Distribution of Mineral Components in the Alimentary Tract of Sheep

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SUMMARY

The patterns of mineral distribution in the ruminal and upper duodenal ingesta from sheep maintained on two different types of diet, orchardgrass hay only and orchardgrass hay plus flaked corn, were investigated.

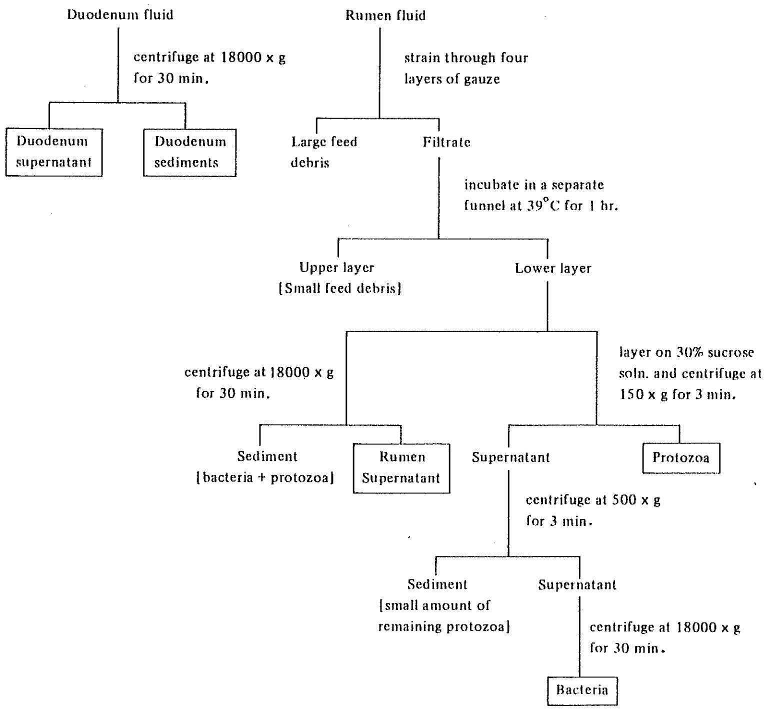
Concentration of Na, K, Ca, Mg, Mn, Fe, Cu and Zn in fractions of rumen and duodenum supernatant, duodenum sediments, bacteria, protozoa and feed were determined. Changes of pH value, depending on site of gastrointestinal tract and type of ration, seemed to affect mineral distribution in those five fractions in a manner characteristic with each element. Isotachophoretic analysis of macro elements suggested that Ca and Mg in rumen may scarcely exist as single cationic forms but as complex ions.

INTRODUCTION

Significant differences have been reported on the apparent availability of minerals in ruminant animals when fed rations of different compositions[1,2]. The chemical forms of minerals have been considered to be one of the major factors to determine the availability of dietary minerals, although little is known of the forms in which minerals are present in diets and in the gastro-intestinal contents[3]. Besides the chemical forms of minerals, the pH conditions in the alimentary tract which are often modified by dietary variables may have a strong influence on either solubility and binding of minerals or the mineral distribution in gastro-intestinal content. Only a restricted amount of information, however, has been obtained as to the behavior and distribution of minerals in the passage of digesta along the alimentary tract. It is the object of this paper to examine the effects of dietary composition on the distribution of mineral concentration in the ruminal and upper duodenal content of sheep.

MATERIALS AND METHODS

Four Suffolk ewes, each equipped with rumen fistula and duodenal canula were divided into a Hay group(H-group) and a Corn group(C-group). Each ewe was kept in a metabolic cage and fed a diet of 2.5% of body weight per day consisting of orchardgrass for the H-group and orchardgrass plus flaked corn (1:1) for the C-group. After a two week allowance for adaptation to the diet, samples of rumen and duodenum fluid were collected from ewes 2 hours after their morning feeding and separated into five fractions as shown in the following flow chart.



Analyses for Cu, Fe, Zn, Mn, Ca, Mg, Na and K were carried out on acid digesta of all samples from fractions and feed by atomic absorption and flame spectrophotometry.

Hydrogen ion concentration in supernatant fractions were determined by pH meter. The isotachophoretic separation of ionic species of Ca^{++}, Mg^{++} and Na^{+} in the supernatant fraction was examined using a Shimazu IP-2 capillary isotachophoresis apparatus according to the method of Beckers *et al*[4] and everaerts.

RESULTS AND DISCUSSION

The pH condition of rumen fluid was slightly acidic in the C-group and almost neutral in the H-group, presenting average pH values of 5.7 and 6.7 respectively. Duodenum fluid was acidic and pH values in the H-group and C-group were 2.5 and 2.0 respectively.

The distributions of Na, K, Ca and Mg concentration in rumen and duodenum content are shown in Fig. 1 to 4. Each bar in the figures expresses the average of four determinations. Na and K concentration in feed were higher in the H-group than in the C-group. This difference in Na concentration by group was observed in all fractions. On the contrary, K concentration in fractions was found to be lower in the H-group than in the C-group. An unexpectedly high concentration of Na in bacteria and duodenum sediments in both groups was observed. Na and K bicarbonate function as buffering components in the rumen and usually a considerable amount of Na and a lesser amount of K flow into the rumen as saliva[5]. The differences in Na and K concentration in the rumen supernatant between the H-group and the C-group may be caused by pH variables which are produced as a result of respective patterns of rumen fermentation.

Ca and Mg showed lower solubility in the rumen compared with Na and K. Ca concentration in rumen supernatant were about 1% of feed in the H-group and 2% in the C-group. In the duodenum supernatant, Ca concentration were 12% of duodenum sediments in the H-group and 17% in the C-group. It appeared likely that the higher solubility of Ca may be related to the circumstances of lower pH. Mg solubility in rumen supernatat was slightly higher than Ca and also appeared to be pH dependent. The bacteria fraction contained Mg at a higher concentration than Ca.

The distributions of Mn, Fe, Cu and Zn concentration are shown in Fig. 5 to 8. The features of distribution observed in common in these four transition metals were a noticeable accumulation of metals in the bacterial fraction and a much higher accumulation in the C-group than in the H-group, except in the case of Cu. The solubility of those metal elements in the rumen was very low, although a comparatively higher solubility of Mn in the C-group was observed. The Mn concentration of rumen supernatant in the C-group was 4.9% of feed and 0.7% in the H-group. Taking into account this difference in Mn solubility in the rumen together with the higher solubility in acidic circumstances of the duodenum, Mn solubility appears to change under the strong influence of pH. Fe solubility in the rumen was particularly low and concentration of it were 0.3% of feed in the H-group and 0.4% in the C-group. On the contrary, massive accumulation of insoluble Fe in the duodenum was observed in both the H-group and the C-group. No difference in Fe solubility between the H-group and the C-group was observed. The Zn concentration in supernatant fraction was heigher in duodenum than in rumen and it's solubility seemed to be pH-dependent. The concentration of Cu in the doudenum supernatant was less than in the rumen supernatant. Considerably high accumulation of Cu in duodenum sediments was observed in both the H-group and C-group. Thus, Cu showed lower solubility in more acidic circumstances, suggesting the existence of insoluble residue which has a strong affinity for Cu in the rumen and in the duodenum. Bremner[3] reported that the strength of binding of the metals to the insoluble rumen residues were in the order Cu > Zn > Mn and there was a greater association of Cu with the microbial material in the rumen. Moreover, Dick *et al.*[6] reported that the complex of Mo and S (thiomolybdate), produced in rumen of sheep, reacted with Cu to form an absolutely insoluble copper salts. It was conceivable in the present study that either Cu association with microbial materials or generation of insoluble cupric thiomolybdate might be involved in the accumulation of Cu in duodenum sediment fraction. In isotachophoresis of supernatant fractions using analytical systems with pH of the leading electrolyte similar to supernatant pH, neither Mg^{++} nor Ca^{++} could be detected in rumen supernatant. Taking account of those ions detected in mixture solutions of sample and standard solutions, Ca and Mg in rumen supernatant might scarcely exist as single cationic forms but as complex ions. In the duodenum sample, however, these cations were separated by isotachophoresis.

It is perhaps not without significance that mineral distribution might be more strongly influenced by qualitative factors in feed such as chemical forms of minerals, pH circumstances produced by content of fermentable substances and type of fermentation rather than by mineral content in feed. In order

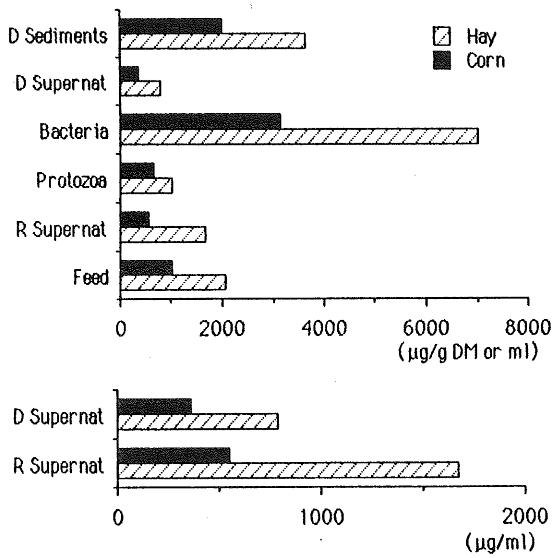


Fig.1 . The distribution of Na in the rumen and duodenum content from ewes which were maintained on orchardgrass hay (Hay) and orchardgrass hay plus flaked corn (Corn).

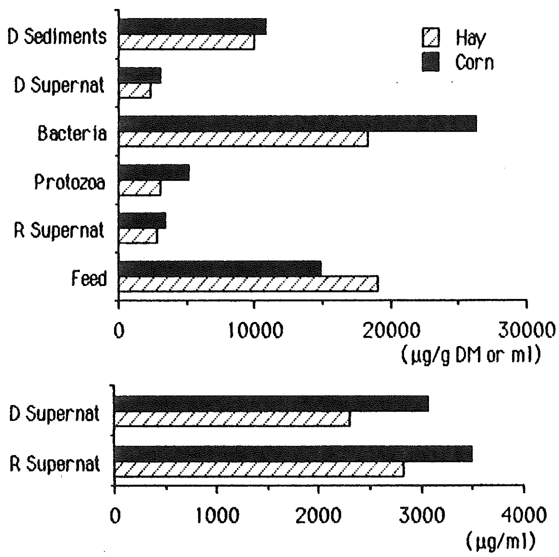


Fig. 2. The distribution of K in the rumen and duodenum content from ewes which were maintained on orchardgrass hay (Hay) and orchardgrass hay plus flaked corn (Corn).

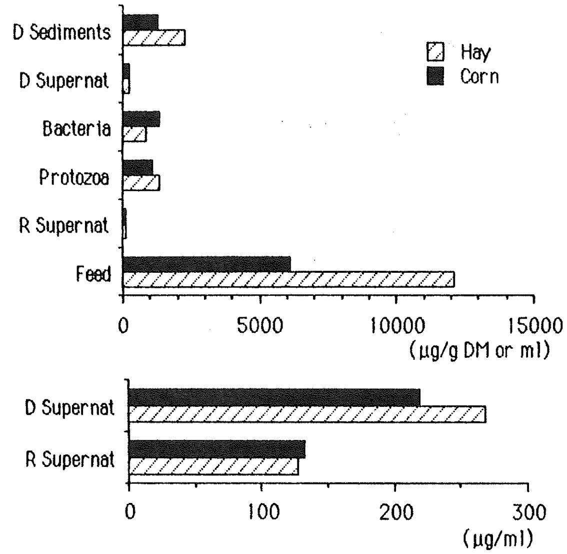


Fig. 3. The distribution of Ca in the rumen and duodenum content from ewes which were maintained on orchardgrass hay (Hay) and orchardgrass hay plus flaked corn (Corn).

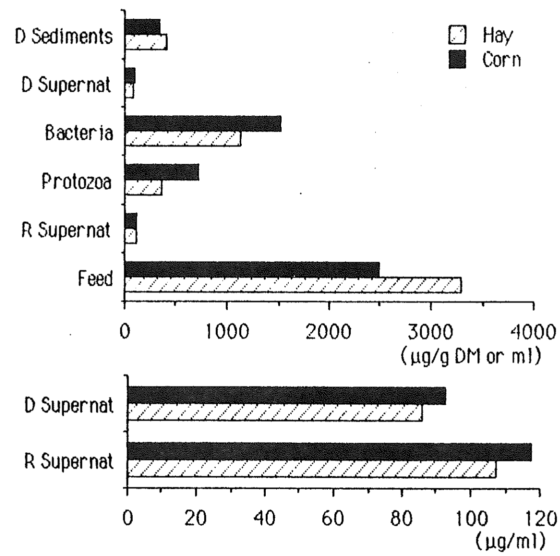


Fig. 4. The distribution of Mg in the rumen and duodenum content from ewes which were maintained on orchardgrass hay (Hay) and orchardgrass hay plus flaked corn (Corn).

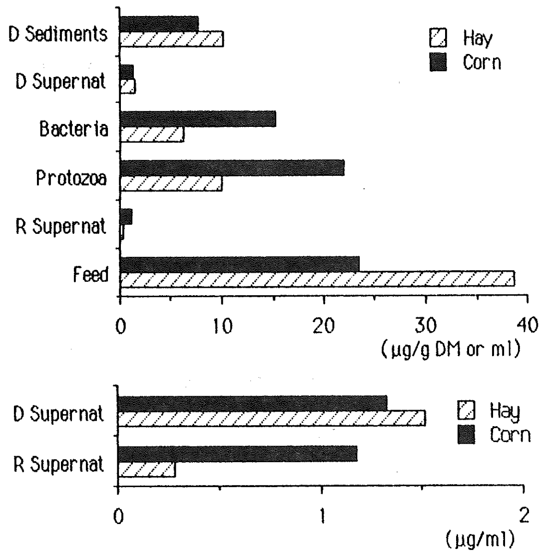


Fig. 5. The distribution of Mn in the rumen and duodenun content from ewes which were maintained on orchardgrass hay (Hay) and orchardgrass hay plus flaked corn (Corn).

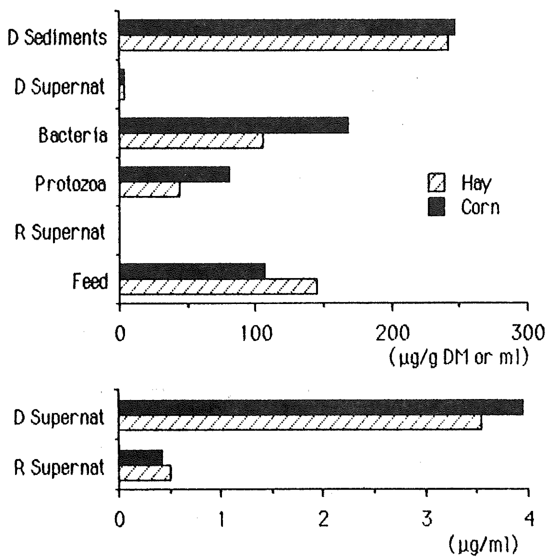


Fig. 6. The distribution of Fe in the rumen and duodenum content from ewes which were maintained on orchargrass hay (Hay) and orchardgrass hay plus flaked corn (Corn).

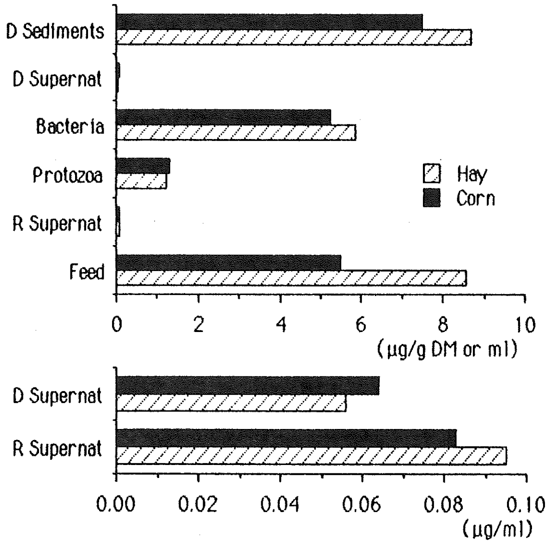


Fig. 7. The distribution of Cu in the rumen and duodenum content from ewes which were maintained on orchardgrass hay (Hay) and orchardgrass hay plus flaked corn (Corn).

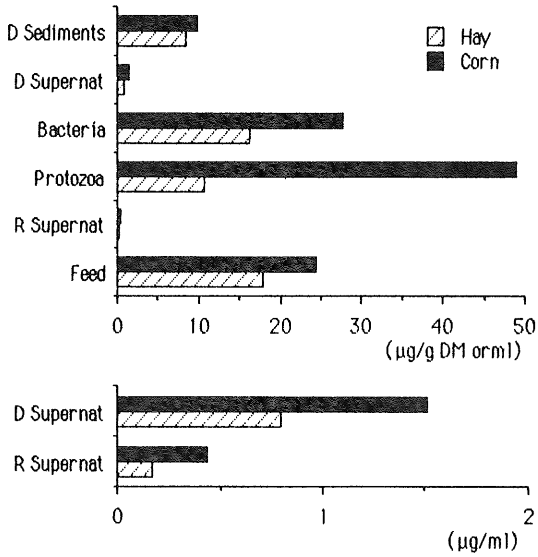


Fig. 8. The distribution of Zn in the rumen and duodenum content from ewes which were maintained on orchardgrass hay (Hay) and orchardgrass hay plus flaked corn (Corn).

to understand the significance of distribution in the alimentary tract in terms of mineral availability, further study on mineral distribution at the site of absorption will be needed.

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