Metabolism of dietary fibre components in man assessed by breath hydrogen and methane

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1. Breath hydrogen and methane were measured in eight normal individuals after acute and separate administration of different chemical components of dietary fibre.
2. Hemicellulose, raffinose and lactulose increased H₂ production, while cellulose, pectin and lignin did not. Methane production was found to be individual and unaffected by any of the substances. Differences in physical properties of the same chemicals appear to have no influences on H₂ and CH₄ production.

Dietary fibre can be defined as that component of plant cell resistant to human alimentary enzyme action (Trowell, 1974). However, some studies on fibre show some hydrolysis by colonic bacteria, but, which components of fibre are hydrolysed and the extent of their breakdown in man is not clear (Williams & Olmsted, 1936). During anaerobic bacterial metabolism gaseous hydrogen (H₂) and methane (CH₄) are produced. These gases either pass in flatus or are excreted in the expired breath. Since mammalian cells do not produce H₂ and CH₄ the measurement of these gases in the breath could be used as a simple and non-invasive measure of the intestinal fermentation of dietary fibre (Newman, 1974).

In this study we were interested to see the degree of breakdown of individual chemical components of dietary fibre when given separately to fasted individuals and the response followed over a short period.

MATERIALS AND METHODS

Participants in the study were eight normal volunteers (four males and four females), 23 to 47 years of age. They had no gastrointestinal problems and were in good health.

The procedure involved fasting for 15 h from 24.00 hours to 15.00 hours the following day. Ten or 20 g of the fibre component were administered raw in 400 ml water with blackcurrant syrup as flavouring (B.P.C., Boots Co. Ltd, Nottingham). The meals were taken at about 09.00 hours. The time interval between each experiment was at least 1 week. Substances studied were the oligosaccharide raffinose (crystalline: BDH Chemicals, Poole, Dorset), the polysaccharides fibrous cellulose (Solka-Floc SW-40, Brown Corporation, New York), microcrystalline α-cellulose (FMC Corporation, Philadelphia), sodium carboxymethyl cellulose (type 7HF, Hercules Corporation, Illinois), hemicellulose (from Soley Hardwood – RLX 4121-36, Charleston Research Center, Westvaco), pectin NF 3442 high methyl and pectin LM 3466 low methyl content (Citrus Growers Incorporation, California), lignin (Indulin AT: Kraft processed pinewood, Westvaco, Charleston, South Carolina). The control pattern was established with 400 ml water containing blackcurrant juice flavouring. Additional controls were the non-absorbable artificial disaccharide lactulose 50% solution (Duphar Laboratories, Southampton) and the starches: Textrex extender G and Celca-Sec 500, both potato based (Celanesel, Charlotte, North Carolina).

End-expiratory breath samples were taken by a modified Haldane-Priestly Alveolar
Table 1. Breath hydrogen (μmol/l) from subjects given different chemical components of dietary fibre
(Mean values and standard deviations)

<table>
<thead>
<tr>
<th>Chemical 20 g</th>
<th>No. of subjects</th>
<th>Peak</th>
<th>Total (6 samples)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>sd</td>
</tr>
<tr>
<td>Control</td>
<td>8</td>
<td>0.27</td>
<td>0.14</td>
</tr>
<tr>
<td>Starch</td>
<td>7</td>
<td>0.27</td>
<td>0.32</td>
</tr>
<tr>
<td>Cellulose</td>
<td>7</td>
<td>0.36</td>
<td>0.23</td>
</tr>
<tr>
<td>Hemicellulose*</td>
<td>5</td>
<td>0.77</td>
<td>0.59</td>
</tr>
<tr>
<td>Pectin</td>
<td>6</td>
<td>0.36</td>
<td>0.23</td>
</tr>
<tr>
<td>Lignin</td>
<td>5</td>
<td>0.36</td>
<td>0.18</td>
</tr>
<tr>
<td>Raffinose*</td>
<td>6</td>
<td>2.05</td>
<td>0.77</td>
</tr>
<tr>
<td>Lactulose</td>
<td>6</td>
<td>2.18</td>
<td>1.46</td>
</tr>
</tbody>
</table>

NS, not significant.
* Ten g only in sample.

Table 2. Total breath methane (μmol/l) from subjects given different chemical components (20 g) of dietary fibre (6 samples)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Control</th>
<th>Starch</th>
<th>Cellulose</th>
<th>Hemi-cellulose*</th>
<th>Pectin</th>
<th>Lignin</th>
<th>Raffinose*</th>
<th>Lactulose</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.P.</td>
<td>11.50</td>
<td>10.96</td>
<td>13.86</td>
<td>—</td>
<td>12.73</td>
<td>10.55</td>
<td>11.50</td>
<td></td>
</tr>
<tr>
<td>A.S.</td>
<td>0.14</td>
<td>0.18</td>
<td>0.09</td>
<td>0.09</td>
<td>0.41</td>
<td>0.73</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>D.S.</td>
<td>0</td>
<td>0.09</td>
<td>0.09</td>
<td>0.50</td>
<td>—</td>
<td>0.23</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

* Ten g only administered

Results

Subjective symptoms. Some subjects experienced abdominal distension and variable amounts of gaseousness, particularly with lactulose, raffinose and hemicellulose in that order. One participant had diarrhoea with lactulose.

Transit time. The average time for the breath H₂ to increase after lactulose was 1.5–2 h.

Breath H₂. As shown in Table 1 the base line control values are peak 0.27 ± 0.14 μmol (0.14–0.46 μmol/l) and total 1.00 ± 0.73 μmol (0.23–1.91 μmol/l). Starch, cellulose, pectin and lignin did not significantly alter the excretion pattern. Hemicellulose (10 g) produced a peak excretion of 0.77 ± 0.59 μmol (0.14–1.36 μmol/l) and a total 1.82 ± 1.32 μmol/l (0.18–3.59 μmol/l). Raffinose (10 g) and lactulose (20 g) considerably increased gas production, with the breath H₂ reaching values of 2.27 μmol/l and over for the peak and 3.18–16.36 μmol/l total.

Breath CH₄. Base line measurements showed that of the eight participants, three excreted more than 0.91 μmol/l, two excreted about 0.46 μmol/l and three did not excrete any. Table 2 summarizes the total CH₄ excretion following the administration of the different
substances for a representative of each of the three groups. There was no appreciable change in excretion for any of the substances.

Differences of physical and chemical Properties. The ingestion of polysaccharides with different physical properties (i.e. particle size) and some chemical changes of the following substances, cellulose [AV-101 (50); AV-102 (100); SW-40 (140); Na.COOH-Me]; pectin [LM-1466 (low ester); NF-3442 (high ester)]; starch [C-S 500 (fine); T-EG (coarse)], did not make significant changes in the expired H₂ and CH₄.

DISCUSSION

Anaerobic bacterial breakdown of dietary fibre components produce the gases H₂ and CH₄ as some of the final products of their metabolism (Gray & Gest, 1965; Calloway, Colasito & Mathew, 1966). Our acute study indicates that few of the different components of dietary fibre when ingested on a single occasion result in the production of H₂ and CH₄. This might imply that the substances are not being metabolized. Alternatively they could have been metabolized along other pathways, for example partially degraded to volatile fatty acids and other short chain products (Williams & Olmsted, 1936; Cummings, 1973).

Starch did not produce H₂ and CH₄, presumably because of hydrolysis by α-amylase in the upper part of the small intestine. Lignin is resistant to hydrolysis by colonic bacteria (Cummings, 1973; Southgate, Branch, Hill, Drasar, Walters, Davies & Baird, 1976). It was expected that pectin, which is reputed to be extensively hydrolysed, would result in an increased H₂ and CH₄ production (Werch & Ivy, 1941; Cummings, 1976). This did not happen and this may be due to hydrolysis along paths not leading to H₂ production. Modest production of H₂ by hemicellulose may be due to the comparatively small amount used (10 g) yet the gas production is not comparable to 10 g raffinose.

The mouth to caecum transit time may be a variable both between individuals and chemicals. Neither of these seem to apply as the lactulose transit time was comparable in all subjects (1.5-2 h) and prolonged following of the breath gases for 10 to 12 h rendered no delayed increase.

The CH₄ excretion pattern remained individual as has been previously observed (Calloway & Murphy, 1969; Bond, Engel & Levitt, 1970). But what is difficult to explain is the lack of increased production by CH₄ excretors, who presumably have the appropriate bacteria, when provided with the correct substrate.

The physical nature of the substances may be a factor affecting bacterial hydrolysis. We looked into this in our study particularly with cellulose and pectin. Differences in physical property (i.e. particle size) and some chemical change appear to make no appreciable change in the H₂ excretion pattern. This also applies to CH₄ excretion.

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REFERENCES