Dietary Fiber

Komal Mehta, Avinash Kaur**

INTRODUCTION

Fibre nutrition has been an area of increasing interest for study by nutritionists the world over for the past 25 years. 'Dietary fiber', 'unavailable carbohydrate' or 'roughage' are the different terms used to define that part of the plant food which is not digested by the endogenous secretions of the human digestive system. The sum total of all these fractions, which go unhydrolysed, was first known as "Unavailable Carbohydrate". Since lignin is not a carbohydrate, Trowell introduced "dietary fiber" (1) as a preferable term though pectic substances are not fibrous. Recently the term **"Plantix"** (2) has been given to this totally undigestible material.

Based on the current research, dietary fiber may be classified into three major groups according to structure and properties.

1. Cellulose: This dietary fiber is the chief constituent of the framework of plants. Humans cannot digest cellulose because they lack the necessary digestive enzymes. Cellulose therefore remains in the digestive tract and acts as bulk. This bulk helps move the food mass along and stimulates peristalsis. Cellulose makes up the principal structural material in plant cell walls and provides most of the material referred to as "Crude fiber".

2. Non Cellulose: This group of dietary fibre polysaccharides includes five types of compounds: (a) hemicellulose, (b) pectins (c) gums (d) mucilages, and (e) algal substances. They absorb water and thereby slow down the gastric emptying time. All of them except hemicellulose are gum like water soluble substances that aid in binding cholesterol and controlling its absorption. They also prevent colon pressure by providing bulk for normal intestinal muscle action.

3. Lignin: This substance is the only non carbohydrate type of dietary fiber. It is a large compound that forms the woody part of plants. In the intestine, it combines with bile acids to form insoluble compounds, thus preventing their absorption (3).

The main food sources of the various types of dietary fibre are indicate in Table I.

Table 1

Selected food sources of various classes of Dietary Fibre

Dietary fibre Class:	Grains	Fruits	Vegetables
Cellulose	Bran Whole wheat Whole rye	Apples Pears	Beans, peas, Cabbage family, Root vegetables, Tomato
Non cellulose polysaccharides			
Hemicellulose	Bran Cereals Whole grains		
Pectins		Apples Citrus fruits Berries, especially strawberries	Green beans Carrots
Gums	Oatmeal	Food Products thickener, stabilizer	Dried beans other legumes vegetable gums used in food processing
Mucilages		Food products thickener, stabilizer	
Algal substances		Food products thickener, stabilizer	
Noncarbohydrate			
Lignins	whole wheat Whole rye	Strawberries Peaches Pears Plums	Mature vegetables

The general term 'fibre' was initially applied to a variety of nondigestible carbohydrate and non-carbohydrate substances for which specific hydrolytic enzymes were found to be lacking in the human digestive system. Confusion resulted mainly from the erroneous interchange of the two terms 'dietary fibre' and 'crude fibre'.

* Dieticians, Adipostat Clinic, 103-104, Lady Ratan Tata Medical Centre, Bombay 400 021.

'Dietary fiber' refers to the total amount of naturally occurring material in foods, mainly of plant origin that is not digested. This includes (a) Plant dietary fibre from foods such as whole grains, legumes, vegetables, fruits, seeds, and nuts: (b) undigested animal tissue polysaccharides; (c) undigested pharmaceutical products; and (d) undigested biosynthetic polysaccharides. Refined diets in Western countries usually contain very little fiber in energy foods like starches, sugar and fats. Diets in the rural communities of developing countries contain much more fibre. Research suggests that these higher fibre diets are protective against a wide variety of Western civilization diseases.

Crude fiber is the material, which remains after vigorous treatment of food sources with acid and alkaline agents in the laboratory. Strong laboratory processes also remove a good portion of the total dietary fiber that cannot withstand such treatment. Since the proportions of total dietary fiber and crude fibre varies, widely among specific foods, the fiber values given in earlier food value tables have limited usefulness. However, as new laboratory procedures are being developed, better information is being made available.

Currently the term **'crude fiber'** is frequently used. The term of choice, though not perfect, is dietary fiber. It refers to the non-digestible residues of plant foods: (1) cellulose; (2) non-cellulose polysacchardies, including hemicellulose, pectins, gums, mucilages and algal substances; and (3) the single non-carbohydrate member lignin. Though all resist digestion by the human enzymes, they are invaluable in nutrition and related diseases (3).

RECOMMENDED DIETARY FIBRE ALLOWANCE

The establishment of a recommended daily allowance for dietary fiber, suggests that the fibre level should be such quantity so as to result in a 36-hour transit time (4).

Crude fibre represents as little as 1/7th of the total dietary fibre found in food substances. For example the crude fibre in puffed wheat on the basis of g/100g is 2.0 while the dietary fibre is 15.4g. Crude fibre values are commonly tabulated in Food Composition Tables. These values only amount for approximately 50-90% of the cellulose, 10-40% of the lignin and 20% of the hemicellulose. These values have very limited use in predicting the 'accurate' dietary fiber values of foods (5).

The foods which contain a high amount of crude fibre are cereals and flours made from whole grain, starchy roots such as yam, mature leguminious seeds, nuts, leafy vegetables and fruits.

The average intake values for crude fibre are subject to individual variations and vary according to the dietary habits and patterns of the individual. The average crude fibre intake in Britain is 4.2 g/day; but the total appears to have changed little over the last 100 years (6).

Indian diets have fairly high dietary fiber content; therefore, the dietary requirements as recommended by the I.C.M.R. do appear excessive (2). An average Indian diet contains about 6 to 8.5g of crude fibre. Today due to western influence and urbanisation, the consumption of highly refined food has increased, thereby reducing the intake of dietary fiber. Thus the incidence of diseases connected with low levels of fibre intake are rapidly increasing in the urbanized class of society.

In some parts of India, high fiber diets are common in the poorer class of society. Here the emphasis must be to look for the deleterious effects of such diets on the vitamin & mineral metabolism.

FIBRE CONTENT OF THE INDIAN DIET

Krentler (1980) (7) has listed foods giving their approximate fibre content according to the serving size.

PRODUCT	SERVING SIZE	CRUDE FIBRE (gm per serving)	DIETARY FIBRE
Cereal, bread, flour			
Whole grain flour	½ Cup	-	13.2
White flour	½ Cup	-	4.0
Oatmeal cooked	1 cup	0.5	-
Corn flakes	1 Cup	0.2	3.08
Bread whole wheat	1 slice	0.4	2.0
Legumes			
Chick peas	½ Cup	5.0	-
Beans	½ Cup	4.3	-
Lentils	½ Cup	3.9	-
Nuts & seeds			
Sunflower seeds	31/2 OZ	3.8	-
Sesame seeds	31/2 g	2.4	-
Walnuts	½ Cup	2.1	-
Peanuts roasted (with skin)	1 Tbspn	0.5	1.4
Pistachio nuts	30 Nos	0.3	-
Cashew roasted	6-8 Nos	0.2	-

* 150 ml = 1 Cup

PRODUCT	SERVING SIZE	CRUDE FIBRE	DIETARY FIBRE
		(gm per serving)	
Fruits and vegetables			
Peas green	2/3 Cup	2.0	7.0
Pear	1 Medium	-	3.9
Carrot	2/3 Cup	1.5	3.8
Banana	1 Medium	-	3.1
Cabbage, cooked	2/3 Cup	-	2.8
Apple with skin	1 Medium	2.0	2.6
Strawberries	½ Cup	1.0	1.6
Tomato raw	1 Medium	-	1.4
Plum	1 Medium	-	1.1
Potato	31/4" diameter	0.9	-
Orange	3" diameter	0.8	-
Corn(canned)	½ Cup	0.7	-
Raisins (dried/seedless)	½ Cup	0.6	
Beans fresh green	½ cup	0.5	-
Spinach	½ cup	0.4	-
Celery leaves	1 large	0.4	-
Grapes green (seedless)	18-20 Nos	0.2	-
Fruit juice	1 Cup	0.2	-

* 150 ml = 1 Cup

PHYSIOCHEMICAL PROPERTIES & EFFECTS OF FIBRE

In most diseases either fat, sugar or cholesterol have to be restricted, but fibre is one constituent in diet, which is allowed in general in all diseases. Fibre is said to have beneficial effect in many diseases, which are discussed below.

(1) Diseases of the gastro-intestinal tract

(a) Effect on colonic motility

The most convincing evidence, that dietary fibre has an important role in the maintenance of normal health, relates to its effects on colonic motility. Fibre has been shown to speed up intestinal transit time when it is slow, slow it down when it is fast, enlarge small stools and moderate high pressures.

(b) Effects on faecal energy excretion

Increasing the fibre content of the diet increases the faecal energy excretion, principally in the form of fat and nitrogen. By virtue of its water holding capacity, fibre also helps in the formation of soft stools with bulk, which can be easily evacuated.

Research suggests that fibre from different sources differs in its ability to increase stool weight. Cereal fibre in the form of bran increases stool weight more than most other fiber sources. **The larger the particle size of the bran, the more effective it is.** Most feeding experiments suggest that for every gramme of extra cereal fibre consumed each day, mean wet stool weight increase from 3-9 g daily (8).

(c) Helps in weight reduction

An increased intake of dietary fibre appears to be useful for the treatment of both obesity and diabetes mellitus. Fibre-rich food is usually satisfying without being calorically dense. Supplementing a normal diet with gel-forming fibres, such as guar gum, leads to an increased satiation probably due to a slower gastric emptying (10).

Recent long-term studies have confirmed the usefulness of viscous fibres as an adjunct to the regular dietary management of obesity. Apart from the beneficial effect of caloric restriction, dietary fibre may improve some of the metabolic aberrations seen in obesity. Gel forming fibres are particularly effective in reducing elevated LDL-cholesterol without changing the HDL-fraction. The impaired glucose tolerance of manifest diabetes is also improved. These effects are probably in part associated with the gelling property of the fiber, which leads to an increased viscosity of the unstirred layer thereby delaying the absorption process (10). However it has been shown that dietary guar gum supplementation is unable to reduce insulin resistance in gross obesity if the overweight status is constantly maintained (11).

Dietary fibre or foods containing a high amount of dietary fibre are very low in caloric content. Dietary fibre yields only 2-3 calories /g (9). Thus a high fiber diet is recommended for weight reducing regimes.

(d) Ano-Rectal Disorders

A large number of patients suffer from a variety of anal and lower rectal disorders and most find treatment with a high fibre diet very beneficial. A soft formed stool, which can be easily passed without straining, usually produces an improvement in the symptoms resulting from these disorders.

Most patients with haemorrhoids present with bright red anal bleeding after defaecation. Bleeding and prolapse are often precipitated by a period of constipation and it is possible that straining at stools is the cause of this condition. High fibre diet prevents constipation and helps to relieve this condition.

(e) Fibre and Bowel Function

Dietary fiber consists of water-soluble and insoluble plant compounds that are resistant to digestion by small bowel enzymes but are fermented to varying degrees by colonic bacteria. Many physiologic effects of fiber may be related to the degree of fermentation. An increase in dietary fibre increases stool weight and the number of defaecations and decrease bowel transit time.

Dietary fibre increases the bulk of the faecal mass by virtue of their water holding capacity and the stools therefore become bulkier and most moist. High fibre diets therefore go a long way in the prevention and cure of constipation. As the contents move rapidly, it reduces the transit time in the colon thereby resulting in reduced reabsorption of water from the colon, again contributing to bulkier and moister stools (12).

Some of the dietary fibre gets fermented in the large intestine. The products of fermentation like the short chain fatty acids also helps to accelerate the movement of the faeces through the colon. This action coupled with the additional unfermentable residue increase the faecal bulk.

The proportion of dietary fibre fermented will depend on various factors, some of which are:-

(a) Chemical and physical structure of the dietary fibre,

(b) the microflora present and

(c) The residence time in the large intestine

Present evidence suggests, that the dietary fibre from wheat bran is less well fermented and contributes to faecal mass by its presence, where as the thin walled less lignified cell walls of vegetables and fruits are virtually completely digested and their bulking effect are due to an increased bacterial mass (8).

(2) Effect On Cardiovascular System

(a) Lipid lowering effect

High fibre protects against hyperlipidamia and ischemic heart disease. Low intake of this dietary component is related to other risk factors of heart disease in susceptible genotypes such as obesity and diabetes.

Gums and pectic substance have hypocholesterolemic and hypotriglyceridemic effects. This action of dietary fibre is very important in the treatment of atherosclerosis, coronary heart disease, hypercholesterlomia and hyperlipidemia (13).

Diets rich in fibre alter biliary lipid and bile salt metabolism making bile less saturated with cholesterol. Such bile would be less likely to precepitate its cholesterol and form gallstones.

(b) Fiber, Lipid Metabolism and Coronary Heart Diseases

The dietary fibre protects against hyperlipidaemic and ischemic heart diseases. Low intakes of this dietary component are related to other risk factors of heart disease in susceptible genotypes such as obesity and diabetes.

The ability of guar gum and oat bran to alter post prandial lipid and lipoprotein composition when added to a test meal (42% total calories as carbohydrate, 16% as protein & 42% as fat) was examined in 6 males and 6 females who consumed both low (0.49) and high (15.49) fiber test meals on separate days. The results showed that gender and fibre supplementation influence postprandial glycemia, lipemia and lipoprotein composition (14).

Certain beneficial effects of fiber in the human diet may be mediated by short chain fatty acids (SCFA's) produced during anaerobic fermentation in the colon. Two studies, both involving in-vitro incubation with human fecal bacterial as inoculum, were conducted to assess fermentation of various fibre sources and to quantitate the SCFA's produced. In experiment 1, substrate fermentibility based on total SCFA production ranked as follows: Citrus pectin > soy fibre > sugarbeet fibre > peafibre > oat fibre. Fermentation of soy fibre led to higher proportions of propionate and butyrate than did fermentation of other substrates. In experiment 2, fermentation of gum arabic, a mixture of arabic, guar and apple pectin resulted in greater SCFA production than did fermentation of either oat fiber or corn bran. Fermentation of gums led to more propionate and butyrate production than did that of apple pectin. It may be possible to select fibre sources capable of supporting stipulated amounts of both total and individual SCFA production in the human colon (15).

The effect of a diet rich in natural fibre (NF) or extractive fibre (guar gum) on 12 male IDDM out patients was evaluated. The treatment lasted for 2 months. During the first month the patients were put on isocaloric diet containing 30g of fibre and then were randomly subdivided into two groups. One group followed an isocaloric diet rich in fibres (70 gm/day) while the second group followed an isocaloric diet enriched by guar (9 g of guar added to 30 g of natural fibres/day). Reduced serum levels of HbA_{1C} and several amino acids, showed that metabolic control significantly improved under each dietary regimen (16).

Dietary fibre with a high content of viscous gums, such as oats, have been shown to reduce LDL - cholesterol (10)

(3) Fiber & Diabetes Mellitus

It has been reported that a greater incidence of diabetes is found in populations that are exposed to affluence and urbanization, than in isolated populations used to hard work and limited food. This may be due to a change in diet, particularly to an increased consumption of refined carbohydrates (6). However, factors other than diet may play an important role in the development of diabetes. Dietary factors may act indirectly for example through an increased incidence of obesity.

Fibre has proved to be useful in the treatment of diabetes mellitus. Jenkins et al (1977) (17) showed that post prandial glycemia and rise in serum insulin after consumption of carbohydrate containing meals were reduced by the addition of guar flour or pectin or both.

Fibre is beneficial for diabetic patients because (1) Absorbed glucose is released slowly into the blood circulation hence resulting in decreased insulin secretion. Diabetic patients on high carbohydrate high fibre diets have lower insulin secretions. Dietary fibre has a blood glucose reducing effect as is manifested by a diminished glycemic index.

(2) It causes increased satiety so that less food is eaten and thereby it helps to keep the energy intake in check. This helps in overweight diabetics because it has been proved that as the weight decreases the number of insulin receptor increases.

Jenkins et al 1977 (17) have shown that post-prandial rise in serum glucose and insulin is reduced with the intake of a high fibre diet.

Dietary fibre has a blood-glucose reducing effect as is manifested by a diminished glycaemic index (19). Guar gum possesses distinct hypoglycemic properties. The other fraction of the guar bean, guar by-product (GBP), was studied to determine if it possesses any hypoglycemic properties. The analysed data indicated that GBP, like guar gum, possessed hypoglycemic properties: because of the different chemical characteristics of these 2 guar bean fractions, it seems that their hypoglycemic properties are due probably to different mechanisms (20). Low dose of guar may help improve glycaemic control in diabetic patients. This may be achieved with a low incidence of gastrointestinal side effects (21).

The beneficial effect of dietary fibre in the metabolic control of non-insulin-dependent diabetes mellitus (NIDDM) patients was evaluated. Realistic high-fibre and regular low fibre diets were given for 8 week each to NIDDM patients whose diabetes was being controlled satisfactorily by diet alone. The high fibre diet induced lower fasting blood glucose levels ($p < 0.01$) and decreased the ratio of low-density lipoproteins to high-density lipoproteins ($p < 0.025$): no difference was found in HbA_{1C} between the two diet periods. Continuous glucose monitoring also showed a difference in fasting glucose levels that remained after identical low-fibre test meals. The incremental glucose responses did not differ. The fasting and incremental post-prandial levels of insulin, C-peptide glucagon and somatostain did not change, whereas the mean triglyceride concentrations were lower after the high-fibre diet (22).

The use of diets rich in unabsorbable carbohydrate (fibre) has been advocated for the treatment of non-insulin dependent diabetes mellitus (NIDDM). Soluble viscous fibres such as guar gum are most effective in normalizing carbohydrate intolerance in such patients while particulate fibres such as cellulose have little or no effect. While the latter are known to affect many aspects of nutrition when consumed in great quantity, little is known of the toxicity of guar gum. Consumption of 30 grams of guar gum per day for prolonged periods is without serious consequences, (23). Increased intake of viscous fibre leads to a gradual reduction in fasting glucose levels in diabetics. The reason for this is unclear but it cannot readily be explained by a delayed absorption process. Since insulin levels are also simultaneously reduced, these findings suggest that insulin resistance be alleviated.

Recent studies with the euglycemic clamp technique support this possibility. Glucose uptake by isolated fat cells as well as insulin sensitivity and responsiveness are also increased (10). Guar gum can reduce post prandial blood glucose, insulin requirements, and serum total cholesterol levels in type 1 diabetic patients, (24).

Long-term high fibre, low fat diet in gestational diabetes is recommended. A case is reported of a 30 years old caucasian who developed gestational diabetes in her first pregnancy requiring 58 IU insulin daily and who subsequently adopted a high fiber, low fat diet and who was able to maintain normal glucose tolerance throughout a second pregnancy (25).

(4) Effect On Serum Calcium, Iron, Zinc & Other Minerals

Fibre may also produce a small lowering of serum calcium, iron, and zinc. These changes are significantly noticed when the diet rich in fibre are consumed for relatively long periods of time. Studies done (18) showed lowering of trace element fractions by prolonged consumption of rice hemicellulose.

CONCLUSION

So far, it has not been defined what is meant by a high fibre diet. Nobody would treat diabetes without being fairly specific about the amount of carbohydrate to be present in the diets. Yet the medical profession has made remarkably little attempt at suggesting what level of fibre intake we should recommend to our patients.

However, excellent sources of fibre like wholegrain cereals, pulses such as peas, beans and lentils, fresh fruits and vegetables, dried fruits and vegetables, dried fruits and nuts contribute to the dietary fibre intake if eaten regularly in good quantities and can be added to the diet to increase the fibre intake.

For all kinds of ailments there are restriction of food in some form or other, fibre is the only food, which is allowed for almost all diseases.

However, it is not a good idea to increase fibre intake suddenly. A sudden increase makes a patient feel distended with abdominal discomfort and increased flatulence especially if the initial fibre intake is low. It is far better to gradually increase the fiber intake.

The dietary fibre intake should not vary greatly from day to day. Patients may be made aware that it may take several months before they get the maximum benefit from the diet.

Some patients like to take their additional fibre in the form of bran, but on the whole it is far better to persuade people to take a well-balanced, high fibre diet that they can enjoy for the rest of their lives.

REFERENCES

1. Trowell N. Fiber a natural hypochlestermic agent. AM J. Clin Nutr. 1977; 25: 464.

2. Rao A R, Vidya S. Prasad D. Dietary fiber – update 1980 Ind. J. Nutr. Diet 1981; 18: 397.

3. William Rodwell. Essentials of Nutrition and Diet therapy. Mosby College Publishing, Missouri. 5th edition. 1990; 56-61.

4. Spiller G. A., Chernoff M.C., Hill R. A., Gates J. E., Hosser JJ, Shipley E. Effect on transit time, fecal weight and volatile fatty acids of purified cellulose, pectin and low residue diets in humans. Fed. Proc. 1978; 37: 755.

5. Fleck H. Introduction to Nutrition, Mac-Millan Publishing, New York. 1976: P 61, 393.

6. Davidson S, Passmore R, Brock J. F, Truswell A. S. Human Nutrition and Dietetics. Churchill Livingstone, Edinburgh 6th edition. 1975.

7. Kreutler P A, Nutrition in perspective. Prentice – Hall Inc. New Jersey, 1980; P 69.

8. Birch G.G, Parker K. J. Dietary fiber. Applied Science publishers, London and New York. 1983.

9. Pomare E W. Dietary fiber: when is it worth a trial? Drugs 1977; 14: 213.

10. Smith U. Dietary fiber, Diabetes & Obesity Int. J. Obesity 1987; 11/Supp (1): 27-31.

11. Cavallo – Perin P. Bruna A, Nuccio P. et al. Dietary guar gum supplementation does not modify insulin resistance in gross obesity. Diabetol Lat. 1989; 22/2: 139-142.

12. Southgate D, A, T, Penson J. M. Dietary fiber – Testing the dietary fiber hypothesis. Applied Science Publishers Ltd., New York. 1-19.

13. Akiba Y, Matsumoto T. Effects of several types of dietary fibers on lipid content in liver and plasma, nutrient retention & plasma transaminase activities in force, fed growing chicks J. Nutr. 1980; 110: 1112.

14. Carol L. Redard, Paul A. Davis, Barbara O. Scheeman. Dietary fiber & gender: effect on postprandial lipemia. Am. J. Clin Nutr. 1990; 52: 837-45.

15. Evan C. Titgemeyer, Leslie D. Bourquin, George C. Fahey, Keith a. Gerleb – Fermentability f various fiber sources by human fecal bacteria in vitro. Am J. Clin Nutr. 1991; 53: 1418-24.

16. Bruttomesso D., Briani G., Bilardo G. et al. The medium term effect of natural or extractive dietary fibers on plasma amino acids & lipids in type I diabetes. Diabetes Res Clin Pract. 1989; 6/2: 149-155.

17. Jenkins D. J. A., Leeds A. R, Gassull M. A., Cochet B, Alberti G. M. Decrease in post prandial insulin & glucose concentrations by guar & pectin. Annals of Internal Medicine. 1977: 86(1): 20.

18. Mod R.R., Ory R. L. Morris N.M. Normand F. L. Chemical Properties and interactions of rice hemicellulose with trace minerals J. Agric F D Chem – May – June 1981: P 449.

19. Tenscher A, Carbohydrates & dietary fiber in diabetic diet (germ). Schivez Med Wochenschr 1986; 116/9:282-287.

20. Track N. S., Lar V. W. and Chur S S – Guar by product improves carbohydrate tolerance in healthy human subjects. Diabetes Res Clin Pract. 1985; ½: 115-119.

21. Jones D. B, Lousley S, Jelfe R. et al. Low dose guar improves diabetic control. Jr Soc Med. 1985: 78/7 L 546-548.

22. Hegander B., Asp N – G, Ependic S. et al. Dietary fiber decreases fasting blood glucose levels & plasma LDL concentration in Non insulin dependent diabetes mellitus patients. Am J Clin Nutr 1988; 47/5: 852-858.

23. Mclvor M. E, Cummings C C & Mendaloff A. I. Long term ingestion of guar gum is not toxic in-patients with non-insulin dependent diabetes mellitus. Am J Clin Nutr. 1985; 41/9; 891-894.

24. Ebeling P., Yki Jarvinen H, Aro et al. Glucose & lipid metabolism & insulin sensitivity in type I diabetes am. J. Clin Nutr. 1988; 48/1: 98-103.

25. Paisey R. B, Savage P, Moreland I & Cooke P. Long term high fiber low fat diet in gestational diabetes. Diabetic Med. 1985; 214: 286-287.