INGESTED SOIL AND ANIMAL NUTRITION

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Summary

Grazing animals ingest soil along with herbage, and this ingested soil can be a source of elements to animals over and above amounts contributed by the herbage. The effects of ingested soil on animal nutrition are discussed, particularly in relation to the elements cobalt, iodine, selenium, calcium and magnesium.

INTRODUCTION

SOILS are usually considered to influence animal nutrition through the quantity and quality of the herbage they produce, so that the sequence is soil-plant-animal. The fact that soil is ingested by grazing animals indicates that a direct soil-animal effect also needs to be considered.

Soil is taken in by animals along with herbage, as soil adhering to leaves, as soil on roots, and as earthworm casts. Grazing of root crops to ground level or below is another source. The bulk of the ingested soil is probably taken in accidentally along with herbage and is a consequence of intensive management. Soil ingested because of depraved appetite is probably of rare occurrence.

Under New Zealand conditions with animals wintered outdoors, sheep can ingest up to about 75 kg of soil annually, and dairy animals up to about 600 kg. While these are large amounts of soil, they are less than perhaps 2% of annual fresh matter intakes. However, because elements may be present in soil at much higher concentrations than found in pasture, this soil may have important nutritional effects.

FACTORS INFLUENCING SOIL INGESTION

Soil content of faeces can be calculated from ash content after suitable corrections. A more rapid and accurate method is the measurement of the titanium content using X-ray fluorescence (Healy, 1968a). Titanium is present in only small amounts in clean herbage, and hence faeces, in the absence of soil. It is abundant in soil and its presence in faeces can be used to measure soil content. Known or assumed faeces outputs enable the quantity of soil ingested to be calculated. Amounts of soil ingested follow the pattern of soil content in faeces (Healy, 1968a).

Factors influencing soil ingestion have been described by Healy (1968b) and will be considered only briefly here.

Soil Type: Well-drained soils with strong structure are usually associated with clean pastures and relatively low levels of soil ingestion; poorly drained soils with weak structures results in soiled pastures and high soil ingestions.

Stocking Rate: The higher the stocking rate the greater the ingestion of soil, Soils of good physical properties will lessen this effect but even on these soils ingestion can rise rapidly with small increases in stock numbers as pasture availability falls.

Earthworms: High earthworm populations are associated with high dry matter production (Watkin and Wheeler, 1966). In wet periods, especially on poorly drained soils, surface casting increases markedly: casts contribute to soiling of pasture. Casts may also be taken in directly when located in the pasture itself, or when picked up from the soil surface during close grazing.

Management: Ingestion may be less under rotational grazing compared with set-stocking. Supplementary feeding will lessen soil ingestion in the winter. The height to which pastures are grazed will affect ingestion, etc.

In view of these factors it is not surprising that there is a marked seasonal variation in soil ingestion. Highest intakes are in the late autumn and winter when nutritional demands are high. and pastures are closely grazed, soiled, and characterized by abundant earthworm casts. Intakes are lowest in periods of flush growth and when nutritional demands are low.

EFFECTS OF SOIL INGESTION ON ANIMALS

EXCESSIVE WEAR OF SHEEP INCISOR TEETH

The most obvious effect in sheep is on wear of incisor teeth. If the rate of wear is excessive, ewes are reduced to gummies at a comparatively early age and are unable to graze in competition with younger animals.. Early culling or the running of older ewes in a separate flock under favourable grazing conditions are a consequence (Healy, 1968b) .

NUTRITIONAL EFFECTS

In its passage through the alimentary tract, soil is subjected to a range of conditions involved in digestive processes. Changes in element concentration in digestive liquors may follow and, if these occur at sites where there is active absorption, there will be changes in tissues and blood composition. Other less obvious changes may also result from the presence of soil.

LABORATORY STUDIES

The feeding of soils to animals under controlled conditions is demanding and expensive. Laboratory studies enable a wider study of the effects of soil and may be a useful preliminary to animal studies.

Liquors were collected from fistulated and cannulated animals stall-fed flash-dried pasture, free of soil, at Applied Biochemistry Division, Palmerston North. Ruminal, duodenal and ileal liquors were used in the study. Macro- and micro-element concentrations in the liquors were determined before and after shaking with various soils; considerable changes in element concentration resulted (Healy, 1972). Different soils were shown to produce different effects, many of which were consistent with known soil properties. Changes in the amounts of selenium in solution in the liquors after shaking with different soils illustrate the kinds of changes produced (Fig. 1).

ANIMAL STUDIES

Short-term studies using soil containing radioisotopes (Healy *et al.*, 1970), as well as longer term feeding studies, have shown that soil can be a source of elements to animals.. In this section the elements cobalt, iodine, selenium, calcium and magnesium, all of which are important nutritionally, will be considered in relation to soil ingestion.

Cobalt

Rigg and Askew (1934, 1936) studied the effect of soil drenches on animals in a bush sick area in the Nelson district. A drench of approximately 10 g of soil (Nelson soil) , given twice a week for 7 months (only approximately 600 g soil), produced animals of excellent condition compared with controls which were clearly cobalt deficient. Another soil, Wakatu, was incapable of preventing cobalt deficiency.

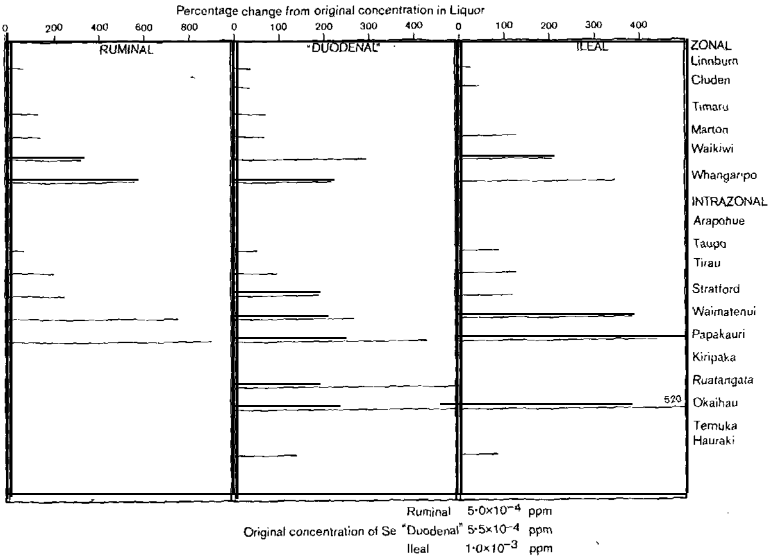

FIG. 1: ***Changes in selenium in liquors after shaking with soil.***

Almost 40 years ago, these workers commented that "soils are just as important as the pasture growing thereon in supplying certain essential constituents required by stock."

Selenium

The ability of soil to supply selenium has been demonstrated in two ways.

Using soil containing radioactive selenium (^{75}Se) given as a single drench, Healy *et al.* (1970) have shown that ^{75}Se is taken up rapidly into the blood and subsequently into other tissues. At the end of the 10-day period over which the study was conducted, 34% of the ^{75}Se originally held on the soil had been absorbed by the animals.

In a longer term study using newly weaned lambs housed indoors, Dr G. F. Wilson and the writer have shown that soil fed *at* a *rate* of 50 g per day resulted in a significant increase in blood selenium at the end of 6 weeks. Two soils were used, Egmont black loam and Papakauri silt loam, with total selenium contents of 1.18 and 1.82 ppm, respectively. Mean blood seleniums for the three groups after 6 weeks were:

Control group	0.105 ppm
Group receiving Egmont black loam	0.140 ppm
Group receiving Papakauri silt loam	0.165 ppm

Iodine

During lambing in 1971, an abnormally high number of lamb deaths were observed at the Department of Agriculture Field Research Area at Masterton (Healy *et* al., 1972) . Necropsies revealed enlarged thyroids. Clinical examination of surviving lambs showed that, while prevalence of enlarged thyroids was high (65%) in lambs from low-stocked areas, the condition was almost entirely absent in lambs from high-stocked areas. Studies of soil ingestion had shown that faeces from ewes on high-stocked areas contained much more soil than did faeces from low-stocked areas where feed was in good supply over the winter. Iodine in herbage was low and did not differ for the two areas. Iodine in faeces followed the pattern of soil content, higher on high-stocked areas (Table 1).

The data suggest that ingested soil was a source of iodine to ewes on high-stocked areas and that this accounts for the virtual absence of enlarged thyroids in the lambs.

TABLE 1: IODINE AND SOIL CONTENT OF FAECES

Date and Stocking Rate	*Soil in Faeces (% DM)*	*Iodine in Faeces (ppm in DM)*
Mar. 18, 1971:		
High	15	1.0
Low	2	0.5
May 20, 1971:		
High	21	2.0
Low	3	0.5
Sep. 9, 1971:		
High	63	1.0
Low	7	0.1

Calcium and Magnesium

In a balance trial carried out in association with Dr N. D. Grace of Applied Biochemistry Division, DSIR, three groups of wethers housed indoors were fed the following daily ration:

Control group — 600 g dried herbage

Egmont group — 600 g dried herbage + 100 g of Egmont brown loam

Waikiwi group — 600 g dried herbage + 100 g of Waikiwi silt loam.

After approximately six weeks, a six-day balance study was carried out, and the results are set out in Table 2. Calcium and magnesium contents of soil, herbage, urine and faeces samples were determined by ashing of samples and extracting with 6N HCl, so that a valid balance study on the elements could be made.

It is not clear at this stage just how ingested soil is increasing retentions. The amounts of the elements contributed by the soils themselves may be involved but this does not wholly explain the increases.

INSECTICIDES AND FERTILIZER INTAKE

Chemicals applied to the soil surface which are relatively stable and are of low solubility will persist in the upper few centimetres of the soil for considerable periods. Such chemicals will find their way into the animal along with ingested soil. Harrison *et al.* (1970) have shown that soil containing "weathered" DDT residues can supply considerable amounts of total DDT to ewes and that these residues can be transferred to lambs.

TABLE 2: EFFECT OF SOIL INGESTION ON MAGNESIUM AND CALCIUM BALANCE IN SHEEP

	*Control**	*Waikiwi**	*Egmont**
MAGNESIUM (g/day):			
Intake	0.924	1.109	1.029
Faecal output	0.846 ± 0.07	0.580 ± 0.15	0.507 ± 0.15
Apparent absorption . .	0.078 ± 0.02	0.529 ± 0.05	0.522 ± 0.05
Urine output	0.166 ± 0.11	0.231 ± 0.24	0.198 ± 0.24
Retention	-0.088	+0.298	+0.324
CALCIUM (g/day):			
Intake	3.120	3.290	3.440
Faecal output	3.443 ± 0.16	1.918 ± 0.31	1.915 ± 0.34
Apparent absorption ...	—	1.372 ± 0.20	1.524 ± 0.22
Urine output	0.073 ± 0.01	0.073 ± 0.02	0.075 ± 0.02
Retention	-0.396	+1.299	+1.449

*Control 600 g dry herbage per day.
Waikiwi 600 g dry herbage per day plus 100 g Waikiwi silt loam per day.
Egmont 600 g dry herbage per day plus 100 g Egmont brown loam per day.
These soils are fully described in "Soils of New Zealand, Part 3" (N.Z. Soil Bureau, 1968).

In current work relating to periodontal disease in sheep, a comparison is being made between sheep on unlimed and limed areas of the same soil in Northland. Analyses of faeces show that faeces from sheep on the limed area contain about 30% more calcium as compared with faeces from the unlimed area. Herbage analysis indicates little difference in calcium intakes from herbage alone and it appears that particles of lime are being taken in directly along with herbage. It is suggested that other fertilizers may be taken in directly in the same manner.

Nutritional disorders in animals can often be related to a particular soil type, but striking anomalies can occur. Sometimes a deficiency will show on one farm and be absent on an adjoining farm. Some of these anomalies may be explained in part by the substantial differences in soil ingestion resulting from differences in management. It has been shown (Healy, 1968a, 1970) that individual animals in the same herd or flock can differ in soil ingestion by a factor of 2 or 3; this may help to explain why only some animals on a farm are affected by a particular nutritional disorder.

Soils, then, appear to have a direct effect on animal health, over and above the indirect effect via pasture; not only the quantity of soil ingested but also the kind of soil ingested is important.

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