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Better Nutrition Better Life

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The influence of dietary fiber on intestinal absorption and diarrhea

VI Mathan, MD, PhD

ABSTRACT Dietary fiber is of considerable interest apart from its probable role in the epidemiology of diseases like carcinoma of the large bowel, diverticulosis and ischemic vascular disease. Information regarding the nature and extent of dietary fiber consumption by populations in tropical developing countries is limited. The possible role of dietary fiber in influencing intestinal absorption, morphology, motility, diarrheal diseases and bacterial flora are discussed. Lacunae in available knowledge are pointed out and possible experimental approaches to answer some of these questions are discussed.

Introduction

The hypothesis that diseases like carcinoma of the colon, diverticulosis and diverticulitis, ischemic vascular disease and diabetes mellitus which have a high prevalence in developed industrial societies may be related to rapid alteration in the character of the diet with introduction of diets of high nutrient density, fat content and low carbohydrate content from vegetable sources, has stimulated considerable interest in research on elements of diet which cannot be digested by the enzymes of the human gastrointestinal tract. This has led to the fiber hypothesis that food residues which cannot be digested by the normal digestive processes of the gastrointestinal tract possibly protect against the above mentioned diseases (1-3). These indigestible residues have been termed dietary fiber but considerable controversy still exists on the precise definition of what dietary fiber is and its chemical characterization and estimation (4). The innumerable methods that are available for the analysis of dietary fiber and the conflicting results produced by the different methods of analysis only highlights the problems of definition in this field, which is essential before detailed investigations can produce meaningful results (5). It is not yet established that vegetarianism is synonymous with a high dietary fiber intake (6). The possible mechanisms of action of dietary fiber are also relatively not understood (7). The lack of precise data on the prevalence of various diseases and the dietary fiber content of the diets of most populations in tropical developing countries has made it difficult to assess the validity of the claims of the beneficial effects of dietary fiber.

Dietary fiber consumption in tropical developing countries.

Most published data on dietary fiber content of food materials is from developed countries and many of the common articles of diet in tropical developing countries have not yet been assayed. The commonly used

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Dietary fiber and intestinal absorption

Data for articles of food in India is based on crude fiber analysis and grossly under-estimates the total content of unavailable carbohydrates. Furthermore, the introduction of newer varieties of staple cereals has introduced what are essentially different cereals to the population. Analysis of the neutral detergent fiber (NDF) (8) content of different varieties of rice in South India in our laboratory, has shown considerable variations between strains which are influenced by different forms of milling also. For meaningful studies of the influence of dietary fiber in populations of tropical developing countries, it is essential that dietary fiber analysis by an accepted standard methodology should be carried out in different regions.

At present it is only possible to extrapolate available data and estimate that the populations on a predominantly vegetarian, high cereal diet, have a high dietary fiber consumption. A recent survey of four different areas in Southern India using the Southgate values (9) showed dietary fiber consumptions from a low of 20 g per day to a high of 42 g per day in different regions (10). Our own analysis showed that the average villager near Vellore consumes between 30 and 40 g of NDF per day.

Intestinal absorption

Optimal absorption of consumed nutrients is essential for the maintenance of metabolic homeostasis and any factor that interferes with absorption in tropical developing countries where people are subsisting on marginally deficient dietary intake would assume considerable public health and economic significance. It has been shown in healthy volunteers in UK that increasing the fiber content of the diet could reduce the absorption of nutrient energy significantly (11). Is this a factor that is acting as a major constraint to improve nutrition in the predominantly vegetarian populations of developing countries? In Southern India, we found that the absorption of nutrient energy is about 90% of the intake and that the mean fecal calorie excretion in apparently healthy people was about 250 kcal per day. This is considerably higher than the reported values of fecal calories around 100 kcal with typical western diets. It is important to determine whether this reduced efficiency of nutrient energy absorption with high fecal calorie excretion is a significant factor in the maintenance of nutritional homeostasis in rural populations in tropical developing countries. It is also important to determine whether this is primarily due to the dietary fiber content or whether there are other factors such as tropical enteropathy (12) which are responsible.

There is considerable interest on the effect of dietary fiber on glucose absorption and the use of high fiber high carbohydrate diets for the therapy of diabetes (13-15). A careful review of available literature shows conflicting results. Under experimental conditions pure cellulose does not seem to influence the blood glucose or insulin response to a test meal while pectins and gums reduce glycemia. It is also not clear whether the reduction in blood glucose after an oral feed with additional dietary fiber is related to impaired absorption, alterations in the site of absorption to the distal parts of the small intestine or due to other factors such as the response of the enteric peptide hormones to the presence of fiber in the lumen of the diet. Inhibition of pancreatic enzymes by purified constituents of dietary fiber has been demonstrated in vitro (16,17). The problem with most of the studies that have been done is that since the exact chemical nature of all dietary fiber in any diet is not known, purified constituents of fiber such as cellulose, pectin or guar gum have been used. It is difficult to extrapolate the results of the addition of pure fiber to glucose or test meals to unabsorbed material relatively high to types of fiber in different countries to the question of fiber on gut physiology.

Since it can bind on the lipids on the serum lipids have been checked. The same effect is the same when used in developing countries (22-24).

Increased demonstrator has been found on the effect of glucose levels. If 3.5 g per day is greater than that of 2.5 g per day, the contri-ble fiber in the stool is likely to in the stool bacterial mi
meals to the clinical situation where people are consuming a mixed diet with a variety of unabsorbable constituents present. Short term metabolic experiments in which there is relatively acute alteration in the diet are unlikely to reflect the effects of adaptation to types of diets which have been consumed for very long periods, over generations. It is probably necessary to design experiments in different population groups using standardized methodology as part of a multi-country collaborative study to find an answer to the question of the influence of dietary fiber on glucose absorption.

Since it has been shown that dietary fiber can bind sterols and bile salts, an influence on the lipid constituents of the diet and the serum lipids is not surprising (18,21). This has been dealt with elsewhere in this workshop. The question of fiber binding trace metals and vitamins and making them unavailable to supply nutrient needs has exercised considerable interest since augmentation of the dietary fiber intake by people in developing countries has been recommended. There is as yet no good evidence that significant malnutrition of trace metals and vitamins can be produced by dietary fiber and again experimental results in animals and humans has given conflicting reports (22-24).

Increased fecal loss of nitrogen has been demonstrated when the dietary fiber intake has been increased (25,26) and we have found that the average fecal nitrogen of healthy people in Southern India is around 3.5 g per day, a figure considerably higher than that reported from western sources. The contributions of endogenous nitrogen and dietary nitrogen to fecal nitrogen losses have not been resolved. With increased fiber in the diet, the fecal bacterial mass is likely to increase and most of the nitrogen in the stool is probably incorporated in the bacterial mass (27). Nutritional significance of this is not clear but it is possible to design experiments to see whether alterations in the diet could increase nitrogen retention and improve the nitrogen balance in populations in tropical developing countries.

Intestinal morphology

The wide prevalence of a small intestinal mucosal morphological abnormality in populations in many tropical developing countries has been documented (12). This mucosal abnormality associated with mild malabsorption has been designated as nonspecific tropical enteropathy and is considered an adaptation to the contaminated environments of the tropics (28). There is experimental evidence to suggest that the consumption of purified fiber fractions particularly pectin and lignin can produce major morphological abnormalities in the small and large intestine of experimental animals (29-32). It is interesting to speculate that dietary fiber may be a major factor in the pathogenesis of tropical enteropathy. The contribution of fiber to this morphological abnormality can be further understood when jejunal biopsies are examined in population groups consuming high dietary fiber in developing countries. Since the available evidence suggests that tropical enteropathy reduces the mucosal surface area in the small intestine this could be a factor in the increased fecal loss of nutrient energy when fiber intake is increased.

Intestinal motility

The effect of dietary fiber on intestinal transit and motility has been extensively studied (33-35). This has prompted the use of increasing quantities of dietary fiber in the treatment of conditions such as diverticular disease and the irritable bowel syndrome with chronic constipation which are widely prevalent in developed countries (36).
Southern India, diverticular disease of the colon is seldom encountered and in our gastroenterology clinic, only 2 cases have been seen in the last 10 years. This is in striking contrast to western studies where this is one of the frequent causes of visits to gastroenterologists and is seen asymptptomatically in many barium enema examinations. The average number of stools that is passed by adult South Indian villagers is more than two per day and the stools are seldom if ever fully formed. We have estimated the intestinal transit time of Southern Indian villagers by marker feeding techniques to be about 24 ± 3 hrs in contrast to studies in UK controls using identical methods where the mean transit time was around 50 hrs. This shortening of intestinal transit with increased stool bulk and frequency is probably directly related to the fiber content of the diet. However since we do not have data on the full chemical analysis of South Indian dietary fiber, all that can be assumed is that a neutral detergent fiber intake of around 30 to 40 g per day produces this very striking change in intestinal transit and fecal bulk. The effect of the fiber on transit seems to be primarily in the time that feces stays in the colon and as such there is no evidence of increased transit in the small intestine due to dietary fiber. Therefore alterations in small bowel transit are unlikely to be a cause of malabsorption but fiber may significantly reduce morbidity due to conditions such as diverticulitis.

Diarrheal diseases

Acute diarrheal diseases are a major cause of morbidity and mortality in most tropical developing countries. While the institution of prompt oral maintenance of hydration has significantly reduced mortality and a wide variety of microbial agents capable of causing acute diarrhea have been identified there are still considerable gaps in our understanding of the pathogenesis and epidemiology of this condition. It has also been documented that in many tropical developing countries there is a wide prevalence of the enteric pathogenic bacteria in apparently healthy individuals (37). It is well documented that dietary fiber is a substrate promoting the growth of bacteria and that it can provide niches where bacteria can colonize and actively grow. It is an intriguing question whether the dietary fiber intake of tropical developing populations is an additional factor which determine their susceptibility to enteric infections by alterations in intestinal microecology (38).

One of the common constituents of several mixtures that are used for the symptomatic relief of diarrheal disease is pectin. Since pectin and other dietary fibers have the property of adsorbing toxins and other substances which damage the intestine (39,40) and can also be substrates for bacterial growth it would be useful to explore further their therapeutic utility. Stabilization of the bacterial flora of the gastrointestinal tract by altering the dietary fiber intake could probably be useful in attempts to prevent acute diarrheal episodes and to promote recovery.

Does fiber contribute to human nutrition?

There is recent evidence that suggests that volatile fatty acids, a breakdown product of fiber by colonic bacteria, are absorbed in the colon and contribute to the total nutrient energy pool particularly for maintenance of the integrity of colonicocytes (41). In populations who consume large amounts of dietary fiber could this form an important source of energy (42). In our own studies, when our subjects were consuming 30 to 40 g of NDF in the diet, we could only recover around 10 to 15 g of NDF from the stool. The breakdown of 20 to 25 g of NDF by the colonic bacteria would be releasing significant amounts of volatile fatty acids absorbed would experimentally.

Conclusion

The dietary fiber in human diet has the gastrointestinal effects outlined that answer the question of whether fiber is beneficial which are in many cases available to experiments in purified dietary fiber in the animal and in human subjects.

In summary, health and bowel conditions are better maintained with good fiber consumption.

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volatile fatty acids which are presumably absorbed from the lumen of the colon. This would be an important area to explore experimentally in the future.

Conclusions

The dietary fiber hypothesis has excited considerable interest in the medical field because of the possibility that deficiency of dietary fiber could give rise to important human diseases. From the point of view of the gastroenterologist and nutritionist in tropical countries the questions are different as outlined above. It is essential to emphasize that answers to these questions can only be obtained when the chemical nature of dietary fiber is better understood and good methods which are standardized and uniformly applied in many different parts of the world are available for characterizing and quantifying dietary fiber. The significance of animal experimental data, or of relatively short-term experiments in humans using the addition of purified fiber to elemental diets, in the epidemiology of dietary fiber related problems in the large populations living on a predominantly vegetarian diet are debatable. In understanding the relevance to human health and disease of a complicated material as dietary fiber, it appears essential that carefully controlled cross cultural longitudinal epidemiologic studies backed up by good laboratory facilities are done.

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