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The critical dietary potassium concentration for induction of mineral disorders in non-lactating Welsh Mountain sheep

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Abstract

Diets with more than 30 g K/kg DM have previously been associated with hypomagnesaemia in grazing cattle, and to test whether such diets lead to mineral disorders in sheep, the absorption of Mg and other elements was investigated using experimental diets to which KC1 had been added to provide 27, 29, 32 or 34 g K/kg DM. The apparent absorption, balance and apparent retention of Mg, and to a lesser extent Ca, were reduced for sheep offered the diets with 32 or 34 g K/kg DM. The absorption and retention of K, Na, P, Zn, Pb and Cd was not affected by treatment. The blood intracellular Ca concentration was reduced by the diets with 29, 32 or 34 g K/kg DM, compared to the diet with 27 g K/kg DM, but the concentration of other elements was unaffected. Blood plasma Ca concentration was increased at the highest level of K inclusion, providing evidence of mild hyperkalaemia and the involvement of Ca homeostatic mechanisms. It is concluded that Mg absorption by sheep will be impaired if the diet contains more than 30 g K/kg DM, equivalent to an intake of approximately 13 g K/d, but that a high K diet may be beneficial before parturition to accustom the sheep to Ca mobilization before lactation.

Keywords: Hypomagnesaemia; Sheep; K; Mg absorption; Ca mobilization

1. Introduction

K is the major functional intracellular cation in mammals, but it is not stored in the body and a regular intake is, therefore, essential to prevent cellular dysfunction (Campbell and Roberts, 1965). A K deficiency in the diet of sheep reduces their appetite and can depress growth if severe (Campbell and Roberts, 1965; Roberts and St Omer, 1965). Utilization of other nutrients can also be impaired (St Omer and Roberts, 1967) and, in particular, the absorption of Mg is reduced (House and Van Campen, 1971; Newton et al., 1972) with a consequent reduction in urinary Mg excretion and endogenous faecal Mg excretion. These effects were recorded in sheep as being in either linear (Greene et al., 1983a) or quadratic (Greene et al., 1983b) proportion to K intake at dietary concentrations of between 6 and 48 g K/kg DM. In cattle, the problem

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of hypomagnesaemia has been connected to the feeding of herbage with more than 30 g K/kg DM (Wolton, 1963). Other research has shown that there is approximately a linear increase in Mg absorption when the Na:K ratio in rumen fluid increases, up to a maximum of 5:1 beyond which there is no further increase (Martens and Rayssiguier, 1980). Wylie et al. (1985) identified the rumen as the site of impaired Mg absorption. At high rumen K concentrations, the potential difference across the rumen wall is increased and more Mg^{2+} ions are retained in the relatively negative rumen contents in comparison to diets high in Na (Care et al., 1967). Wylie et al. (1985) also observed a tendency for reduced Ca absorption at high K intakes, which was not evident in other studies (Suttle and Field, 1967; Khorasani and Armstrong, 1990), but which might be expected from the dominant influence of the plant Na:K ratio on the absorption of both Ca and Mg in sheep (Chiy et al., 1994).

In humans, hypokalemia is also associated with hypomagnesaemia due to the common effect of hyperaldosteronism impairing both K and Mg reabsorption by the kidney (Dirks, 1983). Hypocalcaemia is often simultaneously presented in such cases (Rose, 1989).

In view of the varied results of K supplementation on the absorption of metals in ruminants, in particular Mg and Ca, an experiment was conducted to examine this in sheep.

2. Material and methods

Four non-lactating, 2-year-old Welsh Mountain ewes of mean weight 42 kg were contained in metabolism chambers equipped with faecal and urine separators. They were allocated at random to a balanced Latin Square design (Davis and Hall, 1969) with four treatments (0, 3, 6 or 13 g supplementary KC1/kg concentrate DM) imposed in four periods, each of 2 weeks duration. In each period, the first 8 days were used for adaptation to the new diet and the final 6 days for total collection of refused herbage, faeces and urine. Grass was from a perennial ryegrass (*Loiium perenne*) sward, cut three times per week and offered ad libitum in two feeds per day at 09.00 and 14.00 h. A 200 g DM concentrate supplement was fed to each animal at 08:30 h (Dalgety Sheep Feed containing sunflower, sugarbeet, wheatfeed pellets, rapeseed, micronized maize, peas, barley and vitamins and minerals, chemical composition (g/kg) oil 35, protein 200, fibre 120, ash 95, Na 1.9, Mg 3.9, Ca 4.9, K 12.2 and P 5.3. No refusals were observed. All sheep were offered water ad libitum in a plastic bucket.

Representative samples of offered and refused herbage, concentrate, water, faeces and urine were taken from each sheep daily. The offered and refused herbage, concentrate and faecal samples were weighed and analysed for DM by drying at 95 °C for 16 h. Each sample was ground in a hammer-mill to pass through a 1 mm screen, aggregated over the 6-day measurement period and analysed for DM, CP and modified ADF (MADF) by the methods of MAFF (1986) and for element concentrations by the procedures of Chiy et al. (1998). Urine and water samples were also analysed for element concentrations using these procedures.

The apparent absorption of Na, K, Mg, Ca, P, Zn, Pb and Cd was determined as the intake of each element minus the output of the element in faeces, expressed as a proportion of the intake of the element. The retention of each element was determined as the element that was apparently absorbed (ignoring endogenous losses) minus the output of the element in urine. To determine the element concentration in herbage, a mean value for the concentration of each element from samples of feed offered to the sheep in the four treatments was taken for each period. As a result of the large variation in element concentrations in refused grass, and the possibility of contamination with saliva, the concentrations in offered herbage were used to determine the intake of each element.

Blood serum samples were collected by jugular venipuncture into heparinized vacutainer plastic tubes at the end of each period. Following centrifugation at $1000 \times g$ for 30 min, the plasma and cells were separated and stored at −20 °C before determination of Ca, Cu, Fe, K, P, Mg, Na and Zn by atomic emission spectrophotometer (Spectrometer Pye Unicam, PU 7000/01) by the methods described by Chiy et al. (1998). In brief, solid samples were digested in a microwave oven (Milestone MLS 1200, Leutkirch, Germany) with the addition of 13 mol/L nitric acid. Liquid samples were acidified with 13 mol/L nitric acid and any precipitate was removed by filtration. Urine samples were diluted by a factor of 1:10. The digested solid samples and the liquid samples were analysed for Ca, Cu, Fe, K, P, Mg, Na and Zn by