DIETARY CELLULOSE CONTENT AND UREA UTILIZATION

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Summary

Purified diets were offered to sheep ad libitum in two experiments. Urea was the main source of nitrogen, while energy was supplied as cellulose (20 to 72% ), starch (0 to 32% ) , or sucrose (0 to 35%) . The data indicated that (a) cellulose could serve as a suitable sole source of energy for rumen microbial synthesis, and (b) diets composed largely of cellulose, urea, and minerals could maintain animals in positive nitrogen balance. As the proportion of cellulose in the diet increased, both the intake and digestibility of dry matter declined. Despite this fall in food intake, both cellulose intake and digestibility increased. Nitrogen balances also decreased as food intake declined, but were always positive, usually exceeding 1 g N/day. The data are discussed in relation to the value of cellulose as a source of energy for the utilization of non-protein-nitrogen by rumen micro-organisms.

I. INTRODUCTION

Dietary cellulose may account for a considerable proportion of the organic matter digested by ruminants. However, cellulose is considered by many workers to be an unsuitable energy source for the utilization of non-protein nitrogen by rumen microorganisms (Reid 1953; McDonald 1962; Oxford 1964). Thus, soluble carbohydrates, particularly starch, which are fermented more rapidly than cellulose in the rumen, are fed to improve nitrogen utilization in the rumen and are preferred in diets containing a high proportion of non-protein nitrogen. On the other hand, purified diets containing as much as 50% cellulose have supported weight gains and positive nitrogen balances in both adult and growing sheep (Ellis and Pfander 1958; Oltjen, Sirny, and Tillman 1962). No experiments have been noted which have examined nitrogen utilization in ruminants offered diets containing more than 50% cellulose. A preliminary experiment in this laboratory (Hemsley 1964) showed that a sheep would consume and digest purified diets containing 73% cellulose in sufficient amounts to support positive nitrogen balance. This preliminary observation has been further confirmed in the two experiments reported here.

II. EXPERIMENTAL

Four adult Merino wethers were used in two 4 x 4 Latin square experiments. In Experiment 1, one animal refused to eat the diets offered and was removed from the experiment. The data from this incomplete Latin square ex-

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periment were analysed according to the method described by Yates (1936). The sheep weighed between 45 and 60 kg in Experiment 1 and between 38 and 55 kg in Experiment 2. Purified diets were offered once daily to the sheep ad libitum throughout each 18 day experimental period. The diets were composed of crude cellulose in the form of cotton linters* or cotton droppings† (20-86%), starch (0-32%), sucrose (0-35%), urea (3%), a complete mineral mixture (6%), and indigestible sawdust (5%). The cellulose contents of these diets ranged from 20-72% (Table 1). Intakes, digestibilities and nitrogen balances were estimated over a seven day collection period following a ten day precollection period. Nitrogen was estimated by the Kjeldahl method and cellulose by the method of Crampton and Maynard (1938). Vitamin A (100,000 I.U.) was given to each sheep through the rumen fistula at the beginning of each experimental period.

III. RESULTS

The data presented in Table 1 show that in Experiment 1 both dry matter intake and digestibility were reduced as the proportion of cellulose in the diet increased. Despite this fall in food intake, both the intake and digestibility of cellulose rose with increasing cellulose in the diet. The effects of changes in dietary cellulose content were more pronounced in Experiment 1 (20-57% cellulose) than in Experiment 2 (59-72% cellulose). When the diet containing 72% cellulose was fed, cellulose accounted for 86% of the dry matter apparently digested.

In Experiment 1, nitrogen balances also fell as dietary cellulose content increased and was thus associated with the decline in digestible dry matter intakes. In Experiment 2, nitrogen balances were not significantly affected by raising dietary cellulose content from 59 to 72%. Nitrogen balances were always positive and in most cases greater than 1 g N/day. Body weight changes were also positive in most cases and no significant differences between diets were observed.

IV. DISCUSSION

The data showed that, as cellulose replaced starch and sucrose in the diet, both dry matter intake and digestibility declined despite a rise in both the intake and digestibility of cellulose. This was most apparent in the range 20-57% cellulose in the diet. Above 57% cellulose, no significant changes in intake, digestibility or nitrogen balance occurred. Where starch and sucrose were absent from the diet (72% cellulose), the crude cellulose served as virtually the only source of energy. This diet supported higher intakes of digestible dry matter and higher positive nitrogen balances than those frequently encountered when urea-supplemented low quality roughages (35-45% cellulose) are fed to ruminants (Coombe and Tribe 1963; Hemsley 1964).

The substitution of dietary cellulose with starch and sucrose and its effect on cellulose digestibility and nitrogen balance has also been demonstrated by

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*The short-stapled fibres removed from cotton seed after ginning (0.3% nitrogen, 93% cellulose).
†The short-stapled fibres separated from cotton lint during carding (0.5% nitrogen, 82% cellulose).
## TABLE 1

*Mean intake, digestibility, and nitrogen balance data*

<table>
<thead>
<tr>
<th></th>
<th>Dietary Composition (% of dry matter)</th>
<th>Total Dry Matter Intake (g/day)</th>
<th>Cellulose Intake (g/day)</th>
<th>Cellulose Digestibility (%)</th>
<th>Nitrogen Balance (g N/day)</th>
<th>Body Weight Change (kg/18 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cellulose</td>
<td>Soluble Carbohydrate</td>
<td>Total Dry Matter Intake (g/day)</td>
<td>Cellulose Intake (g/day)</td>
<td>Cellulose Digestibility (%)</td>
<td>Nitrogen Balance (g N/day)</td>
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<tr>
<td>Experiment 1</td>
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<td></td>
<td>1140</td>
<td>230</td>
<td>82</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>66</td>
<td>1050</td>
<td>360</td>
<td>79</td>
<td>72</td>
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<td></td>
<td>34</td>
<td>51</td>
<td>910</td>
<td>400</td>
<td>78</td>
<td>76</td>
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<td></td>
<td>43</td>
<td>41</td>
<td>880</td>
<td>500</td>
<td>74</td>
<td>78</td>
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<tr>
<td>S.E. of means</td>
<td></td>
<td></td>
<td>59</td>
<td>16</td>
<td>±56</td>
<td>±25</td>
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<tr>
<td>(3 sheep)</td>
<td></td>
<td></td>
<td>65</td>
<td>8</td>
<td>720</td>
<td>420</td>
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<tr>
<td></td>
<td>69</td>
<td>4</td>
<td>760</td>
<td>500</td>
<td>75</td>
<td>89</td>
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<tr>
<td></td>
<td>72</td>
<td>0</td>
<td>640</td>
<td>440</td>
<td>77</td>
<td>92</td>
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<tr>
<td>S.E. of means</td>
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<td>680</td>
<td>490</td>
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<tr>
<td>(4 sheep)</td>
<td></td>
<td></td>
<td>72</td>
<td>0</td>
<td>±40</td>
<td>±28</td>
</tr>
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</table>
Ellis and Pfander (1958) who used semipurified diets containing from 21 to 42% cellulose. Dietary nitrogen (protein) content (1.65-2.45% N) was also shown to affect cellulose digestibility, although at the highest dietary nitrogen level, an unexplained reduction in cellulose digestibility occurred. In the experiments reported here, even when almost the whole of the energy supply was derived from cellulose (up to 86% of the dry matter apparently digested), the animals remained in positive nitrogen balance. It is suggested therefore that the synthesis of significant amounts of protein-nitrogen from urea-nitrogen must have occurred even though up to 3 g nitrogen was ingested from sources other than urea. From these results it is apparent that cellulose can be used by rumen microorganisms together with urea for the synthesis of microbial protoplasm. Throughout both experiments, the animals showed positive weight gains for most of the diets offered.

The fall in nitrogen balance which occurred as starch and sucrose were replaced with cellulose, can be largely explained by the fall in the quantity of food digested rather than by any change in its composition. Thus the poor utilization of urea supplements given with many low quality roughages may often be due to physical factors such as lignification preventing rumen microbial attack, rather than to the composition of the energy yielding substrates of the roughage, or to any shortcomings in potential fermentative ability of the existing rumen microbial population.

The findings of previous workers (Hoflund, Quin, and Clark 1948; Arias et al. 1951; Belasco 1956) suggested that maximum cellulose digestion by rumen microorganisms only occurred when some soluble carbohydrate was also supplied. There was no evidence from the experiments reported here that a depression in cellulose digestion occurred as the soluble carbohydrate (starch and sucrose) content of the diet was reduced to zero. It is possible that organic impurities in the crude cellulose used (5-15%) may have satisfied rumen microbial requirements for such nutrients. However, the levels of dietary cellulose used here were far greater than those encountered in natural diets for ruminants. Thus the increase in cellulose digestion by small supplements of soluble carbohydrate observed by the above workers but not under other situations (Campling, Freer and Balch 1962; Hemsley and Moir 1963; Faichney 1965) emphasises the complexity of the situation.

There is considerable evidence, despite conflicting reports, that ruminants can survive, grow and be productive when offered purified diets containing non-protein nitrogen as the only source of dietary nitrogen (Loosli et al. 1949; Thomas et al. 1951; Land and Virtanen 1959). It is also important to determine whether the various carbon sources in ruminant diets are completely interchangeable, i.e. is a balance between readily available energy such as soluble carbohydrate and the less readily available materials such as cellulose in fact essential to the ruminant? The data presented in this paper suggest that cellulose alone is an adequate source of carbohydrate in the nutrition of the sheep. Provided it is available for rumen microbial digestion, cellulose can serve as a suitable energy substrate, together with urea, for microbial protein synthesis and this is reflected in positive nitrogen balances in the animal.
V. ACKNOWLEDGMENTS

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VI. REFERENCES


