RUMEN AMMONIA IN RELATION TO CHARACTERISTICS OF THE DIET AND PARAMETERS OF NITROGEN METABOLISM

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Summary

Relationships between ammonia levels in rumen liquor and dietary nitrogen (N) intake, the N concentration in the diet, blood urea concentration and urinary N excretion were examined in sheep fed near ***ad libitum*** on diets varying widely in chemical composition and digestibility. Rumen ammonia was positively correlated with all measures but the best relationship was with the ratio of N to digestible organic matter in the diet; possible reasons for this are discussed.

I. INTRODUCTION

The quantity of ammonia in rumen digesta appears to be determined chiefly by the nature and quantity of the diet the sheep is offered. The main sources of the ammonia are nitrogen (N) from the diet, N transferred from the blood to the rumen via saliva or the rumen epithelium and N released during the autolysis of micro-organisms. The important avenues of disposal of ammonia are incorporation into microbial protoplasm, absorption, and passage in digesta to the omasum.

The level of ammonia in rumen liquor is of particular nutritional significance as many types of rumen micro-organisms utilize ammonia as a source of N (Allison 1965). Thus at very low levels of rumen ammonia, it is to be expected that mircobial activity in the rumen will be reduced and accordingly protein and carbohydrate digestion will be impaired; associated with this impairment, feed consumption will probably decline. At present, there appear to be no data 'defining the minimum level of ammonia in rumen liquor consistent with satisfactory microbial digestion.

In the course of studies of the digestion of pasture plants by sheep fed at levels approaching ***ad libitum*** intakes, the levels of ammonia in rumen liquor together with various characteristics of the diet and parameters related to the metabolism of N in the animal were measured; preliminary results indicating relationships between some of these variables are presented in this paper.

II. EXPERIMENTAL METHODS

The experimental methods were generally the same as those described for previous experiments (Weston 1966; Hogan and Weston 1967a; Weston and Hogan 1967*a*). The sheep were mature Merino wethers with fistulae in the rumen and near the pylorus in either the abomasum or duodenum; they were kept indoors, given vitamins A and D_3 regularly and treated to control helminths. Three

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to five sheep were used for each diet. Diets of lucerne hay ***(Medicago sativa,)*** wheaten hay *(Triticum vulgare),* Hl ryegrass *(Lolium perenne x* ***Lolium*** *multiflorum),* forage oats *(Avena sativa)* and phalaris ***(Phalaris tuberosa)*** were offered. The lucerne and wheaten hays and one of the five ryegrass diets were purchased commercially and had been sun cured. The other diets were prepared from the individual plant species grown in nearly pure stands, harvested at various stages of maturity and dried artificially with a minimum of heat. The diets covered a wide range of levels of cell wall constituents (46-81% on an organic matter basis), crude protein (6-32%) and soluble carbohydrate (5-18%); organic matter (OM) digestibility varied between 53 % and 83 % .

During digestion experiments, each diet was fed to sheep in a chopped form at a level of intake equal to about ***90%*** of the sheep's ***ad libitum*** intake, which had previously been determined over a period of two weeks or longer. Excreta were collected for eight to ten days. Nine samples of rumen liquor were collected over a period of three days during the digestion experiment with the same sampling schedule as described previously (Weston and Hogan 1967a). The methods of chemical analysis were those described by Weston and Hogan (1967*a*, ***19673).***

III. RESULTS

Relationships between the ammonia concentration in rumen liquor, N intake, the level of N in the diet, blood urea concentration and N excretion in urine are illustrated in Figures 1-6 where the mean values for individual diets are plotted.

Rumen ammonia concentration was positively correlated with (i) N intake, (ii) the N content of the dietary OM and (iii) the N content of the diet expressed in relation to the digestible OM content of the diet (N/DOM) i.e., g dietary N per 100 g of DOM. However, the ammonia concentration appeared to be more

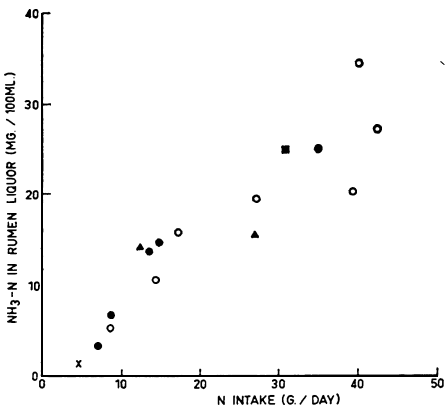

Fig. 1.—The relationship between the mean concentration of ammonia in rumen liquor and the mean intake of N for sheep offered diets of forage oats (○), ryegrass (●), phalaris (▲), lucerne chaff (■) and wheaten chaff (x).

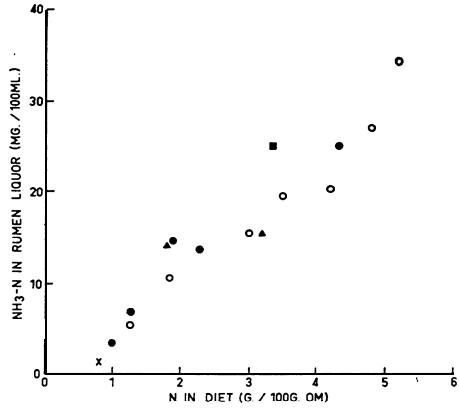

Fig. 2.—The relationship between the mean concentration of ammonia in rumen liquor and the N content of the diet (OM basis) for sheep offered various diets. The symbols are the same as in Figure 1.

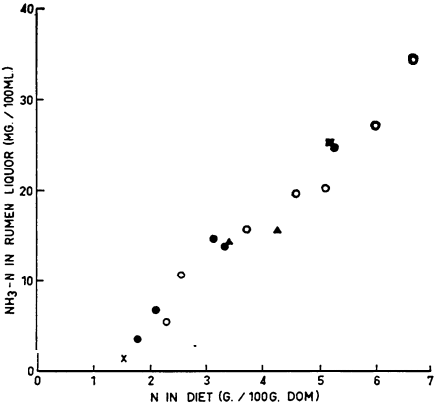

Fig. 3.—The relationship between the mean concentration of ammonia in rumen liquor and the ratio of N to digestible OM in the diet for sheep offered various diets. The symbols are the same as in Figure 1.

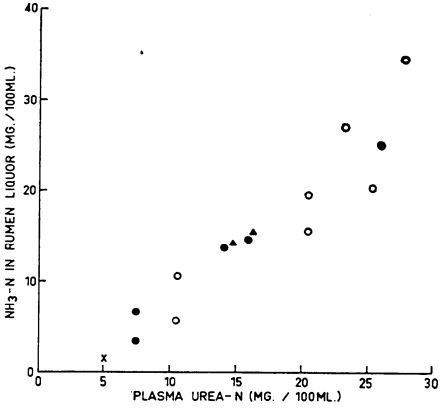

Fig. 4.—The relationship between the mean concentration of ammonia in rumen liquor and the mean concentration of urea in blood plasma for sheep offered various diets. The symbols are the same as in Figure 1.

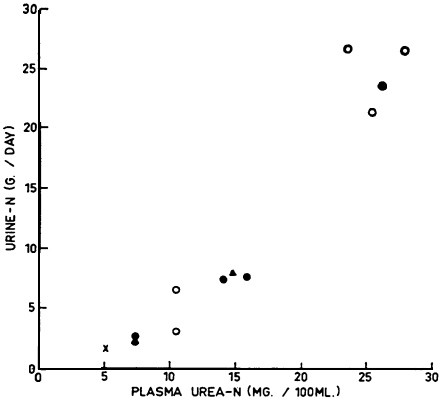

Fig. 5.—The relationship between the mean quantity of N excreted in urine and the mean concentration of urea in blood plasma for sheep offered various diets. The symbols are the same as in Figure 1.

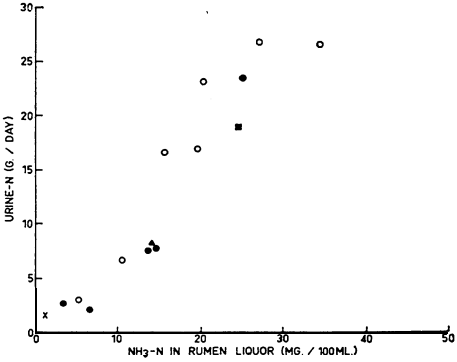

Fig. 6.—The relationship between the mean quantity of N excreted in urine and the mean concentration of ammonia in rumen liquor for sheep fed various diets. The symbols are the same as in Figure 1.

closely related to N/DOM than to the other two measures (Figures l-3) Examination of the relationship between ammonia and N/DOM indicates that ammonia level would be expected to approach zero for diets containing 1.0-1.5 g N per 100 g of DOM.

Figures 4 and 5 show that blood urea concentration was positively correlated with both rumen ammonia concentration and the quantity of N excreted in

the urine. Figure 6 indicates that although ammonia concentration and urine N excretion were also correlated, there was considerable variation within the relationship.

IV. DISCUSSION

The finding that the level of ammonia in rumen liquor was more closely related to N/DOM than to the N content of the diet or N intake is consistent with present concepts of the production and utilization of ruminal ammonia. The rate of synthesis of microbial protein in the rumen appears likely to be proportional to the quantity of energy made available during the fermentation of OM in the rumen, provided other nutritional conditions are favourable (Walker 1965; Hogan and Weston 1967b). Thus at a constant level of N in the diet, increasing amounts of ammonia-N should be incorporated into microbial protein as the quantity of dietary OM digested in the rumen increases. Between diets the latter should be approximately proportional to the quantity of OM digested in the alimentary tract as a whole (Campling, Freer and Balch 1962, 1963; Hogan and Weston 1967*a*). Accordingly, at constant N intake, an increase in the level of dietary DOM should be accompanied by a decline in rumen ammonia due to an enhanced microbial protein synthesis. Under the same conditions, the quantity of N transferred from the blood to the rumen is likely to decline, and so rumen ammonia will tend to be further depressed. The increase in microbial protein synthesis from ammonia when the level of DOM intake is increased and N intake kept constant, should result in a change in the ratio of ammonia-N to amino acid-N in the N absorbed from the digestive tract. This in turn will influence blood urea level as N absorbed in the form of ammonia or urea has a proportionately greater effect on blood urea concentration than N absorbed as amino acids (Egan 1965; Weston and Hogan 1967b). The rate of transfer of N from the blood to the rumen has been shown to increase with increase in blood urea-N at least in the range of 4 to 16-18 mg % (Weston and Hogan 1967b). Thus a decline in N transfer should accompany an increase in dietary DOM when dietary N remains constant.

It was shown in Figure 3 that the level of ammonia in rumen liquor would approach zero when N/DOM in the diet was 1.0-1.5 g N/ 100 g of DOM. If it is assumed that N is absorbed from the rumen chiefly as ammonia, the value of N/DOM at zero ammonia concentration theoretically represents the point at which the quantity of N leaving the rumen in digesta is equal to the quantity of N that enters the rumen. As this N entering the rumen consists of N in saliva and transferred from the blood as well as dietary N, the minimum value of N/DOM consistent with no net loss of dietary N in the rumen must exceed 1.0-1.5 g N/100 g of DOM.

Further data are required on N/DOM and ammonia levels using other diets, particularly pasture legumes, and studies are required to determine the minimum levels of ammonia in the rumen that are necessary for maximum microbial digestion. It is possible that N/DOM might be more useful than the N content of the diet to indicate dietary conditions predisposing to levels of ammonia in the rumen so low that nutritional and production responses could be obtained by giving feed supplements containing N.

The levels of rumen ammonia and blood urea are inter-dependent and affected by the nature of the diet. The two measures appear to be reasonably well correlated at the lower end of the range and so it is possible that when data from other roughages are obtained, blood urea level may be useful in predicting rumen ammonia concentration. Should this be so, blood urea level could indicate whether or not adequate N is available to the rumen microbial population. Limited data obtained using diets of wheaten hay and lucerne hay (Weston, unpublished data) indicate that the values of ammonia and urea obtained under normal conditions of *ad libitum* feeding for sheep in pens, are related in a manner similar to that found in the present studies where feed was offered intermittently at a level of approximately 90% of ***ad libitum*** intake.

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