Review
Composition, properties and health benefits of indigestible carbohydrate polymers as dietary fiber: A review
Deepak Mudgil *, Sheweta Barak
Department of Dairy and Food Technology, Mansinhbai Institute of Dairy and Food Technology, Mehsana, Gujarat 384 002, India

ARTICLE INFO
Article history:
Received 4 April 2013
Received in revised form 3 June 2013
Accepted 26 June 2013
Available online xxx

Keywords:
Dietary fiber
Carbohydrate polymers
Gums
Properties
Health benefits

ABSTRACT
In last few decades, indigestible carbohydrates as dietary fiber have attracted interest of food scientists and technologists due to its several physiological benefits. Dietary fibers are generally of two types based on their solubility, i.e. soluble and insoluble dietary fiber. Significant physicochemical properties of dietary fiber include solubility, viscosity, water holding capacity, bulking and fermentability. Some important dietary fibers are celluloses, hemicelluloses, hydrocolloids, resistant starches and non-digestible oligosaccharides. Inclusion of these fibers in daily diet imparts several health benefits such as prevention or reduction of bowel disorders, and decrease risk of coronary heart disease and type 2 diabetes.

© 2013 Elsevier B.V. All rights reserved.

Contents
1. Introduction ............................................................................................................................................. 2
2. Definition .................................................................................................................................................. 2
  2.1. American Association of Cereal Chemists (AACC, 2001) ................................................................. 2
  2.2. Codex Alimentarius Commission (CAC, 2006) .................................................................................. 2
3. Composition and types of dietary fiber .................................................................................................. 2
  3.1. Cellulose ............................................................................................................................................. 3
  3.2. Hemicelluloses .................................................................................................................................. 3
  3.3. Pectins ............................................................................................................................................... 3
  3.4. Hydrocolloids ................................................................................................................................... 3
  3.5. β-Glucans ......................................................................................................................................... 3
  3.6. Resistant starch ............................................................................................................................... 3
  3.7. Non-digestible oligosaccharides ....................................................................................................... 4
  3.8. Synthetic carbohydrate compounds ............................................................................................... 4
  3.9. Minor associated components ......................................................................................................... 4
4. Physicochemical properties of dietary fiber ....................................................................................... 4
  4.1. Solubility ........................................................................................................................................... 4
  4.2. Water-holding capacity .................................................................................................................... 4
  4.3. Viscosity and gel formation .............................................................................................................. 4
  4.4. Binding ability .................................................................................................................................. 5
  4.5. Bulking ability .................................................................................................................................... 5
  4.6. Fermentability ................................................................................................................................... 5
5. Health benefits ....................................................................................................................................... 5
  5.1. Effects on digestive system ............................................................................................................ 5

* Corresponding author. Tel.: +91 9896672001.
E-mail address: dsmudgil@yahoo.com (D. Mudgil).

0141-8130/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.ijbiomac.2013.06.044
1. Introduction

The term ‘dietary fiber’ first came into existence in 1953 and included cellulose, hemicelluloses and lignin [1]. Dietary fibers are generally considered as ‘roughage’ material which is indigestible in the human small intestine. It mainly comprises the portions of food that are not broken down by the secretions of the human digestive tract. Types of dietary fiber may also be categorized according to their sources, solubility, fermentability and physiological effects. Dietary fibers usually include non-starch polysaccharides, oligosaccharides, lignin and associated plant substances [2]. These can be traditionally obtained from cereals, legumes, fruit and vegetables. Resistant starch is also included in dietary fibers as it resists digestion to its component sugars, glucose, in the human small intestine and passes unchanged into the large intestine [3]. Various types of resistant starch naturally found in whole or partly milled grains and seeds, pulses, some breakfast cereals, e.g. corn flakes and cooked potatoes. Colorless, odorless and tasteless forms of resistant starches are now also available commercially. These commercial products can be used to prepare variety of fiber enriched food products without any significant change in taste and texture. Dietary fibers are extensively studied in recent years because of their beneficial physiological effects such as lowering of blood cholesterol, improvements in large bowel function and attenuation of post-prandial blood glucose and insulin levels. Dietary fiber may also be broadly classified according to its solubility. The two broad types of fiber are: insoluble and soluble dietary fibers [4]. Oats, fruit, vegetables and pulses are rich sources of soluble fiber. Gums or hydrocolloids are also a rich source of soluble dietary fiber [5,6]. Partially hydrolyzed guar gum prepared via enzymatic hydrolysis gives over 75% of soluble fiber [7,8]. Wholegrain cereals and cereal brans are particularly good sources of dietary fiber in cell wall form. Wheat bran generally contains up to 50% dietary fiber while oat bran contains up to 20% dietary fiber [3]. Because insoluble and soluble fibers are found in different proportions in fiber-containing foods and have different properties, it is important to eat a variety of fiber-containing foods and also there is great need for composition analysis and characterization of variety of fibers in different food stuffs [9]. Mudgil et al. studied the effect of soluble fiber on cookie quality and found that the incorporation of soluble fiber substantially improved the cookie quality [10]. The effects of dietary fiber fortification on the properties of various products such as bread [11], pasta [12], ice cream, yoghurt, minced meat product [13]. Apart from the beneficial physiological effects such as cholesterol lowering, diabetes control and digestive system improvements, dietary fibers also improves the growth and activity of beneficial intestinal bacteria. This activity of dietary fiber is known as prebiotic activity. Prebiotic substances are the indigestible food component that beneficially influences the host organism by selective stimulation of growth and activity of beneficial bacteria such as Lactobacilli and Bifidobacteria in the colon, and thus improves the host health. Generally, prebiotic substance such as guar gum, gum acacia, tragacanth gum, fructo-oligosaccharides (FOS) and galacto-oligosaccharides (GOS) act as food for the intestinal bacteria and thus helps in their growth and activity [14].

2. Definition

Understanding of dietary fiber has been increased in recent decades. It is now recognized that dietary fiber includes a broader range of substances and it has greater physiological significance than previously expected. There is no general acceptance about definition of dietary fiber. However, it is generally accepted that a definition based on physiological aspect is necessary. The main physiological characteristic of dietary fiber is its non-digestibility in the small intestine. In addition to non-starch polysaccharides, recent definitions of dietary fiber have also included other non-digestible carbohydrates such as resistant starch, resistant maltodextrins, fructo-oligosaccharides and galacto-oligosaccharides, as well as modified celluloses and synthesized carbohydrate polymers such as polydextrose. The latest definition proposed by Codex Alimentarius includes carbohydrate polymers with a degree of polymerization not lower than 3. They can be naturally present in raw food or can be synthesized. Recent definitions of dietary fiber are given by AACC and CAC.

2.1. American Association of Cereal Chemists (AACC, 2001)

The edible part of plants or analogous carbohydrates that is 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 [15].

2.2. Codex Alimentarius Commission (CAC, 2006)

Dietary fiber means carbohydrate polymers with a degree of polymerization not lower than 3, which are neither digested nor absorbed in the small intestine. A degree of polymerization not lower than 3 is intended to exclude mono- and disaccharides. It is not intended to reflect the average degree of polymerization of a mixture. Dietary fiber consists of one or more of: edible carbohydrate polymers naturally occurring in the food as consumed; carbohydrate polymers obtained from food raw material by physical, enzymatic, or chemical means; synthetic carbohydrate polymers. Dietary fiber generally has properties such as: decrease intestinal transit time and increase stool bulk; fermentable by colonic micro flora; reduce blood total and/or LDL cholesterol levels; reduce post-prandial blood glucose and/or insulin levels [16].

3. Composition and types of dietary fiber

Dietary fiber consists primarily of carbohydrate polymers (non-starch polysaccharides) that are components of plant cell walls, including cellulose, hemicelluloses and pectins, as well as other polysaccharides of plant or algal origin, such as gums and mucilages and oligosaccharides such as inulin [17]. Analogous non-digestible carbohydrates that pass through the small intestine unchanged but are fermented in the large intestine should also be included, for example resistant starch,
fructo-oligosaccharides, galacto-oligosaccharides, modified celluloses and synthesized carbohydrate polymers, such as polydextrose [18]. Associated substances, principally lignin, and minor compounds including waxes, cutin, saponins, polyphenols, phytates and phytosterols, are also included, as they are extracted with the polysaccharides and oligosaccharides in various fiber analytical methods [19]. However, with the exception of lignin, these associated substances when isolated, could not be described as dietary fiber.

3.1. Cellulose

Cellulose is the most abundant polysaccharide found in nature. It is a major component of the cell wall of most plants and hence, present in fruits, vegetables and cereals. It is a linear and unbranched polysaccharide consisting of up to 10,000 glucose monomer units per molecule. The linear molecules are packed closely together as long fiber and are very insoluble and resistant to digestion by human enzymes. Cellulose forms about one fourth of the dietary fiber in grains and fruit and one third in vegetables and nuts. Wheat bran is rich source of cellulose or insoluble fiber [3]. Being insoluble in water it has an ability to bind water which helps in increasing fecal volume and thus promoting regular bowel movements. Although humans are not able to digest cellulose but its partial digestion occurs in the gut by beneficial microflora. About 50% of cellulose is degraded by natural fermentation in colon and produce significant amount of short-chain fatty acids which feed our intestinal cells.

3.2. Hemicelluloses

Like cellulose, hemicelluloses are also a component polysaccharide of plant cell wall [3]. But it differs from cellulose in having monomer units other than glucose. Hemicellulose includes both linear and branched molecules, smaller than cellulose, typically containing 50–200 pentose units (xylose and arabinose) and hexose units (glucose, galactose, mannose, rhamnose, glucuronic and galacturonic acids). The name hemicellulose therefore describes a heterogeneous group of chemical structures that are present in plant foods in water soluble and insoluble forms [20]. About one third of the dietary fiber in vegetables, fruits, legumes and nuts consists of hemicelluloses. Hemicelluloses promote regular bowel movements by increasing hydration of the stools. Hemicelluloses also directly bind cholesterol in the gut, preventing cholesterol absorption [7]. Bacteria in the gut digest hemicelluloses increasing the number of beneficial bacteria in the gut and creating short-chain fatty acids which colon cells use as fuel and decrease cholesterol.

3.3. Pectins

Pectins are the polysaccharides found in plant cell walls as well as in the outer skin and rind of fruits and vegetables, e.g. the rind of an orange contains 30% pectin, an apple peel 15%, and onion skin 12%. Pectins are mainly composed of chains of galacturonic acid interspersed with units of rhamnose and are branched with chains of pentose and hexose units [21]. They are soluble in hot water and then form gels on cooling hence used as gelling and thickening agents in various food products. Cholesterol lowering effects of pectin is due to its gel-forming capacity [22]. Pectin lowers cholesterol by binding the cholesterol and bile acids in the gut and promoting their excretion.

3.4. Hydrocolloids

The hydrocolloids comprise a wide range of mixed viscous polysaccharides. They are derived from plant exudates (gum arabica and tragacanth), seeds (guar and locust bean gum) and seaweed extracts (agar, carrageenan and alginates). Mucilages are present in cells of the outer layers of seeds of the plantain family, e.g. isabgol (psyllium). These hydrocolloids are used in small amounts as gelling, thickening, stabilizing and emulsifying agents in certain food products [23]. Gums and other mucilages, including psyllium seed husk and konjac root glucomannan, are perhaps the most potent cholesterol-lowering agents of the gel-forming fibers [24]. In addition, mucilage fibers have been shown to reduce fasting and after-meal glucose and insulin levels in both healthy and diabetic subjects; and decreased body weight and hunger ratings when taken with meals by obese subjects [6].

3.5. β-Glucans

β-Glucans are glucose polymers. Unlike in cellulose, the linkages between the units are variable; they have a branched structure and are of smaller size. These properties influence their solubility, enabling them to form viscous solutions [25]. β-Glucans are a major component of the cell wall material in oats and barley grains but are present in only small quantities in wheat [26]. These have generated interest as a source of soluble fiber due to their effects on the glycermic, insulin, and cholesterol responses. These physiological functions made β-glucans a functional dietary fiber. The cholesterol lowering ability of β-glucans is considered to result from effects manifested in the upper gastrointestinal tract which may be related to their ability to form a gel-like network and alter gastrointestinal viscosity [27]. β-Glucans have also been used in various cereal food products such as bread. Cavallero et al. incorporated barley β-glucan rich fractions into wheat bread and observed a significant decrease in glycemic index as compared to control wheat bread when tested on adults [28]. Scientists have also analyzed the effect of β-glucan incorporation in dairy products. In low fat dairy products, incorporation of β-glucans along with other soluble fibers improves their mouthfeel, scooapability or spoonability and sensory properties comparable to those of full-fat products. β-Glucan incorporation into low fat cheese curds has also a positive or beneficial influence on their gelation and rheological characteristics [29]. The addition of β-glucan solutions to milk modifies curd formation, decreases curd cutting time and increase curd yields. These effects appear to be related to the gelling capacity of β-glucans and their ability to form a highly structured and elastic casein–protein–glucan matrix [29].

3.6. Resistant starch

Starch and starch degradation products that are indigestible by enzymes in the small intestine of healthy humans are referred to as resistant starch. It is present in a wide variety of carbohydrate-containing foods in varying proportions. Resistant starches are divided in four subfractions: physically inaccessible starch (RS1), native starch granules (RS2), retrograded starch (RS3) and chemically modified starch (RS4). These are also known as type I, II, III and IV starch, respectively [30]. RS1 starches are resistant because they are in a physically inaccessible form such as partly milled grains and seeds and in some very dense types of processed starchy foods. These are measured chemically as the difference between the glucose released by the enzyme digestion of a homogenized food sample and that released from a non-homogenized sample. RS1 is heat stable in most normal cooking operations and enables its use as an ingredient in a wide variety of conventional foods [31]. RS2 represents starches which have certain granular form.
and resistant to enzymatic hydrolysis. These are measured chemically as the difference between the glucose released by the enzyme digestion of a boiled homogenized food sample and that from an unboiled, non-homogenized food sample. In raw starch granules, starch is packed tightly in a radial pattern and is relatively dehydrated. This compact structure limits the accessibility of digestive enzymes, various amylases, and is responsible for the resistant nature of RS2 such as, ungelatinized starch [31]. RS1 type represents the most resistant starch fraction and is mainly retrograded amylose formed during cooling of gelatinized starch. Therefore, most moist-heated foods contain some amount of RS2. However, repeated cycles of heating and cooling increase RS1 levels in foods like potatoes. RS3 is measured chemically as the fraction, which resists dispersion by boiling and enzyme digestion. It can only be dispersed with KOH or dimethyl sulphoxide [32]. RS4 is entirely resistant to digestion by pancreatic amylases. Chemically modified starch (RS4) includes starch with chemical bonds other than α-(1→4) or α-(1→6). The chemical modifications are the reasons for a reduced starch digestibility in the small intestine and thus formation of RS4. The resistant starch content of a food may change during storage, depending on temperature and water content, and during food preparation [31]. Consequently, an exact quantification of resistant starch in a food item at the time of consumption is impossible. One person may digest a greater proportion of starch in the small intestine, while in another individual this would behave as resistant starch.

3.7. Non-digestible oligosaccharides

Non-digestible oligosaccharides with degree of polymerization from 3 to 10 occur naturally in plant foods, mainly in fruits, vegetables and cereals. They can also be synthesized from monosaccharides and disaccharides by chemical or enzymatic process and from polysaccharides by enzymatic hydrolysis. They are considered as dietary fiber because they perform some physiological functions as their larger polysaccharide counterparts [3]. Due to their fermentability they have prebiotic properties, e.g. fructooligosaccharides (FOS) and galacto-oligosaccharides (GOS) [18,33]. When these oligosaccharides are consumed, the undigested fraction serves as food for beneficial bacteria, such as Bifidobacteria and Lactobacillus species. Clinical studies have shown that administering FOS, GOS, and inulin can increase the number of these beneficial bacteria in the colon while simultaneously reducing the population of harmful bacteria. Other benefits noted with FOS, GOS, or inulin supplementation include increased production of beneficial short-chain fatty acids like butyrate, increased absorption of calcium and magnesium, and improved elimination of toxic compounds [34]. Natural sources of FOS and inulin are Jerusalem artichoke, burdock, chicory, dandelion root, leeks, onions, and asparagus. FOS can also be synthesized enzymatically from sucrose [35]. GOS can be synthesized from lactose while soybeans are the natural source.

3.8. Synthetic carbohydrate compounds

Similar to cellulose, its derivatives prepared synthetically like methylcellulose (MC) and hydroxy-propylmethylcellulose (HPMC), are non-digestible [36]. Unlike cellulose they are soluble, but are hardly fermented by the colonic microflora. Polydextrose is a non-digestible carbohydrate polymer, with an average degree of polymerization of 12. It is synthesized from glucose and sorbitol, using an organic acid (citric acid) as a catalyst. This results in a complex structure which is resistant to hydrolysis by human digestive enzymes. It is partially fermented in the colon and has bulking and prebiotic properties [37]. Resistant dextrins are produced by heating starches at alkaline pH and enzymatic treatment of starches, resulting in a material of degree of polymerization equal to 15.

They are partially indigestible by human digestive enzymes and partially fermented in the colon, thus physiologically considered as dietary fiber [38]. The prebiotic effects of these dextrins are yet to be confirmed.

3.9. Minor associated components

Lignin is not a polysaccharide but is chemically bound to hemicellulose in the plant cell wall and therefore it is intimately associated with plant cell wall polysaccharides. It also influences gastrointestinal physiology. It is present in foods with a ‘woody’ component such as celery and in the outer layers of cereal grains [39]. Phytic acid is associated with fiber in some foods, especially cereal grains. Its phosphate groups bind very strongly with positively charged ions such as iron, zinc, calcium and magnesium and may influence mineral absorption from the gastrointestinal tract [40]. Other plant constituents associated with dietary fiber, e.g. polyphenols (tannins), cutins and phytosterols, can also have physiological effects.

4. Physicochemical properties of dietary fiber

The physicochemical effects of dietary fibers depend mainly on their physicochemical properties: water-holding capacity, viscosity, binding ability, bulking ability, and fermentability [19].

4.1. Solubility

Based on solubility in water, dietary fibers are of two types: soluble (pectin, gums) and insoluble (cellulose, lignin). The soluble and insoluble nature of dietary fibers decides their technological functionality and physiological effects [41]. Soluble fibers are responsible for increase in viscosity and reduce the glycemic response [42] and plasma cholesterol [24]. Insoluble fibers are characterized by their porosity, their low density and are associated with increase in fecal bulk and decrease in intestinal transit [43]. In food processing operations, incorporation of soluble fiber in food products is more beneficial as it provides viscosity, ability to form gels and/or act as emulsifiers, as compared to insoluble fiber.

4.2. Water-holding capacity

Water holding capacity (WHC) is the amount of water that is retained by known weight of dry fibers under specified conditions of temperature, time soaked, and duration and speed of centrifugation. However, a portion of the soluble fibers is lost during measurement which affects WHC; hence the amount of water measured by centrifugation is generally higher than the amount of water absorbed [44]. In general, the polysaccharide constituents of dietary fibers are strongly hydrophilic. Water is held on the hydrophilic sites of the fiber itself or within void spaces in the molecular structure.

4.3. Viscosity and gel formation

Viscosity is a physicochemical property associated with dietary fibers specially soluble dietary fibers such as gums, pectins, psyllium, and β-glucans [45]. Viscosity, or gel-forming capacity, is related to a fiber’s ability to absorb water and form a gelatinous mass. Water soluble fibers are the major component that would increase the viscosity of a solution [43]. Soluble fibers form gels, increasing the viscosity of the contents of the gastrointestinal tract. Because of their viscous nature, gels seem to respond more like solids than liquids in the gastrointestinal tract. This phenomenon
may explain the delayed gastric emptying often associated with the ingestion of fibers. Gels may also provide lubrication to stool.

4.4. Binding ability

Dietary fiber is capable of trapping bile acids in the small intestine. The gel matrix formed by soluble fibers that are eventually excreted in the feces may entrap some of the bile acids released from the gallbladder. This physical entrapment appears to be more pronounced in the terminal ileum where bile acids are usually reabsorbed [46].

4.5. Bulking ability

Insoluble fibers, such as cellulose and lignin, are mostly unfermentable by colonic microflora and increase fecal bulk by their particle formation and water-holding capacity [46]. Wheat bran is among the best bulking agents. Some fermentable hemicellulose fibers, including cabbage, increase fecal bulk by increasing fecal flora. In contrast, highly fermentable fibers, such as pectin, have little effect on fecal bulk.

4.6. Fermentability

The extent to which fibers ferment is highly variable, ranging from not at all with lignins to almost complete fermentation with pectins. Soluble fibers are fermented to a much greater extent by colonic bacteria than are insoluble fibers [46]. Fermentation of soluble fibers may play an important role in some physiologic effects of fiber. Plants contain varying proportions of rapidly fermented, slowly fermented, and unfermentable dietary fibers. Fruits (such as apples and bananas) and vegetables (such as potatoes and beans) are thought to ferment rapidly and may contribute less to fecal bulking than other fibers. Psyllium and wheat bran are thought to ferment slowly and help build up the fecal mass through fermentation, which takes place along the entire length of the colon.

5. Health benefits

5.1. Effects on digestive system

The colonic microflora partially or completely ferments carbohydrates that resist digestion and absorption in the small intestine. The fermentation products such as the short chain fatty acids play a key physiological role. Undigested carbohydrate that reaches the large intestine softens stool consistency and increases stool weight and frequency of defecation. With higher dietary fiber intake stool weight tends to be higher and transit time enhances which may contribute to the prevention of large bowel disorders such as constipation, diverticulitis and large bowel cancers [46]. Most non-absorbed carbohydrates have laxative effects, both by increasing bacterial mass or osmotic effects, and by water binding to remaining unfermented fiber. The etiology of cancer involves both inherited and environmental (dietary) factors. Many large studies, mainly observational, have assessed the relationship between fiber intake and the risk of cancer in the colon or rectum. Intervention studies have addressed the effects of dietary fiber on the recurrence of adenoma, which are generally considered as an early marker for colorectal cancer. The overall evidence for an effect of total fiber intake on the risk of colorectal cancer is not considered sufficient to serve as a basis for guidelines on dietary fiber intake. However, individuals with lesser fiber intakes may have an increased risk.

5.2. Cholesterol lowering effect

Recent observational studies consistently show an inverse association between dietary fiber intake and the risk of coronary heart disease. It is generally considered as adequate levels of dietary fiber intake decreases the risk of coronary heart diseases. Several recent guidelines for fiber intake are therefore based on its effect on the risk of cardiovascular disease. Postulated mechanisms for lower levels of total and low density lipoprotein (LDL) cholesterol include alterations in cholesterol absorption and bile acid re-absorption, and alterations in hepatic metabolism and plasma clearance of lipoproteins [17]. Highly viscous fibers (such as oat β-glucans, pectins, guar gum) influence blood lipid levels, whereas non-viscous fibers, such as wheat fiber and cellulose, generally do not. In some countries the evidence for the cholesterol-lowering properties of certain viscous fibers, especially β-glucans from oats, is considered sufficient for claims on the reduction of the risk of coronary heart disease.

5.3. Reducing glycemic response

Some cohort studies show an inverse association between dietary fiber intake and the risk of developing type 2 diabetes [47]. Some dietary fibers reduce the glycemic response. Viscous fibers have been shown to have such effect both in intact foods as well as in isolated supplement form. Paradoxically, prospective observational data show that the intake of non-viscous dietary fiber, e.g. like that in whole grain cereals, is a better predictor of the risk of insulin resistance and diabetes (risk being lower at higher intakes). Dietary fiber consumption is inversely associated with body mass index. However, results of intervention studies on appetite, energy and total food intake are inconsistent. There are some indications that viscous fibers such as pectins and guar gum delay gastric emptying, and that slowly digested starch and resistant starch increase satiety. There is evidence that the benefits of whole grains, fruits and vegetables outweigh those of the isolated components of these foods (used either as supplements or added to foods). Possibly other, as yet unidentified, substances in such foods can explain this; perhaps it is the overall combination of the dietary fiber, nutrients and bioactive substances, acting synergistically, that is critical to health. However, there are also isolated types of dietary fiber, such as resistant starch, non-digestible oligosaccharides and polydextrose that help in the prevention and alleviation of bowel disorders, and decrease risk factors for coronary heart disease and type 2 diabetes [48].

6. Adverse effects

Diets containing large quantities of dietary fiber may be bulky and of relatively low energy density. This may make them unsuitable for very young and very old people. Isolated or synthetic types of dietary fiber, such as non-digestible oligosaccharides or resistant starch have been reported to cause gastrointestinal symptoms such as flatulence. Generally such effects, if occurring at all, are only seen at high intake levels and may be transitory. There is also some evidence that high intakes of certain types of dietary fiber, particularly those associated with phytate, reduce the absorption in the small intestine of several minerals: iron, calcium, magnesium and zinc [40]. On the other hand, dietary fiber may improve colonic mineral absorption during the fermentation process. However, the significance of this latter observation to overall mineral status and to physiological endpoints such as bone health is uncertain. The balance of calcium and magnesium is not adversely affected by large amounts of cereals, vegetables and fruits. Generally, consumption
of foods naturally rich in fiber is self-limiting due to their bulking character.

7. Applications in food industry

Dietary fibers can be used in processed food products not only to improve the dietary fiber content but also to improve the viscosity, texture, sensory characteristics and shelf-life of food products. Many byproducts of food industry are rich in fiber and can be used as fiber source for incorporation in processed foods. These byproducts may include waste from fruits and vegetables industries (such as fruits and vegetables peel or skin), cereals industry (such as wheat bran, rice bran), etc. These fiber-rich byproducts can be incorporated in food products as inexpensive, non-caloric bulking agents. These can be used for partial replacement of flour and or fat and enhances the water and oil retention to improve the emulsion and or oxidative stabilities. But, the maximum level of fiber incorporation in different food products varies because it may cause undesirable changes in color and texture of foods. Dietary fibers incorporation into bakery products prolongs freshness due to their capacity to retain water. Fibers can modify bread loaf volume, springiness, softness of bread crumb and firmness of bread loaf [49]. Dietary fibers when incorporated in dairy products influences the gelation, sensory and rheological characteristics [29].

8. Conclusion

Recent research conducted on dietary fiber sources concludes that there are so many utilized and under-utilized sources of dietary fiber which are classified as water soluble and insoluble. These carbohydrates remain undigested in alimentary canal of human digestive system. When incorporated in diet, these may perform various physiological functions related to digestive system, diabetes and heart diseases. Due to their certain physico-chemical properties (such as viscosity, water holding capacity, solubility and gel formation), these carbohydrates can also improve the textural and rheological properties of food products. These indigestible carbohydrate sources can be used as partial replacement of flour and or fat in various processed food products.

References