Phosphorus and the grazing ruminant. 4. Blood and faecal grab samples as indicators of the P status of cattle

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Blood plasma and faecal grab samples were evaluated as indicators of P status of cattle grazing at two experimental sites (Glen and Armoedsvlakte). Plasma P_i levels clearly identified the −P cattle at Armoedsvlakte as being P deficient whilst at Glen the −P group tended towards lower levels than the supplemented cattle although differences between them were seldom significant. Plasma levels well below the critical range (2 mg/100 ml plasma) can be useful for identifying a P deficiency but higher levels seem insensitive for distinguishing between groups, as was often observed at Glen. Faecal P levels tended to rank the groups according to their respective intake of P. Poor feed intake of −P cattle at Armoedsvlakte depressed faecal output severely; analysis of grab samples for analysis of percentage P may lead to erroneous conclusions regarding P status. Under these circumstances it would seem advisable rather to determine total P excretion via the faeces to differentiate between the two groups.

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Bloedplasma en misgrypmonsters is ondersoek as maatstawwe van die P-status van weidende vleisbeeskoeie te Glen en Armoedsvlakte. Plasma-P_i-peile het duidelik aangetoon dat die −P-beeste te Armoedsvlakte P-gebrekkig was. Alhoewel die plasma-P_i-peile van die −P-groep te Glen laer geneig het as die groep met P-aanvulling, was die verskille selde betekenisvol. Plasma-P_i-peile wat heelwat laer as die kritiese waarde is (2 mg/100 ml plasma) kan as 'n aanduiding van 'n P-tekort gebruik word, maar hoër vlakke is skynbaar onsensitief om tussen groepe te onderskei, soos by Glen waargeneem. P-konsentrasie in mismonsters het geneig om groepe volgens hul P-inname te klassifiseer. Laer voerinname van −P-beeste te Armoedsvlakte het aanleiding gegee tot 'n erg verlaagde misuitskeiding. Onder hierdie omstandighede kan persentasie P tot verkeerde gevolgtrekkings in verband met die P-status lei en sal dit miskien raadsaam wees om eerder totale P-uitskeiding in die mis te bepaal om tussen groepe te onderskei.

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Introduction

Because pasture samples, both hand plucked and those collected by oesophageally fistulated ruminants, are unsuitable for assessing the P status of grazing ruminants, body tissues and fluids have been used as diagnostic aids. Rib bone samples have proved a reliable indicator in this study (Read, Engels & Smith, 1984a, c) and various others (e.g. Little, 1972) but obtaining samples does require surgery. Blood samples, however, are readily obtainable and have consequently formed the basis of diagnostic tests (Cohen, 1975) despite their providing little information about the status of mineral reserves (Benzie, Boyne, Dalgarno, Duckworth, Hill & Walker, 1955) and their being influenced by excitement, exercise (Gartner, Ryley & Beattie, 1965, cited by Little, Robinson, Playne & Haydock, 1971) and after feeding (Wise, Ordoveza & Barrick, 1963). As P is found largely in the erythrocytes, incorrect handling and storage of samples may cause hydrolysis of this organically bound P and can therefore also cause falsely high readings (Little *et al.*, 1971).

Faecal samples are likewise easily obtainable and, because P homeostasis is achieved in the digestive tract by controlling the secretion and reabsorption of salivary P, faecal losses must be related to intake or absorption (Clarke, Budtz-Olsen, Cross, Finnamore & Bauert, 1973). It has been suggested that faecal grab samples from both cattle (Moir, 1966) and sheep (Belonje & Van den Berg, 1980) may be useful in estimating the P content of the pasture being grazed.

This study evaluates the use of blood plasma and faecal grab samples as indicators of the P status of cattle grazing the natural pastures of Glen and Armoedsvlakte.

Experimental procedure

The general procedure, animals used, treatments applied, experimental sites and forage P levels have already been described (Read *et al.*, 1984a, b).

Blood samples were usually taken from eight cattle from each group at Glen and from six cattle from each group at Armoedsvlakte at different stages of the animals' reproductive cycle.

Faecal grab samples were taken directly from the rectum at intervals of 4 weeks at Glen and 6—8 weeks at Armoedsvlakte, but for the purpose of comparison with blood and bone samples, faecal P concentrations are presented for the same 'experimental periods' only. Faecal samples were dried, ground and analysed for P as described by Read (1984).

Results and Discussion

Blood analyses

Using the terminology of Kiatoko, McDowell, Bertrand, Chapman, Pate, Martin & Conrad (1982) the 'critical concentrations' are those levels below or above the values associated with specific clinical signs. Although most critical levels reported in the literature (Table 1) are based on serum analyses, these have been used for comparison with plasma analyses (Kiatoko, *et al.*, 1982) without correcting for the plasma proteins and, because the mineral concentrations in the present study were determined using the plasma fraction, according to the recommendation of Little, *et al.* (1971), this procedure will again be adopted. Payne (1977), however, reported slightly lower critical levels of P_i (3,6 – 7,2 mg/100 ml) and Ca (8,3 – 10,2 mg/100 ml) in plasma than those serum levels (Table 1) used in the metabolic profile tests (Payne, Rowlands, Manston & Dew, 1973).

Table 1 Some critical levels of serum P_i, Ca and Mg reported in the literature and those adopted in this study

Mineral concentration (mg/100 ml serum)			
P_i	Ca	Mg	Reference
4,0 – 6,0	9,0 – 11,0	1,8 – 3,2	Underwood (1981)
4,0 – 7,0	9,0 – 12,0	2,4^{a}	Simesen (1970)
4,3 – 7,7	8,7 – 10,3	2,0 – 3,0	Payne, *et al.* (1973)
4,0 – 8,0	8,0 – 12,0	2,0 – 3,0	Present study

[a]Mean value only

Blood mineral levels in cattle at Glen

During late pregnancy of 1978 (Table 2), the plasma P_i levels of all three groups of heifers bordered on the upper limits (8 mg/100 ml) and the Ca levels on the lower limits (8 mg/100 ml) of the adopted critical range. P_i levels dropped considerably in all three groups during the following lactation and Ca levels increased. At the end of lactation both the – P and + P groups had significantly ($P < 0{,}05$) lower P_i levels than the PR groups. Clearly the pasture could not supply adequate P for the – P group because even their bone samples (Read, *et al.*, 1984c) showed significantly lower P reserves. The low P_i levels of the + P group were not reflected in their bone samples but were probably caused by their poor intake of dicalcium phosphate lick during this period because blood levels are markedly affected by recent P intake (Little, 1968) and because plasma P levels are more closely related to intake than to the P status (Moir, 1966). By late pregnancy (1979) all minerals were well within their respective critical ranges.

A similar pattern was observed during 1980 whereas during 1981 and 1982 remarkably higher plasma P_i levels were observed in the mature cows, especially during lactation, owing to the absence of the dam's requirement for growth in addition to that for pregnancy and lactation. Plasma P_i levels of the – P group dropped below the critical levels (4 mg/100 ml) during 1983. Ca levels of all three groups also dropped during 1983 despite a slight tendency for higher Ca levels in those groups with lowest P_i levels, which suggests an inverse relationship between P and Ca, as reported by the NRC (1980). The observed relationship was more apparent during late lactation and weaning (r = – 0,454) than during early lactation (r = – 0,257). The explanation offered by Underwood (1966) is that both P and Ca are mobilized from bone reserves during dietary inadequacies and since only P is required, excess Ca remains and plasma levels increase.

Plasma Mg levels of all groups remained within the critical range (between 2 and 3 mg/100 ml) throughout the experimental period without any consistent pattern emerging (Table 2).

There were no significant differences in plasma P_i, Ca or Mg levels in blood samples from calves of dams in the three groups at Glen (Table 3). It would seem that plasma P_i levels of all calves born to the young 'heifers' were lower, although still above the critical levels (4 mg/100 ml), than any of the following years.

Table 2 P_i, Ca and Mg concentrations (mg/100 ml plasma) in blood samples of the cattle at Glen[a]

			Mineral concentration (mg/100 ml plasma)		
Year	Physiological status	Treatment	P_i	Ca	Mg
1978	Late pregnancy	– P	8,09^{a}	8,08^{a}	2,67^{a}
		+ P	7,38^{a}	8,57^{b}	2,34^{b}
		PR	8,97^{a}	7,78^{a}	2,60^{ab}
1979	Early lactation	– P	5,06^{a}	9,45^{a}	2,52^{a}
		+ P	4,42^{a}	9,18^{a}	2,57^{a}
		PR	4,93^{a}	9,47^{a}	2,73^{a}
	Late lactation/weaning	– P	1,93^{a}	8,89^{a}	2,49^{a}
		+ P	2,64^{a}	8,81^{a}	2,55^{a}
		PR	4,00^{b}	8,20^{a}	2,34^{a}
	Late pregnancy	– P	5,33^{a}	10,44^{a}	3,20^{a}
		+ P	5,47^{a}	9,84^{b}	2,96^{a}
		PR	6,02^{a}	9,07^{c}	2,59^{b}
1980	Early lactation	– P	3,06^{a}	7,75^{a}	2,54^{a}
		+ P	4,77^{a}	7,85^{a}	2,47^{a}
		PR	–	–	–
	Late lactation/weaning	– P	2,91^{a}	9,60^{a}	2,49^{a}
		+ P	3,78^{b}	8,52^{b}	2,72^{a}
		PR	4,03^{b}	8,58^{b}	2,39^{a}
1981	Late lactation/weaning	– P	5,57^{a}	8,74^{a}	2,18^{a}
		+ P	6,87^{a}	9,18^{a}	2,63^{b}
		PR	6,59^{a}	8,36^{a}	2,40^{ab}
	Late pregnancy	– P	4,42^{a}	9,56^{a}	2,39^{a}
		+ P	5,77^{b}	9,30^{a}	2,70^{b}
		PR	4,02^{a}	9,34^{a}	2,51^{a}
1982	Early lactation	– P	5,35^{a}	10,21^{a}	2,70^{a}
		+ P	8,14^{b}	9,82^{ab}	2,71^{a}
		PR	5,41^{a}	9,46^{b}	2,91^{a}
	Late lactation/weaning	– P	5,85^{a}	10,18^{a}	2,80^{a}
		+ P	5,58^{a}	8,59^{b}	2,44^{b}
		PR	6,18^{a}	9,32^{ab}	2,70^{ab}
	Late pregnancy	– P	4,94^{a}	8,94^{a}	2,48^{a}
		+ P	5,43^{a}	8,57^{a}	2,46^{a}
		PR	5,11^{a}	8,37^{ab}	2,45^{a}
1983	Early lactation	– P	3,29^{a}	8,45^{a}	2,90^{a}
		+ P	3,98^{a}	7,62^{b}	2,79^{a}
		PR	6,01^{b}	7,10^{c}	2,95^{a}
	Late lactation/weaning	– P	2,59^{a}	7,41^{a}	2,84^{a}
		+ P	5,34^{b}	6,88^{ab}	2,75^{a}
		PR	5,22^{b}	6,61^{b}	2,43^{b}

[a,b,c]Differences between treatments tested within individual periods and years; treatments with same superscripts do not differ significantly ($P < 0{,}05$)

Table 3 P_i, Ca and Mg concentrations (mg/100 ml plasma) in blood samples of calves at Glen

Year	Treatment of dam	Mineral concentration (mg/100 ml plasma) P_i	Ca	Mg
1979	−P	4,61	9,04	2,17
	+P	4,59	8,60	1,99
	PR	4,98	9,37	2,19
1980	−P	5,33	8,90	2,43
	+P	6,90	9,13	2,36
	PR	7,35	8,77	2,21
1981	−P	7,20	8,70	2,14
	+P	7,64	9,64	2,01
	PR	8,08	9,55	2,14
1982	−P	9,60	9,49	2,30
	+P	9,13	9,03	2,21
	PR	9,17	9,30	2,27
1983	−P	7,82	8,12	2,04
	+P	8,62	8,44	2,37
	PR	8,18	8,41	2,09

Blood mineral levels in cattle at Armoedsvlakte

During 1978 and 1979 plasma P_i levels of both groups were similar, although Ca levels of −P cattle were lower during late pregnancy (1979). Plasma P_i levels in −P cattle declined dramatically during 1980 and, except for late pregnancy (1981) were significantly ($P < 0,05$) lower than those of the +P group (Table 4). According to the decline in rib P levels, reserve P was mobilized from the skeleton of the −P cattle during this period (Read, *et al.*, 1984c). The P_i levels in whole blood of reproducing cattle in an earlier trial at Armoedsvlakte (Theiler, Green & Du Toit, 1928) were similarly below 1 mg/100 ml, whereas the supplemented cattle had levels of 5 mg/100 ml, again in good agreement with those of the present trial. Using only plasma P_i levels as an indicator it may be concluded that the −P group were P deficient because levels below 2 mg/100 ml generally indicate a deficiency (Gartner, McLean, Little & Winks, 1980).

Although the −P group occasionally had lower plasma Mg levels than the +P group, both groups were always within the adopted critical range.

Table 4 P_i, Ca and Mg concentrations (mg/100 ml plasma) in blood samples of the cattle at Armoedsvlakte[a]

Year	Physiological status	Treatment	Mineral concentration (mg/100 ml plasma) P_i	Ca	Mg
1978	Late pregnancy	−P	5,88[a]	8,08[a]	2,22[a]
		+P	5,48[a]	7,83[a]	2,28[a]
1979	Lactation	−P	3,38[a]	9,15[a]	2,38[a]
		+P	3,81[a]	9,01[a]	2,28[a]
	Late pregnancy	−P	4,83[a]	7,63[a]	2,12[a]
		+P	5,02[a]	9,06[b]	2,35[a]
1980	Lactation	−P	1,96[a]	8,94[a]	2,18[a]
		+P	4,87[b]	8,20[a]	2,41[b]
	Late pregnancy	−P	1,62[a]	9,24[a]	1,90[a]
		+P	6,33[b]	7,97[a]	2,42[b]
1981	Lactation	−P	2,04[a]	10,11[a]	2,03[a]
		+P	6,94[b]	8,67[b]	2,55[b]
	Late pregnancy	−P	3,59[a]	9,47[a]	2,00[a]
		+P	5,17[a]	7,96[a]	2,39[a]
1982	Lactation	−P	1,45[a]	12,02[a]	2,71[a]
		+P	3,82[b]	10,71[a]	2,74[a]
	Late pregnancy	−P	2,01[a]	10,58[a]	2,30[a]
		+P	5,40[b]	9,18[b]	2,49[a]
1983	Lactation	−P	1,25[a]	10,13[a]	2,15[a]
		+P	4,37[b]	8,54[a]	2,70[b]

[a,b]Differences between treatments tested within individual periods and years; treatments with same superscripts do not differ significantly ($P < 0,05$)

Faecal P levels

Cattle at Glen

Except during early lactation (1981) faecal P levels tended to rank the groups according to their respective intakes of P, although it was only during late pregnancy (1979 and 1980) that all three groups differed significantly ($P < 0,05$). However, the results (Table 5) do suggest certain discrepancies, e.g. during early lactation (1981) when none of the groups differed in faecal P levels, yet the PR group received considerably more supplementary P than the +P group (12 g/day vs 7 g P/day) and both these groups more than the unsupplemented −P group, and unless the PR group consumed considerably more pasture, resulting in a higher faecal output, with low P levels or that the digestibility of the diet consumed and/or the metabolic efficiency, milk yield or milk composition differed from the other groups, all of which seem unlikely. These discrepancies cast doubt on the reliability of this indicator. Secondly, during late lactation/weaning (1981) when according to the data, both the −P and +P groups differed significantly from the PR group, the lick intake (8 and 6 g P/day for +P and PR groups, respectively; Read, 1984) suggested that the +P and PR groups might rather have differed from the −P group which received no supplementary P. These results would seem to agree with the conclusion of Winks, Lambert & O'Rourke (1977) that '. . . faecal P alone was a poor indicator as responses invariably occurred when faecal phosphorus was relatively high and ceased when levels were considerably lower.'

Cattle at Armoedsvlakte

As an indicator of P intake, faecal P levels classified the two groups correctly, but only during the initial stages of the trial, i.e. late pregnancy (1978) and lactation (1979) despite there being no significant differences in either blood plasma or rib bone samples between the two groups on either of these

Table 5 P levels (percentage DM) in faeces of cattle at Glen[a]

Year	Physiological status	Treatment −P	+P	PR
1979	Late lactation/weaning	0,209[a]	0,217[a]	0,418[b]
	Late pregnancy	0,197[a]	0,258[b]	0,311[c]
1980	Early lactation	0,308[a]	0,348[a]	0,447[b]
	Late lactation/weaning	0,241[a]	0,269[a]	0,402[b]
	Late pregnancy	0,222[a]	0,283[b]	0,324[c]
1981	Early lactation	0,286[a]	0,272[a]	0,325[a]
	Late lactation/weaning	0,239[a]	0,266[a]	0,386[b]

[a,b,c]Differences between treatments tested within individual periods and years, i.e. treatments in a row with same superscripts do not differ significantly ($P < 0,05$)

occasions. The rest of the data (Table 6) again cast doubt on the validity of faecal P as an indicator of P intake by the grazing ruminant, as the −P group were clearly P deficient, whereas the +P were not. However, it may not be the sample that is unreliable but rather the sampling method and expression of P levels. Considering the vastly different intakes (Read, *et al.*, 1984b) and therefore faecal outputs of the cattle, it is not surprising that both groups have similar levels of faecal P expressed as percentage dry matter of a faecal grab sample, whereas the mass of P excreted per day via the faeces may be totally different. These results therefore clearly illustrate why Cohen (1974) suggested that the P intake of cattle may be estimated from regression equations of the intake of a specific feed source on total daily faecal P excretion, using different equations for different feed sources in order to eliminate differences in digestibility.

Table 6 P levels (percentage DM) in faeces of cattle at Armoedsvlakte[a]

Year	Physiological status	Treatment	
		−P	+P
1978	Late pregnancy	0,214[a]	0,303[b]
1979	Lactation	0,249[a]	0,358[b]
	Late pregnancy	0,280[a]	0,313[a]
1980	Lactation	0,273[a]	0,259[a]
	Late pregnancy	0,221[a]	0,280[a]
1981	Late pregnancy	0,258[a]	0,290[a]
1982	Lactation	0,275[a]	0,283[a]

[a,b]Differences between treatments tested within individual periods and years, i.e. treatments in a row with same superscripts do not differ significantly ($P < 0,05$)

Conclusions

The conclusions drawn from the results of plasma analyses agree with the general thesis that low plasma P_i levels reflect low P intakes but that plasma levels are unsatisfactory for distinguishing between higher levels, as was also demonstrated by Little (1968) and Belonje (1978), and therefore that higher levels cannot be interpreted with confidence, as suggested by Gartner, *et al.* (1980).

Faecal P levels proved insensitive for distinguishing between supplemented and unsupplemented cattle, especially at Armoedsvlakte. The severe depression in feed intake caused by the P deficiency resulted in a lower faecal output and analysis for percentage P in faecal dry matter produced contradictory results. If faecal output varies considerably, it would be advisable rather to determine total P excreted via the faeces (g/day). However, if faecal output is determined indirectly this indicator would still be unsuitable for grazing cattle.

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