

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 H_2 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 H_2 and CH_4 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 (H_2) and methane (CH_4) are produced. These gases either pass in flatus or are excreted in the expired breath. Since mammalian cells do not produce H_2 and CH_4 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 (Celanese, Charlotte, North Carolina).

End-expiratory breath samples were taken by a modified Haldane-Priestly Alveolar

Table 1. *Breath hydrogen ($\mu\text{mol/l}$) from subjects given different chemical components of dietary fibre*

Chemical 20 g	No. of subjects	Peak		Total (6 samples)		
		Mean	SD	Mean	SD	
Control	8	0.27	0.14	1.00	0.73	
Starch	7	0.27	0.32	0.86	1.14	NS
Cellulose	7	0.36	0.23	1.09	1.09	NS
Hemicellulose*	5	0.77	0.59	1.82	1.32	$P < 0.05$
Pectin	6	0.36	0.23	1.18	1.09	NS
Lignin	5	0.36	0.18	0.91	0.59	NS
Raffinose*	6	2.05	0.77	5.64	2.09	$P < 0.01$
Lactulose	6	2.18	1.46	7.64	4.68	$P < 0.005$

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

Table 2. *Total breath methane ($\mu\text{mol/l}$) from subjects given different chemical components (20 g) of dietary fibre (6 samples)*

Subject	Control	Starch	Cellulose	Hemi-cellulose*	Pectin	Lignin	Raffinose*	Lactulose
G.P.	11.50	10.96	13.86	—	—	12.73	10.55	11.50
A.S.	1.14	0.18	0.09	2.18	0.41	—	0.73	0
D.S.	0	0.09	0.09	0.50	—	0	0.23	0

* Ten g only administered

sampling method (Metz, Gassul, Leeds, Blendis & Jenkins, 1976), at hourly intervals over the test period. H_2 and CH_4 in the breath samples were measured by gas chromatography (Pye Series 104) using molecular sieve packed glass columns and a katharometer. Carrier gas was nitrogen (oxygen free) at flow rate of 65 ml/min; oven temperature, 50° ; detector temperature, 100° ; bridge current, 140 mA; sensitivity for 1 $\mu\text{mol/l}$ of H_2 and 1 $\mu\text{mol/l}$ CH_4 , 10% of full scale deflection of recorder; analytical reproducibility, coefficient of variation less than 3%, n 20.

Measurements used for comparison were the peak H_2 and CH_4 (maximal value recorded) and the total H_2 and CH_4 (summation of all values recorded), and expressed in $\mu\text{mol/l}$.

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 H_2 to increase after lactulose was 1.5–2 h.

Breath H_2 . As shown in Table 1 the base line control values are peak 0.27 ± 0.14 μmol (0.14 – 0.46 $\mu\text{mol/l}$) and total 1.00 ± 0.73 μmol (0.23 – 1.91 $\mu\text{mol/l}$). 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 $\mu\text{mol/l}$) and a total 1.82 ± 1.32 $\mu\text{mol/l}$ (0.18 – 3.59 $\mu\text{mol/l}$). Raffinose (10 g) and lactulose (20 g) considerably increased gas production, with the breath H_2 reaching values of 2.27 $\mu\text{mol/l}$ and over for the peak and 3.18–16.36 $\mu\text{mol/l}$ total.

Breath CH_4 . Base line measurements showed that of the eight participants, three excreted more than 0.91 $\mu\text{mol/l}$, two excreted about 0.46 $\mu\text{mol/l}$ and three did not excrete any. Table 2 summarizes the total CH_4 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-3466 (low ester); NF-3442 (high ester)]; starch [C-S 500 (fine); T-EG (coarse)], did not make significant changes in the expired H_2 and CH_4 .

DISCUSSION

Anaerobic bacterial breakdown of dietary fibre components produce the gases H_2 and CH_4 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 H_2 and CH_4 . 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 H_2 and CH_4 , 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 H_2 and CH_4 production (Werch & Ivy, 1941; Cummings, 1976). This did not happen and this may be due to hydrolysis along paths not leading to H_2 production. Modest production of H_2 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 CH_4 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 CH_4 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 H_2 excretion pattern. This also applies to CH_4 excretion.

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