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Influence of diet on flatus volume in human subjects

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SUMMARY Ten flatulent but otherwise healthy subjects were studied while consuming two or three different diets. Flatus collections showed that a bean-containing, high crude-fibre diet produced more flatus (mean 49·4 ml/hr) than either a diet with a restricted crude-fibre content (mean 26·7 ml/hr) or a liquid chemically defined diet (mean 10·9 ml/hr). There was a close correlation between the crude-fibre content of the diet and the production of flatus. The results are consistent with the conclusion that flatus is not the result of swallowing air, but arises mainly from bacterial fermentation of indigestible carbohydrate, eg, cellulose, passing into the colon.

Since the time of Hippocrates, clinicians have been interested in the effect of diet on flatulence. Fries (1906) was the first to measure flatus volume in man, when, in a single experiment, he noted the production of about 1 litre of flatus daily. Previous investigations into the effect of diet on the volume of flatus have shown highly divergent results.

Askevold (1956), using a rectal catheter, performed 286 flatus collections on three schizophrenic women while they were taking several diets with varying amounts of fibre, fat, carbohydrate, and protein. He was unable to demonstrate any significant effect of diet on flatus volume in these subjects.

On the other hand, Steggerda and Dimmick (1966) investigated the effect of beans on production of flatus by maintaining five healthy male subjects for seven days on five different diets containing increasing quantities of beans. Using only a two-hour postprandial collection period on the fourth and seventh day of each dietary period, they showed a marked increase in flatus which was proportional to the amount of beans in the diet.

Blair, Dern, and Bates (1947) showed a 50% increase in flatus when their subjects consumed either a high carbohydrate diet or one containing 4% soy protein. Kirk (1949) was more interested in the fibre content of the diet. He investigated 12 normal subjects who consumed either a cabbage-free diet or one containing 600 g of brussel sprouts. The inclusion of the brussel sprouts increased flatus volume by 44%.

It is the purpose of this communication to report the effect of three carefully chosen diets on volumes of flatus of flatulent subjects using prolonged and repeated collections, and briefly to consider the mechanisms involved in producing flatus in these subjects.

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Materials and Methods

Ten subjects were studied, six women and four men. Ages ranged from 25 to 65 years. All subjects were troubled by excessive flatus, and all had been thoroughly investigated at the gastroenterological outpatients' clinic; no evidence had been found of organic disease. The nature of the study was explained to the patients who all willingly consented to these investigations.

The composition of the three diets is given in Table I. Each diet contained approximately 1,800 calories. Diet A was a high carbohydrate, liquid chemically defined diet (Vivasorb). Diet B had a restricted quantity of carbohydrate and a low crude fibre content. Diet C had a high crude fibre content and contained 20% by weight of a proprietary brand of baked beans. The beans accounted for 35% of the carbohydrate and 57% of the crude fibre content of this diet. Each diet was weighed and issued by a dietician, and the allocation order of the diets was

Diet	*Carbohydrate (g)*	*Fat (g)*	*Protein (g)*	*Crude Fibre (g)*	*Calories*
A	406·8	1·33	38	0	1,800
B	100	108	87	2·4	1,751
C	148	108	64	9·4	1,810

Table I *Composition (per day) of the diets* varied. Three meals daily were served at 900 am, 1230 pm, and 500 pm.

Immediately after breakfast each subject was requested to defaecate. Laxatives, purgatives, or enemas were not used because of their effects on colonic motility. After defaecation a rectal catheter was inserted 9 cm beyond the anus for flatus collection. Before the present study a pilot trial was conducted to test techniques for collecting flatus. The most suitable rectal catheter was the St. Bartholomew's barium enema catheter which has an inflatable balloon and three large perforations near its tip. Flatus was collected by the displacement of water in an inverted gas jar according to the method of Alstead and Patterson (1948). The collection period was six hours. In view of the known effects of somatic activity on propulsion (mass movements) in the human colon (Holdstock, Misiewicz, Smith, and Rowlands, 1970) the amount of physical activity during the collection period was standardized by the performance of a set of exercises at hourly intervals.

There were 13 satisfactory collections from the first five subjects while taking diets B and C. Subjects 6-10 were studied over a three-week period while being maintained on each of the three diets for seven consecutive days. There were 43 satisfactory collections over this period. Out of a total of 68 collections, 12 were unsatisfactory because of faeces blocking the catheter, but blockage was usually not a problem provided that the rectum was completely evacuated at the time of defaecation.

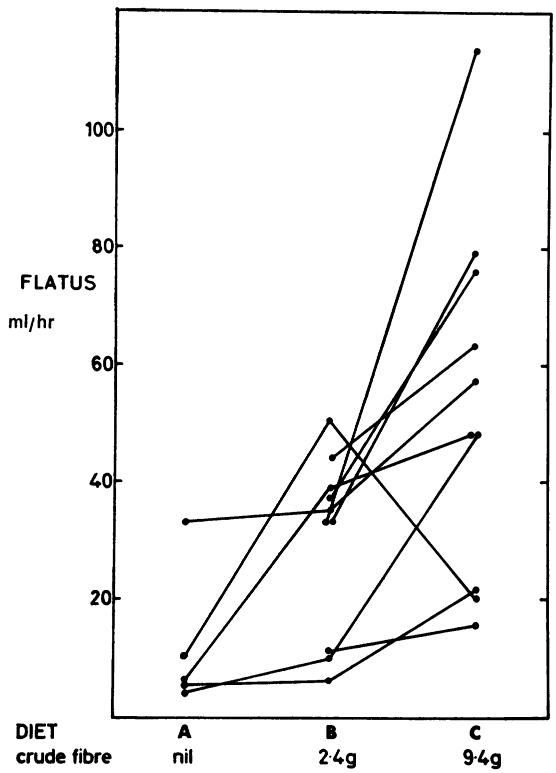

Fig. 1 *Changes in mean flatus volumes for each subject*

Results

The results are summarized in Table II. The average flatus volumes on the three diets were: 10·9 ml/hr on diet A (Vivasorb); 26·7 ml/hr on diet B (restricted carbohydrate and crude fibre); 49·4 ml/hr on diet C (bean-containing, high crude fibre diet). Standard deviations were not recorded because the results from diet A took the form of a log normal distribution. When the means for each subject were compared according to the t test, there was a highly significant increase in the volume of flatus for subjects taking diet C compared with the same subjects taking diet A ($P < 0·01$) or diet B ($P < 0·05$). In the more prolonged studies with subjects 6-10 there was on average a 221% increase in flatus

Subject	*Sex*	*Age*	*Diet A*			*Diet B*			*Diet C*		
			Mean	*n*	*Range*	*Mean*	*n*	*Range*	*Mean*	*n*	*Range*
1	M	25				33	1		79	1	
2	F	39				33	1		114	1	
3	F	53				44	2	29-58	63	2	52-73
4	M	30				11	2	1-21	15	1	
5	F	45				38	1		77	1	
6	F	55	33	3	17-48	35	2	34-35	57	5	34-83
7	M	65	10	2	2-17	48	2	38-57	20	1	
8	F	34	5	3	2- 9	6	5	3-12	21	4	7-30
9	M	57	6	5	2-13	39	3	28-49	48	3	22-69
10	F	29	4	3	2- 6	10	1		48	1	

Table II *Results of flatus collections in 10 subjects*[1]

[1]Flatus volumes in ml/hr.
n = number of satisfactory collections.

production on changing from diet A to diet B. This with a paired t test just failed to reach significance ($p < 0.01$). Only subject no. 7 had a decrease in flatus while taking diet C: for technical reasons only one satisfactory collection was obtained from this subject while taking the bean diet.

The changes in the mean flatus volumes for each subject are plotted graphically in Figure 1. It is apparent that there is a close correlation between increasing the crude fibre content of the diet and enhanced production of flatus.

Discussion

VARIABILITY OF FLATUS VOLUME

There are two important factors which help to explain much of the controversy in the earlier literature. As can be seen from Table II, there is a considerable day-to-day variation in flatus production in subjects taking the same diet. Repeated collections are therefore necessary. The second problem lies in the technique of collecting flatus. Blockage of the catheter is likely if faeces are retained in the rectum after defaecation. Likewise, subjects with diarrhoea cannot be studied. Many of the earlier reports clearly failed to consider these problems sufficiently.

CARBOHYDRATE DIGESTIBILITY AND FLATUS

The results reported here suggest that the type of carbohydrate in the diet is an important factor in flatus production. Murphy (1964) also found low flatus volumes in subjects fed a chemically defined (astronaut's) diet. If gas production was largely the result of fermentation of undigested carbohydrate, it would be anticipated that subjects fed Vivasorb would have low flatus volumes, since this diet is well absorbed in the proximal small intestine where Drasar, Shiner, and McLeod (1969) have shown only small numbers of bacteria to be present normally. Furthermore, Winitz, Adams, Seedman, Davis, Jayko, and Hamilton (1970) found that the provision of a glucose-based chemically defined diet as the sole means of nutritional support to four healthy subjects was accompanied by a marked reduction in faecal microflora.

Steggerda (1968) found that the gas-forming components of soy bean included the indigestible oligosaccharides of the stachyose and raffinose type, and furthermore he showed that gas production by the anaerobic bacterial fermentation of soy bean homogenates could be markedly inhibited by antibiotics and bacteriostatic agents. It is of further interest that a trypsin inhibitor has been identified in soy bean (Finkenstadt and Laskowski, 1965).

SWALLOWED AIR AND FLATUS

It is currently believed that about 70% of alimentary gas is swallowed air (Alvarez, 1942; Andersen and Ringsted, 1943; Saltzman and Sieker, 1968). Wangensteen and Rea (1939) showed that swallowed air was the most important factor in producing abdominal distension in dogs with mechanical intestinal obstruction. Maddock, Bell, and Tremaine (1949) showed that when nervous subjects were subjected to unpleasant investigations such as pyelography, they could swallow large volumes of air which was sometimes passed as flatus within 30 minutes. However, it seems unlikely that the fourfold increase in flatus production in the present study can be explained solely on the basis of air swallowing, especially in view of Hood's finding that adults swallow more air with liquids than with solids (Hood, 1966). Furthermore, the composition of flatus collected after a bean meal argues against air swallowing as the causative factor. Steggerda and Dimmick (1966) found low concentrations of nitrogen (19-37·7%) and high concentrations of gases produced by fermentation, such as carbon dioxide (23·1-51·4%), methane (13·9-22·4%), and hydrogen (8-27%).

PRODUCTION OF FLATUS IN THE COLON

Levitt and Ingelfinger (1968) used a constant infusion technique to obtain quantitative data on hydrogen and methane production in healthy man. They found that hydrogen was produced in all subjects, was mainly confined to the large intestine, and was almost completely dependent upon ingested fermentable substances. Calloway (1966) showed that the peak breath hydrogen concentration occurred about five or six hours after a bean meal, ie, at a time when food residues reach the lower ileum and upper colon where bacteria are abundant.

FERMENTATION OF CRUDE FIBRE

Enteric microflora are capable of fermenting urea and most of the organic substances present in foods but not lignin (Calloway, Colasito, and Matthews, 1966). Earlier workers (Williams and Olmsted, 1936; Humel, Shepherd, and Macy, 1943) have shown the disappearance of cellulose during its passage through the gut of man. In a recent careful study over a nine-day period on a single subject, only 42·5% of ingested cellulose was recovered in the faeces, using copper thiocyanate as a marker (Milton-Thompson, 1971). Although the enzyme cellulase has not been demonstrated in the gastrointestinal mucosa or pancreatic secretions of man, Mangold (1934) showed that the gases produced by faecal bacterial fermentation of cellulose in human subjects included carbon dioxide, methane, and hydrogen. More recently, Milton-Thompson (1971) has recovered $^{14}CO_2$ from the breath of several subjects fed ^{14}C-labelled cellulose. Finally, Goldstein, Karacadag, Wirts, and Kowlessar (1970) have shown in men that coliform bacteria are able to utilize the hemicellulose, D-xylose, for their own metabolism.

It is concluded, therefore, that the most important factor in the production of flatus is the fermentation of undigested food residues by colonic microflora.

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