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Effect of increasing Fe intake on the Fe and Cu content of tissues in grazing sheep.

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ABSTRACT

Twelve Romney wether lambs, average weight 28 kg, were randomly divided into two groups, namely an untreated control and an Fe treated group. All animals were grazed together on a ryegrass/white clover pasture for 12 weeks. The Fe intake of the control animals was estimated to be 247 mg/day while that for the treated animals was 827 mg/day with the extra Fe ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) given orally in a gelatin capsule.

Increasing the Fe intake had no effect on DM intake or growth rates but significantly ($P < 0.05$) increased the Fe content of the lungs, spleen and digestive tract. No other changes in Fe concentrations were found in the other soft tissues or bone.

There was a marked decrease [50%] in the Cu content of the liver (a major storage organ for Cu) when the Fe treated lambs were compared with the control animals. The fact that a moderate increase in the intake of Fe can markedly reduce the Cu status of lambs may be a more important finding than has been previously realised.

Keywords Sheep, Fe, Cu, bone, soft tissues, liver, Cu status.

INTRODUCTION

The Fe intakes of grazing animals can be high particularly in the winter when the ingestion of soil is markedly increased (Healy 1967). Other sources of Fe include drinking water from bores and wells (Campbell *et al.*, 1974) and pastures grown on soils with a high and fluctuating soil water table as water logging causes an increase in the Fe uptake of plants (Islam and Elahi, 1954; Jones, 1977). High Fe intakes caused poor performance in dairy cows and this appeared to be associated with hypocuprosis-like signs (Coup and Campbell, 1964). Later other studies showed that when cows were fed high Fe diets (1200-2500 mg/kg DM) a dramatic decrease in the Cu content of the liver occurred (Standish *et al.*, 1969; 1971; Campbell *et al.*, 1974). Similarly when calves were fed a barley straw diet containing 800 mg Fe/kg DM decreases in liver, plasma and erythrocyte Cu concentrations, as well as plasma caeruloplasmin levels, were observed (Humphries *et al.*, 1983). However, none of the clinical signs normally associated with Cu deficiency, induced by high intakes of Mo in the presence of S, such as reduced growth rates, skeletal lesion and impaired reproductive performance, occurred when the Cu status

was reduced by high Fe intakes (Humphries *et al.*, 1983; Phillippo *et al.*, 1985). Whilst the influence of Mo on Cu metabolism in ruminants has been well documented less is known about the effect of Fe on Cu metabolism, particularly in sheep. This paper reports on the effect of high Fe intakes on the Fe and Cu content of tissues from grazing sheep.

MATERIAL AND METHODS

Animals

Twelve Romney wether lambs, weighing an average 28 kg, were randomly divided into 2 groups, one group being the control while the other was given orally 580 mg Fe ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) daily in a gelatin capsule. The sheep were grazed as a single group on a ryegrass/white clover pasture. The duration of the experiment was for 12 weeks and began in March. All animals were weighed at 2-weekly intervals and drenched at 3 or 4 weekly intervals to control internal parasites. Dry matter intakes were determined during the 6th and 7th week of the experiment using techniques previously described (Ulyatt, 1971).

Sample collection

Pasture samples were collected at weekly intervals, dried and ground for chemical analysis. The animals were slaughtered at the end of the experiment and the various organs and tissues collected and subsampled according to procedures already described (Grace, 1983; Grace and Lee, 1988).

Analytical procedures

Details of tissue and pasture sample preparation, subsampling, wet ashing and analysis for mineral elements have been fully described elsewhere (Grace, 1983; Grace and Lee, 1988).

Statistics

Analysis of variance was used to determine significance differences among treatment means.

RESULTS

Pasture elemental concentrations

The mean elemental content of the pasture grazed was Na, 2.9; K, 30.8; Ca, 6.7; Mg, 2.4; P, 3.9 and S, 3.9 (g/kg DM) and Co, 0.16; Cu, 7.8; Mo, 0.13; Zn, 33.8; Fe, 206; Mn, 105 (mg/kg DM) as well as Se, 35 µg/kg DM.

Growth rate and DM intake

The mean (\pm SE) daily gains (g/d) of the control and Fe treated sheep were 177 \pm 18 and 187 \pm 11 respectively while the mean (\pm SE) daily DM intakes (kg/d) were 1.27 \pm 0.03 and 1.20 \pm 0.04 respectively.

Tissue Fe and Cu concentrations

A summary of the Fe and Cu content of various organs and tissues in the control and Fe treated groups are shown in Table 1.

TABLE 1 Effect of increasing Fe intakes on the Fe and Cu content of organs and tissues in grazing sheep.

Fe intake (mg/d)	247	827	Significance of difference	247	827	Significance of difference
<u>Tissue Minerals</u>	<u>Fe</u>			<u>Cu</u>		
	<u>(µg/g) fresh tissue</u>			<u>(µg/g) fresh tissue</u>		
Organs and soft tissues						
Brain	14.9 \pm 0.64	16.7 \pm 0.84		3.5 \pm 0.12	3.4 \pm 0.16	
Lungs	75.0 \pm 5.22	97.0 \pm 9.3	*	2.7 \pm 0.13	2.6 \pm 0.03	
Heart	47.6 \pm 2.71	51.4 \pm 1.52		4.2 \pm 0.0	3.9 \pm 0.14	
Liver	69.9 \pm 3.98	78.0 \pm 4.82		239.0 \pm 19.4	131.0 \pm 18.3	***
Spleen	111.0 \pm 9.9	175.0 \pm 22.1	*	1.0 \pm 0.03	1.1 \pm 0.07	
Pancreas	15.3 \pm 1.35	18.7 \pm 1.67		1.3 \pm 0.10	1.4 \pm 0.02	
Kidney	76.0 \pm 15.2	100.0 \pm 18.3		4.3 \pm 0.10	4.3 \pm 0.19	
Digestive tract	19.9 \pm 1.93	35.2 \pm 2.79	***	1.3 \pm 0.05	1.3 \pm 0.11	
Carcass	20.9 \pm 2.22	19.3 \pm 0.35		1.19 \pm 0.07	0.8 \pm 0.05	**
Wool	17.0 \pm 2.9	18.0 \pm 2.4				
Plasma	1.7 \pm 0.08	1.8 \pm 0.097		0.9 \pm 0.14	0.9 \pm 0.07	
Bones						
Scapula	31.1 \pm 1.71	32.1 \pm 1.95		0.36 \pm 0.01	0.38 \pm 0.03	
Humerus	18.3 \pm 0.71	16.6 \pm 0.92		0.18 \pm 0.02	0.16 \pm 0.01	
Ulna/Radius	12.3 \pm 0.63	15.1 \pm 1.43		0.22 \pm 0.02	0.16 \pm 0.02	
Rib	43.3 \pm 3.16	39.9 \pm 2.23		0.56 \pm 0.08	0.58 \pm 0.04	

Increasing the Fe intake from 247 to 827 mg/day significantly increased the Fe content of the lungs, spleen and especially the digestive tract. The Fe content of the other soft tissues and bone were not affected. In the case of Cu there was a marked decrease in the liver mean Cu concentrations (239 to 131 µg/g fresh tissue; $P < 0.001$) and a decrease in carcass mean Cu concentrations (1.19 to 0.8 µg/g fresh tissue, $P < 0.05$). The plasma Cu levels were not changed.

DISCUSSION

Confirming the earlier findings for cattle (Humphries *et al.*, 1983; Phillipppo *et al.*, 1985) increased Fe intakes (247 v 827 mg/d) also reduced markedly the Cu content of the liver in the grazing lamb. The plasma Cu levels were not decreased in the Fe treated lambs as they were not Cu deficient. Copper deficiency is only associated with liver Cu concentrations of below 20 µg Cu/g fresh tissue. Growth rates and DM intakes were similar for the Fe treated and control groups. However, from the observed rate of liver Cu depletion it is likely that the lambs would have become Cu deficient within 24 weeks. The decrease in carcass Cu concentrations is difficult to explain as there were no significant changes in plasma or bone Cu levels.

Iron intakes exceeding 827 mg/day for several months of the year, particularly during the winter when soil contaminated pastures are grazed would be commonly encountered by many lambs in New Zealand and therefore could contribute to a lowered Cu status of these animals. Although a considerable proportion of the soil Fe is released into the digestive tract (Healey, 1972) the amounts of Fe which are physiologically available to interfere with the absorption of Cu or its metabolism are difficult to assess. Experimentally it has been demonstrated that both soluble $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ and insoluble Fe salts (hydrated $\text{Fe}(\text{OH})_3$ and saccharated FeCO_3) are equally effective as antagonists of Cu metabolism (Standish *et al.*, 1971; Campbell *et al.*, 1974; Humphries *et al.*, 1983).

The metabolism of Cu is complex since a Mo induced Cu deficiency in cattle as a result of increasing Mo intake in the presence of S, is associated with poor growth, skeletal lesions and reproductive problems (Humphries *et al.*, 1983; Phillipppo *et al.*, 1985). In contrast a similar degree of Cu deficiency induced by

increasing the Fe intake in cattle was not associated with any change in animal performance (Phillippo *et al.*, 1985). The mode of action of Mo on Cu metabolism has been explained in terms of the formation of thiomolybdates in the rumen which then complex with Cu and reduce its absorption (Suttle, 1983) or metabolism by the liver (Allen and Gawthorne, 1987; Mason *et al.*, 1988). The poor fertility caused by Mo is thought to be associated with a decreased release of luteinizing hormone and an altered ovarian steroid secretion (Phillippo *et al.*, 1987).

The mechanism of the antagonistic effect of Fe on Cu is not understood but high Fe intakes have no influence on the Cu metabolism of the preruminant calf while the effects of Fe on Cu appear to be independent of the dietary S (Humphries *et al.*, 1985). It is therefore speculated that the availability of Cu might be reduced through the formation of mixed Fe and Cu sulphides in the rumen or that Fe may inhibit the transport of Cu.

The effect of Fe on the Cu status of lambs could be far more important than has previously been thought, and therefore in situations where Cu deficiency has been diagnosed in ruminants attempts should also be made to assess the dietary intakes of Mo and Fe.

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