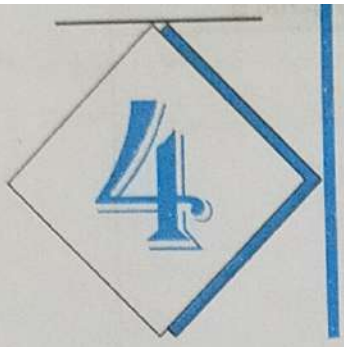


CARBOHYDRATES — PART II
DIETARY FIBRE

Dietary fibre is defined as that portion of food derived from plant cells, which is resistant to hydrolysis/digestion by the elementary enzyme system in human beings. It consists of hemicelluloses, cellulose, lignins, oligosaccharides, pectins, gums and waxes. Some bacteria in the large intestine can degrade some components of fibre releasing products, that can be absorbed into the body and used as energy source.

Crude fibre is defined as the residue remaining after the treatment with hot sulphuric acid, alkali and alcohol. The major component of crude fibre is a polysaccharide called cellulose. Crude fibre is a component of dietary fibre. Several other carbohydrate and related compounds called pectins, hemicellulose and lignins are found in plant foods and are also resistant to digestion. These together with cellulose are collectively known as dietary fibre.

i) Insoluble fibres are indigestible and insoluble in water. ii) Soluble fibres are indigestible but soluble in water. Total fibre is the sum of insoluble and soluble fibre. Functional fibre is isolated, extracted or synthetic fibre that has proven health benefits. Resistant starch n functions as dietary fibre. Legumes are the primary source of resistant starch with as much as 35 per cent of legume starch escaping digestion.

COMPONENTS OF DIETARY FIBRE

Chemically dietary fibre is a 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 4.1 gives details about fibre, its occurrence, chemical nature and sources.

Table 4.1: Fibre – Its Occurrence, Chemical Nature and Sources

Fibre	Occurrence	Chemical nature	Source
Insoluble fibre Cellulose	Cell wall constituent	Cellulose is a poly saccharide made up of glucose. β-glucose units are linked by 1, 4 linkage. Due to difference in the chemical structure, cellulose is not acted upon by amylases present in the digestive juices. Cellulose is poorly fermented.	Whole wheat flour, bran, root vegetables, legumes, peas, outer covering of seeds, apples
Hemi cellulose	Secretions, cell wall material	Hemicelluloses are poly-saccharides containing pentoses, hexoses and uronic acid. They are hydrolysed by hot dilute acids but are not acted upon by the digestive juices. Fermentability by intestinal micro flora is influenced by structure and type of sugar.	Bran, whole grains
Lignin	Woody part of plants	Part of the plant cell wall and contributes to the structural rigidity of plants. It is thought to be responsible for the resistance of cell wall to microbial degradation. Insoluble in water, and is not digested by colonic bacteria.	Mature root vegetables such as carrot, fruits with edible seeds, strawberries.
Soluble fibres Pectins	Intracellular cementing material	Pectins are compounds formed by the combination of large number of galacturonic acids – anhydro galacturonide residues, part of the carboxyl group existing as methyl esters. On hydrolysis pectin yields mainly galacturonic acid and small amounts of galactose and arabinose. Pectins are water soluble and in the presence of sucrose and citric acid pectin forms a gel. Completely metabolised by colonic bacteria.	Apples, guavas, citrus fruits, carrots, strawberries.
Gums	Secreted at the site of plant injury by specialised secretory cells and can be exuded from the plants.	Gums are composed of variety of sugar and sugar derivatives. Gums are composed of a variety of sugars like galactose and glucuronic acid as well as uronic acids, arabinose etc. Gums are highly fermented by colonic bacteria.	Gum arabic, oatmeal, barley, legumes.

Dietary Fibre

Function :-

Effect of fibre on the GI tract is influenced by the characteristics of fibre itself, the particle size, the interaction between fibre and other dietary component & bacterial flora.

(1) Water holding Capacity : • Dietary fibres (water soluble - pectins, gums & hemicellulose) have high water holding capacity so that stools are soft, bulky & readily eliminated. Coarse bran is effective but fine bran has little effect.

- A high fibre intake prevents or relieves Constipation
- The large bulky stool also represents a dilution of colon content, then any potential toxic substances like carcinogens would become diluted be less harmful.

(2) Fibre generally increases motility of the small intestine & colon and decreases transit time. If transit time is shortened, then there could be less time for exposure of the mucosa to harmful toxicants.

(3) Delayed Gastric emptying: Soluble fibres (Pectins, mucilages & gums) retard gastric emptying. This can have two benefits:

i) Increased satiety

ii) Decreased nutrient diffusion rate thereby also reduces rate of glucose absorbtion into the blood circulation.

(4) Adsorption or Binding Capacity: Pectins, mucilages & gums have the ability to bind ~~substances, they with~~ like bile acids & steroid materials. the chelating effects has following benefits:

~~i) lowered serum cholesterol level~~

i) Diminished absorption of lipids: ~~soluble & insolu~~ By adsorbing fatty acids, cholesterol and bile acids, fibres reduces their absorption into the small intestine & enhance their excretion in the faeces.

ii) Increased fecal bile acid excretion: Adsorption of bile acids to ~~fibres~~ fibres prevents the use of bile acids for micelle formation & bile acids bound to fibres can not be reabsorbed & recirculated &

excreted.

iii) Lowered serum cholesterol levels:

Oats, Psyllium, guar gum, pectin lower serum cholesterol. With the excretion of bile in the faeces less bile undergo enterohepatic recirculation so cholesterol is used for synthesis of new bile acids.

(5) Degradability or Fermentability:

Pectin, gums, oats, wheat bran, Psyllium are fermented by intestinal bacteria to short chain fatty acids (Acetic, butyric & propionic acid), carbon dioxide & methane. ~~Short chain fatty acids~~ So fibres can modify intestinal flora so that harmful substances are detoxified.

Non-fermentable fibres (cellulose & lignin) promotes microbial proliferation. ~~These~~ certain colonic bacteria can inhibit or delay tumour formation.

(6) High fibre-diet have lower coefficient of digestibility.

(7) Some forms of dietary fibres bind with minerals like Calcium, Zinc, magnesium, iron & result in possibility of there mineral deficiency.

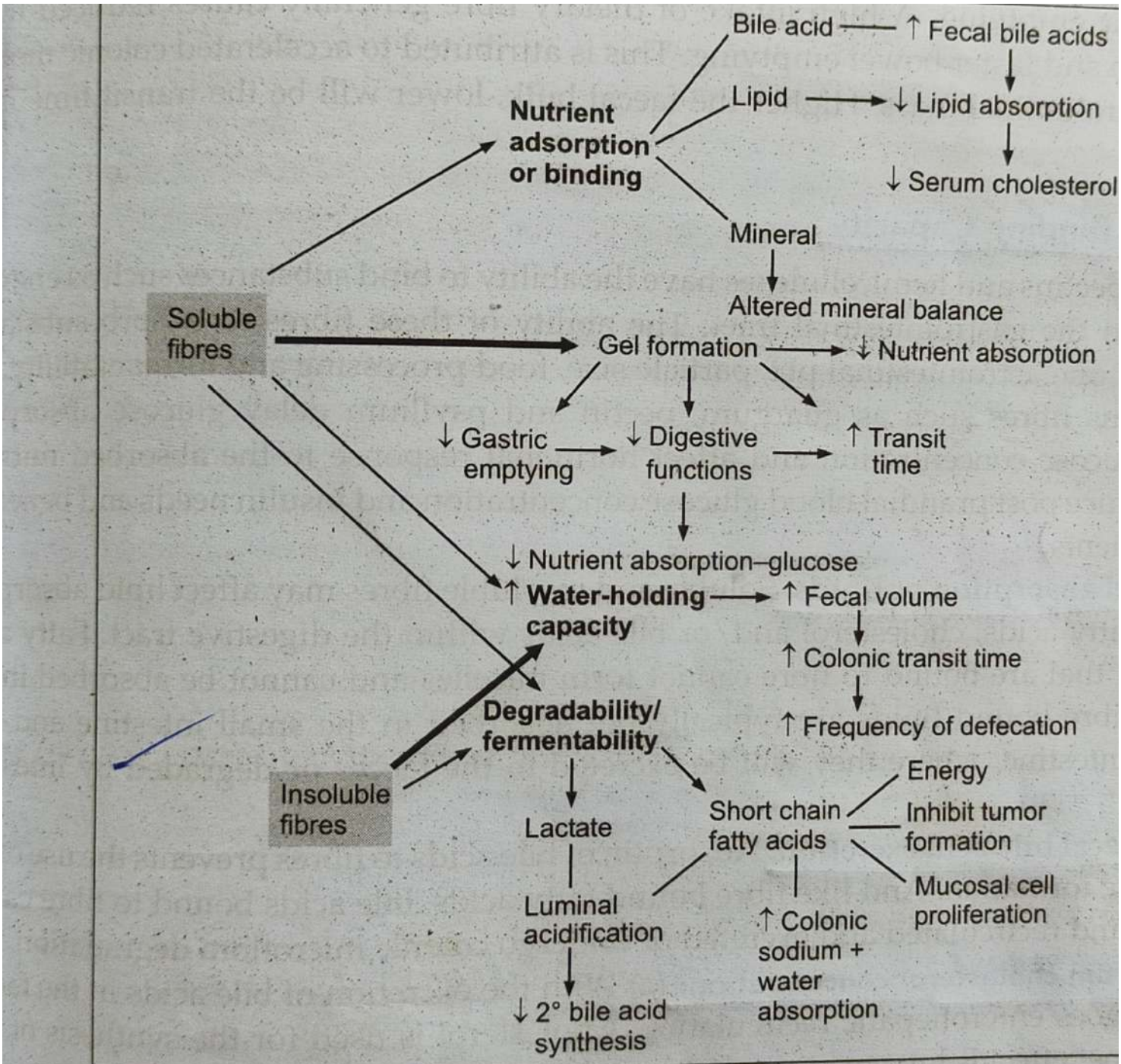


Figure 4a: Gastrointestinal response to soluble and insoluble fiber

ROLE OF FIBRE IN PREVENTION OF DISEASES

Coronary Heart Disease

High fibre in the diet reduces cholesterol. Pectin (apples, guavas) lowers the level of serum cholesterol and enhances the excretion of faecal steroids. It has no effect on serum triglycerides and HDL cholesterol. Guargum (extracted from seeds of cluster beans) has hypocholesterolaemic effect. Legumes, vegetables and fruits can lower the level of serum cholesterol, but the effect is usually small compared with the well known effect on HDL and serum triglycerides. Psyllium which contains soluble fibre reduces cholesterol.

Studies show that blood pressure can be reduced by using fibre rich diets. Dietary fibre also reduces serum fibrinogen levels, which in turn lower the risk of blood clot formation and myocardial infarction.

Oat products, which contain high amount β-glucan content has hypocholesterolemic effect. One of the postulation was that cholesterol synthesis is inhibited by acetic propionic and butyric acids, generated by the colon bacteria and concurrent clearance of LDL cholesterol.

Fenugreek seeds are rich in fat, protein and fibre. Fenugreek seeds contain 20 per cent mucilaginous fibre and 50 per cent total fibre. The mechanism of hypocholesterolemic effect of fenugreek seeds is same as that of rice bran oil. Incorporation of fibre in the diet brings about reduction in serum cholesterol by preventing its absorption. Twenty-seven per cent of total energy from fat, 59 per cent carbohydrate and 55 g dietary fibre/2500 calories produce most favourable lipid profile.

ii) Colon Cancer

Several mechanisms have been proposed to explain the protective action of dietary fibre against colon cancer.

- The fibre dilutes bile acids or binds to it thereby preventing its role in mutation or cell proliferation.
- Fermentation of dietary fibre results in production of short chain fatty acids lowering the intestinal pH. This inhibits conversion of primary bile acids to secondary bile acids. The secondary bile acids are believed to promote mutation in intestine.
- At low pH the solubility of free bile acids is reduced, diminishing their availability for carcinogenic activity.
- Fermentation of dietary fibre results in production of butyrate which has been shown to be antineoplastic.

Figure 4c: Fenugreek seeds contains 20 per cent mucilaginous fibre and 50 per cent total fibre.

- Dietary fibre exerts its beneficial effect by speeding the passage of faeces through the large intestine so that carcinogens are in contact with the intestinal wall for much shorter period of time.
- Additionally the bulk and water of the faeces may dilute the carcinogen to a nontoxic level.
- Dietary fibre also influences the colonic microbial metabolism, influences fermentation in the colon and the production and distribution of short chain fatty acids in the colon. It modifies pH, increases the faecal nitrogen and influences mutagens and faecal enzymes in the colon.
- Many human studies find that the consumption of Fructo Oligo Saccharides (FOS) increases beneficial bifidobacteria in the gut, while decreasing concentrations of potentially harmful E. coli, clostridia and bacteroids.

These agents have both complementary and overlapping mechanism of action, including the induction of detoxification enzymes, inhibition of nitrosamine formation, provision of substrate for formation of antineoplastic agents, dilution and binding of carcinogens in the digestive tract, alteration of hormone metabolism and antioxidant effects. It appears extremely unlikely that any one substance is responsible for all the associations seen.

iii) Diabetes Mellitus

Dietary fibre and complex carbohydrates benefit Type I and Type II diabetics. Such diets lower

- insulin requirements,
- increase peripheral tissue insulin sensitivity,

- decrease serum cholesterol and triglyceride values,
- aid in weight control, and
- lower B.P.

Soluble fibres such as pectin, gums, hemicellulose (in fruits) increase intestinal transit time, delay gastric emptying, slow glucose absorption and lower serum cholesterol. 20–30 g of soluble fibre should be taken.

Insoluble fibre such as cellulose and lignin (vegetables, grains) decrease intestinal transit time, increase faecal bulk, delay glucose absorption and slow starch hydrolysis.

Diets high in carbohydrate and fibre improve glucose metabolism without increasing insulin secretion. They lower fasting serum and peripheral insulin concentrations in response to oral glucose administration in both diabetic and non-diabetic individuals.

High fibre diets promote weight loss. They increase satiety, delay gastric emptying by releasing certain gut hormones. Starch, fatty acids and nitrogen from high fibre foods may be less well absorbed. Also high fibre foods usually take longer time to eat.

Fenugreeek seeds contain high fibre which is useful to diabetics. In addition, it also contains trigonelline—an alkaloid known to reduce blood sugar level. Fenugreek also lowers the levels of serum lipids such as cholesterol and triglyceride.

The quantity of fenugreek seeds to be taken daily depends upon the severity of diabetes. The doses vary from 25 g to 50 g. To begin with 25 g of fenugreek seeds may be taken in two equal doses of 12.5 g each (approximately two teaspoons) along with lunch and dinner. The seeds can be taken as such after over night soaking in water or in powder form as a drink in water or in butter milk, 15 min before the meal. The fenugreek seed powder can be incorporated in preparations such as chapati, rice, dhal and vegetables. It has been observed that the requirement of antidiabetic drugs decrease with the use of fenugreek.

Intestinal Diseases Fibre Prevents Constipation

Movement of material through the colon is stimulated in part by the presence of residue in the lumen. When chronic insufficient bulk characteristic of a low-fibre diet occurs in the colon, the colon responds with stronger contractions to propel the smaller mass distally. This chronic increased force leads to the creation of diverticula, which are herniations of the mucosal layer through weak regions in the colon musculature. Adequate intake of dietary fibre may prevent the formulation of diverticula by providing bulk in the colon so that less forceful contractions are needed to propel it.

The composition and health of colonic microflora affect the fermentation of carbohydrates. Antibiotic treatments may alter colonic bacteria, reducing fermentation and causing diarrhoea.

Individuals with inflammatory bowel disease (e.g., Crohn's disease and ulcerative colitis) may experience exudative diarrhoea when nutrient absorption is diminished, which

adds to the increased osmotic load from the presence of mucus, blood and protein from an inflamed gastrointestinal tract. Dietary fibre intake may improve symptoms of patients with inflammatory bowel disease.

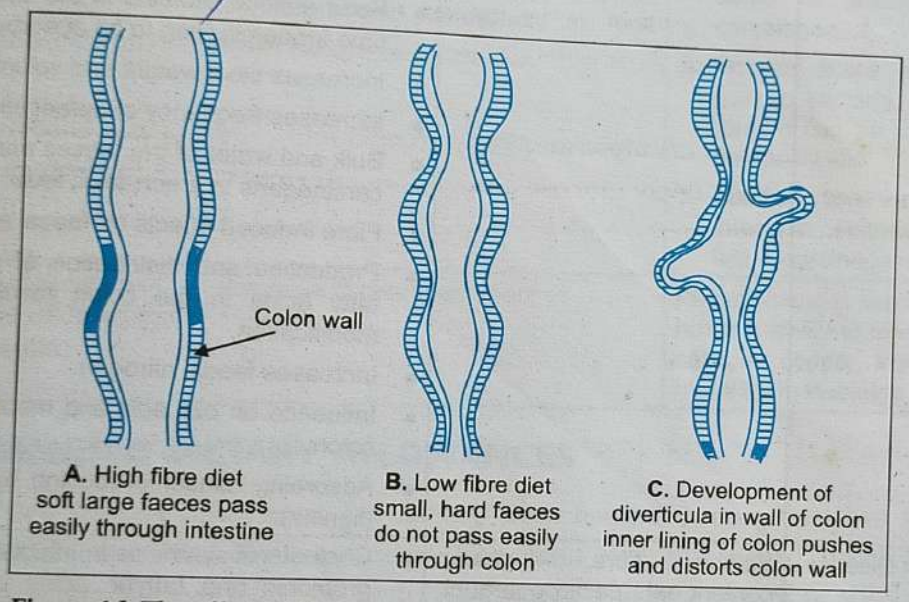


Figure 4d: The effect of fibre and lack of fibre in the diet on stool formation.

Weight Control

Fibre acts as a physiological obstacle to energy intake by at least three mechanism:

- Fibre displaces available energy and nutrients from the diet.
- Fibre increases chewing, which limits intake by promoting the secretion of saliva and gastric juice resulting in an expansion of the stomach and increased satiety and reduction in rate of ingestion.
- Fibre reduces the absorption efficiency of the small intestine.

Obesity	Soluble fibre	satiety is increased. • Diets high in fibre are low in calories.

Limitations of excess consumption of fibres : Vegetarians who eat high fibre excrete more oestrogen. It may cause abdominal discomfort and diarrhoea due to bacterial action in colon. Other limitations are given in Table 4.4.

Table 4.4: Limitations of Excess Consumption of Fibres

Disease	Type of fibre	Physiological mechanism
Increased risk of colonic cancer	Soluble fibres such as gum arabic, carrageenan, which are used as stabilisers and emulsifiers in food industry.	1. Reduce the ability of insoluble fibres to absorb and excrete carcinogen. 2. Soluble fibres are digested by colonic bacteria. The carcinogen formed can be deposited on the mucosal cells. 3. Soluble fibre may cross the intestinal epithelium and carry with it carcinogens in solution.
Decreased absorption of minerals like calcium, iron, magnesium, zinc	Insoluble fibres, seed coats	Phytate found in seed coat of legumes has the ability to bind metal ions like calcium, copper, iron and zinc and make them insoluble.

RECOMMENDED DIETARY ALLOWANCES

Recommended dietary allowance, for dietary fibre has not been prescribed so far not only for India but also for most of the countries. Food and Nutrition Board, Institute of Medicine, USA recommended approximately 14 g/1000 kcals. The proportion of soluble to insoluble fibre should be 1:2 and the intake is preferred through diet made up of various sources. It is advisable to device 50 per cent each of the daily requirement of dietary fibre equally from cereal and fruit and vegetable sources for optimum effect. American diabetic association recommends 25-38 g of dietary fibre per day per person suffering from diabetes. Indian diets provide 50-100 g/day when the whole grain cereals, pulses and vegetables are consumed daily. Americans have a fibre intake of about six grams per day.

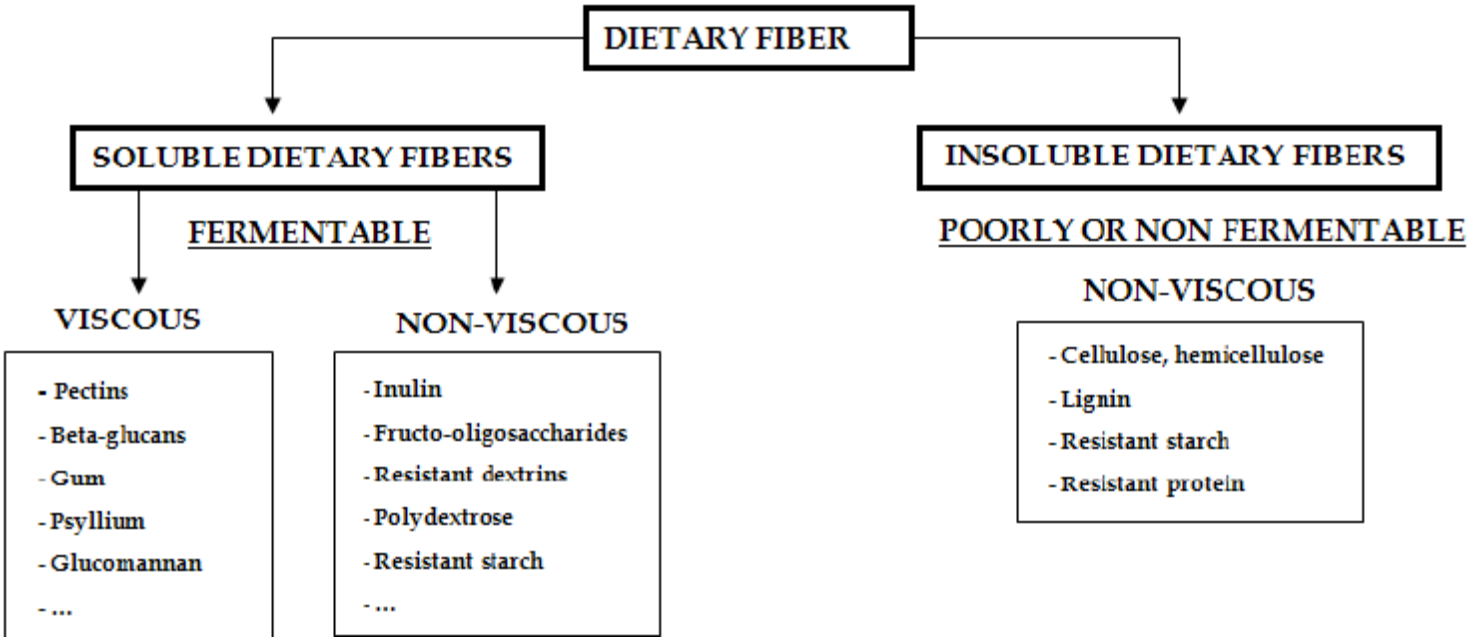
SOURCES

Studies conducted at National Institute of Nutrition showed that dietary fibre content increases as the maturity of green leafy vegetables increases. Although the daily consumption of green leafy vegetables is only around 100 g per day, it is a good source of soluble dietary fibre in Indian diets. There is no effect of cooking on dietary fibre content. Majority of fruits had 30 per cent of dietary fibre as soluble dietary fibre.

Refined and processed foods contain very low amounts of dietary fibre and sugar, oil, milk and meat do not contain any dietary fibre.

Though foods of plant origin in the diet contribute to most of the dietary fibre requirements, individually the extent of intake is influenced by a number of factors like the nature of source, maturity, moisture content, proportion in the diet and the mode of processing and preparation. Total dietary fibre content in these sources may vary from 1 to 5 per cent.

Some of the natural sources of dietary fibre are listed in Table 4.5 Most fruits and vegetables in fresh state have fibre. Total Dietary Fibre values in the range 1 to 2.2 per cent or with an


DIETARY FIBER
SOLUBLE DIETARY FIBERS
INSOLUBLE DIETARY FIBERS
FERMENTABLE
POORLY OR NON FERMENTABLE
VISCOUS
NON-VISCOUS
NON-VISCOUS
- Pectins
- Beta-glucans
- Gum
- Psyllium
- Glucomannan
- ...
- Inulin
- Fructo-oligosaccharides
- Resistant dextrins
- Polydextrose
- Resistant starch
- ...
- Cellulose, hemicellulose
- Lignin
- Resistant starch
- Resistant protein