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MAGNESIUM ABSORPTION IN THE CÆCUM OF RATS RELATED TO VOLATILE FATTY ACIDS PRODUCTION

Y. RAYSSIGUIER and C. REMESY

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INTRODUCTION

The mode of magnesium absorption is not yet well known. Behar (1974) reported that in the rat intestine Mg appears to be transported principally by solvent drag. Opposite results concerning the relative importance of the different zones of the digestive tract have been obtained, magnesium may be absorbed either in the small intestine (Aikawa, 1959) or in the lower parts of the alimentary canal (Chutkow, 1964). The present study was to determine the role of the cæcum in magnesium digestion in rats with very different cæcal size.

MATERIALS AND METHODS

36 Sherman rats weighing 180 ± 2 g at the start of the experiment were used. They received a semi-synthetic diet containing 1.15 g/kg of Mg. The rats were divided into two groups, one receiving a control diet : per kg of feed : 200 g caseine, 650 g starch, 50 g oil, 50 g cellulose, necessary minerals and vitamins, which has already been described (Rayssiguier, Larvor and Barlet, 1973).
For the other group, 200 g of wheat starch were replaced by 200 g of raw potato starch. This second diet caused enlargement of the caecum. Starch was used rather than sugars such as lactose because the latter directly affects intestinal absorption of the alkaline earths.

From 12 rats of each group, fed ad libitum during 20 days, blood was collected in the caecal vein and the aorta after laparotomy under Nembutal (R) anaesthesia. Vessels were punctured directly using a needle (0.5 x 16 mm). The caecums were removed, weighed and immediately frozen with their contents for later analysis (Rémésy, 1973). After 11 days adaptation to the different diets, nutritional balance study was performed on 6 rats of each group given limited feed during 9 days.

The magnesium was measured by atomic absorption (Perkin Elmer 303 apparatus) and the volatile fatty acids (VFA) by gas liquid chromatography (Rémésy and Demigné, 1974. )

Results
Growth was identical in the two groups of rats (4 to 5 g/day). The rats fed on the raw potato starch diet showed increases in caecal weight (table 1). The increase in caecal VFA and decrease in pH (table 1) were evidence of increased microbial fermentation resulting from the presence of substrate in the caecum. There was also an increase in the arteriovenous difference in VFA in the caecum, but there was no difference in the respective proportions of the three main VFA either in the caecum or in the blood (tab. 2).

In these animals the magnesium concentrations in the blood of the aorta and of the caecal vein increase significantly and the arteriovenous difference of magnesium concentration widens also (table 3). Faeces weight increases. There is a better magnesium absorption which is compensated by increased urinary excretion of magnesium, so that the retention coefficient is not altered (table 4).

Discussion
Because of its special structure, raw potato starch is not attacked by rat enzymes. The presence of carbohydrate substrates in the caecum results in development of the flora (Baker et al., 1950; Masson and Palmer, 1973) which affects the production of volatile
TABLE 2
Comparison of volatile fatty acids (VFA) concentrations in the caecal contents and the caecal arteriovenous differences of rats fed the control or crude potato starch diet.

<table>
<thead>
<tr>
<th>Diet</th>
<th>Total VFA mM</th>
<th>% C₂</th>
<th>% C₃</th>
<th>% C₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control diet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Témoins</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caecal content</td>
<td>109.5 ± 5.5</td>
<td>69.5 ± 0.7</td>
<td>21.3 ± 0.4</td>
<td>9.1 ± 0.8</td>
</tr>
<tr>
<td>Caecal arteriovenous difference</td>
<td>1.19 ± 0.2</td>
<td>65.3 ± 1.5</td>
<td>25.8 ± 0.6</td>
<td>8.8 ± 1.4</td>
</tr>
<tr>
<td>Raw potato starch diet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amidon cru de pommes de terre</td>
<td>188.5 ± 12.8</td>
<td>67.7 ± 2.0</td>
<td>26.6 ± 1.9</td>
<td>5.6 ± 0.5</td>
</tr>
<tr>
<td>Caecal content</td>
<td>3.74 ± 0.5**</td>
<td>68.6 ± 2.6</td>
<td>27.0 ± 2.5</td>
<td>4.3 ± 0.6</td>
</tr>
</tbody>
</table>

Significance of the difference between control and raw potato starch: (***) P < 0.01.

TABLE 3
Influence of diet on the blood magnesium level in the aorta the caecal vein (expressed in mg of Mg/100 ml) and arteriovenous differences in plasmatic concentrations of magnesium.

<table>
<thead>
<tr>
<th>Diet</th>
<th>Aorta</th>
<th>Caecal vein</th>
<th>Δ AV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control diet</td>
<td>1.43 ± 0.02</td>
<td>1.90 ± 0.03</td>
<td>0.47 ± 0.03</td>
</tr>
<tr>
<td>Crude potato starch diet</td>
<td>1.55 ± 0.02**</td>
<td>2.27 ± 0.06**</td>
<td>0.72 ± 0.07**</td>
</tr>
</tbody>
</table>

Significance of the difference between control and raw potato starch: (***) P < 0.01.
fatty acids and the pH (Rémésy, 1973).

With the semi-synthetic diet used (control diet), the VFA concentrations were much lower than those obtained with a commercial rat diet made of cereals and seed cakes (Rémésy and Demigné, 1976), which favored caecal fermentations and was in this respect similar to the potato starch diet. However, with the potato starch diet, the percentage of butyrate was particularly low.

In ruminants, production and concentration of VFA in the rumen are related (Leng and Brett, 1966). In rats, there is, with the same diet, a good correlation between VFA caecal concentration and the VFA arteriovenous difference (Rémésy and Demigné, 1976). Then, although the rate of blood flow through the caecum wall was not known, our results were highly suggestive of an increase in the caecal production and absorption of VFA with the raw potato starch diet. When the caecal concentration of VFA increased 1.72 times, the total caecal weight increased 3.69 times and the arteriovenous difference increased 3.14 times. The non-proportionality of these figures resulted certainly of the complexity of the relations between caecal weight and caecal surface of absorption, between caecal VFA concentration and VFA rate of passage through the mucosa, with the additional effect of the reduction of pH (which increases the absorption of VFA; Aafjes, 1967; Myers, Jackson and Packett, 1967). Anyway, the increase in arteriovenous difference of VFA concentration could not be due to a decreased blood flow, because the caecal blood vessels appeared highly repleted in the raw starch group.

The same remarks are valid for caecal Mg absorption, which was clearly increased (table 3), and this is confirmed by the increase in global Mg digestibility (table 4).

An increase in caecal volume is usually accompanied by improved divalent cation digestibility, in germ free rats (Reddy, 1971) in antibiotic treated rats (Larvor, 1966) in lactose fed rats (Fournier, Susbielle and Bescol-Liversac, 1959) or in raw starch fed rats (present case).

The effect of lactose on earth-alkaline ions digestibility is, at least for a part, different from others, and do not seem to need an increase in caecum size, because it appears very early (30 minutes : Lengemann, Wasserman and Comar, 1959) and persists in

<table>
<thead>
<tr>
<th>Diet</th>
<th>Crude potato starch diet</th>
<th>Significance of the difference between control and raw potato starch</th>
<th>mg/d</th>
<th>% intake</th>
<th>Absorption mg/d</th>
<th>Urinary Mg mg/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter intake g/d</td>
<td>21.39 ± 0.30</td>
<td>2.84 ± 0.08**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude potato starch diet</td>
<td>21.39 ± 0.30</td>
<td>2.84 ± 0.08**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter intake g/d</td>
<td>20.84 ± 0.31</td>
<td>2.94 ± 0.08**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control diet (g)</td>
<td>20.84 ± 0.31</td>
<td>2.94 ± 0.08**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faecal Mg mg/d</td>
<td>15.35 ± 0.17</td>
<td>14.08 ± 0.40**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urinary Mg mg/d</td>
<td>9.60 ± 0.24</td>
<td>10.49 ± 0.33**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mg retained mg/d</td>
<td>35.85 ± 0.38</td>
<td>47.62 ± 1.31**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urinary % intake</td>
<td>6.15 ± 0.51</td>
<td>6.59 ± 0.52**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mg absorbed mg/d</td>
<td>3.88 ± 0.52</td>
<td>4.28 ± 0.62**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
caecumectomized rats (Fournier, Susbielle and Dupuis, 1960). But a reduction in intestinal pH also occurs (Robinson and Duncan, 1931), which suggests a long-term additional mechanism similar to raw starch.

What is the less clear is the part played by the microbial flora: the present data suggest a stimulation of Mg absorption in the caecum by the VFA and/or decreased pH. This is not very concordant with the data obtained with germ-free or antibiotic treated animals. An alternative hypothesis could be a selective effect of raw starch on bacterial flora, favoring VFA producing bacteria, and inhibiting some other enterobacteria detrimental to earth alkaline resorption.

In the ruminants (Tomas and Potter, 1976) it has been shown that most of the net absorption of magnesium occurs before the pylorus and it could be of some veterinary and zootechnical interest to consider the influence of VFA in this absorption.

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Summary

Rats were fed with a semi-synthetic diet with or without raw potato starch. (The level of minerals was the same in the two diets.) Because of its special structure raw potato starch was not attacked by rat enzymes. The rats fed on the raw potato starch diet showed increase in caecal weight. The increase in caecal volatile fatty acids (VFA) and decrease in pH were evidence of increased microbial fermentation from the presence of substrate in the caecum. There was also an increase in the arteriovenous difference in VFA and Mg in the caecum. Nutritional balance study was performed and confirmed the better Mg absorption in rats fed on the raw potato starch diet.

The lower parts of the digestive tract seem to play an important role in Mg absorption and further studies on the relations between caecal volume, pH, VFA, microbial activity and Mg absorption are necessary.

References

LENG R.H., BRETT D.J., 1966. Simultaneous measurements of the rates of production of acetic, propionic and butyric acids in the rumen of sheep of different diets and the correlation between production rates and concentrations of these acids in the rumen. — Br. J. Nutr., 20, 541-552.


