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on

Dietary fibers and its physiological importance

Content writer

DR. SANDIP KUMAR SINHA

ASSOCIATE PROFESSOR

Department of Human Physiology

Vidyasagar University

Paschim Medinipur – 721102

❖ Learning Objectives:

After going through this study, you will be able to –

- describe the chemical composition and nature of dietary fibre (DF);
- illustrate the importance of good and proper sources of dietary fibre which is essential for life;
- emphasize the critical relationship between dietary fibre and protection diseases in maintaining total health and physical fitness;
- describe the role of soluble dietary fibre (SDF) and insoluble dietary fibre (ISDF) for maintaining health issues;
- discuss the nutritional management of DF against lifestyle disorder; and
- promote the best use of DF for better community health.

1. Introduction:

Importance of the dietary fibers was discovered only few years ago. Although Hippocrates commented about the laxative effect of the dietary fiber only few individuals paid attention to the dietary fiber. Only in the 19th century proper medical experiments about the dietary fibers started. After that scientist recognized the importance and the benefits of the dietary fibers with some questionable results.

Dietary fiber (DF) or sometimes **roughage** is the indigestible portion of plant foods. “All polysaccharides and lignin in the diet that are not digested by the endogenous secretions”. So, this definition includes polysaccharides and lignin in skeletal frame work of plant cells as well as some food additives. Regarding definition of DF there are several views given below-

According to **Trowell (1976)** plant substances not digested by human digestive enzymes, including plant cell wall substances (cellulose, hemicellulose, pectin and lignin) as well as the intercellular polysaccharides such as gums and mucilages. Largely identical to undigested (unavailable) carbohydrates plus lignin.

Chemical definition by **Furda (1981)**: the sum of the plant non-starch polysaccharides and lignin.
Physiological definition: the remnant of plant foods resistant to hydrolysis by the elementary enzymes of humans.

Dietary fiber is the edible plant or animal material not hydrolyzed by the endogenous enzymes of the human digestive tract as determined by the agreed upon method. [FAO/WHO, 1998 (Codex Alimentarius Commission)]

On the other hand, **Spiller (2001)** defining that dietary fiber is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fiber includes polysaccharides, oligosaccharides, lignin, and associated plant substances. Dietary fibers promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and / or blood glucose attenuation).

Dietary fiber having two main components: **soluble** (prebiotic, viscous) fiber that is readily fermented in the colon into gases and physiologically active byproducts, and **insoluble** fiber that is metabolically inert, absorbing water as it moves through the digestive system, easing defecation (**DRI, 2005**). It acts by changing the nature of the contents of the gastrointestinal tract, and by changing how other nutrients and chemicals are absorbed (**Eastwood and Kritchevsky, 2005**). Soluble fiber absorbs water to become a gelatinous, viscous substance and is fermented by bacteria in the digestive tract. Insoluble fiber has bulking action and is not fermented (**Anderson et al., 2009**). Insoluble fibers also decrease cholesterol and can help lower blood glucose. Beans, oat bran, fruit and vegetables contain water-soluble fiber.

Advantages of consuming fiber are the production of healthful compounds during the fermentation of soluble fiber, and insoluble fiber's ability (via its passive hygroscopic properties) to increase bulk, soften stool and shorten transit time through the intestinal tract. Insoluble fibers also decrease cholesterol and can help lower blood glucose. Beans, oat bran, fruit and vegetables contain water-soluble fiber. In contrast, fibers in cell walls are water insoluble. These include cellulose, hemicellulose and lignin. Such fibers increase fecal bulk and speed up the passage of food through the digestive tract. Wheat bran and whole grains contain the highest amounts of insoluble fiber, but vegetables and beans also are good sources. A disadvantage of a diet high in fiber is the potential cause for significant intestinal gas production and bloating. Constipation can occur if insufficient fluid is consumed with a high-fiber diet.

2. Sources of fiber:

Plant foods are the only sources of DF: fruits, green leafy vegetables, nuts cereals and grains. Meat, milk and eggs do not contain fiber. The form of food may or may not affect its fiber content. Canned and frozen

fruits and vegetables contain just as much fiber as raw ones. Other types of processing, though, may reduce fiber content. Drying and crushing, for example, destroy the water-holding qualities of fiber. Fiber-rich plants can be eaten directly. Or, alternatively, they can be used to make supplements and fiber-rich processed foods. The **American Dietetic Association (ADA)** recommends consuming a variety of fiber-rich foods.

2.1 Plant sources:

Some plants contain significant amounts of soluble and insoluble fiber. For example, plums (or prunes) have a thick skin covering a juicy pulp. The plum's skin is an example of an insoluble fiber source, whereas soluble fiber sources are inside the pulp (**Stacewicz-Sapuntzakis et al., 2001**). The removal of seeds, peels or hulls also reduces fiber content. Whole tomatoes have more fiber than peeled tomatoes, which have more than tomato juice. Likewise, whole wheat bread contains more fiber than white bread.

Roberfroid (1993) suggested that DF is subdivided into Insoluble (IDF) and soluble (SDF) dietary fiber depending on their solubility in water. However, the DF can be grouped into two major types (a) soluble/viscous/fermentable and (b) insoluble/nonviscous/slowly fermentable. In **1998, FAO/WHO** discussed a document on carbohydrates recommended dropping the terms “soluble” and “insoluble” fiber. The physiological effects of total dietary fiber (TDF), in the forms of insoluble and soluble fractions of foods, have a significant role in human (**Schweitzer and Edwards, 1992**).

2.1.1 Soluble fiber: It is found in varying quantities of plant foods, including:

- Legumes (peas, soybeans, lupins and other beans)
- Oats, rye, chia, and barley
- Some fruits and fruit juices (including prune juice, plums, berries, bananas, and the insides of apples and pears)
- Certain vegetables such as broccoli, carrots, and Jerusalem artichokes
- Root tubers and root vegetables such as sweet potatoes and onions (skins of these are sources of insoluble fiber)
- Psyllium seed husk (a mucilage soluble fiber) (Fig.1)

2.1.2 Insoluble fiber: These are including:

- Whole grain foods
- Wheat and corn bran
- Nuts and seeds
- Potato skins
- Flax and hemp seed
- Lignans
- Vegetables such as green beans, cauliflower, zucchini (courgette), celery, and nopal
- Some fruits including avocado, and bananas
- The skins of some fruits, including kiwifruit and tomatoes (Fig.1) (Alvarado et al., 2001).



Fig 1: Different sources of SDF and ISDF

3. Chemical composition of dietary fiber:

Dietary fiber includes non-starch **polysaccharides** (arabinoxylans, cellulose) and **lignin** (polymer of phenylpropane) that are not digested or absorbed in the human small intestine and many other plant components such as resistant dextrins, inulin, waxes, chitins, poly-phenols, proteins, gums, mucilages, pectins, beta-glucans and oligosaccharides ((DRI, 2005). The plant cell wall is the main source of dietary fiber (Asp, 1987).

Marlett (1992) discussed that **Pectin**, which was negligible in grains, constituted approximately 15% to 30% of the fiber in fruits, vegetables, legumes, and nuts. **Hemicelluloses** composed about half of the total fiber in grains, and approximately 25% to 35% of total fiber in other foods. **Cellulose** was one third or less of the total fiber in most foods, except for legumes, in which it was about one half. Values for total dietary fiber content generally agree with those reported previously. The soluble fiber fraction was lower than what has been reported because the distribution of total fiber between the soluble and insoluble fractions is determined by the method of analysis. The analyses used in this study demonstrated that the concentration of dietary fiber in many frequently consumed foods is 1% to 3%.

4. Calories production:

Calories or kilojoules (as used on nutrition labels) are intended to be a measure of how much energy is available from the food source. This energy can be used immediately, for example allowing the body to move during exercise, or to make the heartbeat. Energy that is not used immediately is stored as sugars in the short term and later converted to fats, which act as energy reserves.

Energy is extracted from food in a chemical reaction. Because of the principle of conservation of energy, energy can only be extracted when the chemical structure of food particles is changed. Since insoluble fiber particles do not change inside the body, the body should not absorb any energy (or Calories/kilojoules) from them.

Because soluble fiber is changed during fermentation, it could provide energy (Calories/kilojoules) to the body. As of 2009, dietitians have not reached a consensus on how much energy is actually absorbed, but some approximate around 2 Calories (8.5 kilojoules) per gram of soluble fiber. Regardless of the type of fiber, the body absorbs fewer than 4 Calories (16.7 Kilojoules) per gram of fiber, which can create inconsistencies for actual product nutrition labels. In the US, soluble fiber must be counted as 4 Calories per gram, but insoluble fiber may be (and usually is) treated as zero calories per gram and not mentioned on the label.

Table 1: Dietary Reference Intakes (DRI) for Fiber.	
Age	g/day Fiber
Children	
1-3 years	19
4-8 years	25
Males	
9-13 years	31
14-18 years	38
19-50 years	38
51+ years	30
Females	
9-13 years	26
14-18 years	26
19-50 years	25
51+ years	21
Pregnancy	
≤18 years	28
18+ years	28
Lactation	
≤18 years	29
18+ years	29

5. How much you will intake DF:

The ADA recommends a minimum of 20–35 g/day for a healthy adult depending on calorie intake (e.g., a 2000 cal/8400 kJ diet should include 25g of fiber per day). The ADA's recommendation for children is that intake should equal age in years plus 5 g/day (e.g., a 4-year-old should consume 9 g/day).

According to **Institute of Medicine (2002)**, DRI of dietary fiber for many people required to changes in their daily eating practice. Eating several servings of whole grains, fruits, vegetables and dried beans each day is good way to boost fiber intake. Anyone with a chronic disease should consult a physician before greatly altering a diet. If you are not used to eating high fiber foods regularly, these changes should be made gradually to avoid problems with gas and diarrhea. Also, drink plenty of water to minimize intestinal gas. If problems with gas continue to be an issue, gas-reducing over-the-counter and prescription drugs are available. ^[15]

6. Mechanism of action:

The main action of dietary fiber is to change the nature of the contents of the gastrointestinal tract, and to change how other nutrients and chemicals are absorbed.^{[2][3]} Soluble fiber binds to bile acids in the small intestine, making them less likely to enter the body; this in turn lowers cholesterol levels in the blood.^[4] Soluble fiber also attenuates the absorption of sugar, reduces sugar response after eating, normalizes blood lipid levels and, once fermented in the colon, produces **short-chain fatty acids (SCFA)** as by products with wide-ranging physiological activities (mention below). Although insoluble fiber is associated with reduced diabetes risk, the mechanism by which this occurs is unknown (**Weickert and Pfeiffer, 2008**).

For most soluble fiber sources, the potential actions (Fig.2) are the following:

- Alter energy intake and gastric emptying.
- Alter emulsification of dietary fat in the conditions prevailing in the stomach and small intestine.
- Alter the secretion rate of pancreatic enzymes and reduce the activity of gut lipases.
- Slow and/or reduce the intestinal absorption of dietary fatty acids and cholesterol as well as glucose absorption and insulin response.
- Bind bile salts in the small intestine and as a result increase ileal and fecal excretion of fat, cholesterol and bile salts.
- Alter chylomicron secretion and thus, postprandial lipid and lipoprotein metabolism.

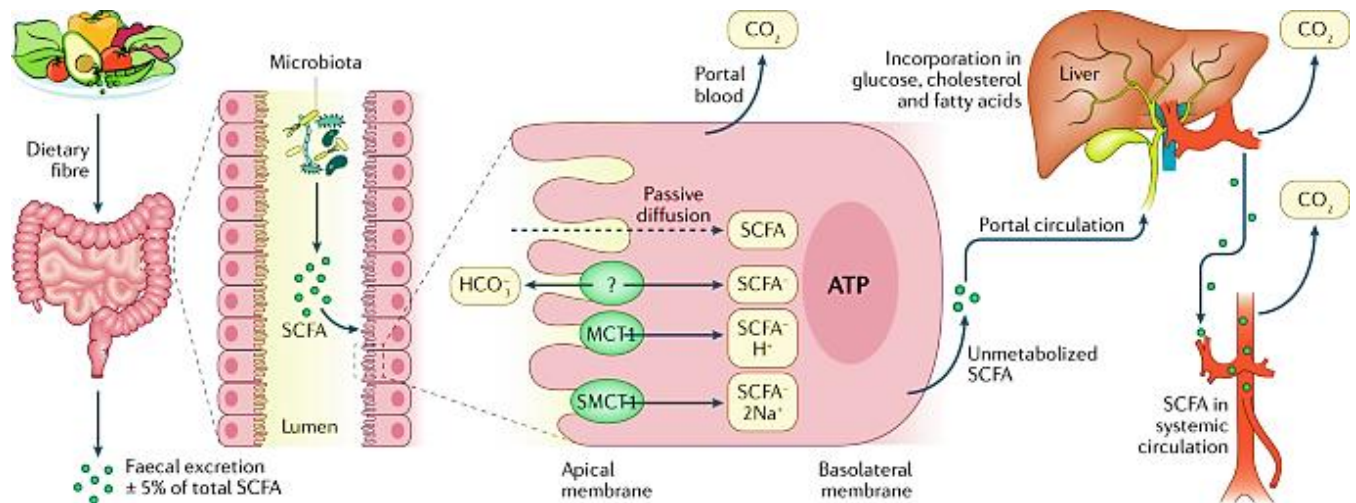


Fig 2: Metabolism of dietary fiber and its conversion in to short chain fatty acid (SCFA) for regulations of different physiological functions

- Alter hepatic levels of LDL receptor. Most soluble viscous dietary fiber sources lower fasting plasma and LDL cholesterol after chronic intake.
- Favorably alter risk factors such as hyperinsulinemia or thrombotic indices

7. Physiological Advantages & Disadvantages of Natural Fibers:

Natural fibers are most densely found in the edible skins of certain foods. Natural fibers are referred to as **dietary fiber** that consists of the bulk of food that your body cannot absorb. **Soluble fiber** travels through the body until it reaches the digestive tract where it then dissolves in water to form a sticky, gel like substance. This gel holds food in your digestive tract for longer which can help with blood sugar control and ensure that you get all the nutrients from your food. When soluble fiber is fermented, short-chain fatty acids (SCFA) are produced. SCFAs are involved in numerous physiological processes promoting health (Wong et al., 2006). **Insoluble fiber** travels to the digestive tract where it then absorbs water and expands. This expanded mass then helps push waste products through your digestive tract which promotes regular bowel movements and is also thought to reduce your risk of bowel infections. Despite these numerous benefits getting too much fiber can have negative side effects.

7.1 Advantages:

7.1.1 Teeth: DF requires more chewing to increase the secretion of saliva. It protects against dental caries. Keeps gums healthy.

7.1.2 Stomach: DF increases the secretion of saliva and gastric juice. Decreases the rate of evacuation of stomach contents into small intestine that prolongs the feeling of satiety. Enhances satiety prevents overeating and weight gain (**Quarterly Medical Review, 2005**).

7.1.3 Intestine Health: According to American Dietetic Association, insoluble fiber improves the health of the intestinal tract by increasing stool volume and stimulating normal bowel contractions (peristalsis) thus reducing transit time through the colon. Fiber makes your solid waste easier to eliminate because it enlarges and softens it, thereby **reducing constipation**, irritable bowel syndrome (IBS) and diverticulitis. Because fiber adds bulk to your stool, it cleans your intestines. DF also beneficial for the bacterial population in the large intestine.

7.1.4 Prevents Colon Disease and Hemorrhoids: According to the Mayo Clinic.com, a high-fiber diet can reduce your risk of hemorrhoids, diverticular disease and other colon diseases.

7.1.5 Weight Loss: Foods high in fiber usually contain less calories per volume of food as refined foods or foods without fiber. Because high-fiber foods contain bulk, it takes more time to chew. This allows more time for your stomach to realize that it is satisfied, and may help prevent you from overeating. Also, because of the bulk, high-fiber foods are more massive and fill your appetite for a longer amount of time than refined carbohydrates like white breads and pastas. This also may mean that you can afford to eat healthier by buying less, but higher quality, fibrous foods. Increasing consumption of dietary fiber with fruits, vegetables, whole grains, and legumes across the life cycle is a critical step in stemming the epidemic of obesity found in developed countries (**Mayo Clinic.com**). **Slavin (2005)** suggested that addition of functional fiber to weight-loss diets should also be considered as a tool to improve success.

7.1.6 Regulates Blood Sugar Levels: Insoluble fiber is helpful in reducing the risk of acquiring type-2 diabetes. Soluble fiber assists in treating diabetes. Soluble fiber slows down digestion in the stomach and small intestine. This helps to slow down the conversion of other carbohydrates into glucose, thus stabilizing blood glucose levels. It slows down the absorption rate of sugar, which keeps insulin levels balanced. The presence of fiber in carb-rich foods actually lowers the glycemic index of that food (**Quarterly Medical Review, 2005; Mayo Clinic.com**).

7.1.7 Decrease Blood Cholesterol: Soluble fiber appears to reduce blood cholesterol (lowers low-density lipoprotein, or "LDL" or "bad" cholesterol.) levels. This is because the fiber binds with bile acids and cholesterol in the digestive tract, preventing them from being absorbed by the body (**Quarterly Medical Review, 2005; Mayo Clinic.com**).

7.1.8 Increases Heart Health: According to the American Dietetic Association, you can reduce your risk of heart disease if you consume an adequate amount of fiber. Fiber reduces the cholesterol levels in your blood. Fiber also reduces hypertension and inflammation to prevent heart attacks. Soluble fiber can reduce risk of **coronary heart disease** by daily intake of 3g or more per day of beta-glucan soluble fiber from either whole oats or barley, or a combination of whole oats and barley or 7g or more per day of soluble fiber from psyllium seed husk. Influence the plasma triglyceride levels and blood clotting properties; as a result, decrease the risk of heart disease and gallstones. It may also reduce the absorption of salt (thus reducing the risk of raised blood pressure) and toxins. The National Academy of Sciences' Institute of Medicine recommends fiber **intakes of 38 g for men and 25 g for women under age 50 and 30 g for men and 21 g for women age 51 and older** body (**Quarterly Medical Review, 2005; Mayo Clinic.com**).

7.1.9 Cancer treatment: Soluble fiber may also have cancer benefits. Modified citrus pectin, when fed to rats, appeared to reduce the size of tumors. In some as yet unknown way, the pectin appears to interfere with cancer cells linking together to form tumors. Interrupts the enterohepatic circulation of estrogens, reducing estrogen levels and decrease the risk of **breast cancer**. Data collected from 20 populations in 12 countries showed that average stool weight varied from 72 to 470 g/day and was inversely related to **colon cancer risk (Cummings, 1992)**. DF balances intestinal pH (**Cummings et al., 2001**) and stimulates intestinal fermentation production of short-chain fatty acids and then it may reduce risk of **colorectal cancer (Fotiadis et al., 2008)**. In short, the best available evidence suggests that vegetables and fruits have far more cancer-preventing potential than do grains (**World Cancer Research Fund, American Institute for Cancer Research, 1997**).

7.1.10 Blood Triglycerides: In 2002, **Parks** suggested that concern with low-fat, high-carbohydrate diets that are currently recommended to protect against the development of heart disease is that these diets may increase blood triglyceride levels (an independent risk factor for CHD). Fiber intake may play a role in the reduction of **blood triglycerides**. A review of pertinent studies suggests that if the high-carbohydrate diet is also a high-fiber diet, one will see a small reduction in fasting triglyceride levels, rather than an increase, as usually seen with high-carbohydrate, low-fiber diets (**Anderson, 2000**).

7.2 Disadvantages of Eating Too Much Fiber: There is only one minor disadvantage from eating dietary fiber. If you eat too much at one time, it could cause discomfort, constipation and some others' problems.

7.2.1 Loss of good cholesterol: One of the functions of soluble fiber is that it helps remove cholesterol from the blood. However, cholesterol is not all bad and research has suggested that **high density lipoprotein (HDL) cholesterol has a number of benefits including protecting the heart and brain.** Soluble fiber removes this 'good' cholesterol along with the less beneficial **low-density lipoprotein (LDL) cholesterol.** Therefore, consuming too much soluble fibre can lead to low levels of HDL cholesterol in your blood.

7.2.2 Constipation: One of the benefits of insoluble fiber is that it promotes regular bowel movements which in turn reduce constipation. However, both types of fibre require water to work effectively. Therefore, consuming excessive fibre can cause the water in your digestive tract to dry up making your stools dry, hard and difficult to pass. This can then lead to constipation and difficulty excreting waste materials.

7.2.3 Wind: As discussed above both types of fibre interact with water. This process causes gases such as carbon dioxide, methane and hydrogen to be produced. Therefore, eating too much fibre can cause high levels of these gases to be present in the digestive tract. This can then lead to you having a bloated stomach and passing wind regularly.

7.2.4 Poor mineral absorption: Another benefit of soluble fibre is that it holds food in the digestive tract for longer so that all the nutrients can be absorbed. However, eating too much fibre can actually have the opposite effect and prevent your body from absorbing a number of minerals including calcium, iron, zinc, vitamin C, and magnesium, but this is caused by the presence of phytate (which is also thought to have important health benefits), not by fiber.

7.2.5 Gastrointestinal Distress

Because viscous fibers are fermented in the large intestine, high intakes may result in gastrointestinal discomfort (e.g., flatulence, abdominal fullness). When 4 to 12 g/day of hydrolyzed guar gum were consumed, moderate to severe flatulence was reported (**Patrick et al., 1998**). **Heijen et al., (1998)**

suggested that when as much as 32 g/day of resistant starch was consumed, 91% of persons studied reported bloated feelings.

8. Dietary Fiber supplements: These are a few examples forms of fiber that have been sold as supplements or food additives. The supplementary DF available in the market like **vegetable gum** (IBS treatment), **psyllium husk** (better bowel movement, reduce constipation), **Maltodextrin-Soluble Fiber** (ferment the sugar molecules into SCFA in presence of Bifidobacteria and Lactobacillus species), **Flax seed** (richest sources of lignans leads to produce phytoestrogens), **Guar gum** (maintain healthy blood sugar levels and control appetite), **Inulin** (prebiotic fermentable fiber and increase the mass and health of intestinal *Lactobacillus* and *Bifidobacterium* populations), **Marine Alginate from Brown Kelp** (overall cleansing effect of Colon as well as maintaining a soft, hydrated stool) and **Bio Bran MGN-3 250 (450 mg tablet)** (stimulate NK cells and macrophages leads to immune busting). These may be marketed to consumers for nutritional purposes, treatment of various gastrointestinal disorders, and for such possible health benefits as lowering cholesterol levels, reducing risk of colon cancer, and losing weight (**Parisi et al., 2002; Kaur and Gupta, 2002; MacDermott, 2007 and Roberfroid, 2007**).

Soluble fiber supplements may be beneficial for alleviating symptoms of irritable bowel syndrome (IBS), such as diarrhea and/or constipation and abdominal discomfort (**Friedman,1989**). Prebiotic soluble fiber products, like those containing inulin or oligosaccharides, may contribute to relief from inflammatory bowel disease (**Ewaschuk and Dieleman, 2006**) as in Crohn's disease (**Guarner, 2005**) ulcerative colitis (**Seidner et al., 2005**) and *Clostridium difficile* (**Ward and Young, 1997**) due to part of short-chain fatty acids production with subsequent anti-inflammatory actions upon the bowel (**Cavaglieri et al., 2003**). Fiber supplements may be effective in an overall dietary plan for managing irritable bowel syndrome by modification of food choices (**MacDermott, 2007**).

9. Conclusion

It is a challenge for the clinicians and dietetic professionals to look into the changing pattern in the dietary intake and the nutrition transition in relation to its contribution to the emerging epidemics of non-communicable diseases and to act with an insight into the diagnosis, pathogenesis, prevention and management of the same. Dietary fiber as a preventive as well as curative agent in the daily diet has been well established. Different types of fiber have different functions with different mechanisms of action. The results of increased dietary fiber from high-fiber foods or from fiber supplements were similar. In

addition, the beneficial effect of dietary fiber was seen for soluble and insoluble dietary fibers. Food technologists should find ways and means of reducing refined flour in the food products and bring out fiber rich food products in the market for the better future aspect of community health.

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