TAIL-BONE DENSITY COMPARED WITH OTHER INDICATORS OF PHOSPHORUS DEFICIENCY IN CATTLE

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SUMMARY

Single photon absorptiometry was used to measure tail-bone density of phosphorus deficient and phosphorus supplemented steers grazing stylo-based pastures and the results were compared with plasma inorganic phosphate (PIP) and rib cortical bone thickness (CBT) as measures of phosphorus status. Dietary phosphorus deficiency in the unsupplemented steers was severe with liveweight gains only about half those of supplemented steers. All 3 diagnostic indicators discriminated adequately between supplemented and unsupplemented steers. Plasma inorganic phosphate gave the highest level of discrimination while CBT and tail-bone density provided lesser degrees of discrimination but similar to one another. Tail-bone density had advantages over rib CBT, being non-invasive, having no restriction on the frequency of repeat measurements and being less affected by steer age. Tail-bone density was positively correlated with liveweight gain, PIP and CBT. The results show that tail-bone density has promise as a diagnostic indicator for phosphorus deficiency in cattle and as a research tool but there is a requirement for further and extensive evaluation of the technique.

Keywords: grazing steers, phosphorus deficiency, single photon absorptiometry, bone density.

INTRODUCTION

The reliable diagnosis of phosphorus (P) deficiency in cattle has not been adequately resolved despite an ongoing and concerted effort to identify and develop effective diagnostic indices. In recent experiments with growing cattle in northern Australia, plasma inorganic phosphate (PIP) concentration, rib-bone cortical bone thickness (CBT), faecal P concentration and urinary hydroxyproline excretion were evaluated for their effectiveness as diagnostic indicators of P deficiency (Wadsworth *et al.* 1990). None was entirely satisfactory but PIP was the most effective diagnostic index for determining responsiveness to supplementary P. Rib-bone CBT was not as effective as PIP but it has the advantage of reflecting the adequacy of dietary P over the medium to long term and can be useful in assessing animal P status in terms of bone mineral reserves (Little 1984). However, CBT measurements require surgery and repeated measurements cannot be taken to monitor changes in P status except at extended intervals, thus limiting the application of the technique. Non-invasive methods using photon and X-ray absorptiometry or the transmission speed of ultrasound for measuring bone density offer an alternative to the rib-bone biopsy technique for estimating animal P status. One such method uses single photon absorptiometry (SPA) to measure the density of cancellous bone at the proximal end of the 9th tail bone in cattle (Murray *et al.* 1994). This technique was applied to P-adequate and P-deficient steers at Lansdown in north Queensland and the results were compared with PIP and CBT measurements to make a preliminary assessment of its potential for diagnosing P deficiency in cattle.

MATERIALS AND METHODS

Cattle used in the study were Droughtmaster steers grazing a subset of paddocks within a larger experiment. The pastures were unfertilized grass/legume swards based on Verano (*Stylosanthes hamata* cv. Verano) or Seca (*S. scabra* cv. Seca) stylo in combination with native grasses and Indian couch (*Bothriochloa pertusa).* Bicarbonate extractable P (Colwell 1963) in the surface 10 cm of soil was only 3 ppm. Phosphorus supplement as sodium orthophosphate was provided in the drinking water in half of the paddocks to provide daily intakes of 5-7 g P/steer and common salt was provided as blocks in all paddocks. Stocking rate was the same for supplemented and unsupplemented treatments. From August 1990 to August 1991 paddocks (3.8 ha) were each set-stocked with 3 steers of different ages, a weaner (starting age 8 months), a yearling (20 months) and a 2-year-old (32 months). The 2 older steers in each paddock grazed the same paddock during the previous year. Measurements were made on the steers from 5 supplemented and 5 unsupplemented paddocks in August 1991. The experiment was destocked from August 1991 to July 1992 due to drought but paddocks were each restocked with a weaner and yearling steer from July 1992 to June 1993. Measurements on 15 unsupplemented and 16 supplemented steers were made in June 1993.

Steers were weighed after overnight fasting (food and water) to determine liveweight change. They were bled via the jugular to provide plasma for PIP determinations. Rib-bone biopsy samples were taken from the second last rib for CBT measurements (Little 1984). Estimates of tail-bone density were made using SPA as described by Murray *et al.* (1994). Analysis of variance, with individual animals as replicates, was used to test for treatment differences in PIP, CBT and tail-bone density.

RESULTS

Liveweight gains were depressed overall during 1990/91 due to adverse seasonal conditions. Dry conditions prevailed throughout 1992/93 but the combination of pasture spelling in the previous year and reduced stocking rate resulted in much improved weight gains. In both years there was a large response to P supplement ($P < 0.01$) with the liveweight gain of steers receiving P supplement averaging 67 kg/hd for the period 1 August 1990 to 31 July 1991 and 150 kg/hd for the period 28 July 1992 to 10 June 1993 compared with gains of only 35 and 59 kg/hd for unsupplemented steers during the same periods. Dietary P deficiency depressed the growth rate of unsupplemented steers from the outset of each grazing period so that there was a positive response to P supplement whenever the steers were gaining weight (Figure 1).

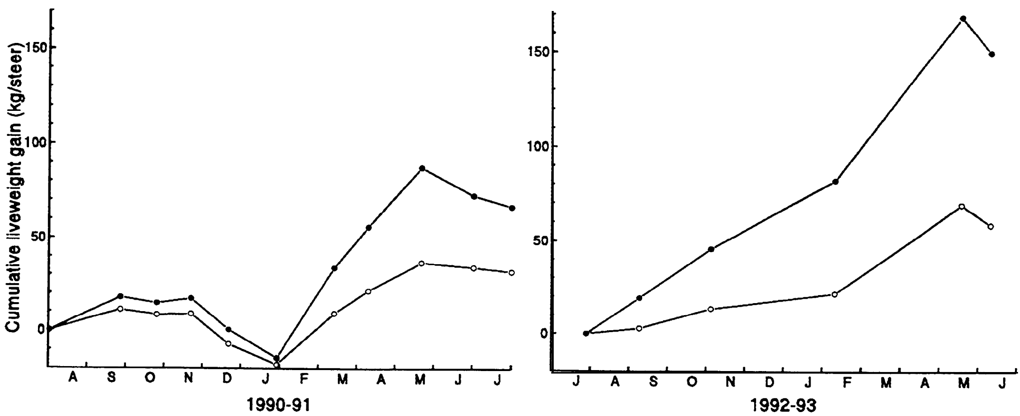

Figure 1. Cumulative liveweight change of steers with phosphorus supplement (closed circles) and without supplement (open circles) in 1990/91 and 1992/93

Plasma inorganic phosphate, CBT and tail-bone density of supplemented and unsupplemented steers differed significantly ($P < 0.001$ except for tail-bone density in 1990/91 when $P = 0.003$) at the end of both grazing periods (Figure 2). Absolute values for each parameter were similar on both occasions though the differences between supplemented and unsupplemented steers were slightly larger in the second year. There was a significant effect of age-of-steer on liveweight gain in 1990/91 (see Jones and Coates 1992) but no such effect was observed in 1992/93. There was also an effect of steer age on CBT in 1991 ($P < 0.05$) where values were about 0.4 mm lower in weaner steers than in yearling or 2-year-old steers for both supplemented and unsupplemented groups. There was a trend for lower CBT in weaner versus yearling steers in the supplemented group in 1993. Steer age had no effect on PIP or tail-bone densitv.

All possible 2-way simple correlations (paddock means used to overcome variation due to steer age) between the 4 parameters, liveweight gain, PIP, CBT and bone density were positive and significant (Table 1). The correlations were generally higher for the 1993 data set and the closest correlation was between CBT and bone density. Best subset regression analysis indicated that CBT and bone density together best explained the variation in liveweight gain ($R^2 = 0.75$) but there was little improvement over the use of either indicator alone (average $R^2 = 0.7$).

DISCUSSION

All 3 diagnostic indicators, PIP, CBT and tail-bone density discriminated clearly between the P-deficient and P-adequate steers. In spite of the difference in liveweight gain between the 2 study periods, year effects made little difference to the numerical values of the diagnostic indicators (Figure 2). Plasma inorganic phosphate gave the highest level of discrimination between treatments as determined

Table 1. Correlation coefficients for relationships between the paddock means of liveweight gain (LWG), plasma inorganic phosphate (PIP), rib-bone cortical bone thickness (CBT), and tail-bone density (DEN) of steers grazing stylo-based pasture in 1991 and 1993

		LWG	PIP	CBT
	PIP	0.748		
1991	CBT	0.809	0.770	
	DEN	0.816	0.741	0.852
	PIP	0.729		
1993	CBT	0.851	0.830	
	DEN	0.864	0.842	0.878

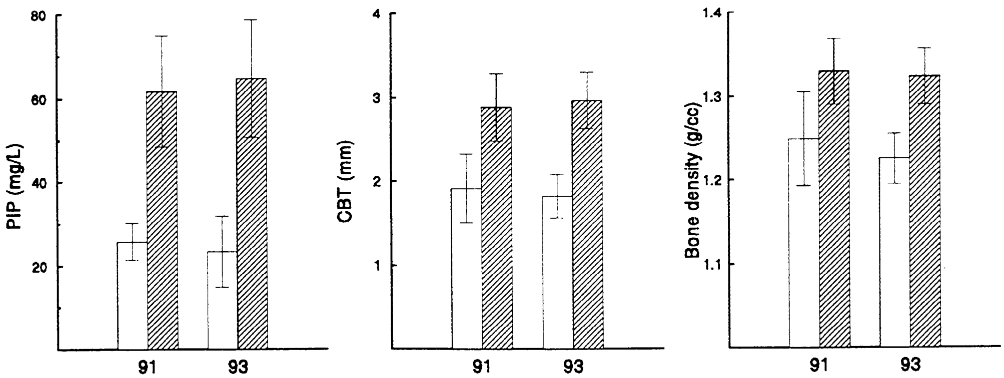

Figure 2. Group mean values for plasma inorganic phosphate (PIP), rib-bone cortical bone thickness (CBT) and tail-bone density of steers without supplement (plain) and with phosphorus supplement (cross hatched) in 1991 and 1993. Standard deviation bars are shown.

by the difference between treatment means relative to within-treatment variation while the lowest level of discrimination occurred with the tail-bone density measurements in 1991. The significant correlations among liveweight gain and the diagnostic indicators (Table 1) was to be expected because dietary P was the dominant factor affecting all these parameters in this experiment.

The coefficients of variation (CV) for CBT and SPA-derived bone mineral density (bone mineral density = bone density - 1) were almost identical and ranged from 10 to 22% for the 4 groups of steers (2 years by 2 treatments) compared with a CV range of 17 to 36% for PIP. The magnitude of between animal variation, relative to the difference that is likely to occur between groups of animals of different P-status, appears to be a problem with both CBT and bone density measurements. Results from individual animals may be misleading and the sample size (n) needs to be high enough to give a reliable estimate of the population mean. In this study the unsupplemented steers were severely P deficient so that there was every opportunity for the diagnostic indicators to discriminate between the supplemented and unsupplemented steers. Obviously it would be more difficult to reliably discriminate between marginally P-deficient and normal cattle and it is the difficulty in diagnosing marginally P-deficient cattle that has been of ongoing concern to both researchers and producers alike. Nevertheless, the results of this study indicate that SPA derived tail-bone density measurements appear to have comparable discriminatory power to rib-biopsy CBT measurements in differentiating between steers of different P status. The preliminary results also indicate that tail-bone density may be less affected by animal age than CBT. In contrast to rib-biopsy CBT measurements, bone density measurements can be taken at any desired interval so that changes in bone mineral status can be monitored (eg. in response to internal demand for P for soft tissue growth, pregnancy or lactation, or in response to an imposed treatment) thus providing a potentially useful research tool for phosphorus nutrition studies.

While PIP gave the highest level of discrimination between supplemented and unsupplemented steers in this study, its use in diagnosing P deficiency has some important limitations as described by Ternouth (1990) and Wadsworth *et al.* (1990). Moreover, PIP level is usually sensitive to current P intake and does not necessarily reflect animal P status in terms of skeletal reserves of P. Tail-bone density, however, provides a measure of bone mineral reserves and reflects past as well as current P intake so that tail-bone density measurements could usefully complement PIP measurements.

Although SPA-determined tail-bone density successfully discriminated between P-deficient and P-adequate steers in this study, its value as a diagnostic indicator for P deficiency has yet to be determined. Values that reliably indicate deficiency or sufficiency of dietary P must be determined together with any effect on such values of age, sex or physiological status of the animal, normal seasonal changes in forage quality that affect the growth and/or condition of the animal, and nutrient deficiencies other than P. The optimum time of the year to measure tail-bone density for diagnostic purposes also needs to be determined. Because of the complex interactions of P with other nutrients it is unlikely that a single indicator will reliably diagnose P deficiency in cattle in all situations. However, results to date indicate that the measurement of tail-bone density by means of SPA may prove to be a useful diagnostic index, especially if it is used in conjuction with another index such as PIP. It also has the potential to be a valuable research tool in phosphorus nutrition studies.

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