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Super-Efficient Starch Absorption
A Risk Factor for Colonic Neoplasia?

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We tested the hypothesis that super-efficient starch absorption, by reducing the supply of carbohydrate to the colon, may be associated with and possibly promote colonic neoplasia. By means of breath hydrogen measurements following a potato meal and comparison with the hydrogen response to lactulose, the amount of starch escaping small bowel absorption was measured in 10 patients who had a colonic adenoma removed endoscopically and in 10 controls. The subjects' consumption of starch and fiber was assessed. Percentage unabsorbed starch was approximately half as much in the patients (5.3%) compared with the controls (10.9%, $P < 0.05$). Consumption of starch and dietary fiber, and mouth-to-cecum transit times were not significantly different. Unabsorbed starch was calculated to contribute to 6.0 g/day colonic carbohydrate in the patients and 10.9 g/day in the controls ($P < 0.05$). This study confirms that unabsorbed starch provides an important quantity of colonic carbohydrate and suggests that super-efficient starch absorption, by reducing this provision, may promote colonic neoplasia.

KEY WORDS: starch absorption; fiber; colorectal neoplasia.

For many years, it was assumed that, in the absence of malabsorption of sugars such as lactose, fiber was the sole dietary source of carbohydrate entering the colon. However, recent studies have shown that starch is not completely absorbed by the small intestine (1, 2). Unabsorbed starch entering the colon may behave in a manner similar to many types of dietary fiber. For example, both starch (3) and to a lesser extent, fiber (4) are degraded by the colonic bacteria to short-chain fatty acids.

The degree of starch malabsorption varies with different food sources (1, 5). Furthermore, in subjects consuming a standardized meal, a recent study found marked variation in starch malabsorption between individuals, with between 2% and 20% of the starch eaten escaping absorption in the small intestine (2). In view of this finding, and since dietary fiber may exert a protective effect against the development of colorectal cancer (6–8), we hypothesized that people who absorb starch particularly well, such that little reaches their colon, may be at greater risk of colonic neoplasia. We have called this better-than-average starch absorption "super-efficient." We recognize that starch absorption may well have a continuous "normal" distribution of values and the term "super-efficient" is not meant to imply the existence of a separate group, but rather describe those individuals with a level of starch absorption towards the upper end of this range.

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MATERIALS AND METHODS

Ten patients who had had either one or two colonic adenomas removed endoscopically were studied. Nine had only a single polyp, six being found in the sigmoid, two in the descending, and one in the ascending colon. The remaining patient had two polyps, both in the sigmoid colon. All the polyps were retrieved and were less than 2 cm in size. All were tubular or villous adenomas and free from malignant transformation on histological examination. The patients were compared with 10 controls individually matched for sex (six men, four women) and age (mean age of both groups: 62 years). None of the subjects had had gastrointestinal surgery, none was taking any regular medication, and none had taken antibiotics within the previous three months. No subject gave a history to suggest lactose malabsorption. To reduce the possibility that any of the control subjects had an asymptomatic neoplasm, all provided three fecal specimens which were found to be negative for occult blood. In order to allow a reasonable interval for the return of their usual colonic bacterial activity, the patients were studied a median of four months (range: 3–7) after diagnostic large bowel investigation. All subjects were in good health when studied, and all abstained from alcohol for at least 24 hr before each study day.

The subjects were studied after a 14-hr fast, preceded by a carbohydrate-free evening meal. On two separate days one to two weeks apart, they consumed, in random order, either 6.5 g of the nonabsorbable disaccharide lactulose or a carefully standardized meal of potatoes. The potatoes were peeled, cut to an approximately equal size and boiled for 30 min. This meal provided 60 g starch, 3.3 g fiber, 1.3 g sugars, 4.6 g protein, and 0.3 g fat. The lactulose was diluted in 200 ml water, and the same quantity of water was drunk with the potato meal. The subjects were required to consume the potato meal or the lactulose over 10–15 min, to remain largely sedentary, and they were not allowed to smoke during the test (9). The protocol of this study received local ethical committee approval.

One of the products of bacterial fermentation of carbohydrate entering the colon is hydrogen. Respiratory hydrogen is derived almost entirely from colonic bacterial action (10). Using a modified Haldane-Priestley tube, end-expiratory samples of breath were collected and hydrogen measured by means of a Key-Med monitor at 15-min intervals. The amount of hydrogen produced from carbohydate in the colon is linearly proportional to the amount of carbohydrate substrate (11, 12). Since it also varies considerably with different colonic flora (11), the lactulose was used to provide a measure of each individual's colonic bacterial capacity to produce hydrogen. Mouth-to-cecum transit time of the head of the potato meal or lactulose was taken as the first sustained rise in breath hydrogen of five or more parts per million (13). Measurements were continued until hydrogen generation by the potato meal or lactulose was complete. A period of 8–13 hr of measurement was necessary for breath hydrogen to return to its fasting baseline value. The quantity of potato starch entering the colon was calculated for each subject by relating the integrated area under the curve

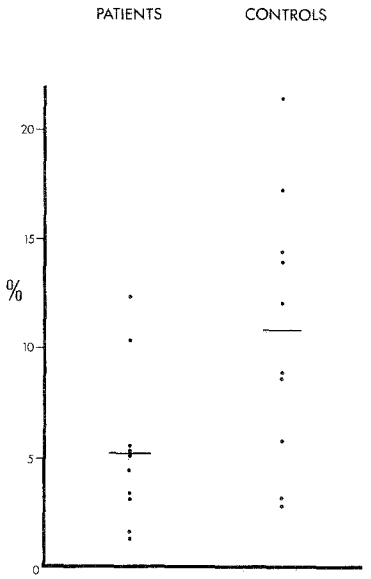

Fig 1. Percentage unabsorbed starch in 10 colonic adenoma patients and 10 controls.

minus the baseline value of hydrogen production by the potato meal and by the lactulose (12). Since fermentation of the small amount of fiber in the potatoes would add to the hydrogen production (14), and assuming 60% breakdown of this fiber, a deduction of 2 g was made from each calculated value as an approximate correction for this contribution.

The subjects completed dietary records on two weekdays, a Saturday, and a Sunday when their diet was typical of their usual eating habits. None of the patients had been instructed to eat a high-fiber diet or had changed their diet following the diagnosis of their colonic adenoma. From these records, using a computer program of standard food tables (15), one dietitian calculated each subject's intakes of starch and fiber.

The statistical significance of differences was calculated by either the Mann-Whitney U test (unabsorbed starch) or Student's paired T test (transit times and dietary intakes).

RESULTS

Less than half as much starch escaped into the colons of the patients (mean 5.3 ± SEM 1.1%) compared with the controls (10.9 ± 1.9%, $P < 0.05$, Figure 1). The range of values of our subjects of 2–22% is closely comparable to that previously reported by Stephen et al (2) of 2–20%. The chosen dose of lactulose of 6.5 g seems appropriate for the study, being in between the mean values of the patient and control groups. Fasting breath hydrogen in all the subjects was less than ten parts per million, which is considerably below values that we

TABLE 1. SUBJECTS' MEAN ± SEM INTAKES OF STARCH AND FIBER (G/DAY)

	Patients	*Controls*
Starch	112 ± 10	103 ± 15
Fiber	14.3 ± 1.7	14.6 ± 2.0

or others have found in patients with small bowel bacterial overgrowth (16).

Mouth-to-cecum transit time was not significantly different between the two groups for either the potato meal (patients: 301 ± 37 min, controls: 287 ± 34 min) or the lactulose (patients: 125 ± 11 min, controls: 121 ± 12 min). Transit time and percentage unabsorbed starch were not significantly correlated in either group or in the total 20 subjects.

There were no significant differences in the dietary intakes of starch and fiber between the patients and controls (Table 1). In both groups, potato and wheat products were the source of more than 90% of the starch eaten. Since the propensity for starch malabsorption is similar for these two foods (1, 5), the measured values for unabsorbed potato starch should provide a good approximation in these subjects of the unabsorbed starch from all food sources. As the subjects' daily intakes of starch were assessed, values for the amounts of starch escaping small bowel absorption can be calculated. On this basis, a mean of 6.0 ± 1.4 g of starch would pass each day into the colons of the patients, compared with a mean of 10.9 ± 1.9 g in the controls ($P < 0.05$). Comparing these values with the subjects' dietary fiber consumption, unabsorbed starch provided additional colonic carbohydrate of 42% in the patients and 75% in the controls.

DISCUSSION

This study shows that in patients who develop colonic adenomas, less starch from a potato meal reaches their colon than in controls. It also confirms the recent finding of a considerable variation between individuals in starch malabsorption (2).

The factors underlying this difference in starch absorption in the two groups are unclear. Mouth-to-cecum transit times were similar, both for unabsorbed potato starch and for lactulose. Since this measurement encompasses both gastric and small bowel transit, it is uncertain whether the time the potatoes were present in the small bowel was an important determinant of starch absorption. However, a recent study has shown that even a considerable prolongation of the time a meal resided in the jejunum was associated with only a small increase in carbohydrate absorption (17). Thus, it seems probable that differences in small bowel transit time are not the only reason for the variability of starch absorption between individuals.

Physical form may be important in determining differences in the absorbability of starch (18). It was decided, therefore, to use a complete starch-containing food rather than isolated starch. The potato meal was chosen in view of its high starch and low fiber content and because potatoes are an important dietary source of starch.

Approximately 6 g of unabsorbed starch were calculated to enter the patients' colons each day, compared with nearly 11 g in the controls. Since fiber intakes were almost identical in the two groups, the difference of about 5 g unabsorbed starch daily appears to be the only difference between the amounts of dietary carbohydrate reaching the colons of the patients and controls. Is this quantity of carbohydrate sufficient to exert some protective effect against colonic neoplasia? A study of diet and colorectal cancer in two populations found that a difference in consumption of 13.7 g fiber daily was associated with a fourfold difference in the incidence of large bowel cancer (8). The manner of the protective action of dietary fiber is uncertain. One proposed mechanism is that fiber, following its degradation to short-chain fatty acids by the colonic bacteria, lowers pH, which in turn reduces carcinogen formation in the colonic lumen (19, 20). If this is the case, then since starch is degraded more completely in the colon than most types of fiber (3, 4), starch entering the large bowel may lower colonic pH and thereby inhibit carcinogenesis more than the same amount of many forms of fiber.

We would have liked to have studied patients with colorectal carcinoma. However, the bowel preparation necessary for the barium enema or colonoscopy needed to detect the cancer greatly changes colonic bacterial activity and breath hydrogen response to carbohydrate (21). Experience with antibiotics suggests that the metabolism of colonic bacteria may take as long as three months to return to its usual state (22) and during this time patients with a carcinoma would have had surgery. We chose, therefore, to study patients with colonic adenomas, as these lesions are potentially premalignant (23).

We also faced a choice of controls between

healthy people in whom a symptomless colonic adenoma had not been excluded and patients whose large bowel had been proven to be structurally normal, but who probably possessed a condition, such as constipation or irritable bowel syndrome, characterized by abnormal intestinal function. We chose the former controls. In the control subjects' age group, colonic adenomas are found in 20% of women and 34% of men (24). We did not feel it would be ethical to ask the control subjects to undergo invasive large bowel investigation. However, all the control subjects were shown to have three negative fecal occult blood tests, making the possibility that any of them had an asymptomatic neoplasm less likely. Moreover, our findings would suggest that any contamination of the control group would tend to diminish rather than increase the significant difference between the two groups.

Our findings confirm that unabsorbed starch provides an important quantity of colonic carbohydrate and thus a diet rich in starch-containing foods may have some protective effect against colorectal cancer. In populations consuming a relatively low-fiber diet, super-efficient starch absorption, by reducing the provision of carbohydrate to the colon, may promote colonic neoplasia.

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