samples are both inexpensive to collect , readily available and in some instances less elusive than the animals themselves. Faecal nitrogen has been found to be positively correlated with dietary protein (Mould and Robbins ,1981; Holechek, Vavra and Arthur, 1982(a); Wofford, Holechek, Galyean, Wallace and Cardenas, 1985), intake (Arnold and Dudzinski, 1963), dietary dry matter digestibility (Greenhalgh and Corbett, 1960; Leslie and Starkey, 1985) and weight change in mature game species (Gates and Hudson, 1982). These positive relationships permit the use of chemical composition of faeces as an index of the quality of the grazing available. Monitoring and comparing faecal components for several species in different areas should also give insight into their nutritional ecology and give an indication of marginal areas and critical times (Erasmus, Penzhorn and Fairall, 1978). This becomes important in veld conditions as in certain areas and in certain times of the year shortages occur with N being the most limiting nutrient in winter on natural pastures in Africa (Bell, 1975) and P the most limiting mineral in pastures (Du Toit, Louw and Malan, 1940). Phosphorous is claimed to be deficient in the whole of the country with the exception of the shrub bushveld (Bothma, 1989).

Moir (1960) and Belonje (1980) proved faecal P to be correlated with P intake. Insufficient dietary P decreases voluntary feed intake, retards growth, normal skeletal development and reproduction in cattle (Wadsworth, Maclean, Coates and Winter, 1990). According to Grant, Meissner and Shultheiss (1995), both faecal N and faecal P should be used in conjunction when

predicting the nutritional status of wild herbivores. Researchers have used faecal nutrient levels to predict dietary nutrient levels in elk (Mould and Robbins, 1981; Leslie and Starkey, 1985), black-tailed deer (Leslie and Starkey, 1985), white-tailed deer (Jenks ,Leslie, Lochmiller, Melchiors and Warde, 1989), moose (Leslie , Jenks, Chilelli and Lavigne, 1989), duiker, eland, hartebeest, mule deer, thomsons gazelle (Robbins,1983) and domestic livestock (Belonje and van den Berg, 1980; Belonje, 1980; Holechek *et al*, 1982 (a); Grant, 1989). From the above it can be seen that faecal analyses has been widely used. However, most of the researchers only looked at faecal N and no work has been done with wild herbivores in South Africa. This study aims to develop prediction equations for future use. A number of methods exist to predict nutritional quality, which are reviewed for background.

1. 2 REVIEW OF TECHNIQUES USED TO DETERMINE NUTRITIONAL QUALITY

Nutritional quality can be determined by two methods:

1 Direct approach, examining the animal's diet

2 Indirect approach, by using an index

1.2.1 Direct approach:

1.2.1.1 Fistulation

Fistulation is a proven and accepted technique in a controlled environment, particularly with domesticated animals (monogastric and herbivores). Fistulation of animals developed because of the animal's ability to be selective when grazing, which means that fistula samples should best represent the diet selected by grazing animals. This technique comprises the fistulation of animals, the core of the fistula routine and the routine collection of fistula samples. Since animals have to be handled frequently it is restricted to domestic or "tame" wild herbivores.

Limitations in the use of fistulas are:

- Surgery (Grant, 1989) .
- Incomplete collection, losses of diet sample material during fistula sample collection (Holechek *et al*, 1982(a)).
- Animals can only be grazed for short periods to prevent regurgitation (Vavra, Rice and Hansen, 1978).
- Chemical changes during mastication and salivation(Holechek *et al*, 1982(a)).
- Chemical changes during sample preparation for laboratory analysis (Theurer, 1970 as reported by Holechek *et al*, 1982(a)).
- Fistula samples overestimate fibre and lignin and underestimate soluble carbohydrates (Rice, 1970 as reported by Holechek *et al*, 1982(a)).

- Fistula sample N content differs from that of the forage fed (Holechek *et al*, 1982(a)).
- Fistula samples represent only a portion of the total grazing period (Vavra, Rice and Hansen, 1978).

Two types of fistulae are possible, i.e. oesophageal and rumen fistulae. Oesophageal fistulae have an advantage over rumen fistulae if the objective is to collect samples which represent the actual forage consumed (Holechek *et al,* 1982(b)), whereas rumen contents represent a mix .

1.2.1.1.1 Oesophageal fistulation

During the past 20 years this technique has been used more widely to evaluate diets of domestic range ruminants than any other technique. Refinement of surgical procedures and pre and post operative care have lead to a decrease in infections and mortalities.

The advantages of this technique over rumen fistulation are:

- Removal of rumen contents subjects animals to physiological stress.
- Rumen fistulation is limited to large animals.
- Oesophageal samples are more representative of the diet selected than rumen samples.

The oesophageal fistula forage is unsuitable for the assessment of dietary P because salivary contamination increases the ash content and therefore the P content (Vavra *et al* , 1978). Rumen contamination of oesophageal fistula samples in cattle have been reported primarily when collections were made between 1000 and 1600h, the time of day that cattle normally ruminate. Samples with rumen contamination cannot be used for accurate chemical analyses (Holechek *et*

al, 1982(a)). Collection periods longer than 30 minutes increase the chance of regurgitation (Holechek *et al*, 1982(a)), resulting in contamination.

A recent advancement in fistulation is the development of a radio-controlled fistula valve to evaluate diet selection with time and identification of key grass species in the fistulate (Beckerling and Raats, 1995).

1.2.1.1.2 Rumen fistulation

The advantages of this technique over oesophageal fistulation are :

- Rumen fistulae are more easily established and maintained.
- Less care is needed during sampling.

However, the restrictions to using this technique are:

- Much time and effort are needed to empty and wash the rumen and then replace the contents after sampling.
- Removing the rumen contents may adversely affect the animal's physiology because there is an inflow of fluids from the body (Holechek *et al,* 1982(a)).
- An empty rumen may stimulate animals to feed and graze haphazardly and in so doing decrease selectivity (Holechek *et al,* 1982(a)).
- Rumen contents are also not representative because of previous meals and fermentation.

1.2.1.2 Microscopic analysis of faecal samples

The microscopic analysis of faecal or oesophageal fistula samples to determine the composition of the diet is used primarily for wildlife (Vavra *et al,* 1978) when rare or endangered species are examined, where unmanageable animals are studied, or where several herbivores occupy the same range (Vavra *et al,* 1978).

The advantages of this technique are:

- Unlimited sampling.
- Minimal population disturbances.
- It requires small sample sizes (Anthony and Smith, 1974)

The disadvantages associated with this technique are:

- An underestimation of shrubs when woody stems comprise the bulk of the shrub diet.
- An overestimation of forbs when forbs dominate.
- An underestimation of forbs when legumes dominate the diet.
- Correction factors will not improve the estimate if the diet contains a combination of the above (Gill, Carpenter, Bartman, Baker and Schoonveld, 1983).
- Quantification of food items like flowers, tubers and acorns are not possible (Vavra *et al,* 1978).
- With an increased digestion of lignin the chance of it passing through the digestive tract is decreased and so also the chance of it being identified (Vavra *et al* 1978).

1.2.1.3 Hand collected forages

This technique involves recording the animal's feeding preferences. It requires little equipment and provides a sample free of salivary contamination. However, it is laborious and tame animals are required. It is an unreliable method due to the ability of ungulates to select the most nutritious forage available (Howery and Pfister, 1990). Therefore clipping or agronomic techniques are inadequate (Wofford *et al* ,1985). Utilisation is difficult to detect when grazing is light and when more than one herbivore is present, as it may not be possible to separate effects (Smith and Shandruck, 1979).

1.2.2 Indirect approach:

1.2.2.1 Body Indices

1.2.2.1.1 Blood

Blood has been used to determine both dietary N as well as dietary P. Kopf, Brown and Drawe (1984) used blood characteristics to predict N intake and reported that plasma urea nitrogen (PUN) was the only characteristic affected by N intake. The best prediction was $r^2 = 0.60$. However, Bahnak, Holland, Verme and Ozoga (1979) reported that low protein and energy levels increase PUN as a result of mobilisation of protein for energy. Therefore PUN is of limited value and cannot be used when the diet is inadequate. Dietary P has been predicted by using inorganic P in blood. This can only be used under controlled conditions which includes the determination of

reference levels. Blood P increases with increased P levels in the diet and also with excitement. Mobilisation of skeletal P increases blood levels even though it means a depletion of reserves (Engels, 1981). Homeostatic regulation of mineral metabolism is complex
therefore, blood P concentrations may not be sufficiently sensitive to assess P status (Pfister and Howery, 1990). Moir (1966) concluded that P in blood represents P intake rather than P status. Blood samples are furthermore not practical to assess the nutritive quality of wild herbivores as they require immobilisation by an experienced operator and cannot be done routinely.

1.2.2.1.2 Carcass weights

Although body condition and carcass weight change with diet quality many other factors affect it, such as rutting, lactation and competition from other animals. Kidney fat indices are affected by the rut as it decreases voluntary food intake (Ozoga and Verme, 1970). This makes changes in body weight unsuitable for predicting dietary quality. The response in these criteria occurs after a critical nutritional period, thus too late to correct management.

1.2.2.1.3 Bone composition

Bone ash gives a practical indication of P status. Changes in body reserves are also indicated by this technique. If slaughtering of the animal is not possible, a rib bone biopsy is done.

Disadvantages of this technique according to Grant (1989) are:

- Rib biopsy requires surgery and is expensive.

- It is difficult to obtain repetition on the same animal as surgery is required.
- There is a large variation in the P concentration of ribs.
- P concentration of bones is affected by Ca levels; with a decrease in Ca, P decreases.
- Mineral concentration of bone changes with lactation and during fast growth.

1.2.2.1.4 Liver and miscellaneous samples

For this technique to be satisfactory, the donor must be free of disease, and must have grazed in one area for longer than 6 months to be adapted to the area. It is not practical for general use due to the small size of the sample, inaccuracy of sampling site on the liver and the necessity of surgical knowledge and post operative care of each animal (Boyazoglu, 1973). These samples can also not be stored for lengthy periods before analysis.

Analyses of hair, urine and milk have also been used to determine P status but are unsatisfactory. Phosphorous concentration in hair was poorly correlated with seasonal differences in P content of pastures (Cohen, 1974). Urine P levels are increased by a deficiency of dietary energy and reduced salivary flow rate, making this technique unsuitable.

1.2.2.1.5 Chemical analyses of faecal samples

All the above techniques require expensive procedures to collect samples e.g. immobilisation or slaughtering. Faecal samples allow one to periodically resample populations thus investigating more precisely the fluctuating relationship between diet and food availability. In this regard faecal samples could easily be collected by ranchers (Hinnant, 1979 as reported by Holechek, 1982). The

technique does not require tame or surgically fitted animals and so does not necessitate the destruction of individuals. The positive relationship between quality of feed, digestibility, food intake and production in ruminants and other herbivores permits use of the chemical composition of faeces as an index of the quality of grazing available to a species at a given time (Erasmus*et al* ,1978). Faecal sample variation is much lower than that between samples collected with fistulated animals giving a more representative sample (Holechek*et al* ,1982). However, faecal analysis is only suitable for group samples of at least 10 animals. For individual animals, the daily variation in excretion of faecal P is unacceptably high (Grant, 1989). Hinnant (1979) as reported by Holechek (1982) suggested that faecal samples could easily be collected by ranchers during periods of suspected nutritional stress. Barrow and Lambourne (1961) as cited by Grant (1989) reported that faecal analyses can not be used for animals that are under any form of metabolic stress or those that are in a negative feed balance.

It is believed that faecal indices have potential for evaluation of nutritive quality of the range animal's diet particularly when differences over time rather than absolute values are of primary concern (Holechek, Vavra and Arthur, 1981) and so was further examined.

1.3 OBJECTIVES

The objectives of this study were to determine: the accuracy of faecal indices in predicting dietary quality, which dietary factors affect the accuracy of this prediction, which animal factors affect the accuracy of dietary quality predictions; and which environmental factors affect samples.

CHAPTER 2

FACTORS AFFECTING THE NITROGEN AND PHOSPHOROUS CONTENTS OF FAECAL SAMPLES .

2.1 INTRODUCTION

The determination of nutritional status of wild herbivores is expensive and time consuming. As discussed before, faecal samples may be an inexpensive and relatively easy method (Mould and Robbins, 1981; Wofford *et al,* 1985; Grant *et al,* 1995). The question is how and when to collect samples to obtain reliable results, because the nutrient content of veld collected samples may be influenced by various factors. The question was addressed by examining the influence of recent rain, age of samples, presence of dung beetles, method of storage, length of storage time, fungal growth (mould), and the length of time that samples were dried. In addition, the difference in N and P content of faecal samples of males and females were examined, as this may differ during the rut, and the difference in N and P content of faecal samples of juvenile and adults. Individual variation was also examined to determine how many samples should be collected from different species.

2.2 METHODS

2.2.1 Preparation of samples:

Faecal samples that were to act as control samples, as well as those to be used for treatments were collected from impala grazing the natural lawns of the golf course at Skukuza in the Kruger National Park. These samples were used as soil contamination of the samples could be kept to a minimum and the animals had a uniform diet. Samples of 10 pellets each were collected from about 50 dung heaps. Heaps with obviously small pellets were avoided to prevent samples from young impala still drinking milk being collected (Cook, Irwin, Bryant and Thomas 1994) . Samples were mixed by gently shaking them in a brown paper bag to allow a random distribution of pellets and to avoid breaking the pellets. The mixed sample was then divided into two equal groups. The control was placed into small white paper bags (ash free) and dried at 60°C to constant weight. Once the other group had received a treatment, described below, it was dried as above. Both samples were milled in a Tecator mill to pass through a 1mm sieve and duplicate samples were analysed for N and P.

2.2.2 Chemical analyses:

2.2.2.1 Dry matter determination:

Dry matter content was determined by accurately weighing off a sample and drying it at 60° C to constant weight.

2.2.2.2 Organic matter:

After the above DM analysis, samples were incinerated for 4 hours at 600° C and the ash percentage calculated (AOAC, 1984). Organic matter was calculated by subtraction of ash from DM.

2.2.2.3 Nitrogen content:

Exactly 1.0g sample was used for the macro-kjeldahl method (AOAC, 1984) to determine N which was expressed on a DM basis.

2.2.2.4 Phosphorous content:

Exactly 1.5g sample was used and digested using wet digestion according to Heckman (1968). The sample was then accurately diluted with distilled water to 250ml and read against the following standards: 10, 30, 50, 80 and 100mg/kg P in an atomic spectrophotometer. Phosphorous was expressed on an organic matter basis.

2.2.3 The effect of rain:

Rain is thought to have a leaching effect on faecal minerals as it affects the rate of erosion of faecal pellets (Wigley and Johnson, 1981). The effect of rain was therefore investigated to establish whether samples can be collected after rain. Samples were divided into four equal groups. The first group served as control whereas the other three groups were treated. The treatments were 5, 10 and 20mm of rain which was administered artificially by placing the

groups on the ground with 4 containers that had been marked at the amount needed around the sample. A hose pipe was turned on to give a mist rain and sprayed over the samples until the marks of the containers were reached. The pellets of the samples that received 10 and 20mm were cracked and broken whereas those receiving 5mm were still intact. The samples were then allowed to dry off to get rid of excess moisture. Samples were taken randomly from each of the three treatments as well as from the control and dried as described above. The control sample received no rain.

2.2.4 The effect of age:

To determine how fresh samples collected in the veld for N and P analyses should be to ensure reliable results, samples were left outside in the sun to dry. This trial was done in February when the average minimum temperature was 23.2 °C and the average maximum temperature 32°C. From the second day onwards, a representative sample was taken and dried in the oven at 60°C. From the second day samples were lighter and some of the pellets had started to crack. Sampling continued until the sample disintegrated which was after 4 days. The control samples were placed in the oven immediately after collection.

2.2.5 The effect of dung beetles:

Dung beetles are very active in summer and it is often difficult to find samples without dung beetle activity. To examine the effect of the presence of dung beetles in a dung heap, or on a ball of dung, samples were collected from heaps where small dung beetles could be seen on the samples. Samples were also obtained by removing the dung ball from a dung beetle and by collecting pellets that had been obviously broken up by dung beetles. The control samples

were collected in the same area but were free of dung beetles or had not been broken up by dung beetles.

2.2.6 The effect of drying samples:

When samples are collected in the veld it is not always possible to put the wet samples in the oven to dry immediately. For that reason the effect of drying the samples in a dry ventilated room was investigated. The effect of drying samples in bags in the sun was also examined. These samples were collected in the same way as above. The treatment groups were split and placed in paper bags and one group was left out of the sun in a ventilated room to dry, whereas the other group was dried in the sun. No fungal growth was observed. Once the samples were air dried which was after 6 days, they were then placed in the oven and dried to constant weight. The control samples were immediately placed in the oven after collection

2.2.7 The effect of length of storage time:

It is not always possible to analyse samples immediately once they are dry. For this reason samples were dried, placed in paper bags and left for one year before analysing . Samples were collected and dried in the same way as above. The dried samples were then split into two groups. The control samples were analysed immediately whereas the treatment samples were left in paper bags and analysed a year later.

2.2.8 The effect of fungal growth:

Samples put in the oven to dry are often too compacted or do not dry fast enough, giving an opportunity for fungi to grow. To test the effect of mould on P and N concentrations in faecal samples , samples were divided into two equal groups. The control groups were placed in paper bags, with the thickness of the sample in the bag being approximately 1cm, and dried in the oven until constant weight. The other group was placed in paper bags with the thickness of the sample in the bag being approximately 4cm. These bags were then put in a protected area away from sunlight to dry. Once fungal growth had occurred, samples were dried in an oven at 60°C until constant weight.

2.2.9 The effect of length of drying time:

The samples were collected in the same way as above, split into two equal groups, and dried at 60°C. The control samples were taken out after four days once a constant weight had been reached, whereas the other samples were taken out after fourteen days.

2.2.10 The effect of males and females:

Ozoga and Verme (1970) and Grasman and Hellgren (1993) reported that male deer had a voluntary reduced intake. Samples from male and female impala were collected separately in May when the males were in rut to see if this would affect the P and N contents of the faeces.

2.2.11 The effect of juveniles and adults:

According to Cook *et al* (1994) faecal samples from juvenile animals still drinking milk can not be used to represent nutritional content. To examine when these faecal samples become representative, faecal samples were collected from the heaps where the pellets were slightly smaller and represented juvenile animals. These samples were collected in April and May once the animals were weaned. Control samples were collected from the same herd from heaps with bigger pellets representing adult animals.

2.2.12 The effect of between and within species variation:

To determine how many samples are needed in different species before samples can be pooled, samples from 20 impala , 15 buffalo (*Syncerus caffer*), 16 blue wildebeest (*Connochaetes taurinus*), 8 kudu (*Tragelaphus strepsiceros*) and 8 giraffe (*Giraffa camelopardalis)* were collected and analysed separately. The samples were each collected from animals in the same herd in the same area and on the same day during May.

2.2.13 Statistical analyses:

Students t tests were used to determine whether two samples differed significantly from each other.

2.3 RESULTS AND DISCUSSION

2.3.1 Rain:

Up to 20mm simulated rain had no significant influence on N levels in faeces, whereas 10mm of rain already decreased P concentrations significantly ($p=0.033$). The samples that received 20mm of rain had a more significant ($p=0.011$) decrease in P concentrations than those receiving only 5mm. The levels of N in samples that received 20mm also tended to be lower (Table 2.1).

Table 2.1. The effect of rain on the N and P levels in impala dung

Treatment	N(g/kg DM)	P(g/kg OM)	n
Control	22.8	3.7	4
5mm rain	23.2	3.7	4
10mm rain	23	3.5*	4
20mm rain	21.9	3.5*	4
S.D.	0.28	0.02	

*= Differed significantly from control $p<0.05$

n = number of faecal samples

Jenks ,Soper, Lochmiller and Leslie(1990) found that N concentrations in deer faeces were not affected by rain. They covered the faeces when rainfall was greater than 1mm.
Samples thus received very little direct precipitation. The pellets they collected had thus not even been eroded. The effect of rain is probably through leaching by eroding the pellets.

Because of the present results with faecal N and P, and as it is difficult to determine the exact amount of rain that faeces in the veld receive, it is better to avoid collecting samples after rain.

2.3.2 Age:

Samples that were left in the sun for two days or longer had significantly lower P ($p=0.04$) and N ($p=0.01$) concentrations when compared to control samples (Table 2.2).

Table 2.2. The effect of age on the N and P levels in impala dung

Treatment	N(g/kg DM)	P(g/kg OM)	n
Control	23.2	3.7	5
Sun dried 1 day	22.7	3.6	5
Sun dried 2 days	21.4*	3.5*	5
Sun dried 3 days	21.6*	3.4*	5
Sun dried 4 days	21.3*	3.2*	5
S.D.	0.05	0.02	

* = differed significantly from Control $p<0.05$

n = number of faecal samples

This is contrary to the findings of Jenks *et al* (1990) who reported that faecal N levels in deer faeces under natural conditions were not affected by exposure. The difference could be because Jenks *et al* (1990) only collected whole pellets whereas in the present investigation pellets were collected even if they were cracked. The temperatures between the two experiments also differed greatly with the temperatures in this study being higher. Jenks *et al*

(1990) also did not examine the effect on P. This effect of exposure on faeces indicates that only fresh samples that have not been exposed for more than one day should be collected.

2.3.3 Presence of dung beetles:

Samples that had been contaminated by dung beetles had a significantly higher N ($p=0.0001$) content than those which were free of contamination. There was also an indication for P to be higher (Table 2.3).

Table 2.3. The effect of dung beetles on the N and P levels in impala dung

Treatment	N(g/kg DM)	P(g/kg OM)	n
Control	20.3	1.09	7
Dung beetle	24.6*	1.26	7
S.D.	1.98	0.18	

* = differed significantly from control $p<0.05$

n = number of faecal samples

The increase in P and N could be due to the dung beetle itself or flies or mites which are also present in samples that are favoured by dung beetles. The presence of dung beetles on samples can quite easily be recognised and therefore these samples should be avoided.

2.3.4 Method of storage:

There was no significant difference in N or P levels of control samples ($p>0.05$) and those that were air dried in a ventilated room. This corresponds with the findings of Jenks *et al* (1990) who found that there was no effect on faecal N when samples were exposed to laboratory conditions for less than 12 days (Table 2.4). Samples that were dried in paper bags in the sun, however, had a significantly lower N ($p=0.0008$) and P ($p=0.002$) level than control samples (Table 2.5).

Table 2.4. The effect of air drying on the N and P levels in impala dung

Treatment	N(g/kg DM)	P(g/kg OM)	n
Control	22.5	5.77	4
Air dry	22.7	6.06	6
S.D.	1.8	0.14	

* = differed significantly from the control $p<0.05$

n = number of faecal samples

Table 2.5. The effect of sun drying on the N and P levels in impala dung

Treatment	N(g/kg DM)	P (g/kg OM)	n
Control	23.2	3.7	3
Sun dried	21.6*	3.1*	3
S.D.	0.05	0.02	

* = differed significantly from the control $p<0.05$

n = number of faecal samples

2.3.5. Length of storage time:

There was no significant difference between control samples and those that were analysed a year later in either N (p=0.74) or P (p=0.64) (Table 2.6).

Table 2.6. The effect of length of storage time on the N and P levels in impala dung

Treatment	N(g/kg DM)	P(g/kg OM)	n
Control	12.3	2.29	16
Samples stored for 1 year	12.6	1.91	16
S.D.	1.93	0.52	

n = number of faecal samples

2.3.6. Fungal growth:

In samples that developed mould, N content was significantly lower (p=0.005) and P content significantly higher (p=0.003) than in control samples (Table 2.7).

Table 2.7. The effect of fungal growth on the N and P levels in impala dung

Treatment	N(g/kg DM)	P(g/kg OM)	n
Control	22.9	3.4	4
Fungal growth	18.5*	3.7*	4
S.D.	0.35	0.02	

* = differed significantly from the control $p<0.05$

n = number of faecal samples

To prevent fungal growth, samples should not be too compacted or layered too thick in the bags and they should be placed where they can dry quickly.

2.3.7. Drying time:

There was no significant difference ($p>0.05$) in N or P content of control samples and those that were left in the oven for 14 days providing they are dried at 60^0 C (Table 2.8).

Table 2.8. The effect of length of oven drying on the N and P levels in impala dung

Treatment	N(g/kg DM)	P(g/kg OM)	n
Control	22.5	5.77	4
14 days oven dried	22.1	5.66	4
S.D.	1.9	0.03	

n = number of faecal samples

2.3.8. Males vs. females:

The individual samples collected from males and females showed no significant difference in either N (p=0.215) or P (p=0.260) (Table 2.9).

Table 2.9. The difference between males and females in N and P levels in impala dung

Sex	N(g/kg DM)	P(g/kg OM)	n
Male	19.7	4.2	11
Female	21.1	4	7
S.D.	1.2	0.8	

n = number of faecal samples

This implies that faecal samples can be collected in May at random to represent the nutritional status of all mature impala.

2.3.9. Juveniles vs. adults:

The samples collected from the juveniles after weaning and adults showed no significant difference in either faecal P or N (Table 2.10).

Table 2.10. The difference in faecal N and P levels between adult and juvenile impala

	N(g/kg DM)	P (g/kg OM)	n
Adult	18.8	4.62	4
Juvenile	19.2	4.59	4
S.D.	0.64	0.14	

n = number of faecal samples

2.3.10. Between and within species variation:

Belonje and Van Den Berg (1980) and Jenks *et al (1990* proved that to cut costs pooled samples can be used to determine P and N concentrations. To determine how many samples should be collected to represent a group of wild herbivores in an area, individual variation for N and P in browsers and grazers was examined in summer (Table 2.11). In order to detect differences (at the 10% significance level) in the range 0.5g/kg the current variances obtained (Table 2.11 & 2.12) indicate that about 43 samples should be collected for impala, 11 for giraffe, 32 for kudu, 7 for buffalo and 16 for blue wildebeest. However, when statistical resolution need not be as fine, (such as distinguishing differences betweeen area and between season) 20 samples from browsers and 10 from grazers should as a general rule be sufficiently representative.

Table 2.11. Variation in faecal P within species

Species	Impala (g/kg OM)	Buffalo (g/kg OM)	Blue wildebeest (g/kg OM)	Giraffe (g/kg OM)	Kudu (g/kg OM)
Average	4.4	3.8	3.9	2.38	2.9
S.D.	1	0.4	0.6	0.51	0.86
cv, %	22.7	10.5	15.4	21.4	21.7
n	20	15	16	8	8

n = number of faecal samples

Table 2.12. Variation in faecal N within species

Species	Impala (g/kg DM)	Buffalo (g/kg DM)	Blue wildebeest (g/kg DM)	Giraffe (g/kg DM)	Kudu (g/kg DM)
Average	17.2	10.1	12.8	20.4	20.8
S.D.	1.24	0.45	1.24	1.38	1.04
cv,%	7.21	4.46	9.72	6.75	5
n	20	15	16	8	8

n = number of faecal samples

2.4 RECOMMENDATION

Faecal samples can be collected and stored efficiently by veld staff doing normal duties. Samples up to a day old, showing no signs of dung beetle activity can be collected and air dried in a ventilated room at room temperature or oven dried at 60°C, until constant weight. They can also be dried for or up to 14 days in paper bags, provided small amounts are stored. Dried samples can be stored for up to 1 year before analysis. Samples should not be collected on the first day after heavy rains. Once collected, samples should be dried in thin layers to avoid fungal growth. Once animals are weaned faecal samples can be collected from them to represent the herd for analyses of N and P content. If samples are to be pooled in summer and 0.5g/kg variation in faecal P and N is required, 43 samples should be collected for impala, 32 for kudu, 11 for giraffe, 7 for buffalo and 16 for blue wildebeest. It would appear as if 10 samples for grazers and 20 for browsers would be a recommended amount to collect.

CHAPTER 3

FACTORS AFFECTING THE PREDICTION OF NITROGEN AND PHOSPHOROUS CONCENTRATIONS IN THE DIET OF IMPALA.

3.1 INTRODUCTION

Positive relationships that exist between faecal N and P, and dietary N and P permit the use of faecal components in determining grazing quality. 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 (Moir ,1966; Grant, 1989). Both P and N were thus examined. The aim of this experiment was to establish dietary concentration from P and N excretion, a calibration study was undertaken with a combination of different P and N levels in the diets. Factors were also examined which may affect this relationship e.g. high tannin levels present in browse, which according to Mould and Robbinson (1981) will increase faecal N excretions and so bias the prediction of dietary quality, and level of intake (Read, 1984) where individual differences in intake will affect faecal output.

3.2 METHODS

3.2.1 Animals:

Four impala rams caged separately were used. Cages consisted of a cement interior area which was roofed and contained the feeding troughs and a cement exterior area with no roof, which the impala used to defecate.

Pelleted diets were formulated with different P and N levels. The following diets were fed (Table 3.1).

Table 3.1. Experimental design and dietary treatments

Trial nr	Diet nr	P (g/kg OM)	N (g/kg DM)	Digestibility (%DM)	S.D of digestibility
1	1	2	20.8	67.7	2.55
1	2	2.63	20.8	64.3	2.05
1	3	3.2	20.8	61.5	3.57
1	4	3.8	20.8	62.2	3.31
2	5	1.4	13.3	62.9	2.89
2	6	3.1	13.6	64.3	4.79
2	7	1.5	10.2	61.3	5.04
3	8	2.5	11.8	60	5.07
3	9	1.9	15.2	60.6	8.65
4	10	2.1	12	58.1	5.65
4	11	2.6	13.6	54.5	4.85

S.D = standard deviation

In trial 1, 4 different diets were fed using a change over design, with each animal receiving 1000g of concentrate per day and lucerne *ad lib*. These diets were formulated to establish the effect of different levels of P intake, at a constant N intake, on P and N excretion. Trial 2 comprised 3 different diets (5-7) which were alternated using a change over design with animals 3 and 4 receiving the same diet. These animals also received exactly 1000g of concentrate daily and grass hay *ad lib*. Grass hay was substituted for lucerne to lower the P intake as much as possible. The diets consisted of a high N with a high P, a high N with a low P and a low N with a low P. These diets simulated veld conditions in summer and winter (Grant, *et al* 1995) . Trial 3 comprised 2 diets (8 and 9) which were fed to the first two impala only. Both animals received the same diet at the same time which comprised 1000g of concentrate and lucerne *ad lib*. Trial 4 comprised two diets (10 and 11) which again had different P and N levels and their digestibilities were lower than the diets of trials 1 to 3. All 4 animals received the same diet of 1000g of concentrate each day and lucerne *ad lib*. It was attempted to maintain a constant energy level for all trials. Trial 4 however proved to be of lower digestibility (Table 3.1). Trials 1 to 3 were the control or original calibration trials. The lucerne/hay intake was determined by weighing the hay supplied each day, and weighing back the remainder before the next feeding.

3.2.2 Faecal collection:

Faeces was collected every morning at the same time after the impala were fed, for the duration of the trial. Faecal samples were collected from a clean cement floor, by collecting the total faeces in a bucket and weighing it accurately to determine total faecal output. Approximately 10% of the total faeces was then placed in a plastic bag to be frozen. The frozen sample was grouped per

animal for each trial, analysed in duplicate and for each trial a control samples was analysed the variance for P analyses of the control samples was 0,63g/kg and for 0,97g/kg for N.

3.2.3 Chemical analyses:

N and P were analysed as described in Chapter 2 (Results in Addendum A).

3.2.3.1 Acid detergent fibre:

Exactly 1.0g sample was used and digested according to the Dosi Fiber or Fibertec system (Goering and Van Soest, 1970), after which the sample was dried overnight and ashed at 500° C for 4 hours.

RCD = residue in crucible after drying

RCA = residue in crucible after ashing

%ADF = RCD-RCA/original sample mass x 100

3.2.3.2 Acid detergent lignin:

Exactly 1.0g sample was digested according to the Dosi Fiber or fibertec system (Goering and Van Soest, 1970) and dried overnight. To each sample 25ml of a 72% H_2SO_4 solution was added and extracted for 3 hours. The samples were then filtered, allowed to dry overnight and ashed at 500^{0}C for 4 hours.

3.2.3.3 Acid detergent insoluble nitrogen:

Exactly 2.0g sample was used and digested as for ADF (Goering and Van Soest, 1970). After drying overnight at 105°C the remaining sample was weighed accurately into a kjeldahl flask and analysed for N (AOAC,1984).

3.2.4 The effect of level of intake:

To examine the effect of a restricted food intake, simulating drought or winter conditions, the amount of concentrate (diets 10 and 11) that the animals received was halved to 500g and the lucerne intake was restricted to half of what each animal ate *ad lib.* in the control trials (diets 10 and 11). Faeces was collected in the same way as described above.

3.2.5 The effect of bush intake:

Bush intake was thought to have an effect on the reliability of dietary N prediction, because of the protein binding effect of tannins present in bush. The bush species selected were red bushwillow (*Combretum apiculatum*), Wild raisin sp. (*Grewia sp.*) and buffalo thorn (*Ziziphus mucronata*). These three were chosen because of their different tannin levels (Furstenburg, 1991) (Table 3.2). The preference of impala (Wentzel, 1990) (Table 3.2) for these species were also taken into account.

Table 3.2. Tannin concentrations and percentage of bush species in diets of impala

Species	Minimum Tannin concentration (% DCT)	Maximum Tannin concentration (% DCT)	Percentage in diet (%)
Ziziphus mucronata	0.01	1.82	5.8
Grewia sp.	0.02	10.43	4.8
Combretum apiculatum	3.67	38.2	1.8

DCT = Dry mass condensed Tannin concentration

Adapted from Furstenburg (1991) and Wentzel (1990)

From Table 3.2 it can be seen that impala apparently prefer the species with the lower tannin content. Browse was provided in the form of palatable cuttings that included smaller twigs and leaves. The exact amount provided, which 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 could be eaten, was weighed accurately. Browse was supplemented with 1000g of concentrate corresponding to that provided with *ad lib.* lucerne in the control trials . The overnight moisture loss was determined and taken into account when any remaining browse was weighed back the following day before fresh browse was given. The *Grewia sp.* were also fed at two different levels to see what effect

level of bush intake had on faecal N and P. Faeces was collected and analysed in the same way as explained above.

3.2.6 The effect of lower digestibility:

To examine the effect of lower digestibility, animals were fed diets 10 and 11 that had lower digestibility. Each animal received 1000g concentrate and lucerne *ad lib.* Trials 1-3 served as the control for this study.

3.2.7 Statistical analysis:

Students t tests were used to determine whether two samples differed significantly from each other. Simple and multiple regressions were used to set up prediction equations. Modified students t tests (Zar, 1974) were used to determine if slopes and intercepts of regression equations differed significantly from each other.

3.3 RESULTS

3.3.1 Initial trials:

3.3.1.1 Adaptation and trial lengths:

In order to determine the length of the adaptation period, impala were fed a diet for one month, and faecal samples were collected every week and analysed to determine if there was a carry- over effect from the previous diet. For P excretion the only significant difference was found in animal 2 between the first week of the adaptation period and the trial ($p=0.03$). This animal received low P in the previous trial and in the first week of adaptation high P. In the adaptation period P excretion was significantly higher than in the trial. For N excretion significant differences between the first week of the adaptation period and the trial were found in all 4 animals ($p=0.004$), these animals had low dietary N in the previous trial and then received a higher dietary N in the first week of adaptation, which resulted in elevated N excretion. This carry over effect lasted for 1 week, therefore the adaptation period was shortened to a week. A trial period of 2 weeks was tested to determine if the P and N levels changed in the second week. Daily samples were collected and analysed. As the animals had been adapted to the diet there was no significant difference in either P or N excretion over the two week period. A trial period of 1 week was therefore adequate, with extra days included if rain occurred.

3.3.1.2 Method of faecal collection:

To determine whether urine contamination influenced the N level of the faeces, 2 faecal samples were collected. A clean faecal sample was first collected by picking up the most recent dung lying intact on the top of the dung heap. The rest of the faeces was then collected separately and a second sample that was very wet and contaminated by urine was taken from the bottom. The two samples were analysed and tested. Even though the difference in N content between the two samples was not significant, due to the difference of 0.5g more N in the contaminated sample, only clean samples were collected for the trial.

3.3.2 Prediction of dietary P concentration

When P was fed at concentrations varying from deficient P to oversupply of P, with varying N levels in the diet but with constant digestibility (trials 1-3), dietary P concentration could be predicted by a simple linear regression equation using faecal P concentrations (Table 3.3-Equation 1 & Fig 3.1).

Table 3.3. Simple linear regression equations predicting dietary P concentration (Y) (g/kg OM) from faecal P concentration (X) (g/kg OM).

Trial type	Equation nr	r^2	b	c	se of b	se of c	n	probability	S.D
Trials 1-3	1	0.67	0.34*	0.28	0.04	0.24	36	0.0001	0.36
Trials 1-3	2	0.97	0.39*		0.01		36	0.00001	0.38
Low intake	3	0.58	0.21*	0.71	0.06	0.34	12	0.0001	0.29
Trials 1-3 & low intake	4	0.61	0.31*	0.38	0.04	0.21	48	0.0001	0.39
Trials 1-3 & Low intake	5	0.96	0.37*		0.01		48	0.0001	0.4
Browse	6	0.08	0.07	1.09*	0.06	0.25	16	0.27	0.21
Trials 1-3 & Browse	7	0.7	0.35*	0.16	0.03	0.17	52	0.0001	0.37
Trials 1-3 & Browse	8	0.96	0.38*		0.01		52	0.0001	0.37
Trials 1-3 & Low digestibility	9	0.65	0.33*	0.35	0.04	0.21	44	0.00001	0.36
All data	10	0.66	0.32*	0.27	0.03	0.16	64	0.0001	0.37
All data	11	0.96	0.37*		0.01		64	0.0001	0.38

* indicates significance

b = slope

c = intercept

se = standard error

S.D = standard deviation

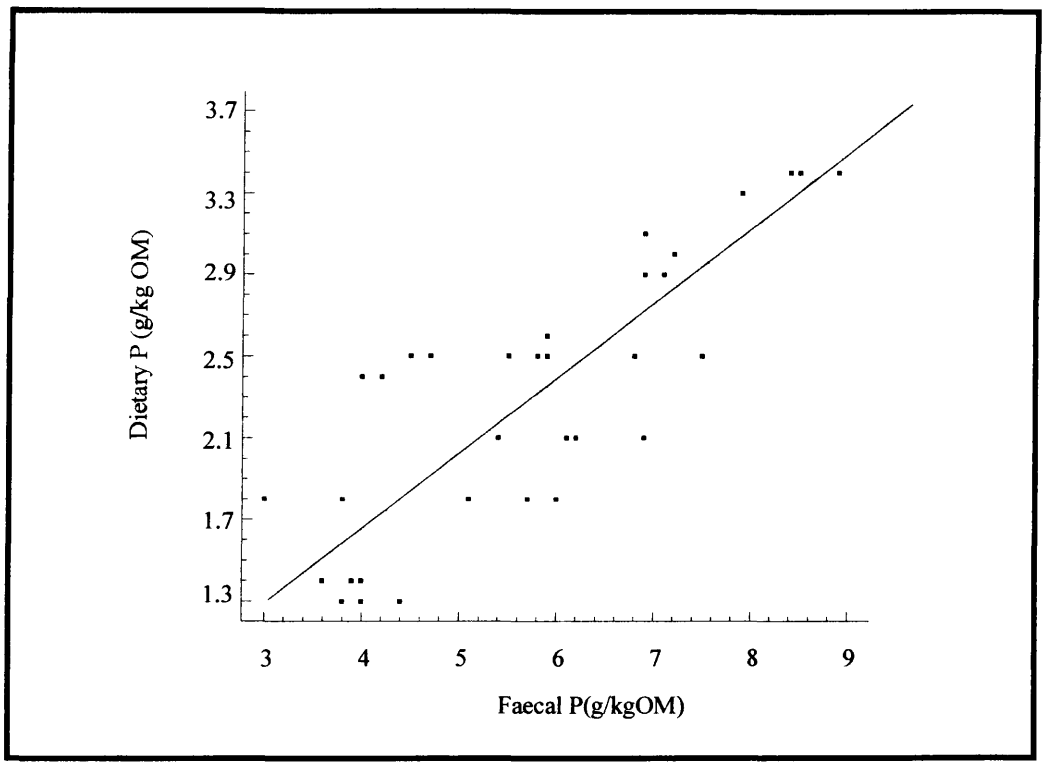

Figure 3.1. Simple linear regression predicting dietary P concentration from faecal P concentration for trials 1 to 3.

The intercept of this regression equation was not significant, therefore the regression could be made to pass through the origin (Table 3.3-Equation 2 & Fig 3.2), which simplifies the prediction.

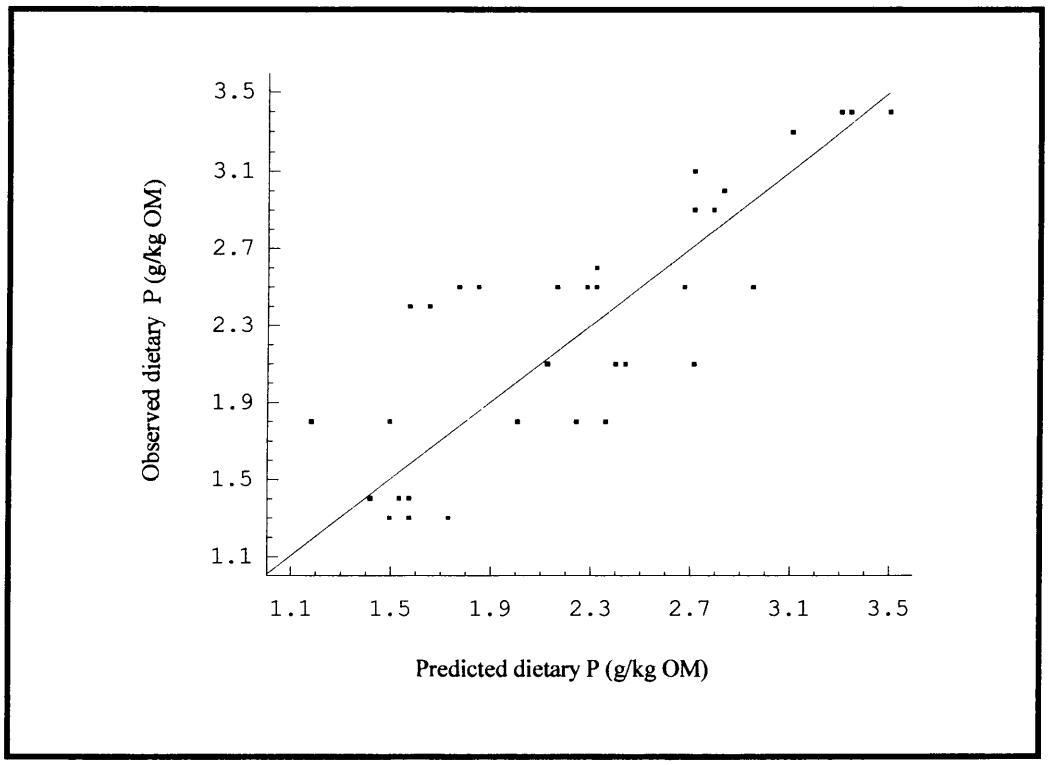

Figure 3.2. Simple linear regression of predicted dietary P concentration versus observed dietary P concentration for trials 1 to 3. Line was forced to pass through the origin.

As the excretion of faecal P and N are linked, it was thought that including faecal N with faecal P in a multiple regression would improve the prediction. However, faecal N weakened the prediction and faecal N was not significant (p= 0.7185).

3.3.2.1 The effect of a restricted intake on dietary P prediction:

When the effect of restricted intake on faecal P concentration was examined the prediction of dietary P concentration from faecal P concentration was weaker (Table 3.3-Equation 3). The

intercept and slope of this regression equation however, were not significantly different from the intercept and slope of the original regression equation ($p>0.05$). When faecal N concentration was added to the prediction, the N was not significant ($p= 0.57$) and the prediction weakened (r^2 0.51). When the restricted intake data was added to the original data (Equation 1), the slope of the regression equation (Equation 4) did not change significantly and as the intercept of the regression equation was not significant, the line was passed through the origin (Table 3.3-Equation 5 & Fig 3.3).

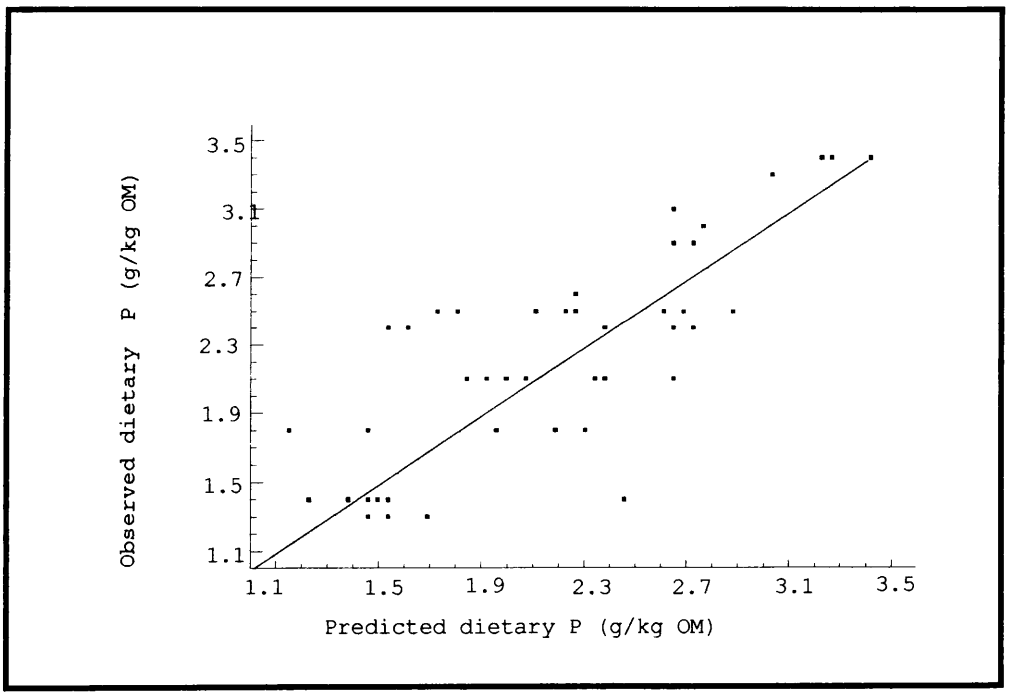

Figure 3.3. Simple linear regression of predicted dietary P concentration versus observed dietary P concentration for trials 1 to 3 and restricted intake data. Line was forced to pass through the origin.

3.3.2.2 The effect of bush intake on dietary P prediction:

For the trials where browse was fed with the pelleted diets, no significant relationship between faecal P and dietary P concentrations could be found as the variation in faecal P concentration was large compared to the variation in dietary P concentration (Table 3.3-Equation 6). However, when the data from the bush trials was added to the original regression equation (Equation 1), the slope of the regression equation did not change significantly nor did the standard error increase much (Table 3.3-Equation 7). This regression equation did not have a significant intercept either and the regression could be passed through the origin (Table 3.3-Equation 8 & Fig 3.4).

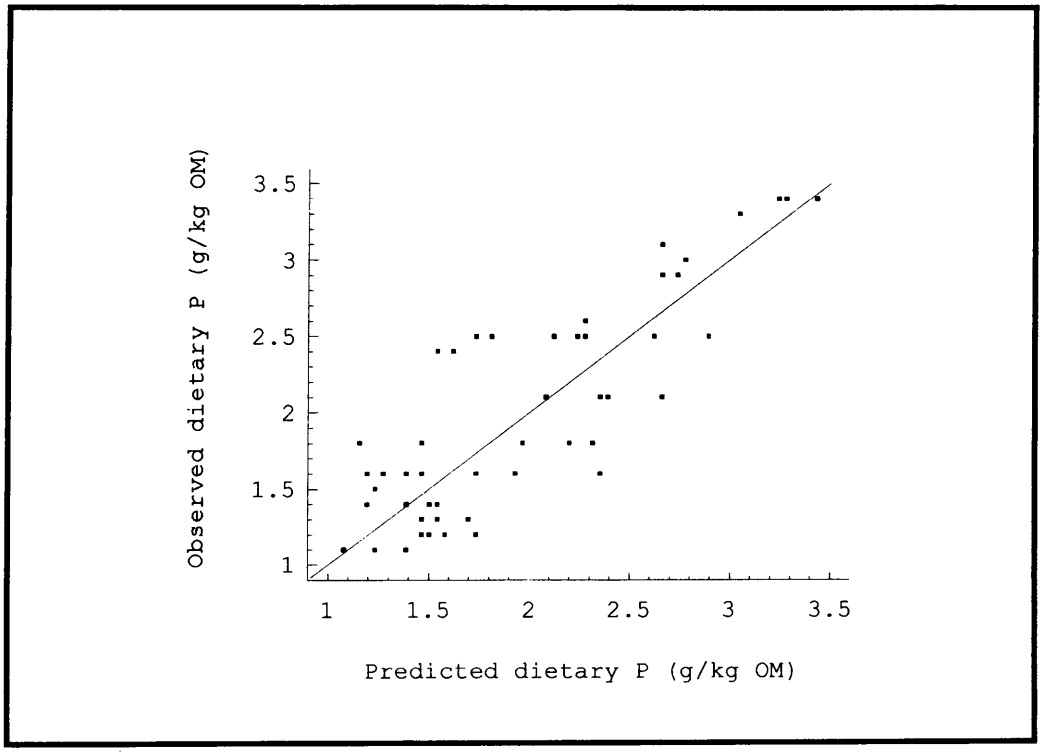

Figure 3.4. Simple linear regression of predicted dietary P concentration versus observed dietary P concentration for trials 1 to 3 and browse data . Line was forced to pass through the origin.

3.3.2.3 The effect of a lower digestibility on dietary P predictions:

Once the data from trial 4 was added to that of trials 1-3 the r^2 of the regression weakened slightly (Table 3.3-Equation 9).

3.3.2.4 Combined dietary P prediction:

Neither restricted intake or bush data significantly changed the slope of the original regression equation and the intercepts were not significant. This means that all data could be included into one regression equation (Table 3.3-Equation 10). The intercept of this regression equation was again not significant, so it could be passed through the origin for simplification (Table 3.3-Equation 11 & Fig 3.5). The prediction indicated that dietary P concentration is about 37 % of faecal P concentration.

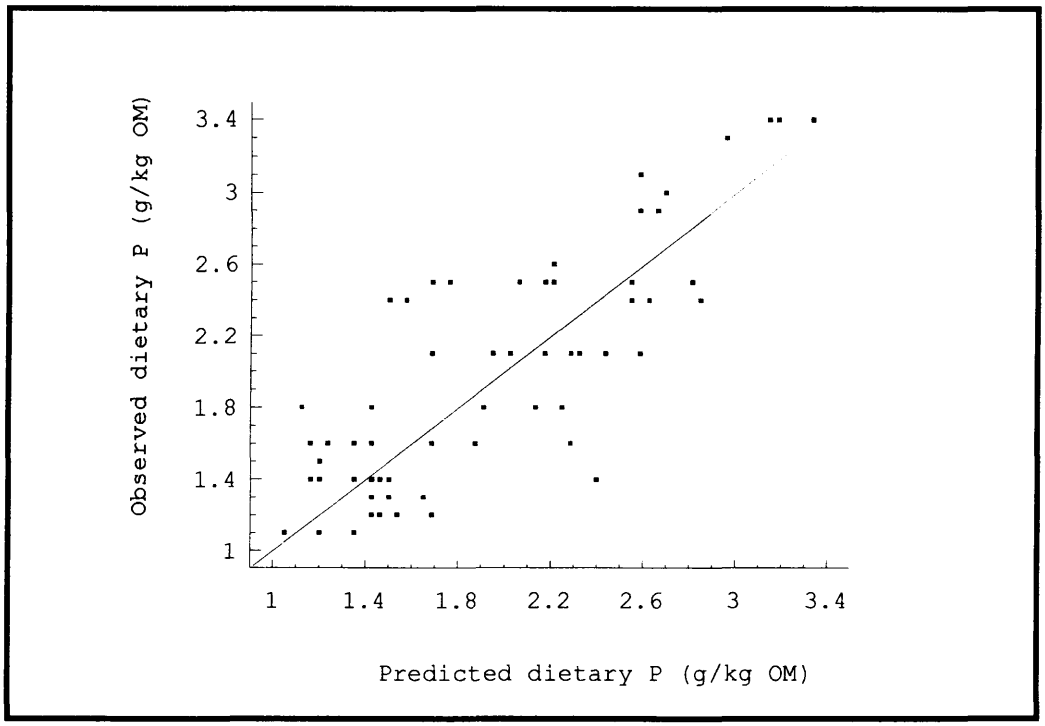

Figure 3.5. Simple linear regression of predicted dietary P concentration versus observed dietary P concentration for all the data. Line was forced to pass through the origin.

3.3.3 Predictions of dietary N concentration:

For trials 1-3 where N and P intakes varied from high to low levels 63% of the variation in dietary N concentration could be explained by faecal N concentration (Table 3.4-Equation 1) .

Table 3.4. Simple linear regression equations predicting dietary N (Y) (g/kg DM) from faecal N concentration (X) (g/kgDM).

Trial type	Equation nr	r^2	b	c	se of b	se of c	n	probability	S.D
Trials 1-3	1	0.63	1.24*	-6.9*	0.16	2.99	36	0.0001	2.33
Trials 1-3 & Low digestibility	2	0.47	1.06*	-4.29	0.17	3.18	44	0.04	2.55
Low intake	3	0.09	0.42	5.17	0.43	7.71	12	0.35	2.15
Browse	4	0.27	-0.56*	28.37	0.24	4.87	16	0.04	2.93
Trials 1-3 & Browse	5	0.15	0.53*	6.11	0.17	3.38	52	0.001	3.43

* indicates significance

b = slope

c = intercept

se = standard error

S.D = standard deviation

However, when P concentration in the faeces was also taken into account, dietary N could be predicted more reliably (Table 3.5-Equation 1 & Fig 3.6) .

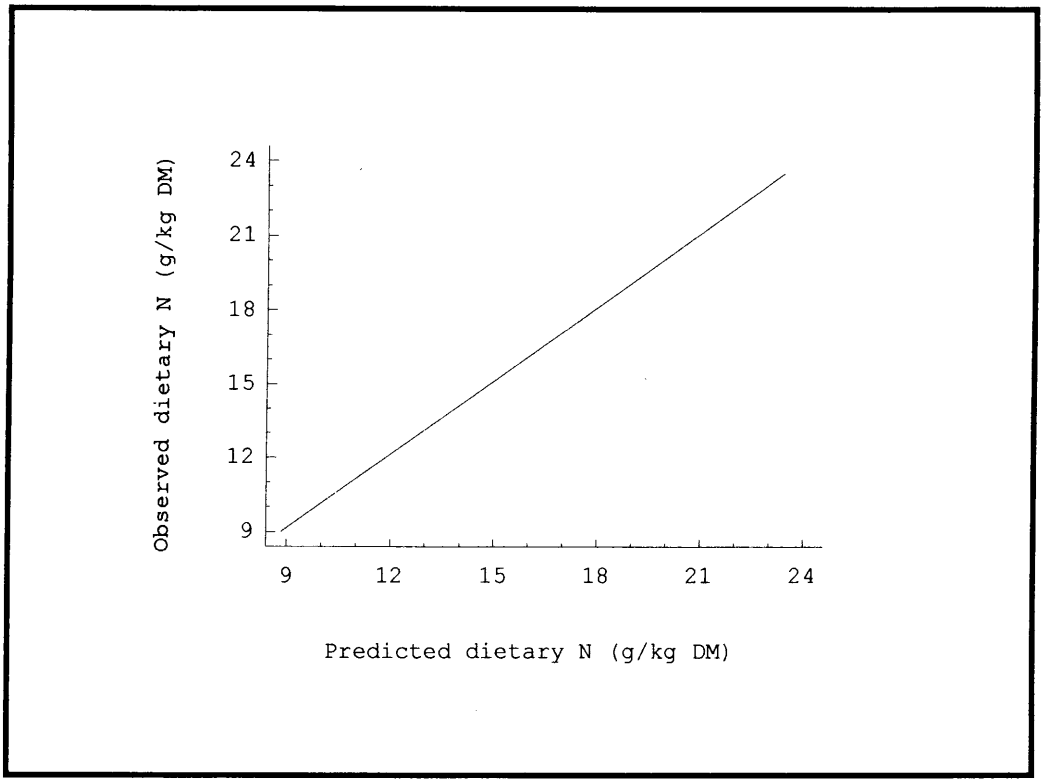

Figure 3.6. A multiple regression predicting dietary N concentration from faecal N and P concentrations for trials 1 to 3.

Table 3.5. Probability values for multiple linear regressions predicting dietary N concentration (g/kg DM) from faecal indices (g/kg DM)

Trial type	Equation	nr	r^2	P faeces	N faeces	ADIN	ADL	S.D
Trials 1-3	Y=-4.5+0.8(N)+1.0(P)	1	0.71	0.0017	0.0002			2.04
Trials 1-3 Low intake	Y=-5.01-0.75(N)+0.74(P)	2	0.6	0.0032	0.000			2.33
Browse	Y=2.9-0.75(N)+0.74(P)	3	0.17	0.78	0.18			3.03
Trials 1-3 & Browse	Y=6.13+0.38(N)+0.54(P)	4	0.16	0.1	0.05			3.37
	Y=13.2-0.29(N)+0.52(ADIN)	5	0.1		0.43	0.06		3.31
	Y=1.54+0.27(N)+0.05(ADL)	6	0.49		0.06		0.00	2.61
	Y=3.9+0.2(N)+0.5(ADL) +0.2(ADIN)	7	0.63		0.92	0.93	0	2.12
	Y=4.2+0.036ADIN+0.05ADL	8	0.64			0.72	0.00	2.08
	Y=2.1+0.73(P)+0.05(ADL)	9	0.53	0.01			0.00	2.05
	Y=0.1+0.1(ADIN)+0.05(ADL)	10	0.83			0.000	0.00	1.45
Digestibility	Y=-2.04+0.61(N)+1.0(P)	11	0.57	0.0016	0.0037			2.38
Digestibility & Trials 1-3	Y=-2.8+0.67(N)+0.92(P)	12	0.52	0.0013	0.0007			2.36

Faecal P concentration was added to the prediction of dietary N concentration as Grant *et al* (1995) reported that when dietary P concentrations were very low , N concentrations in the faeces increased even though fodder N concentrations decline.

3.3.3.1 The effect of a restricted intake on dietary N predictions:

In the trials where intakes of animals were restricted to simulate winter , prediction of dietary N from faecal N was very poor (Table 3.4-Equation 3). As this regression equation was not significant the data from trials 1 to 3 (Equation 1) was added to this regression equation . The best prediction of dietary N was again from faecal N and faecal P (Table 3.5-Equation 2 & Fig 3.7).

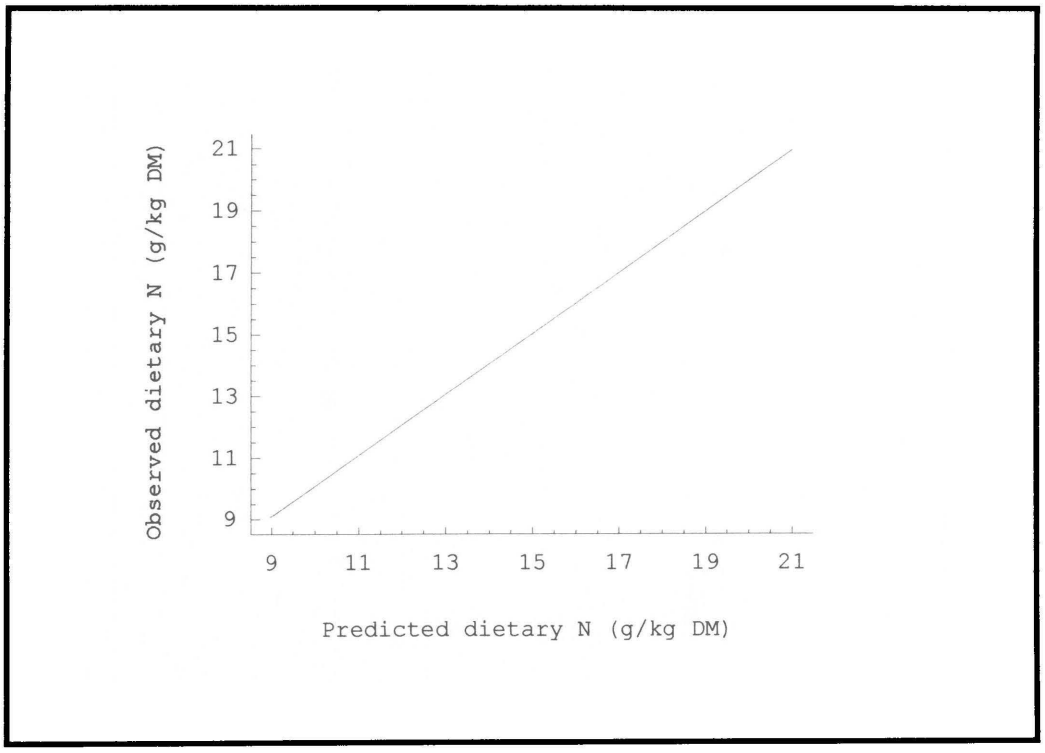

Figure 3.7. A multiple regression predicting dietary N concentration from faecal N and P concentrations for trials 1 to 3 and restricted intake data.

3.3.3.2 The effect of bush intake on dietary N prediction:

When the results of the trials with bush were examined to predict dietary N concentration, faecal N concentration was a poor predictor (Table 3.4-Equation 4), and the slope had a significant negative slope. The slope and intercept of this regression equation also differed significantly from the slope and intercept of the regression equation of trials 1 to 3. When P was included with N in this prediction, both N and P became insignificant and the prediction remained poor (Table 3.5-Equation 3). As the variation in dietary N of the bush data was limited, these results were added to the data of the original 3 trials, however the prediction of dietary N concentration from faecal N concentration remained poor (Table 3.4-Equation 5). Adding faecal P did not improve it and both faecal P and N were insignificant (Table 3.5-Equation 4).

Tannins present in bush decrease the neutral detergent soluble content of bush and this can be traced by an increase in lignin content (Robbins, Hanley, Hagerman, Hjeljord, Baher, Schwartz and Mauts ,1987a). When bush is eaten, faecal N concentration is not a good indicator of dietary N concentration as it includes tannin-bound protein as well as non digested fiber bound protein (Robbins *et al*, 1987a). If faecal ADIN is included as a predictor of dietary N it represents the insoluble or non digested N. When faecal ADIN in the present investigation was added to the regression with faecal N concentration, the latter became insignificant and the standard error was unsatisfactory (Table 3.5-Equation 5). To represent the tannin- bound N, faecal ADL concentration was added to the regression with faecal N concentration to predict dietary N

concentration but the prediction was poor and faecal N was not significant (Table 3.5-Equation 6). For the prediction of dietary N concentration using faecal N concentration, faecal ADL concentration and faecal ADIN concentration, both N and ADIN were insignificant. However the prediction improved (Table 3.5-Equation 7). The tolerance of using ADL and ADIN to predict dietary N concentration was then examined and the prediction using these variables improved (Table 3.5-Equation 8 & Fig 3.8).

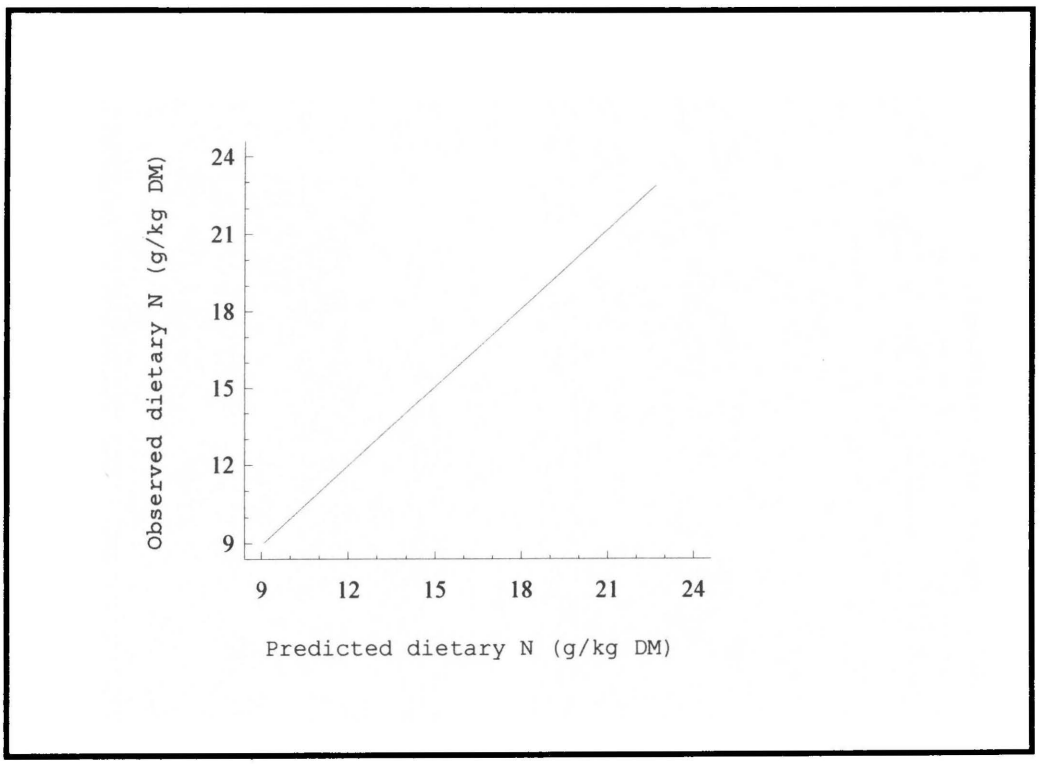

Figure 3.8. A multiple regression predicting dietary N concentration from faecal ADL and ADIN concentrations for trials 1 to 3 and browse data.

If faecal P concentration was added to the regression with faecal ADL concentration to predict dietary N concentration, the prediction weakened (Table 3.5-Equation 9). When the results of the

diets with the highest tannin levels >220g/kg were removed from the above regression, as in nature it would be unlikely that the animals would eat such large amounts of bush with such high tannin contents, the prediction using faecal ADL and faecal ADIN concentrations improved (Table 3.5-Equation 10).

3.3.3.3 The effect of a lower digestibility on dietary N prediction :

When the data from trial 4 with the lower digestibility was added to the simple linear regression predicting dietary N from faecal N concentration of trials 1 to 3, the prediction weakened (Table 3.4-Equation 2). This was also the case with the multiple regression of trials 1 to 3 (Table 3.5 - Equation 11). If the data from trial 4 with lower digestibilities were added to the multiple regression equation of trials 1 to 3 and the restricted intake data (Table 3.5-Equation 1), the prediction also weakened (Table 3.5-Equation 12).

3.4 DISCUSSION

Faecal P concentration was highly significantly correlated with dietary P concentration (p= 0.001). This corresponds with the findings of Leslie and Starkey (1985) for free ranging elk and deer and Howery and Pfister (1990) for white-tailed deer. Researchers have found the same in domestic ruminants by using either total faecal P output (g/day) or total faecal P concentration (% dry matter) (Moir, 1960; Cohen 1974; Belonje and Van den Berg 1980a&b; Holechek *et al,* 1982; Holechek, Galyean, Wallace and Wofford, 1985;). In this study the best prediction for dietary P was obtained from the regression equation of Y = 0.34X +0.28, using faecal P

concentration. The intercept was not significant so the equation could be passed through the origin Y = 0.393X. Contrary to Grant *et al* (1995), we found that faecal N concentrations did not improve the prediction of dietary P concentrations. Lower dietary digestibility also had a small effect on the prediction of dietary P and it appeared that the tannins in browse did not have an effect on P excretion or the prediction of dietary P concentration, which corresponds with findings of Leslie and Starkey (1985). Contrary to Read (1984), a lower intake had an effect on the amount of faeces excreted but had no effect on the prediction of dietary P. It would therefore appear that one prediction equation could be used in the case of impala to predict dietary P regardless whether they are grazing or browsing or if they have a restricted intake. Approximately 37% of faecal P concentration reflects dietary P concentration. It appears that the prediction of dietary P form faecal P in impala is robust and not disturbed by level of intake or digestibility of the diet.

For the prediction of dietary N concentration, the best prediction was from multivariate models, which corresponds with findings of American (Holloway, Estell and Butts, 1981) and local workers (Grant *et al,* 1995). Dietary N concentration could be predicted satisfactorily by faecal N and P concentrations. Other researchers reported that for elk, deer, duiker, eland, hartebeest and cattle only faecal N concentrations are needed to predict faecal N concentrations. However, in these studies no other faecal variables including faecal P were examined. The prediction of dietary N concentration from faecal P and N concentration weakened at lower dietary digestibilities. Faecal N concentration can provide a good estimate of dietary N concentration provided the diet does not contain high levels of soluble phenolics such as tannins (Wofford *et al* ,1985). Faecal N

concentration is elevated whenever diets contain tannins (Hobbs, 1987; Cook *et al,* 1994). In this 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 concentrations may be used as an indication of bush utilisation by impala as bush has a higher lignin content than grass. When faecal ADL was above 160g/kg but below 220g/kg, indicating browse utilisation, the regression equation with faecal P and N was poor, but ADL and ADIN gave good results as discussed. However with faecal ADL below 160g/kg, indicating grass utilisation, faecal ADL and ADIN were poor predictors, whereas faecal N and P proved useful.

3.5 CONCLUSION

Using a combination of faecal indices, dietary P and N concentrations can be predicted satisfactorily in impala either grazing or browsing, or if they have a restricted intake, in winter or during a drought period.

CHAPTER 4

MULTISPECIES PREDICTION EQUATIONS FOR DIETARY N, P AND DIGESTIBILITY

4.1 INTRODUCTION

One of the aims of this chapter was to determine the value of faecal analyses in determining the nutritional status of other Southern African herbivores. This chapter examines the possibility of extrapolating the results from the impala calibration trial to make it possible to use 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. The prediction of dietary P concentration from faecal P concentration was found to be fairly robust and one might expect to be able to estimate dietary P concentrations for a wide range of species fairly accurately. The prediction of dietary N concentration on the other hand, is influenced by P intake and phenolic compounds making the prediction more complex (Mould and Robbins, 1981; Howery and Pfister, 1990 and Cook *et al,* 1994).

4.2 METHODS

Veld data from trials with blue wildebeest, zebra (grazing on veld in camps in the Hans Hoheisen Research Station, in the Timbavati Nature reserve bordering the Kruger National

Park) (Bodenstein, being prepared for a thesis) impala (utilising grass and browse in the Hans Hoheisen Research Station) (Meissner, Pieterse and Potgieter, 1995) and cattle (on natural grazing ,without lick supplementation in the mountain savannah area of Namibia) (Grant, 1989) were used to set-up prediction equations for dietary N, dietary P and where data was available, dietary digestibility. Data from the impala calibration study was also used. Simple linear and multiple regression equations to predict dietary N and P and digestibilities were drawn up for single species. The slopes and intercepts of these regression lines were then compared to the slopes and intercepts of the equations obtained from the impala calibration trial. These slopes and intercepts were tested with students t tests (Zar, 1974). Distributions of data sets were tested with the Kolmogorov- Smirnov two sample test (Statgraphics, version 7.0).

4.3 RESULTS

4.3.1 Dietary P predictions:

Regression equations were compared to determine whether the prediction equations of the different species were comparable. It was also determined whether a single simple regression can be used from which dietary P concentration can be predicted from faecal P concentration where specific equations are not available.

The simple regressions for impala (calibration data), zebra, blue wildebeest and cattle are displayed in Table 4.1 and Figure 4.1. There was no P data available for the field study of impala.

Table 4.1. 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	S.D	p	Dietary N range	Dietary P range
Calibration Impala	0.67	0.34*	0.28	0.04	0.24	36	0.35	0.0001	9.7-20	1.3-3.8
Bwb	0.14	0.21*	0.48*	0.08	0.21	36	0.41	0.02	4.3-12.6	0.45-2.37
Bwb + calibration	0.76	0.36*	0.17	0.02	0.11	72	0.41	0.0001	4.3-21.9	0.45-3.8
Zebra	0.18	0.40*	0.37	0.14	0.37	36	0.45	0.01	4.6-12.5	0.5-2.54
Zebra + calibration	0.73	0.31*	0.49*	0.02	0.09	72	0.42	0.001	4.3-21.9	0.5-3.8
Cattle	0.45	0.32*	0.44	0.04	0.23	65	0.54	0.001	9.6-20	1.3-3.4
Cattle+ calibration	0.53	0.33*	0.38*	0.03	0.15	101	0.49	0.001	4.3-21.9	1.3-3.8
All data	0.66	0.33*	0.37*	0.01	0.07	174	0.47	0.001	4.3-21.9	0.45-3.8

b= slope

c= intercept

n= number of faecal samples

se= standard error

*= significant ($p<0.05$)

S.D = standard deviation

Calibration = impala calibration trials 1-3

Bwb = blue wildebeest

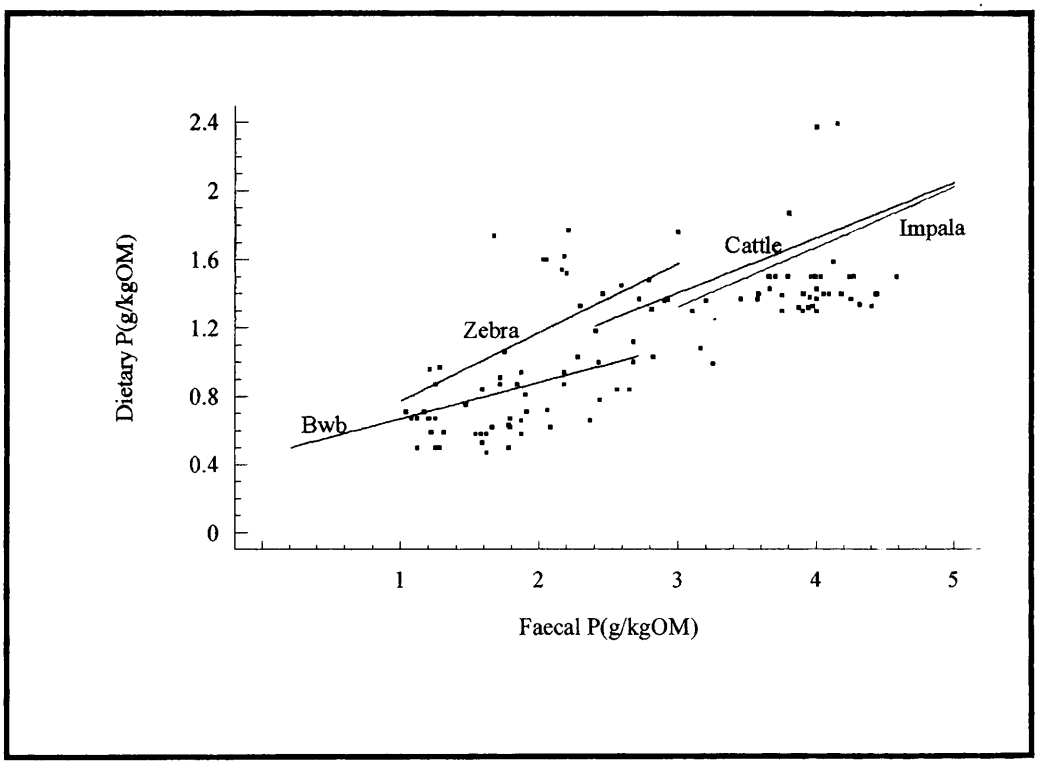

Figure 4.1. Simple linear regressions predicting dietary P concentration (g/kgOM) from faecal P concentration (g/kgOM) for impala, zebra, blue wildebeest and cattle.

If the blue wildebeest regression (Table 4.1) was compared to the impala calibration regression (Table 4.1-Fig 4.1), it was found that the slopes of the two regression equations 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. This test indicated that the distribution of the two regression equations did not differ significantly (Estimated overall statistic D.N.= 0.701).

Therefore, the data from the blue wildebeest was added to that of the calibration study and the slope of this regression equation did not differ significantly from the impala regression equation (Table 4.1- Fig 4.2).

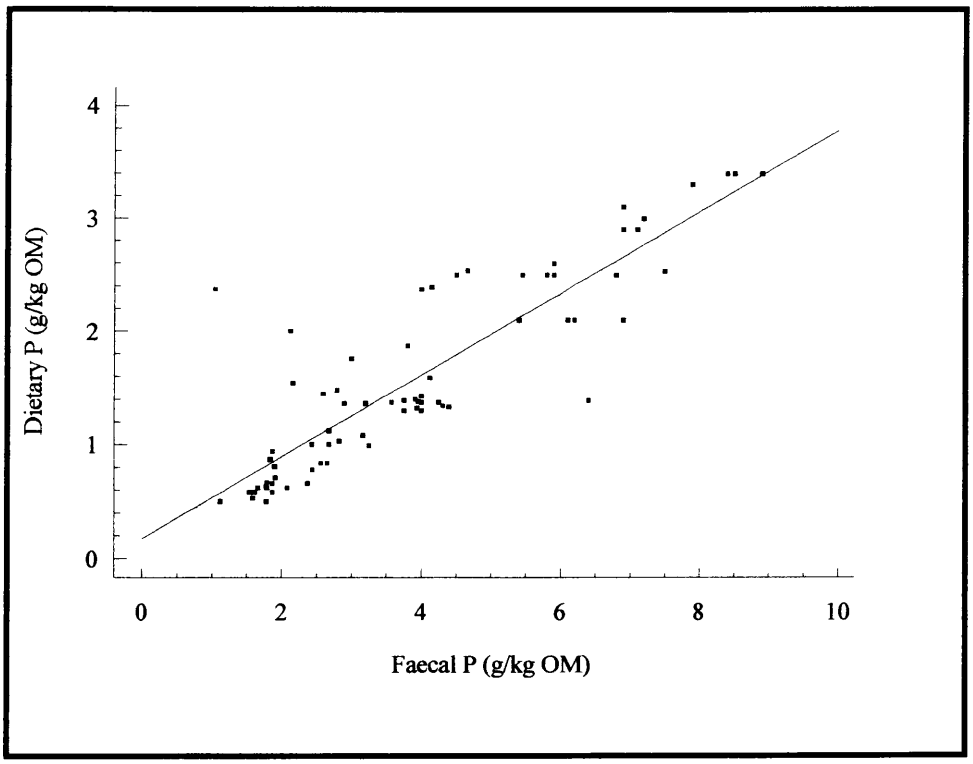

Figure 4.2. Simple linear regression predicting dietary P concentration (g/kgOM)from faecal P(g/kgOM) for blue wildebeest and impala calibration data .

When the regression equation of the zebra data was compared to that of the impala calibration data, no significant differences were found between either the slopes or the intercepts of the

two regression equations. The two data sets were therefore combined in one regression without the slope of the regression equation changing significantly (Table 4.1- Fig 4.3).

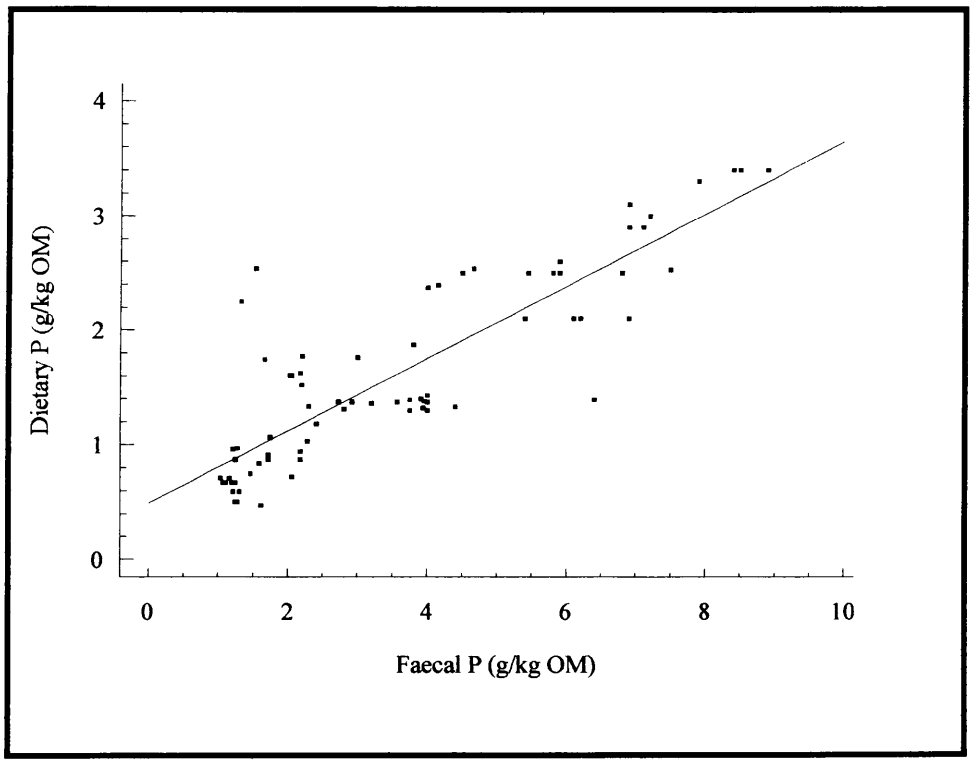

Figure 4.3. Simple linear regression predicting dietary P concentration (g/kgOM)from faecal P(g/kgOM) for zebra and impala calibration data.

There was also no significant difference between the slopes and intercepts of the regression equations of the cattle and the impala calibration data. Adding the two sets of data did not alter the slope of the regression equation significantly (Table 4.1- Fig 4.4).

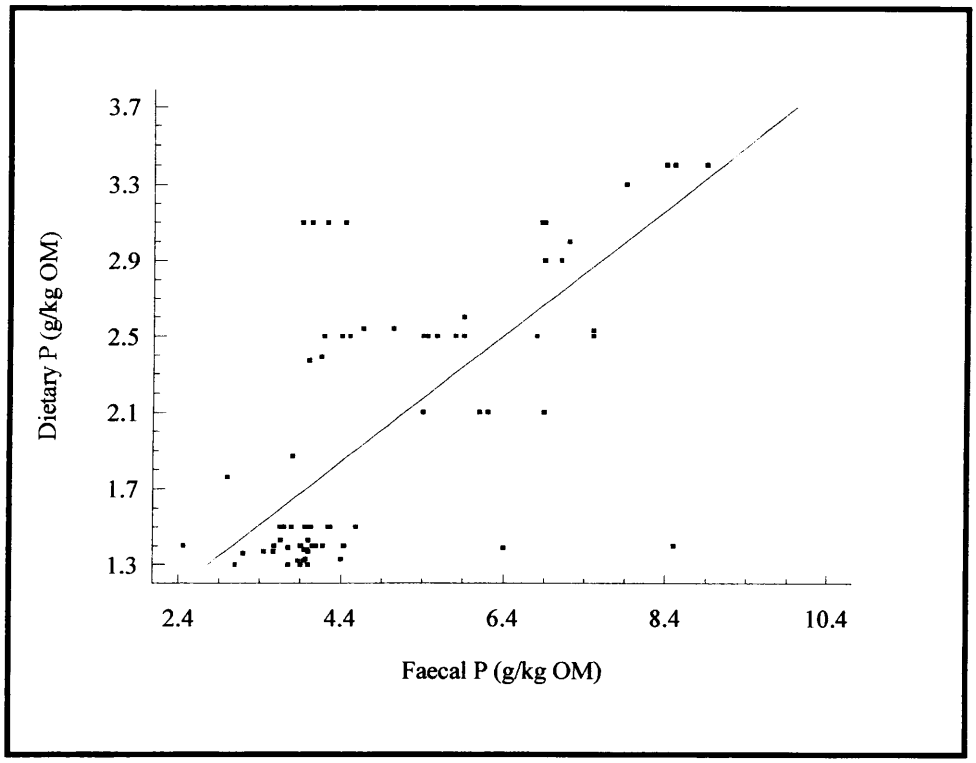

Figure 4.4. Simple linear regression predicting dietary P concentration (g/kgOM)from faecal P(g/kgOM) for cattle and impala calibration data.

All data was then subsequently combined into a single regression equation, and the slope of the regression equation still did not differ significantly from the impala calibration regression, indicating that when data of all four species are combined into one prediction equation (Table 4.1- Fig 4.5), this equation does not differ significantly from that of the individual species.

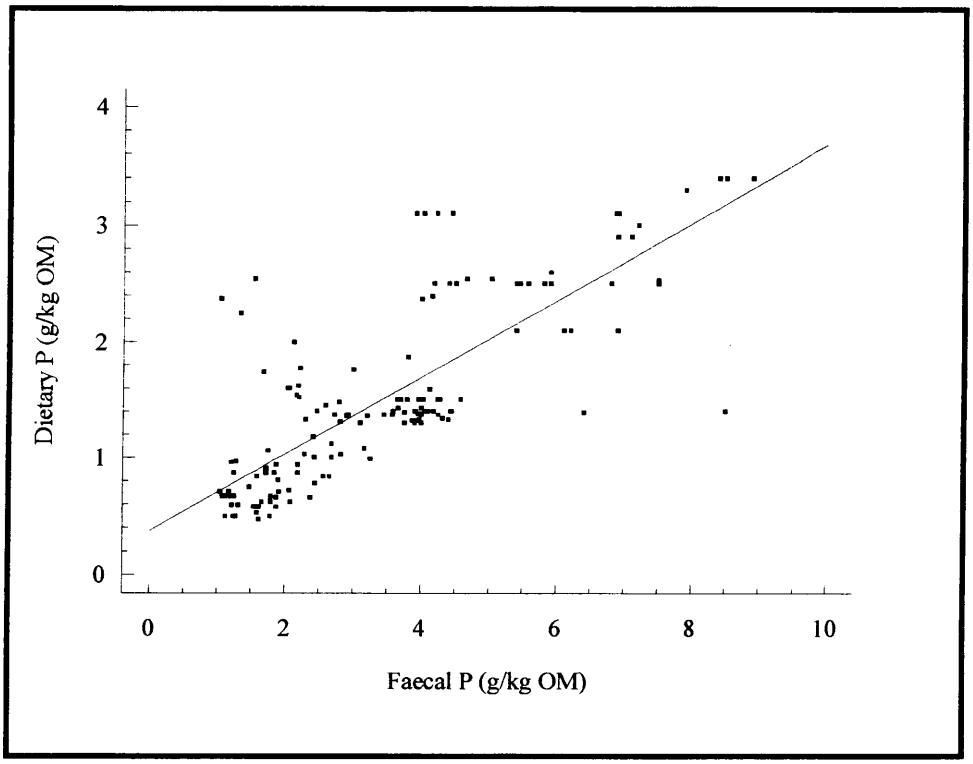

Figure 4.5. Simple linear regression predicting dietary P concentration (g/kgOM)from faecal P(g/kgOM) for all species.

4.3.2 Dietary N prediction:

The results of the simple regression equations for prediction of dietary N concentration from faecal N concentration are displayed in Table 4.2.

Table 4.2. Simple linear regression equations to predict dietary N (Y)(g/kg DM) from faecal N (X)(g/kg DM) for different species

Species	r^2	b	c	se of b	se of c	n	S.D	probability	N range	P range
Calibration	0.63	1.24*	-6.9*	0.16	2.99	36	2.33	0.0001	9.7-20	1.3-3.8
Impala.field	0.34	0.83*	3.8	0.14	1.84	64	2.86	0.0001	9.76-22	1.3-3.8
Bwb	0.45	0.84*	-0.97	0.15	1.59	36	2.1	0.0001	4.3-12.5	0.45-2.37
Zebra	0.41	0.95*	-0.4	0.18	1.63	36	2.2	0.0001	4.6-12.5	0.5-2.54
Cattle	0.46	0.9*	-1.6	0.12	2.08	64	2.67	0.001	9.6-20	1.3-3.4
Zebra & Bwb	0.92	0.81		0.02		74	2.13	0.001	4.3-12.5	0.45-2.54

b = slope

c = intercept

n = sample size

* = significant ($p<0.05$)

S.D = standard deviation

Bwb = blue wildebeest

Calibration = impala calibration study trials 1-3

According to results of previous studies (Grant*et al*,1996) dietary P concentration may play a role in prediction of dietary N concentration. Results of multiple regressions for prediction of dietary N concentration from faecal N and P concentration are consequently displayed in Table 4.3.

Table 4.3. Multiple regression equations predicting dietary N(g/kgDM) from faecal N(g/kg DM), P(g/kg OM), ADL(g/kg DM) and ADIN (g/kgDM) for different species

Regression Sp.	R^2	P	N	ADL	ADIN	S.D	n
Impala calibration trials 1-3 Y= -4.5 +0.8(N) + 1.0(P)	0.71	0.0017	0.0002			2.04	36
Impala calibration all data Y=9.77+0.07(N)+0.26(ADIN)	0.07		0.7		0.01	2.96	56
Impala calibration all data Y=1.06+0.27(N)+0.04(ADL)	0.43		0.04	0.0001		2.55	64
Impala calibration all data Y=3.09+0.05(ADL)+0.13(ADIN)	0.59			0.001	0.09	1.9	56
Impala field data Y=1.89+0.75(N)+0.15(ADL)	0.4		0.0001	0.001		2.92	64
Impala field data Y=2.43+1.32(N)-0.66(ADIN)	0.35		0.0001		0.11	2.85	64

Impala field data Y =5.53+0.18(ADL)+0.69(ADIN)	0.35			0.0001	0.004	2.5	40
Blue wildebeest Y=-0.85+0.85(N)-0.11(P)	0.42	0.8	0.0001			2.13	36
Zebra Y=-0.65+0.89(N)+0.43(P)	0.39	0.54	0.0002			1.99	37
Cattle Y=-0.64+0.47(N)+1.27(P)	0.63	0.000	0.0001			2.18	65

S.D = standard deviation

In Chapter 3 it was suggested that faecal Acid detergent lignin (ADL) should be included in the regression to represent the phenolic compounds taken in with browse. The results of these regressions are also displayed in Table 4.3.

For the field data of impala a simple regression was used to predict dietary N concentration (Table 4.2). The slope and intercept of this regression equation differed significantly from that of the impala calibration trial. Faecal P could not be included in the prediction as the data was unavailable. The inclusion of faecal ADL or ADIN did not improve the prediction.

However, if ADL concentration was selected to only include those concentrations above 160g/kg as previously suggested to indicate when impala are browsing, the prediction was satisfactory.

For blue wildebeest a simple linear regression equation was used to predict faecal N concentration (Table 4.2-Fig 4.6).

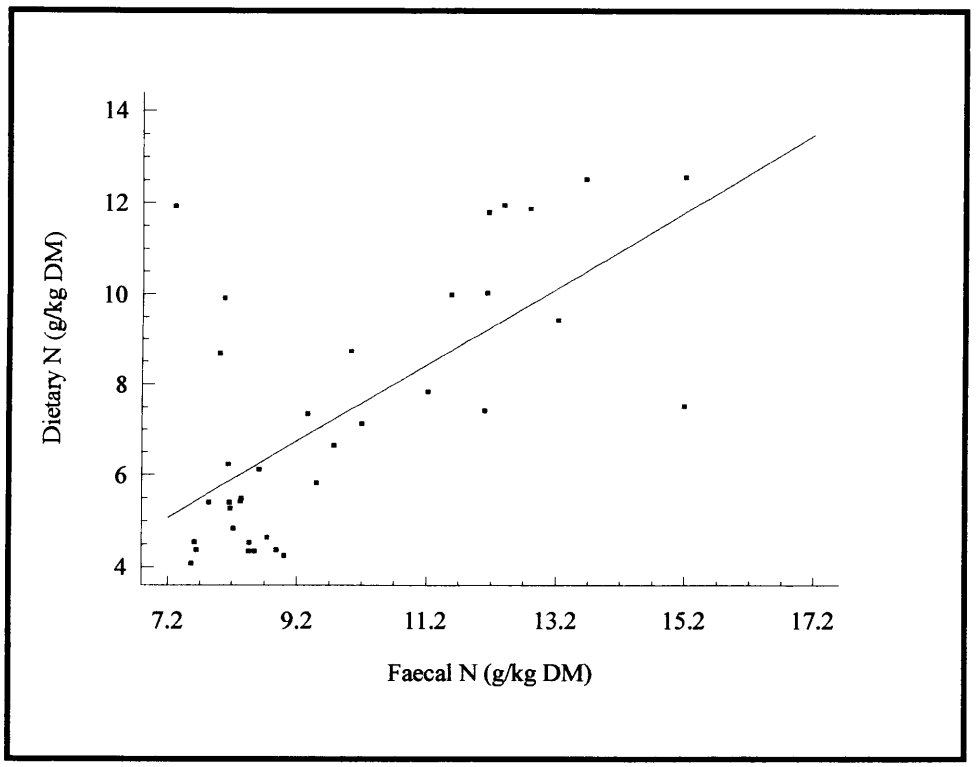

Figure 4.6. Simple linear regression equation predicting dietary N concentration (g/kgDM) from faecal N concentration (g/kgDM) for blue wildebeest

The slope and intercept of this regression equation differed significantly from that of the impala calibration regression.

For zebra the simple regression equation predicting dietary N concentration from faecal N concentration (Fig 4.7) had a significantly different intercept to that of the impala calibration trial, however the slopes of these two regression equations did not differ significantly.

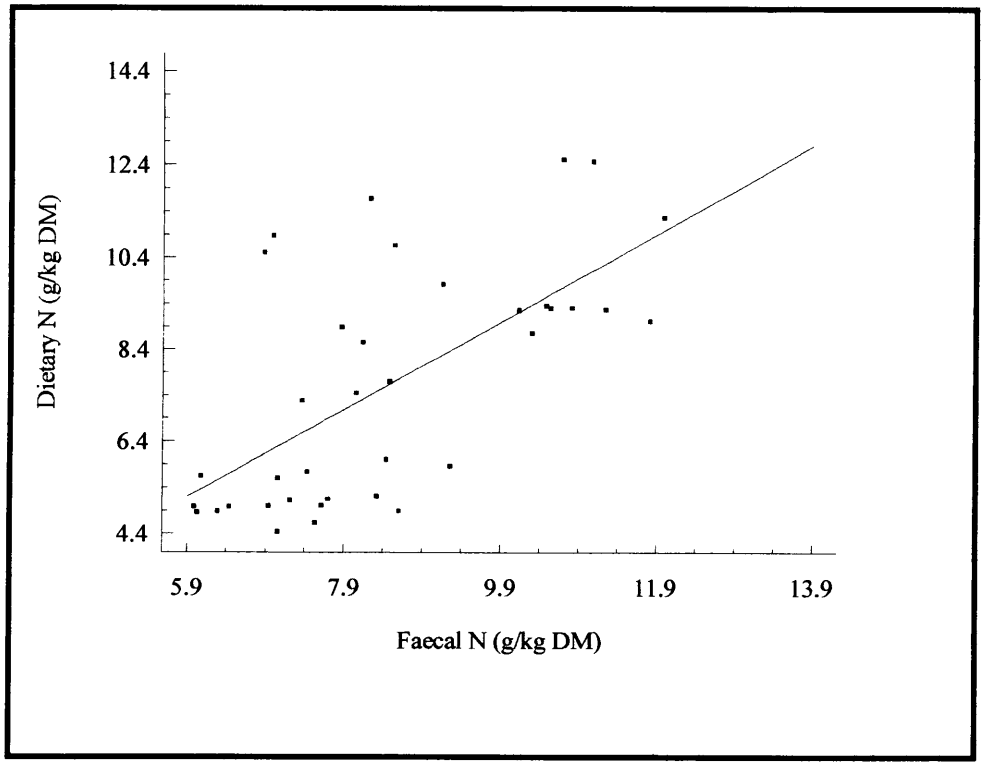

Figure 4.7. Simple linear regression equation predicting dietary N concentration (g/kgDM) from faecal N concentration (g/kgDM) for zebra

For cattle the simple regression equation also differed from that of the impala calibration trial. A multiple regression equation using faecal N and P concentrations to predict dietary N concentration improved the relationship and consequently was used.

4.3.2.1 Overall prediction:

In contrast to P, there was not a single simple regression equation predicting dietary N concentration from faecal N concentration as the slopes and intercepts of the regression equations differ from that of the impala calibration trial. In cattle and the impala calibration trial it appears that the inclusion of faecal P was needed to improve the prediction, but it was not the case for zebra and blue wildebeest. For zebra and blue wildebeest one regression

equation could be established as the two regression equations did not differ significantly. Their intercepts did not differ significantly from zero either and could therefore be passed through the origin (Table 4.2-Fig 4.8). For browsing impala, the inclusion of faecal ADL and ADIN was needed.

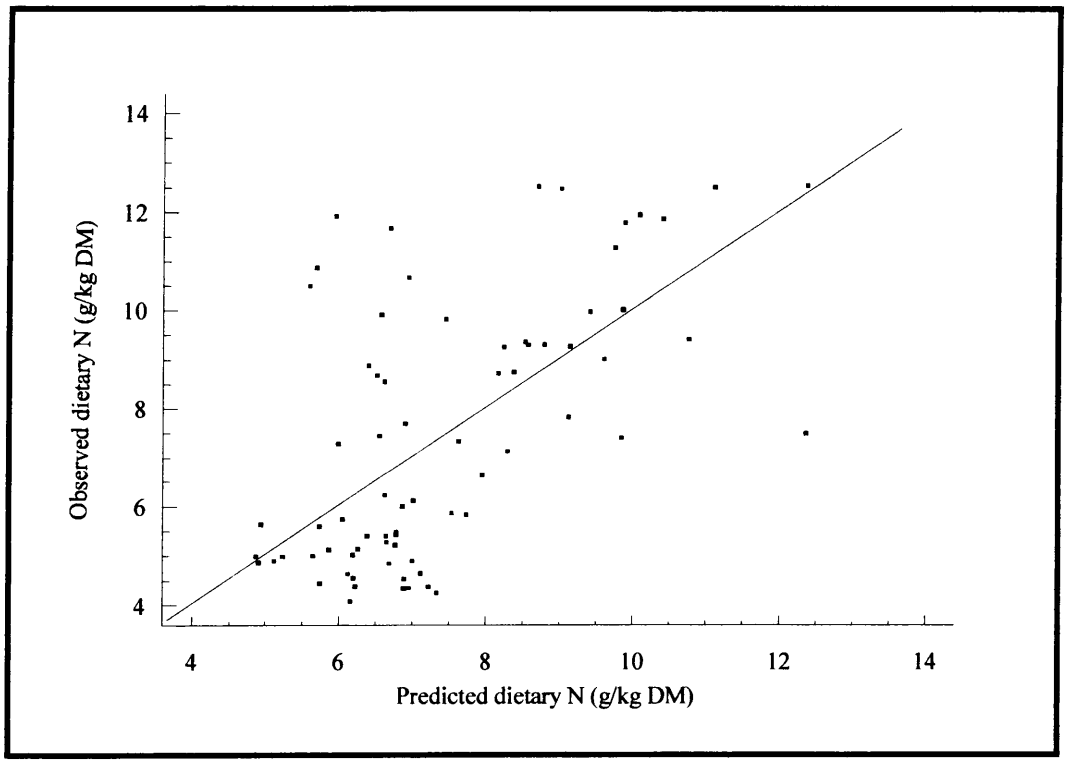

Figure 4.8. Simple linear regression equation of predicted dietary N concentration (g/kgDM) versus observed dietary N concentration (g/kgDM) for zebra and blue wildebeest. Line passes through the origin

4.3.3 Digestibility prediction:

Faecal indices were tested in regression equations to determine which indices were the best predictors of dietary digestibility. Faecal N, P and ADL were tested. Faecal N has been reported to be a reliable indicator of dietary digestibility (Lancaster, 1949; Greenhalgh and

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. The results of these regression equations are shown in Table 4.4 and 4.5.

Table 4.4. Simple linear regression equations predicting dietary digestibility (%DM) from faecal P (%OM) , N(%DM) and ADL(%DM)

Species	Indices	r^2	b	c	se of b	se of c	n	S.D	p
Imp.cal	N	0.26	14.6	35.7	4.16	7.68	36	6.22	0.0013
Imp.cal	P	0.06	11.1	55.1	7.04	4.02	36	7.01	0.124
Bwb	P	0.12	42.6*	33.1*	19.7	4.77	36	9.21	0.03
Bwb	N	0.63	34.3*	9.1	4.45	4.49	36	7.9	0.00001
Bwb	ADL	0.12	-2.66*	81.2	1.19	17.2	36	9.17	0.03
Imp.field	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	0.00001
Zebra	P	0.39	104*	27.0*	22.3	4.01	36	7.12	0.00004
Zebra & Bwb	N	0.54	31.2	15.3	3.68	3.45	72	6.58	0.00001

b = slope

c = intercept

* = significant ($p < 0.05$)

se = standard error

n = number of faecal samples

S.D. = standard deviation

Bwb = blue wildebeest

Imp.cal = impala calibration study trials 1-3

Imp.field = impala field trials

Table 4.5. Multiple regression equations to predict dietary digestibility (%DM) from faecal N(g/kgDM), P(g/kgOM) and ADL(g/kgDM)

Sp. Equation	r^2	N(p)	P(p)	ADL(p)	S.D	n
Impala calibration Y=33.6+17.9(N)-7.39(P)	0.23	0.0003	0.39		6.25	36
Impala calibration Y=53.99+25.1(P)-0.38(ADL)	0.12		0.42	0.03	7.04	36
Impala calibration Y=31.116+23.19(N)-0.73(ADL)	0.42	0.0001		0.06	5.73	27
Impala calibration Y=32.1+21.8(N)+4.24(P)-0.7(ADL)	0.41	0.0001	0.69	0.06	5.83	27
Blue wildebeest Y =9.5+33.5(N) +6.16(P)	0.61	0.0001	0.65		6	36
Blue wildebeest Y=30.5+32.5(N)-1.36(ADL)	0.64	0.0001		0.08	5.74	36
Blue wildebeest Y=-3.50+0.87(N)-0.11(P)+0.01(ADL)	0.63	0.0001	0.69	0.09	5.8	36
Zebra Y=7.32+33.4(N)+53.6(P)	0.69	0.0001	0.004		4.9	36

Zebra Y=17.40+40.2(N)-0.5(ADL)	0.64	0.0001		0.08	5.33	36
Zebra Y= 14.6+32.6(N)+53.5(P)-0.05(ADL)	0.72	0.0001	0.004	0.05	4.7	36

S.D = standard deviation

se = standard error

n= number of faecal samples

For the field impala there was no significant relationship between either faecal N or ADL or the combination. Faecal P results were not available. For the impala calibration the best prediction was from faecal N, P and ADL concentrations. For blue wildebeest faecal N as well as the combination of faecal N and ADL gave satisfactory predictions. For zebra faecal N as well as the combination of faecal N, P and ADL gave satisfactory predictions. There was no digestibility data available for cattle.

4.3.3.1 Overall prediction:

It appears that there are species differences in the prediction of dietary digestibility. For zebra and blue wildebeest the simple linear regression equation using faecal N to predict dietary digestibility could be used. The slopes and intercepts of these two lines did not differ significantly, so these two lines could be combined to form one prediction equation (Fig 4.9).

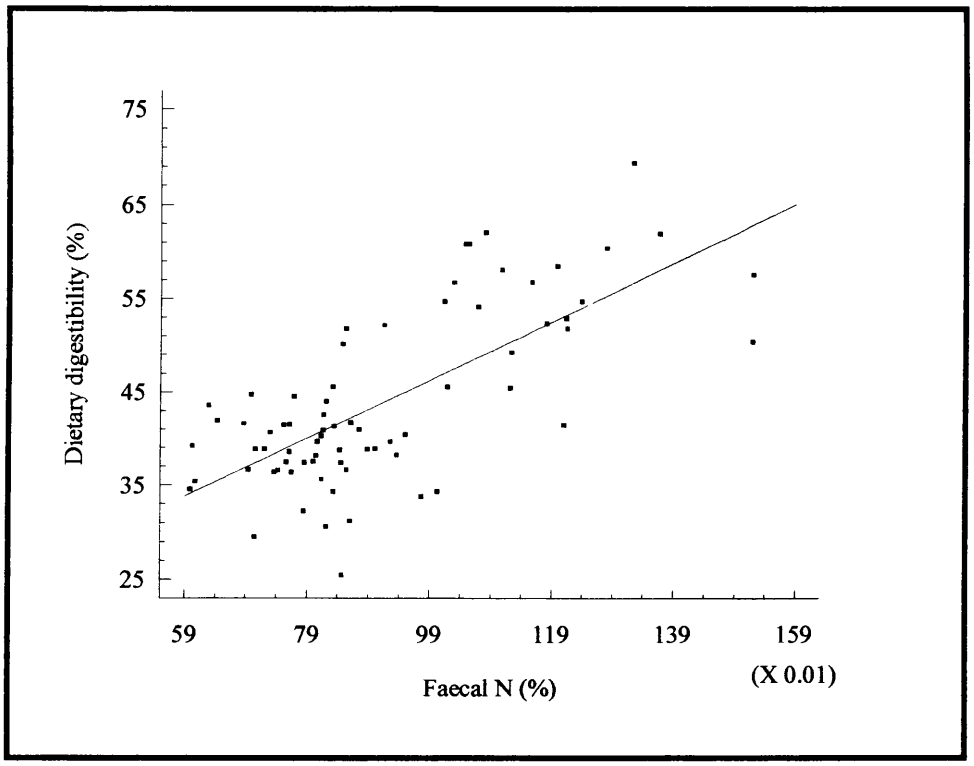

Figure 4.9. Simple linear regression predicting dietary digestibility (%) from faecal N(%) for zebra and blue wildebeest

It appears that faecal ADL was also important in the prediction of dietary digestibility.

4.4 DISCUSSION

The prediction of dietary P concentration from faecal P concentration seems to be fairly robust for all species examined. For the prediction of dietary P, one regression equation could thus be established for all species This prediction equation $Y = 0.33X + 0.37$ is comparable and the slope possibly not significantly different from that found for elk $Y = 0.414X + 0.088$ and deer $Y = 0.305X + 0.096$ (Leslie and Starkey, 1985) (Y, and X, expressed as %). It is also comparable to the prediction equation of Moir (1960) who reported the regression equation

Y= 0.36X+0.57 in dairy cattle grazing tropical pastures (Y, expressed as gP/kgDM X, expressed as gP/kgOM). Holechek *et al* (1985) reported a regression equation of Y= 0.37X -0.22 for steers which has a slope similar to that found in this study (Y, expressed as gP/kgDM X, expressed as gP/kgOM).

It has been reported that faecal P levels lower than 2gP/kgOM indicate a deficiency in most species (Grant, 1989; Grant *et al,* 1995). Using the present regression equation for all species it can be calculated that for the recommended dietary P intake of 0.076%DM (Cohen ,1975), faecal P should be 2.05g/kg. However, if the impala calibration regression was used a concentration of 2gP/kgDM would indicate a deficiency and the associated error is 0.4g/kg OM. This is very close to the recommendation of 2g/kg found in practice in Namibia (Grant, 1989).

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 by Leslie and Starkey (1985) for elk Y = 0.843X +0.170 and for deer Y= 1.025X -0.772. These equations however, differ widely from those predicting dietary N in duiker Y= 0.253X+1.21, eland, Y= 0.288X +0.83, elk Y=0.443+1.02, hartebeest Y= 0.224X +1.23, mule deer ; Y = 0.336X +1.36, Thomsons gazelle Y= 0.267X+1.15 and white-tailed deer Y= 0.340X +1.39 (Robbins, 1983).

In the calibration study the regression equation obtained when impala were utilizing browse differed significantly to when they were grazing (Table 3.4). It would therefore appear that different equations should be used to predict dietary N for grazers and browsers and that in the case of browsers the slope of the regression equation is smaller than for grazers. This

would explain why the regressions for the browsers or selective feeders such as duiker, eland, elk, hartebeest, mule deer, thomsons gazelle, white tailed deer and browsing impala differ from those found in zebra, blue wildebeest, cattle and grazing impala. From the above regression equations for grazers and browsers obtained from the impala calibration study, for browsers a small increase in dietary N results in a large increase in faecal N, for grazers a small increase in dietary N results in a small increase in faecal N. This higher faecal N excretion in browsers could be due to tannins which cause a higher faecal N. This is confirmed by Mould and Robbins (1981) who found that when 100% maple was fed to elk the regression of faecal N vs. dietary N departed from the equation 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 predict dietary N concentration 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%, whereas Munston (1967) reported that 11-12gN/kgDM in grass is required for microbial activity. Using these two indicators for the combined regression for zebra and bluewildebees, 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 11gN is required approximately 13.75gN/kg should be excreted. Therefore, a concentration of approximately 14gN/kg should be excreted and below this would indicate a deficiency in grazers. For browsers this is not as simple as multiple factors affect the prediction.

Wehausen (1995) suggested that dietary N was not indexed directly by faecal N because of tannins. He suggested that a log transformation of faecal N should rather be used to linearize the relationship with digestibility. However, he only examined faecal N and if faecal P and ADL are included into the regression equation this is not necessary. It appears that for some

species a good prediction of dietary digestibility can be obtained by using faecal P, N and ADL. The predictions of dietary digestibility in impala were poor which could be as a result of the fact that there was very little variation in digestibility of the diets. Faecal ADL improved the predictions in some cases but it remains insignificant.

Arman , Hopcraft and Mcdonald(1975a) stated that relationships should be established for each ruminant species by forage type consumed. However, if the role of tannins in the excretion of faecal N and P concentrations can be better understood, perhaps there would then only be two regression equations, one for grazers and one for browsers. It is therefore clear that more work needs to be done examining the effect of tannins and the difference between grazers and browsers.

4.5 CONCLUSIONS AND IMPLICATIONS

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 in all situations. This means that an accurate estimate of dietary P can be made by only looking at faecal P. Dietary P is roughly equal to 37% of faecal P concentration. In southern Africa where P deficiency is one of the most common causes of poor fertility (Read and Engels ,1986), estimation of dietary P could be important to establish whether animals are deficient in P and thus when a P supplement may be beneficial. 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 for browsers a different prediction equation should be established. More work needs to be done to quantify this prediction. The prediction for grazers is better calibrated and may be used to determine whether a N deficiency exists. If one

anticipates such a deficiency one could then take timely management measures to try to avoid losses associated with N deficiencies.

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

CHAPTER 5

5.1 CONCLUSIONS AND RECOMMENDATIONS

Determination of the composition of faecal samples appears to be a very successful way of assessing dietary composition of wild herbivores. This type of sample enables one to monitor the animal indirectly without subjecting the animal to any form of stress and the technique is simple and can be used anywhere. Other techniques that have been used are time consuming, expensive and expertise are required for the collection and analyses of the samples.

For the collection of a reliable faecal sample, a fresh, day old sample that has not been exposed to rain or dungbeetles should be collected. This sample should be oven or airdried, out of the sun and care should be taken to prevent mould formation.

To determine dietary P concentrations from faecal samples in impala, only faecal P concentrations need to be used. It appears that even when impala start utilising browse this prediction does not change significantly. This is also the case when they have a limited intake or when the digestibility of the diet is lower. One prediction can therefore be used for all three cases . For other species i.e. zebra, impala, blue wildebeest and cattle, faecal P concentrations can also be used to predict dietary P concentrations. The prediction equations of the different species do not differ significantly, therefore it appears as if one prediction equation can be used to predict dietary P concentrations in all the above species. It seems as if their is no difference in the prediction equation of grazers and browsers either. However, in this study all species studied were grazers

with the exception of impala which are mixed feeders. Therefore, before one can be certain if this prediction will hold for all browsers one would have to do further research on browsers. The inclusion of other faecal indices did not improve the prediction of dietary P concentration despite the reports indicating that the excretion of faecal N and P are linked for the species studied. Approximately 37% of faecal P represents dietary P. The recommendation is that if faecal P declines to less than 2gP/kgOM a deficiency is likely. This deficiency would affect the animals reproductive and growth potential. If faecal P values are constantly recorded managerial actions can be taken to correct the deficiency and therefore improve production.

The prediction of dietary N concentration from faecal N concentration is not as simple as that of dietary P concentration. For this prediction in impala, faecal N and P concentrations need to be used to predict dietary N concentration . The consumption of browse containing high levels of polyphenols (tannins) affects the prediction and in this study required a separate prediction using faecal ADL and ADIN concentrations. The effect of high tannin levels present in browse on faecal N excretion is not clear. A decreased dietary digestibility and a reduced intake also affect this prediction. When other species were examined it appeared that the predictions used for grazing and browsing animals differed. For grazers only faecal N is needed for the prediction of dietary N concentration and approximately 14g N/kgDM in faeces indicates a deficiency. For browsers more work needs to be done to try to understand the effect that dietary P and tannins have on N excretion and in so doing to quantify levels that will indicate a N deficiency.

The prediction of dietary digestibility is also important to determine nutritional value of herbage. Faecal indices which may be used to predict this are P, N and ADL. The trials that were used in this study were not designed to predict dietary digestibility and therefore not enough data was available to be able to accurately predict what faecal levels indicate a digestibility which is inadequate or what faecal indices should be used to predict digestibility. Trials should be specially designed with this in mind to obtain these answers. When different species were compared no universal prediction could be obtained indicating that species differences affect prediction.

Faecal analyses can be used to give an indication of the quality of herbage consumed and perhaps answer some questions as to why animal numbers decrease or why animals migrate.

5.2 SUMMARY

1. Management should be able to recognise the potential for fluctuations in species composition and attempt to monitor and model the system in such a way that the outcome of future perturberations can be predicted. We therefore need to develop a technique that will record long term nutritional changes, record the rate of change to try and explain the reason for declines in rare specie numbers and to act as an early warning system.

2. Faecal samples are both inexpensive to collect , readily available and in some instances less elusive than the animals themselves. Faecal nitrogen has been found to be positively correlated with dietary protein, intake, dietary dry matter digestibility and weight change in mature game species . These positive relationships permit use of chemical composition of faeces as an index of the quality of the grazing available.

3. Other methods available to monitor nutritional quality are fistulation, microscopic analyses, hand collected forage and analyses of parts of the animal i.e. blood, hair, liver and carcass weights, but these all require trained personnel to collect and analyse samples.

4. In order to obtain reliable faecal samples, they should not be collected directly after rain, they should be free of dungbeetle activity and should not be more than one day old.

5. After collection, samples must be air or oven dried for up to 14 days at 60° C , preventing mould development and they can be stored for up to a year before analyses.

6. If samples are to be pooled and the same variation in faecal P and N for both grazers and browsers is required, more samples are needed for browsers than for grazers.

7. Four impala rams were used for a calibration trial and were fed diets containing differing levels of N and P.

8. Two initial trials determined that the adaptation period should be one week and that clean faecal samples i.e. those free of urine contamination should be collected.

9. Prediction equations were obtained for both dietary P and N concentrations and the effect of level of intake, consumption of browse and digestibility of the diet on these regression equations were examined.

10. Faecal P explained 67% of the variation in dietary P concentration and neither the level of intake, browse or a lower dietary digestibility significantly affected this prediction, or altered the slope or intercept of the regression equation significantly.

11. With all the data combined, the regression was passed through the origin and the prediction indicated that dietary P concentration is about 37 % of faecal P concentration.

12. Dietary N needed faecal N and P concentrations in the prediction equation to ensure a satisfactory prediction. Both a restricted intake and a lower dietary digestibility worsened this prediction.

13. When the impala consumed browse containing high tannin levels, faecal ADL and ADIN were needed to predict dietary N concentration as faecal P and N concentrations resulted in poor prediction.

14. A faecal ADL concentration of above 160g/kgDM indicated that the animals were mostly consuming browse, it also indicates when to use the browse regression equation

15. Faecal analysis has been used to predict nutritional quality in a variety of species, but little work has been done on South African species.

16. Data from trials done with zebra, blue wildebeest, impala and cattle were compared to the results obtained from the impala calibration trial.

17. For dietary P prediction all data could be combined into one regression using faecal P concentration to predict dietary P concentration.

18. It was determined that a faecal P concentration of less than 2gP/kgOM probably indicates a P deficiency.

19. For grazers, faecal N is enough to predict dietary N. However, for browsers it appears that faecal P should be added to the prediction.

20. For grazers approximately 14gN/kgDM should be excreted, below this probably indicates a deficiency.

21. For some species dietary digestibility can be predicted by using faecal P, N and ADL. However, more work needs to be done before an accurate prediction can be made.

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ADDENDUM A

Trial Type	Impala Number	Total Food Intake (g/kg DM)	N Intake (g/kg DM)	N Excreted (g/kg DM)	P Intake (g/kg OM)	P Excreted (g/kg OM)	ADIN Excreted (g/kg DM)	ADL Excreted (g/kg DM)	ADF Excreted (g/kg DM)
Calibration Trial 2	3	17,832.6	12.3	17.2	2.5	5.5	8.04	122	341
	2	18,026.6	9.74	15.8	1.4	4	9.07	130	350
	4	17,166.7	12.2	16.7	1.3	3.8	10.9	92	370
	1	19,916	12.2	15.1	2.5	4.5	8.8	91	384
	1	19,127	9.68	13.2	1.4	3.6	7.31	115	414
	4	16,709.2	9.9	13.9	1.4	4	9.76	98	400
	2	19,189.9	12	16	1.3	4	8.5	136	364
	3	16,554.3	12.3	18.1	1.3	4.4	15	131	372
	3	18,589.3	9.79	16.1	1.4	3.9	10.6	109	337
	2	18,004.3	12.2	16.3	2.5	4.7	11.4	137	320
	1	20,225.4	11.6	15.3	1.3	3.8	10.2	136	390
	4	18,061.1	12.2	17.3	2.5	7.5	9.4	132	359
Calibration Trial 1	3	9,000	19.3	22.3	2.1	6.3		160	401
	1	8,440	19.5	19.3	2.1	6.9			
	4	8,435	19.5	20.3	2.1	6.1		134	386
	3	9,327.9	19.7	20	3	7.2			
	2	9,000	19.4	20.2	2.5	6.8		131	337
	1	9,321.5	19.7	20	2.6	5.9			
	4	9,000	19.4	21.8	2.9	6.9		195	374
	1	8,770	19.4	21.8	2.9	7.1			
	4	8,525	19.5	18.8	2.5	5.9			
	1	9,000	19.4	21.8	3.3	7.9		229	337
	2	7,360	20	19.8	3.1	6.9		221	330
	3	8,580	19.5	17.6	3.4	8.9			
	4	9,598	19.6	21.8	3.4	8.4			
	2	8,220	19.6	17.2	3.4	8.5		208	382
	2	8,356	20	18.8	2.1	5.4			
	3	9,020	19.4	20	2.5	5.8		151	360
Calibration Trial 3	2	13,197.5	12.8	18.6	2.4	4	11.9	167	414
	1	12,677.5	12.9	16	2.4	4.2	10.5	149	417
	2	9,277.1	15	18	1.8	3.8	12.2	159	387
	1	10,880.6	14.1	14.3	1.8	3	9.5	167	432

Low digestibility	3	7,634	15.2	20.5	1.8	6	11.4	162	416
	4	9,431	15.4	19.5	1.8	5.7	10.3	177	439
	2	9,612	15.4	19.8	1.8	6	11	175	427
	1	10,427	15.4	17.6	1.8	5.1	10	194	478
Low digestibility	1	9,029	13.4	19.2	2.1	4.8	9.02	190	470
	2	8,715.8	13.4	19.9	2.1	6.1	9.88	179	450
	3	8,895	13.5	20.4	2.1	5.2	9.92	177	439
	4	8,718.6	13.4	19.8	2.1	5	9.37	187	447
Control for low intake	1	9,444.9	14.3	18.9	2.4	6.9	8.33	170	465
	2	9,280.7	14.3	18.7	2.4	6.2	9.21	196	414
	3	8,833.1	14.1	19.5	2.5	7	7.39	162	386
	4	8,862.8	14.4	21.2	2.4	7.1	10.9	173	418
Low intake	2	5,048.8	9.68	18.7	1.4	4	11.8	114	333
	4	4,788.8	9.75	16.8	1.4	3.8	10.6	177	353
	3	4,785.6	9.76	18.9	1.4	6.4	12.9	146	342
	1	5,441.3	9.64	13.6	1.4	3.2	13.2	111	371
	2	4,826.6	13.71	17.7	2.1	5.2	8.72	202	486
	3	4,838.6	13.7	17.7	2.1	4.5	9.5	177	456
	4	4,796.2	13.7	19	2.1	6.5	9.23	207	492
	1	4,832.2	13.7	17.6	2.1	5.8	8.54	209	517
	3	4,857	14.4	16.5	2.4	7.6	9.32	195	472
	2	4,817.8	14.4	18.6	2.4	7	9.2	178	466
	1	4,868.2	14.4	18	2.4	6.8	8.64	187	467
	4	4,834.9	14.4	18.2	2.4	7.6	9.48	193	461
Bush (Combretum)	1	7,239.3	12.2	21.4	1.6	3.8	16.8	199	420
	2	8,073.2	12.4	23.8	1.6	5	19.2	189	408
	3	7,309.8	12.3	24.5	1.6	4.5	23.1	198	351
	4	8,163.4	12.5	25.1	1.6	6.1	22	194	381
Bush (Grewia)	4	8,332	18.5	18.6	1.6	3.3	15.2	224	478
	3	8,100	18.7	18.2	1.6	3.6	16	249	497
	1	1,159.8	16.6	15.5	1.4	3.1	12.8	259	547
	2	8,673.1	18.2	16.3	1.6	3.1	14	220	501
Bush (Grewia)	3	9,010	17.4	18.4	1.1	2.8	12.5	210	520
	2	9,169.6	17.5	16.7	1.1	3.3	12.3	214	519
	1	9,534.6	17.7	15.7	1.5	3.2	12	258	537
	4	8,815.2	17.3	17.8	1.1	3.6	12.8	220	450