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Dietary Fibre in Indian Diets and Its Nutritional Significance

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Dietary fibre is defined as plant cell components, present as part of diet, and resistant to digestive secretions of the gastrointestinal tract. Thus they are considered as "unavailable carbohydrates". Dietary fibre, however, is not a single entity, but consists of a wide range of complex polysaccharides. Dietary fibre in any food is a mixture of cellulose, lignin and non cellulosic polysaccharides namely hemicellulose, plant gums, pectins, and mucin (Table 1). Dietary fibre is usually determined by fractionation procedures and the one proposed by Southgate is now widely used. The estimate of amount of dietary fibre in a food will depend upon the analytical method used for the estimation and the values so obtained need not necessarily be considered always precise. Dietary fibre estimation is still considered to be only semi-quantitative.

"Crude fibre", which is reported in food composition tables now in general use, represents material left after treating food with hot acid and hot alkali and perhaps corresponds to a part of cellulose and lignin component of dietary fibre and does not include all other components of dietary fibre as defined earlier. The *total* dietary fibre content in foods as determined by modern methods is five to 20 times higher than the earlier reported values for the "crude fibre" content. Chemically dietary fibre is polysaccharide whose basic units are neutral sugars such as glucose, mannose, xylose, arabinose and their derivatives or galacturonic acid. Lignin is a complex material composed of phenolic derivatives (Table 1). Plant foods contain different proportions of these dietary fibre components which are now determined by the standard fractionation procedure proposed by Southgate. Limited data derived from analysis of Indian foods for dietary fibre employing Southgate's method have been reported (Table 2).

Dietary fibre component of common foods consumed in India vary from 2 to 25 g per 100 g. Cereals and pulses are rich sources of dietary fibre, and contain 8-20g fibre per 100 g. Dietary fibre in composite diets is contributed by cereals, pulses, vegetables, fruits, nuts and oilseeds. In Indian diets, however, cereals and millets are more important sources of dietary fibre than vegetables and fruits, etc. Dietary fibre content of some diets, consumed in India based on different cereals is given in Table 3. Nearly 90 percent of dietary fibre in Indian diets is contributed by cereals, not only due to fairly high fibre content of unrefined cereals/millets, but also due to a high consumption of the unrefined cereals/millets in Indian diets. An Indian adult may thus consume 50-120 g dietary fibre/day through his habitual diet depending upon the type and the quantity of cereal/millets consumed (Tables 3 and 4). Diets of pre-school children may contain 20-25 g of dietary fibre/day (Table 5). The desirable level of daily dietary fibre intake by an adult is generally believed to be around 40 g. It would appear that on this basis, dietary fibre content of habitual Indian diets which ranges 55-120 g is on the

TABLE 1
Components of Dietary Fibre

Major class	Property	Chemical steriods
Cellulose	Water insoluble	Linear 1-4 3-glycan
Non-celluose polysaccharides.:		
Pectin	Water soluble	Galacturonic acid, neutral sugars
Hemicellulose	Water insoluble	Xylose, arabinose, galactose, mannose
Gums	Water soluble	Xylose, arabinose, rhamnose
Mucilages	Water soluble	Galactose, galalumeric acid, rhamnose
Lignin	Water insoluble	Polymer of hydroxy phenyl propone derivatives.

TABLE 2
Dietary Fibre Content of Some Common Indian Foods

Food stuff	Energy[a] kcal	Crude fibre[a] gm	Dietary fibre[b] gm	Food stuff	Energy[a] kcal	Crude fibre[a] gm	Dietary fibre[b] gm
Cereals & millets:				**Roots & tubers:**			
Rice	345	0.2	7.6	Sweet Potato	120	0.8	7.3
Wheat	346	1.2	17.2	Potato	97	0.4	4.0
Sorghum	349	1.6	14.3	Yam	79	0.8	5.3
Bajra	361	1.2	20.3	**Fruits:**			
Ragi	328	3.6	18.6	Banana	116	0.4	2.5
				Mango	74	0.7	2.3
Pulses & legumes:							
				Vegetables:			
Greengram whole	334	4.1	15.2				
Greengram dhal	348	0.8	13.5	Amaranth	45	1.0	3.4
Blackgram dhal	347	0.9	14.3	Palak	26	0.6	5.0
Redgram dhal	335	1.5	14.1	Brinjal	24	1.3	2.0
Bengalgram whole	360	3.9	26.6	Ridge gourd	17	0.5	5.7
Bengalgram dhal	372	1.2	13.6	Snake gourd	18	0.8	1.8
				Bottle gourd	12	0.6	2.8
Nuts & oilseeds:				Yellow Pumpkin	23	0.7	0.5
Groundnut	567	3.1	6.1				
Coconut dry	662	6.6	8.9				

Values are for 100 g. food
a: *taken from Nutritive Value of Indian Foods; b: from Kamath and Belavadi, J.Sc. Food Agr. 31, 191 (1980).*

higher side. Hence a reappraisal of the beneficial and undesirable effects of such high levels of dietary fibre in Indian diets becomes necessary.

Beneficial Effects of Dietary Fibre

Health benefits of dietary fibre are being increasingly recognised. Some of the diseases like colon cancer, cardiovascular diseases prevalent in developed countries are attributed to low fibre content of their diets. Dietary fibre has the tendency to absorb water and to act as "bulking agent". It facilitates faster transit of foods in the gastrointestinal tract and reduces the retention time of faeces in the colon. Some of the well established functions of fibre are indicated in Table 6. Dietary fibre could prevent colon cancer and other bowel disorders by decreasing retention time of faeces in the colon. It could bind bile salts and help in increasing the loss of cholesterol and act as a hypocholesterolemic agent and therefore useful in dietary management of cardiovascular diseases.

TABLE 3
Dietary Fibre Content of Average Rural Indian Diet Based on Different Cereals

Cereal/Millet	Energy (Kcal/d)	Crude fibre (g/d)	Dietary fibre (g/d)	Overestimation of[a] energy intake (%)
Rice	2427	3.3	52.0	8.0
Wheat	2433	8.8	107.0	16.2
Sorghum	2449	11.0	89.2	12.8
Bajra	2516	8.8	122.3	18.0
Ragi	2333	22.0	113.5	15.7

Daily intake of cereal : 552 g.
a: By considering dietary fibre as a part of carbohydrate and computed as follows:

$$\frac{\text{Dietary fibre} - \text{crude fibre}}{\text{Energy intake}} \times 4 \times 100$$

Similarly, some of the dietary components, particularly gums, tend to slow down glucose absorption and are useful in management of certain types of diabetes. Dietary fibre may bind xenobiotics and toxins and reduce toxicity of food borne toxins. Because of these favourable functions of fibre in the diet, high fibre diet is considered to be beneficial for maintaining good health. Some of the cereal based Indian diets contain 80-120 g dietary fibre, mostly (90 percent) derived from cereals. The relative effectiveness of such high fibre diets (wherein fibre is mostly derived from cereals) in conferring the above health benefits on Indians in comparison with diets with high fibre content wherein fibre is derived from fruits and vegetables, needs assessment.

TABLE 4
Dietary Fibre Content of Regional Diets

Regional diets	Energy (Kcal/d)	Crude fibre (g/d)	Dietary fibre[b] (g/d)	Overestimation of[a] energy intake (%)
Andhra Pradesh:				
Very low income	2558	4.4	57.7	8.3
Low income	2592	4.7	53.0	7.5
West Bengal:				
Very low income	2621	4.5	56.4	7.9
Low income	2649	4.3	56.9	7.9
Uttar Pradesh:				
Very low income	2650	7.2	48.0	6.2
Low income	2619	6.6	67.4	9.3
Maharashtra:				
Very low income	2595	9.1	81.6	11.2
Low income	2554	7.5	68.6	9.5

a: By considering dietary fibre as a part of carbohydrate by difference and computed as given in Table 3.
b: Actually determined in cooked diet. (Nageswara Rao and Narasinga Rao, Nutr. Met. 24, 244 , 1980)

Possible Undesirable Effects

Nutrient bioavailability: Not withstanding the health benefits of dietary fibre discussed above, fears have been expressed that high fibre diet may reduce nutrient bioavailability. This may become critical in diets high in fibre, but poor in nutrients. Diets of poor Indians in rural areas are rather high in fibre (80-120 g/day) but marginal or even deficient in several nutrients. Although the effects of dietary fibre on various nutrients like "available" carbohydrates, fats, proteins and minerals have been studied, evidence ot significant deleterious effect has been seen only in case of divalent metals like Ca, Mg, Zn and iron.

The reported effects of dietary fibre on the bioavailability of proteins and fats are too small to be nutritionally significant. However, in case of carbohydrates, although the net availability is not affected, dietary fibre, particularly the soluble gel forms (pectins and gums) have been shown to modulate absorption of available dietary carbohydrates. Although the mechanism of this effect is unclear at present, various mechanisms like increased viscosity, delayed stomach emptying time and osmotic effect of diets containing soluble fibre have been proposed. The effect of dietary fibre in delaying carbohydrate absorption is currently exploited in the dietary management of diabetes for preventing excessive rise in blood glucose.

The effect of fibre on divalent metal absorption is considered nutritionally significant. These polysaccharides with reactive groups like hydroxyl and carboxyl can bind divalent cations. Besides, phytates, oxalates, tannins

TABLE 5
Dietary Fibre Content of Diets of Pre-school Children of Different Income Groups

Socio-economic Group	Rice Energy (Kcal/d) (g/d)	Rice Crude fibre (g/d)	Rice Dietary fibre	Wheat Energy (Kcal/d) (g/d)	Wheat Crude fibre (g/d)	Wheat Dietary fibre	Sorghum Energy (Kcal/d) (g/d)	Sorghum Crude fibre (g/d)	Sorghum Dietary fibre	Ragi Energy (kcal/d)	Ragi Crude fibre (g/d)	Ragi Dietary fibre (g/d)
High income	1011	0.9	12.0	1012	1.9	21.6	1015	2.3	18.7	994	4.3	23.0
Middle income	792	1.0	13.0	793	2.1	23.6	776	3.2	20.4	774	5.4	25.1
Low income	701	0.9	12.7	703	2.3	26.0	707	2.8	22.0	678	5.6	28.0
Rural income	610	0.8	12.2	612	2.1	24.5	615	2.6	20.8	589	5.1	26.3

TABLE 6
Some Properties of Dietary Fibre and Their Health Consequences

Function	Health consequence
Water absorbing and bulking property	Energy diluent to formulate low calorie diets
Increased transit time of food in the gut	Reduced risk of inflammatory bowel disease
Bile acid and steroid binding	Hypocholesterolemic agent and reducing the risk of cardiovascular diseases
Retardation of carbohydrate absorption and impaired glucose tolerance	Management of certain type of diabetes
Binding of toxins	As a detoxifying agent
Binding of divalent cations	Reduced bioavailability of Ca, Mg, Zn, Fe

which are closely associated with the fibre can also bind minerals and reduce their bioavailability. This effect on mineral bioavailability assumes importance in high fibre diets consumed in India. The effect on mineral bioavailability depends on the fibre type and the minerals; all fibre types may not affect all minerals to the same extent. Minerals, so affected are Ca, Zn, Fe, Mg. Reduced bioavailability of minerals particularly iron observed in cereal-based Indian diets may be partly due to high fibre and partly due to high phytate and tannins present in such diets. The relative contribution of fibre, phytate and tannins in reducing bioavailability of minerals from cereals based Indian diets needs to be assessed. As far as vitamins are concerned, nothing can be predicted about the behaviour of fibre on vitamin bioavailability from the currently available data. However, as with other macro-nutrients, available information indicates that the effect of fibre, on vitamin availability, if any, need not cause any concern. On the other hand, fibre due to its undergoing colonic microbial fermentation may contribute some vitamins to the host. There is, however, a need to study systematically to what extent high fibre present in Indian diets contributes to low absorption of iron, calcium, etc., with well-designed studies in humans. It is also to be seen whether dietary fibre at the level present does modify vitamin availability and significantly affect already existing deficiencies of vitamins among our population.

Energy availability from high fibre diets: There has been some concern that high levels of dietary fibre may compromise bioavailability of energy from such diets. This concern stems from the consideration that dietary fibre, by definition, is "indigestible" and hence its energy content may not be utilisable by the body. Current estimates of energy content of foods assumes that only the "crude fibre" is indigestible and, in the present conventional methods of food analysis, the rest of the fibre is included as a part of dietary carbohydrate which is computed by difference, i.e. by deducting the protein, fat, moisture, crude fibre and ash content per 100 g from 100. By this procedure, dietary fibre excluding the crude fibre is assumed to yield 4 kcal/g. We know now that dietary fibre content of food is several-fold higher than "crude fibre" and the energy from the rest of the dietary fibre apart from crude fibre may not be fully available. Thus current estimates of energy content of foods and diets could be overestimates and there is, therefore, a need to reevaluate the energy content of foods after taking into account their total (and not just "crude fibre") dietary fibre content.

High fibre diet can compromise availability of energy from diets in two ways: dietary fibre has the property of swelling on water absorption and increasing the bulk of the diet and decreasing its energy density.

With a given capacity of stomach, the amount of food that can be eaten, and the energy intake therefrom will be correspondingly low on a bulky high fibre low-calorie-density diet. This is particularly so with young children who need relatively more calories per kg body wt (100 kcal/kg) than adults (40 kcal/kg). Young children will have to eat two or three times as much of the bulky diet as an adult per kg body weight to meet their calorie needs. The principle of diluting energy density of diet with inclusion of fibre is in fact used to formulate low calorie diets for the control of obesity.

Another way calorie intake on a high fibre diet may be low is due to unavailability of energy from dietary fibre. This may be significant if dietary fibre content is in the range of 80-120 g/day as in habitual Indian diets, based on different cereals and millets. As discussed above, most of the dietary fibre is taken as available carbohydrate in computing energy content of foods given in our food composition table. On this basis, current computation of energy intake on high fibre diet would be an overestimate. Dietary fibre, however, by definition is unavailable carbohydrate not subject to enzyme hydrolysis and absorption in the small intestine. Then we would have overestimated energy intake on cereal based diets by eight and 12 percent (i.e. 200-300 kcal/day/adult). If it were really so, it would have far reaching consequences on present estimates of energy adequacy in our population and also other derived parameters based on energy intakes, namely proportion of population below poverty line, etc. Let us examine this issue in the light of available data.

Microbial Breakdown of Dietary Fibre

Although dietary fibre is conceptually indigestible and unavailable, its possible breakdown by gastrointestinal microflora has been investigated for more than half a century. It is widely known that plant cell-wall materials which constitute dietary fibre, are broken down by symbiotic micro-organisms in rumen from which they derive their energy. There is also considerable evidence to indicate that such complex carbohydrates, as cellulose, hemicellulose and non-cellulosic polysaccharides are broken down by microorganisms of the intestinal flora, particularly in the colon of non-ruminants like rat, rabbit and man. This is based on several studies including *in vitro* studies, balance studies, where faecal loss of calories and fibre components are measured in faeces of rat, man, rabbit, etc. Balance studies with rice and sorghum-based diets in rats by Kamath and Belavadi has indicated that only 20 and 37 percent of fibre from these two diets are excreted in faeces respectively. It is seen that 70-80 percent of the fibre is broken down. It is known that a substantial part of dietary fibre is broken down by the microflora of the lower gut releasing lower fatty acids like acetic propionic, butyric acids, CO_2, hydrogen and methane. These fatty acids can be absorbed and utilised as energy sources. The latter has also been demonstrated by feeding fibre to rats on energy restricted diets. Bacteria recovered from colon, faeces of both men and animals has been shown to possess hydrolysing activity against a variety of polysaccharides. The dietary fibre components thus broken down include pectins, cellulose, hemicellulose, some gums, non-cellulosic glucans, mucopolysaccharides and mucin glycoproteins.

The extent of digestibility of dietary fibre would vary from one fibre component to the other and would also