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The usefulness of faecal phosphorus and nitrogen in interpreting differences in live-mass gain and the response to P supplementation in grazing cattle in arid regions

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ABSTRACT

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The average daily gains of heifers and oxen on commercial and experimental farms in Namibia were used to indicate production differences in several areas and at different rates of phosphorus and protein supplementation. Faecal concentrations of phosphorus and nitrogen were used to indicate concentrations of these nutrients in grazing.

Areas with high concentrations of nitrogen in faeces proved to support high levels of average daily gain. Animals responded positively to phosphorus supplementation only when faecal nitrogen concentrations were above 12 g/kg DM. Nitrogen concentrations in faeces were directly related to average daily gain of heifers, but protein supplementation did not have a significantly positive effect on average daily gain.

Keywords: Faecal, live-mass gain, nitrogen, phospherous, supplementation

INTRODUCTION

To understand differences in production from Namibian pastures, the two most important nutrients—apart from total-dry-matter intake and energy supply—that should be considered, are phosphorus (P) and nitrogen (N), as they are the nutrients most often deficient in natural pastures (Underwood 1981; 'T Mannetjie 1984). These two nutrients should therefore play an integral role in identifying areas of higher production potential. Phosphorus has been proven to be one of the most limiting minerals in beef production in Namibia (Freyer 1967) and in certain areas of South Africa (Bisschop 1964), and significant differences in P concentration were reported for the different production zones in Namibia (Grant 1989). Phosphorus and N are normally supplemented in the different areas so as to overcome these deficiencies, and have done so with varying success. Several recent reports have, however, showed that P supplementation is not always beneficial (Van Niekerk & Jacobs 1985; Groenewald 1986; Read, Engels & Smith 1986) and, because P and N supplementation may be prohibitively expensive, it has become essential to develop practical methods of assessing when supplementation may be beneficial.

Faecal P concentration shows promise as an indication of the P status of animals (Moir 1966; Belonje 1980; Holecheck, Galyean, Wallace & Wofford 1985; Judkins, Wallace, Parker & Wright 1985; Wadsworth, McClean, Coates & Winter 1990), provided that it is

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recognized that faecal P concentration is not only a function of P intake, but also of efficiency of P utilization (Cohen 1975; Engels 1981) and of N and energy intake (Moir 1966). Since faecal N concentration correlates well with pasture digestibility (Lancester 1949; Holecheck, Vavra & Pieper 1982) and the N content of the diet (Moir 1960; Holecheck *et al.* 1982; Leslie and Starkey 1985), the simultaneous determination of N and P in faeces should give a fairly accurate reflection of the P and N status of cattle.

The possible use of faecal P and N concentrations to indicate nutritional reasons for differences in average daily gain (ADG) in the potential production zones, as classified by the Department of Agriculture andTechnical Services (1979), are investigated, as well as whether faecal P and N could indicate at which time supplementation should be recommended. The intention of this study can thus be summarized in the following hypotheses:

- Null hypothesis stating that faecal P and N concentrations do not differ between the higher- and lower-potential production zones.
- Null hypothesis stating that there are no differences in average daily gain (ADG) for animals with different faecal P and N concentrations.
- Null hypothesis stating that the response in ADG to P supplementation was the same for high and low concentrations of faecal P and N.

MATERIALS AND METHODS

Experimental sites and area description

The study was conducted over a period of 3 years in the beef-ranching areas of the central and northern districts of Namibia, which are divided into high- and medium-potential cattle-farming areas by the Department of AgriculturalTechnical Services (1979). Data on production and supplementation rates for cattle on three experimental farms were highly comparable and formed the basis of this study. To be able to relate findings to current farming practises in the area, farmers were requested to collect data on rainfall, body-mass changes and supplement intake. Areas classified as high-potential farming areas (Department of Agricultural Technical Services 1979) broadly fall into two categories:

- The higher rainfall areas of the Kalahari Sandveld—a zone with low P concentrations (Grant 1989)
- The shallower, richer soils of the Highland Savanna where high concentrations of faecal P were reported (Grant 1989).

The Mangetti Research Farm, as well as three commercial farms, represented the high-potential Kalahari Sandveld. The Highland Savanna was represented by Bergvlug Research Farm and two commercial farms. Medium-potential production areas (Department of Agricultural Technical Services 1979) were represented by Sonop Research Farm on shallow turf soils and a commercial farm on the eroded sandstone of the Waterberg. Low P concentrations had been reported from both soil types (Freyer 1967; Grant 1989). During the study period, rainfall on these farms varied from 60–160% of the long-term average.

Determining nutritional reasons for differences in production for the different production-potential zones

Mass gain was used as the indicator of production response. On each farm in the study, ten to 15 young growing heifers and/or oxen, all of the "Bonsmara type" were identified. Once a month, over a period of about thirteen months, these marked animals were weighed, and a faecal sample was collected from the rectum. Faecal samples from the animals were pooled (Belonje 1980), and kept in a frozen state until analysed for P and N. The mean ADG for the month was calculated for the group. Exact composition and intake of lick supplement for the period was calculated. Management practices on commercial farms were not altered, so as to ensure that they represented current farming practices in the area as far as possible.

Processing of samples

Phosphorus content in faecal samples was determined by the phosphovenado-complex method of Hanson (1950) as described by Grant, Biggs & Meissner (1996). Results were expressed as g/kg on an organic-matter basis (OM), as suggested by Moir (1960).

For N analysis, samples were digested according the A.O.A.C. method (A.O.A.C.1965), diluted and read against standards, by means of an ammonia electrode (Orion Research 1983). Results were expressed as g/kg on a dry-matter (DM) basis.

Statistical analyses

The data used to test the effect of production area on ADG were too unbalanced to satisfy the assumptions of a One-Way ANOVA, therefore data from oxen and heifers were used for the growing season, blocking for the effect of sex on ADG in a multiple ANOVA. Differences in faecal P [P(f)] and N [N(f)] and P and protein intake from supplement for heifers for every one of the three production zones (high-production Kalahari Sandveld and Highland Savanna and medium-production Turf and Waterberg Sandveld) were tested by means of One-Way ANOVAs to find the possible reasons for differences in production.

Because of the overlap in concentrations of P(f) and N(f) in the different production zones, the data from heifers for all zones were pooled to determine the factors that influence ADG, independent of specific management practices and area influences. The relationship between N(f) and ADG in the growth season, for animals receiving no supplement, was tested by means of a simple linear regression. For P(f), log P(f) was used to test the relationship between P(f) and ADG, in the growing season, of animals receiving no supplement, as described by Wadsworth *et al.* (1990).

A multiple ANOVA was used to test the relationship of all measured factors with the ADG of the following month. For this purpose, N(f) was divided in above, and below, but including 12 g/kg DM. This concentration was chosen as it is the critical level of N(f) for maintenance according to Moir (1960) and Wofford, Holecheck, Galyean, Wallace & Cardenas (1985). According to Moir (1966), cattle show signs of osteophagia at P(f) concentrations of 2 g/kg OM, thus P(f) was divided into above, and below and including 2,3 g/kg OM, which is just above this critical level.

Where the effect of seasonal variation was examined, monthly data were grouped into three seasons: January to April (rainy season), May to August (cool dry season) and September to December (hot dry season), to coincide with the dormant and rainy seasons in Namibia.

Phosphorus intake from mineral supplement was grouped according to level of intake, respectively, 0, 1–4 and 4–8 g of P/day. Supplements where intake of P was more than 8 g of P per day, were treated separately for the statistical analyses, as these intakes are above the normally recommended levels (Cohen 1980). The effect of the high supplement was tested in a simple regression against ADG. As protein is supplemented in winter when growth is unlikely to be high because of the low levels of protein available from the grazing (Freyer 1967; Van Niekerk & Jacobs 1985), the effect of protein supplement (mainly as urea) was also tested separately in a simple regression.

RESULTS

Differences in areas with different production potential

Highly significant differences were found in ADG among different production zones ($P < 0{,}0002$). Animals from Sandveld areas classified as high-potential cattle-farming areas showed significantly higher gains than animals from the high-potential cattle-farming areas in the highland area, and than those on farms classified as medium-potential cattle-farming areas (Table 1). The first null hypothesis was rejected as the high-potential cattle-farming areas, with the higher ADG, showed significantly higher concentrations of N(f) and P(f), than the medium-potential cattle-farming areas. The supplementation rates in the different areas also differed significantly; cattle from the high-potential sandveld showed significantly higher P intakes from supplement, while those from the medium-potential area showed significantly higher protein intakes from supplement.

Factors affecting Average Daily Gain

The second null hypothesis was rejected as the relationship of N(f) on ADG was highly significant ($P = 0{,}000\,21$) with $R^2 = 70{,}8\%$. For P(f) the relationship was weaker and a regression of log P(f) on ADG showed a relationship that was significant at the 10 % level only ($P = 0{,}07$) with $R^2 = 44\%$ (Table 2).

With reference to the above results, the relationship of P(f) and N(f), and P intake from supplement with ADG, was examined in a multiple ANOVA blocking to determine the effect of season, and evaluate factors playing a significant role in the ADG of the following month (Table 3). The effect of N(f) was highly significant with the higher ADG when N(f) was above

TABLE 1 Differences in faecal nitrogen and phosphorus concentration, and P and protein intake from supplement and average daily gain of heifers through the year in areas of differing production potential and soil type

Production zone	P(f) g/kg	N(f) g/kg	P intake g/day	Protein intake g/day	*n*	ADG g/day	*n*
High sandveld	$2{,}5^{aB} \pm 0{,}08$	$15{,}6^{A} \pm 0{,}4$	$6{,}79^{A} \pm 0{,}35$	$38{,}07^{a} \pm 3{,}8$	79	$357^{A} \pm 58$	85
High hardveld	$3{,}7^{A} \pm 0{,}2$	$12{,}8^{aB} \pm 0{,}29$	$4{,}58^{a} \pm 0{,}68$	$37{,}22^{a} \pm 6{,}4$	77	$5^{a} \pm 62$	84
Medium sandveld	$1{,}9^{ab} \pm 0{,}1$	$10{,}3^{ab} \pm 0{,}54$	$3{,}58^{a} \pm 0{,}77$	$90{,}35^{A} \pm 4{,}6$	20	$-63^{a} \pm 72$	41
Results of one-way ANOVAs testing for differences in factors for the three areas							
P <	0,0001	0,0001	0,0001	0,0001		0,0001	
df	195	194	192	175		209	
F	25,14	22,3	7,41	12,73		9,03	

Superscripts: Upper case (e.g. A) always higher and differs significantly from lower case (e.g. a) within each column ($P < 0{,}05$)

TABLE 2 The relationship between faecal nitrogen and phosphorus concentration and average daily gain for animals receiving no supplement in the growing season

	N(f)		Log P(f)	
	Estimate	*P*	Estimate	*P*
Intercept	–1 185	0,031	835	0,014
Slope	18	0,009	563	0,072
Model	R^2 = 71%	0,009	R^2 = 44%	0,072

TABLE 3 Factors influencing average daily gain as tested by multiple ANOVA

Factor	*P*	ADG g/kg/d	
P(f)	0,806		
N(f)	0,001	N(f) < 12 g/kg	–392
		N(f) > 12 g/kg	220
P intake	0,232		
Season	0,072		
Interactions			
N(f) *x* P intake	0,001		
N(f) *x* season	0,032		

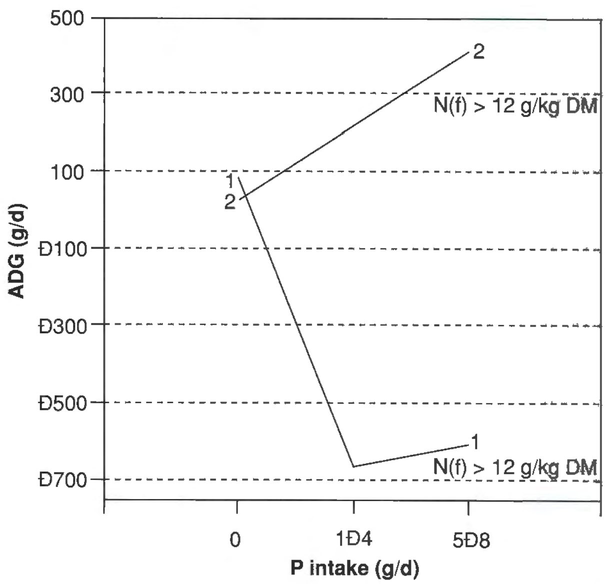

FIG. 1 Response in average daily gain to phosphorus-supplement intake as influenced by level of faecal nitrogen

1: Response with N(f) ≤ 12 g/kg DM
2: Response with N(f) > 12 g/kg DM

12 g/kg. The interaction between N(f) and P intake was also highly significant (*P* = 0,000 5) (Fig. 1), with ADG being significantly higher when N(f) is above 12 g/kg DM. At that level, the ADG, in response to high levels of P supplement, was also significantly higher than when no supplement was given (Fig. 1), thus rejecting the third null hypothesis. Season did not have a significant effect on ADG when the effect of P(f) and N(f) was accounted for.

When the effect of P(f), N(f) and N intake on ADG, again blocking for the effect of season, was examined in a multiple ANOVA, only N(f) showed a significant effect on ADG (*P* < 0,02).

When the P intake from supplement was above 8 g/day, the response in ADG was negative (Fig. 2) with a slope of –69 and R^2 = 18 (*P* = 0,004).

The response of heifers to protein supplement was negative (Fig. 3) with a slope of –3,8 and R^2 = 11% (*P* = 0,002).

DISCUSSION

Of the nutritional reasons examined to classify production zones, the most consistent nutritional factor that could be isolated as being related to high production, was protein intake as reflected by N(f). This is supported by the findings of McLean, Hendricksen, Coates & Winter (1990) who reported a positive relationship between dietary protein and mass when dietary N was above 1,1%. They did not, however, relate mass gains to N(f) as a reflection of total protein intake. In the present study, it was also found that higher levels of supplementation of N as given in the medium-potential production area, did not seem to have a significant effect on improving ADG of the animals in that area. This is further illustrated in the regression in Fig. 3, which shows that N supplementation had a negative effect on ADG.

When the relationship between P(f) and N(f) and mass gains was examined to determine whether results from faecal analyses can give an estimate of the possible mass change of young animals, only N(f) showed a significant effect on the ADG of the following month, and the strong relationship was further demonstrated in the simple regression with an R^2 of 71% (Table 2). The poor relationship between P(f) and ADG found in the present study, in contradiction to the findings of Wadsworth *et al.* (1990), can probably also be explained by the overriding effect of low protein concentrations that lead to a poor response to P supplementation.

The fact that season did not have a significant relationship with ADG in the multiple ANOVA may be due to the related changes in P(f) and N(f) during the season, both increasing during the wet, and decreasing during the dry season.

The significant interaction between N(f) and P intake from supplement (Fig. 1) probably explains the varying results found with P supplementation described in the literature (Falvey 1985; Groenewald 1986; Wadsworth *et al.* 1990; Winks 1990). This may also

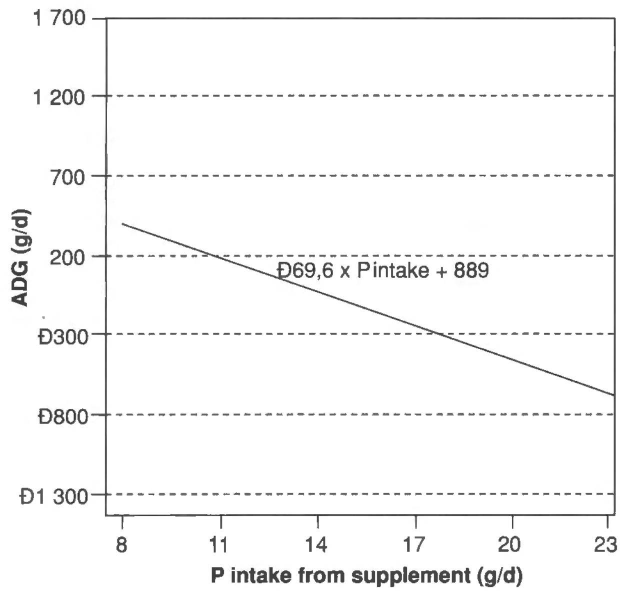

FIG. 2 Response in average daily gain when phosphorus intake from supplement is above 8 g/d

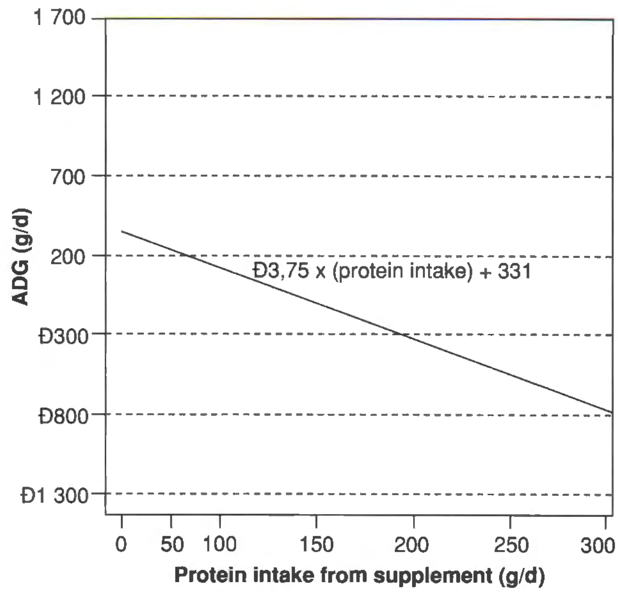

FIG. 3 Response in average daily gain of heifers to nitrogen supplementation as licks

explain the negative effect of P supplementation in the absence of protein and energy supplementation described by Louw (1979) and Van Niekerk & Jacobs (1985).

From the data available in this study, P supplementation should not be considered when N(f) < 12 g/kg DM. This relationship between N(f) and response to P supplementation endorses the findings of Winks (1990) that a response to P supplementation is possible only where dietary N is above 1,5% and dietary P is below 0,15%. Using N(f) to determine when P supplement should have a possible beneficial effect, is indirectly supported by Bisschop (1964) and Winks (1990) who stated that only animals that are in a positive nutritional plane may be expected to respond to P supplementation. Furthermore, this study indicated that independently of P(f) and N(f), care should be taken to avoid intakes of more than 8 g of P/d from supplement, as this had a negative effect on ADG (Fig. 2).

Faecal analysis, in contrast to P supplementation, cannot be used to indicate when N supplement will have a beneficial effect, as no relationship was found between N(f) and protein supplement. Nitrogen supplementation should, however, at least be beneficial in avoiding more severe losses when levels are below 12 g/kg DM as suggested by Van Niekerk & Jacobs (1985). From the regression, it can be seen that supplementation at high levels should also be avoided, as animals show more severe mass losses when high levels of N are supplemented (Fig. 3). This could most likely be the effect of underutilizing the available veld owing to too high intakes of a palatable supplement.

CONCLUSION

Faecal analysis proved to be useful in understanding differences in production from different areas, as well as in estimating when P supplementation could be expected to be beneficial. Nitrogen in faeces proved to be the most important indicator of both. Supplementation of P and N was not found to have an overall beneficial effect on ADG. Haphazard supplementation is therefore unlikely to be beneficial in the long term, as over-supplementation of both P and N can have detrimental effects on ADG. However, P supplementation can improve ADG when P is supplemented strategically, with N(f) as indicator.

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