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HEALTH BENEFITS, EXTRACTION AND UTILIZATION OF DIETARY FIBERS: A REVIEW

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ABSTRACT: *Dietary fiber (DF) is that part of plant material in the diet which is resistant to enzymatic digestion and includes cellulose, polysaccharides such as hemicellulose, pectin substances, gums, mucilage and a non-carbohydrate component lignin. DF is often divided into two parts when it is dispersed in water: a soluble and an insoluble fraction, each fraction has different physiological effects. High-fiber diets are associated with the prevention and treatment of some diseases such as constipation, diverticular disease, colonic cancer, coronary heart disease and diabetes. Daily intake for total fiber for adults has been set at 38 g for men and 25 g for women. DF is obtained by different methods and from different sources. The amount and composition of fiber differ from one food to another. DF from cereal bran is a typical ingredient in high DF food products, but the presence of soluble DF in cereals is quite low, this is not the case with fruits where the ratio between soluble and insoluble DF fractions is more balanced. Influence of different processing treatments (like extrusion-cooking, canning, grinding, boiling, frying) alters the physico-chemical properties of dietary fiber and improves their functionality. Dietary fiber can provide a multitude of functional properties when they are incorporated in food systems. Thus, fiber addition contributes to the modification and improvement of texture, sensory characteristics and shelf-life of foods due to their water binding capacity, gel-forming ability, fat mimetic, antisticking, anticlumping, texture rising and thickening effects. Dietary fiber can be used in various functional foods like bakeries, drinks, beverages and meat products. Dietary fiber can be determined by different methods, mainly by enzymatic gravimetric and enzymatic chemical methods.*

Key words: *Dietary fiber, sources, classification, preparation, application, health benefits.*

INTRODUCTION

Dietary fiber (DF) was originally defined in 1972 by Trowell as “that portion of food which is derived from cellular walls of plants which are very poorly digested by human beings”. American Association of Cereal Chemists (AACC 2000) defined DF as the edible parts of plant or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. The 2009 Codex definition of dietary fiber is “carbohydrate polymers with 10 or more monomeric units, which are not hydrolysed by the endogenous enzymes in the small intestine of humans and belonging to the following categories: 1. Edible carbohydrate polymers naturally occurring in the food as consumed. 2. Carbohydrate polymers, obtained from food raw material by physical, enzymatic or chemical means, 3. Synthetic carbohydrate polymers. (Jones 2014). Worldwide there is a ‘fiber gap’ because intake is far below the recommendations. Indigestible dietary fiber is metabolized by gut bacteria, including *Faecalibacterium prausnitzii*, which has a critical role in colonic homeostasis owing to a variety of functions. Dietary fiber intake has been significantly inversely associated with the risk of chronic diseases (Mitsuro *et al*., 2015). Dietary fiber is often classified as soluble dietary fiber (SDF) and insoluble dietary fiber (IDF), refering to fiber dispersability in water (Gorinstein, *et al*., 2001).

Dietary fiber is naturally present in cereals, vegetables, fruits and nuts. The amount and composition of fibers differ from food to food (Desmedt and Jacobs 2001). DF from cereals are more frequently used than those from fruits, however, fruit fiber have better quality due to higher total and soluble fiber content, water and oil holding capacity and colonic fermentability as well as lower phytic acid content and caloric value (Larrauri, *et al.,*1997). It is generally accepted that those fiber sources suitable for use as food ingredient should have a SDF/IDF ratio close to 1:2 (Jaime, *et al*., 2002). Over the past two hundred years diet has become increasingly processed, leading to greatly reduced fiber content (Burkitt and Trowell, 1975 & Kendall *et al*., 2010). The importance of food fibers has led to the development of a large and potential market for fiber-rich products and ingredients. In recent years, there is a trend to find new sources of dietary fiber that can be used in the food industry (Chau and Huang, 2003). Supplementation has been used to enhance fiber content of foods such as snack foods, beverages, spices, imitation cheeses, sauces, frozen foods, canned meats and meat analogues (Hesser, 1994). Supplementation has been focused on cookies, crackers and other cereal-based products. Dietary supplements are typically marketed in the form of capsules, pills, powder or gel and are not presented for use as a conventional food, meal or diet. Dietary supplements contain one or more dietary ingredients (e.g., vitamins, minerals, amino acids, herbs or other botanicals) (U.S. Food and Drug Administration, 1994; van Kreijl *et al*., 2006; Eussen *et al*., 2011).

A fiber-rich diet is low in energy density, often has a low fat content, large in volume and is rich in micronutrients (Rolls, *et al.,* 1999). Dietary fiber plays an important role in human health, it acts as a protective agent against cardiovascular diseases, diverticulosis, constipation, irritable colon, obesity, colon cancer and diabetes (Gorinstein, *et al*., 2001, & Rodriguez, *et al*., 2006). The physiological effects are related to the physico-chemical and functional properties of dietary fiber. It is widely known that dietary fibers obtained by different methods and from different sources, behave differently during their transit through the gastrointestinal tract, depending on their chemical composition and physico-chemical characteristics and on the processing that foods undergo (Chau and Huang, 2003**;** Herbafood *et al*., 2002 & Jimenez, *et al*., 2000).

During processing, the foods undergo various physical, chemical, enzymatic and thermal treatments, which directly or indirectly affect the composition of total fiber. Incorporation of fiber can change the consistency, texture, rheological behavior and sensory attributes of the end products (Guillon and Champ 2000).

According to Larrauri (1999), the ‘‘ideal dietary fiber’’ should meet the following requirements: have no nutritionally objectionable components; be as concentrated as possible; be bland in taste, color and odor; have a balanced composition and adequate amount of associated bioactive compounds; have a good shelf life; be compatible with food processing; have the expected physiological effects. Therefore, this contribution provides an overview of key research, describing the dietary fibers profile associated with health promoting activities, including the impact of dietary fiber sources and processing.

Classification of Dietary Fiber

Historically dietary fiber was classified as soluble and insoluble based on whether they form a solution when mixed with water (soluble), or not (insoluble) (Periago, *et al*., 2013). Soluble Dietary Fiber (SDF) sometimes called "prebiotic" or "viscous", absorbs water to form a viscous "gel" and is fermented by bacteria in the digestive tract resulting in production of gases, hence possible sensation of "bloating" (Gibson and Roberfroid, 1995 & Fuller and Gibson, 1997). SDF include pectin, oligosaccharides, guar, and gums, most of which are dietary and healthy additives. IDF mainly consist of hemicellulose, cellulose, and lignin and cannot be degraded by enzymes in the human body (Dhingra *et al*., 2012). Insoluble dietary fiber (IDF) does not ferment but absorbs water while passing through the digestive system, resulting in bulky yet soft faeces, easing defecation. Soluble fiber can help lower blood cholesterol and glucose levels, which is found in oats, peas, beans, apples, citrus fruits, carrots and barley. Insoluble fiber can be of benefit to those who struggle with constipation or irregular stools. Whole-wheat flour, wheat bran, nuts, beans and vegetables, such as cauliflower, green beans and potatoes, are good sources of insoluble fiber. Classification of dietary fiber components based on water solubility/fermentability is presented in table (1).

Table 1: Classification of dietary fiber components based on water solubility/fermentability.

Characteristic	Fiber component	Description	Main food sources
Water insoluble/ less fermented	Cellulose	Main structural component of plant cell wall. Insoluble in concentrated alkali, soluble in concentrated acid.	Plants (vegetables, sugar beet, various brands)
	Hemicellulose	Cell wall polysaccharides, which contain backbone of β-1, 4 glucoside Linkages. Soluble in dilute alkali.	Cereal grains
	Lignin	Non-carbohydrate cell wall component. Complex Cross-linked phenyl propane polymer. Resists bacterial -degradation.	Woody plants
Water soluble/ Well fermented	Pectin	Components of primary cell wall with D-galacturonic acid as principal component. Generally water soluble and gel forming.	Fruits, vegetables, legumes, sugar beet, potato
	Gums	Secreted at site of plant injury by specialized secretary cells. Food and pharmaceutical use.	Leguminous seed plants (guar, locust bean), seaweed extracts (carrageenan, alginates), microbial gums (xanthan, gellan).
	Mucilages	Synthesized by plant, prevent desiccation of seed endosperm. Food industry use, hydrophilic, stabilizer.	Plant extracts (gum acacia, gum karaya, gum tragacanth)

Source: (Devinder Dhingra *et al*., 2012).

The health benefits of dietary fiber

Much of the recent literature has revolved around the ability of certain dietary fiber types to affect different physiological systems to understand how dietary fiber influences the characteristics and fermentation patterns of the intestinal microbiome in humans. It is now possible to understand the prebiotic function of fibers using new DNA sequencing procedures that permit complete characterization of the bacterial populations (microbiome) (Wilson, *et al*., 2010).

Over the years, dietary fiber has received much positive attention with regard to its potential as a pharmafood, due to its ability to reduce cholesterol (Andreasen, *et al.*, 2001; Anderson *et al*., 2009; Cui, *et al*., 2011 & Ajila and Prasada Rao, 2013), diabetes and coronary heart disease, prevention and treatment of obesity (Davidson and McDdonald, 1998; Bingham *et al*., 2003; Mann and Cummings, 2009 & Elleuch *et al*., 2011) and ease constipation (Telrandhe *et al*., 2012; Rodriguez *et al*., 2006 & Hauner *et al*., 2012). Nowadays, research show that the ingestion of suitable quantities of food fiber produces many beneficial effects on the digestive tract, such as the regulation of the intestinal function, improvement of the tolerance to glucose in diabetics (Pins *et al*., 2002 & Ajila and Prasada, 2013) or prevention of chronic diseases as colon cancer (Mongeau, 2003) and anti-carcinogenic effects (Scharlau *et al*., 2009 & Ajila and Prasada, 2013). Also, several fibers have demonstrated, in vitro, and in vivo, their capacity for adsorbing carcinogenic agents, (Steinmetz and Potter, 1991; Slavin, 2001 & Rodríguez *et al*., 2006).

In a Harvard study of over 40,000 male health professionals, researchers found that a high total dietary fiber intake was linked to a 40 percent lower risk of coronary heart disease and lower risk of metabolic syndrome, such as high blood pressure, high insulin levels, excess weight (especially around the abdomen), high levels of triglycerides, and low levels of HDL (good) cholesterol *(*Pereira *et al*., 2004). Several studies suggest that higher intake of fiber may offer protective benefits from this syndrome (McKeown *et al*., 2002, 2004). Eating dietary fiber, particularly insoluble fiber, was associated with about a 40 percent lower risk of diverticular disease (Aldoori *et al*., 1998). One of Harvard studies found that dietary fiber was not strongly associated with a reduced risk for either colon cancer or polyps (a precursor to colon cancer) (Fuchs *et al*., 1999). A large-scale 2016 study led by researchers at Harvard T.H. Chan School of Public Health showed that higher fiber intake reduces breast cancer risk. (Farvid *et al*., 2016).

The diets with a high content of fiber, such as those rich in cereals, fruits and vegetables have a positive effect on health since their consumption has been related to a decreased incidence of several types of diseases as due to its beneficial effects like increasing the volume of fecal bulk, decreasing the time of intestinal transit, cholesterol and glycemic levels, trapping substances that can be dangerous for the human organism (mutagenic and carcinogenic agents), stimulating the proliferation of the intestinal flora… etc. (Heredia *et al*., 2002 & Beecher 1999). Summary of functions and health benefits of DF presented in table (2) .

Guar gum is readily fermented by the human fecal microbiota (Salyers *et al*., 1977), improves bowel functioning and relieves constipation in patients (Takahashi *et al.* 1994). Gear *et al*., (1979), It has been postulated that the fiber may act as a protective factor in cancer of the large bowel by shortening transit time, thus reducing the time for formation and action of carcinogens. In addition, through its stool-bulking effect, fiber may lower the concentration of fecal carcinogens thereby reducing the amount of carcinogen that comes in contact with the gut wall. The large amount of fiber from fruits, vegetables and legumes is partly responsible for the low levels of plasma cholesterol (Anderson *et al*., 1973). Pectin (Kay and Truswell 1977), guar gum and gum arabic also show a hypolipidemic effect in humans, lowering both serum cholesterol and triglycerides (Takahashi *et al*., 1993). Dietary fiber can prevent the absorption of harmful substances but will also prevent the absorption of proteins, inorganic salt and some minerals in food, a problem for people who need more of these nutrients, such as actively growing teenagers **(**Yue-yue *et al*., 2017**).**

How much fiber do you need?

Recommended adult intakes for total fiber range from 21 to 40 g/day in countries which have developed guidelines. These guidelines came from the recommendation of consuming 14g/1000 kcal, and then converting the value to g of fiber/d based on energy intake. This means that the higher the recommended energy intake level, the higher the fiber recommendation. The World Health Organization has recommended that total fiber intake be 25 g/day (WHO/FAO, 2003 & Food and Nutrition Board, Institute of Medicine, 2001). Numerous health organizations suggest increasing the consumption of DF, to 30-45 g per day (Bonfeld, 1985; Eastwood, 1987; Grigelmo-Miguel *et al*., 1999a). This current DRI value is an adequate intake level and is based on the decreased risk of coronary heart disease with dietary fiber consumption (Alinorm, 2010). Daily intake for total fiber for adults has been set at 38 g for men and 25 g for women (Trumbo, *et al*., 2002; Soukoulis *et al*., 2009 & Ramirez-Santiago *et al*., 2010). Recommendations for both genders at all age groups (Table 3). Thus, girls and women in each age group have a lower recommended value than do boys or men.

Table 2: Functions and benefits of dietary fiber on human health.

Functions	Benefits
Adds bulk to the diet, making feel full faster	May reduce appetite
Attracts water and turns to gel during digestion, trapping carbohydrates and slowing absorption of glucose	Lowers variance in blood sugar levels
Lowers total and LDL cholesterol	Reduces risk of heart disease
Regulates blood pressure	May reduce onset risk or symptoms of metabolic syndrome and diabetes
Speeds the passage of foods through the digestive system	Facilitates regularity
Adds bulk to stool	Alleviates constipation
Balances intestinal pH and stimulates intestinal fermentation	May reduce risk of colorectal cancers
production of short-chain fatty acids	

Source: (Devinder *et al*., 2012).

Table 3: Recommended adequate intake levels for fiber gram/day.

Age, year	Male	Female
	g/d	
1–3	19	19
4–8	25	25
9–13	31	26
14–18	38	26
19–50	38	25
51	30	21

Adapted from (Institute of Medicine, National Academy of Sciences 2005).
Adequate Intakes for females are increased to 28 g/d during pregnancy and to 29 g/d for lactation.

Using of too much fiber can prevent the absorption of minerals by the body as iron, zinc, calcium and magnesium. Using of high fiber in a short time may cause gas, bloating, and abdominal cramps. Therefore, gradually increasing fiber in nutrition will protect from these side effects. (Erişim tarihi., 2013).

Fiber supplements are also available to increase the intake of dietary fiber; however, most experts recommend that fiber should be obtained through the consumption of foods, because this form allows consumption of many micronutrients and bioactive compounds contained in high-fiber foods, which provide their own nutritional benefits.

Some tips for increasing fiber intake

Eating whole fruits instead of drinking fruit juices, 2. Replace white rice, bread, and pasta with brown rice and whole grain products, 3. For breakfast, choose cereals that have a whole grain as their first ingredient, 4. Snack on raw vegetables instead of chips, crackers, or chocolate bars, 5. Substitute beans or legumes for meat two to three times per a week, also, 6.Drink plenty of water. Fiber works best when it absorbs water, making stool soft and bulky. Getting enough fiber is important for overall health and disease prevention.

Sources of the Dietary Fiber.

Dietary fiber is naturally present in cereals, vegetables, fruits and nuts. The amount and composition of fibers differ from food to food (Desmedt and Jacobs 2001). Several non-starch food provide up to 20–35 g of fiber/100 g dry weight and those containing starch provide about 10 g/100 g of dry weight and the content of fiber of fruits and vegetables is 1.5–2.5 g/100 g of dry weight (Selvendran and Robertson 1994). Lambo *et al*., (2005) reported, cereals to be one of the main sources of dietary fiber, contributing to about 50% of the fiber intake in western countries, 30–40% dietary fiber may come from vegetables, about 16% from fruits and the remaining 3% from other minor sources. Dietary fiber content of various foods is presented in table (4). Fiber can even be produced from sources that might otherwise be considered waste products. For example, wheat straw, soy hulls, oat hulls, peanut and almond skins, corn stalks and cobs, spent brewers grain and waste portions of fruits and vegetables processed.

Obtaining and Analysis of Dietary Fiber:

Recent development in dietary fiber methodology has adopted two general approaches (Asp, 2001): enzyme-gravimetric and enzyme- chemical methods. Enzyme-gravimetric methods, it involves enzyme treatments for starch and protein removal, precipitation of soluble fiber components by aqueous ethanol, isolation and weighing of the dietary fiber residue and correction for protein and ash in the residue (Asp and Johansson 1981; Asp, *et al*. 1992).

According to Hong, *et al*., (2012) generally, there are three methods to gain dietary fiber: Chemical method, physical method and microbial fermentation. Removal of starch and protein can be more complete using chemical method, but the poor selectivity, side-effects and difficultly controlled extraction conditions greatly limit its use (Wang, *et al*., 2004 & Du, *et al*., 2005). What are worse, hemicellulose and soluble dietary fiber which play an important role in physiological function are soluble in alkaline solution. Thus, this method can cause the undesired decrease of overall physiological activity (Zhang, *et al*., 2011). Physical method, such as extrusion cooking, does not cause degradation of the polymer structure or some other deep damage. Therefore, the side chain group can be preserved almost intact, which enables the cation exchange capacity not to be impacted (Ma, *et al.,* 2005; Liu, *et al.,* 2005 & Jacobs and Delcour, 1998). Recently, microbial fermentation of dietary fiber has been widely recognized and accepted due to the high selectivity, mild and easily controlled reaction conditions (Liu, 2008). It has also the advantage of not destroying the structure of natural fiber and no loss of important physiologically functional SDF and hemicellulose. However, the microbial fermentation itself is still in its infancy stage and microbial fermentation of DF may produce toxic substances, thus affecting its safety (Li., 2003). The method was based on the enzymatic removal of protein from the material and the separation into soluble and insoluble fractions by centrifugation, Figure (1), (Mańas, 1992 & Grigelmo, *et al*., 1999). The experimental procedure followed by Manaas, (1992) was a modification of the AOAC method (Prosky, *et al*., 1984).

Table 4: Dietary fiber content of various food sources (g/100 g edible portion).

Dietary fiber	Total	Insoluble	Soluble	Dietary fiber	Total	Insoluble	Soluble
Grains				Cucumbers, peeled	0.6	0.5	0.1
Barley	17.3	–	–	Cauliflower, raw	1.8	1.1	0.7
Corn	13.4	–	–	Celery, raw	1.5	1	0.5
Oats	10.3	6.5	3.8	Carrot, raw	2.5	2.3	0.2
Rice (dry)	1.3	1	0.3	Broccoli, raw	3.29	3	0.29
Rice(cooked)	0.7	0.7	0	**Fruits**			
Wheat(whole grain)	12.6	10.2	2.3	Apple, unpeeled	2	1.8	0.2
Wheat germ	14	12.9	1.1	Kiwi	3.39	2.61	0.8
Legumes & pulses				Mango	1.8	1.06	0.74
Green beans	1.9	1.4	0.5	Pineapple	1.2	1.1	0.1
Soy	15	–	–	Pomegranate	0.6	0.49	0.11
Peas, green frozen	3.5	3.2	0.3	Watermelon	0.5	0.3	0.2
Kidney beans, canned	6.3	4.7	1.6	Grapes	1.2	0.7	0.5
Lentils, raw	11.4	10.3	1.1	Oranges	1.8	0.7	1.1
Lima beans, canned	4.2	3.8	0.4	Plums	1.6	0.7	0.9
White beans, raw	17.7	13.4	4.3	Strawberry	2.2	1.3	0.9
Vegetables				Bananas	1.7	1.2	0.5
Potato, no skin	1.3	1	0.3	Peach	1.9	1	0.9
Bitter gourd	16.6	13.5	3.1	Pear	3	2	1
Beet root	7.8	5.4	2.4	**Nuts and seeds**			
Fenugreek leaves	4.9	4.2	0.7	Almonds	11.2	10.1	1.1
Ladies finger	4.3	3	1.3	Coconut, raw	9	8.5	0.5
Spinach, raw	2.6	2.1	0.5	Peanut, dry roasted	8	7.5	0.5
Turnips	2	1.5	0.5	Cashew, oil roasted	6	–	–
Tomato, raw	1.2	0.8	0.4	Sesame seed	7.79	5.89	1.9
Green onions, raw	2.2	2.2	0	Flaxseed	22.33	10.15	12.18
Eggplant	6.6	5.3	1.3				

Source: Farhath Khanum *et al*., (2000) and Schakel *et al*., (2001)

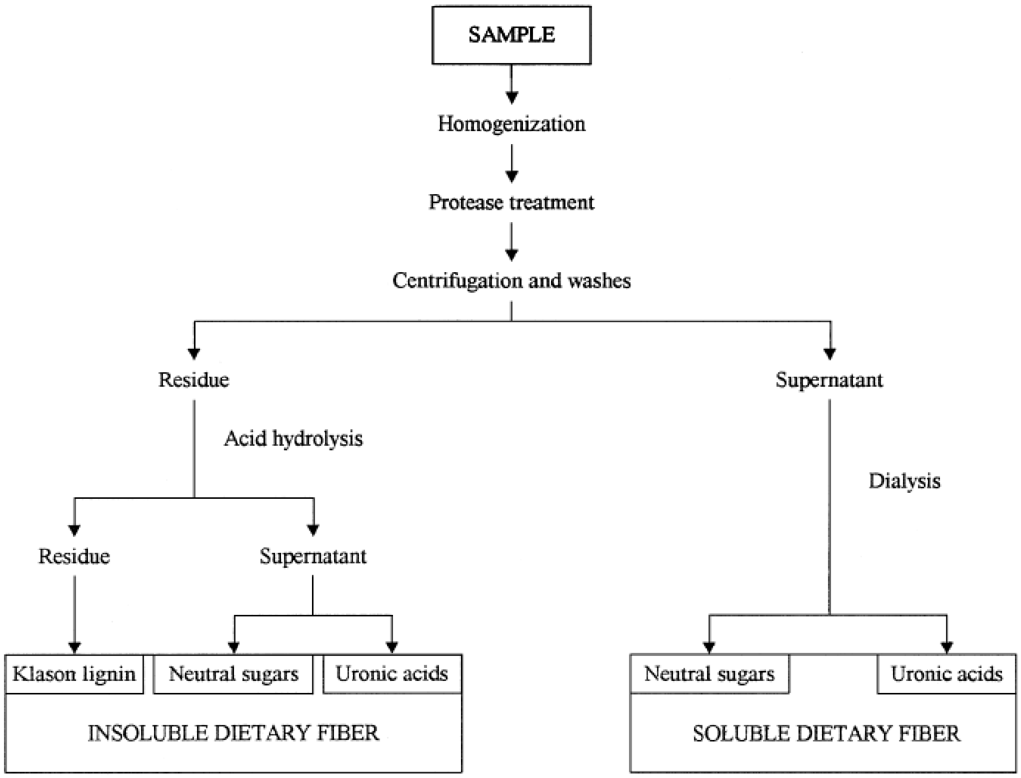

Figure (1): Flow diagram for dietary fiber analysis procedure (Filiz Yangilar *et al.,* 2013).

Enzyme-chemical methods, these methods involve enzyme removal of starch, precipitation with 80% (v/v) ethanol to separate the soluble dietary fiber polysaccharides from low molecular weight sugars and starch hydrolysis products. Enzyme-gravimetric methods involves enzyme treatments for starch and protein removal, precipitation of soluble fiber components by aqueous ethanol, isolation and weighing of the dietary fiber residue and correction for protein and ash in the residue (Asp and Johansson 1981 & Asp, *et al*., 1992). Chemical analysis is generally used to determine the components of dietary fiber, and is often combined with enzymatic methods by using enzymatic treatment to remove the starch and using anhydrous ethanol for precipitation to obtain total dietary fiber. HPLC can be used to determine the composition of dietary fiber by chemical analysis. HPLC is a relatively mature method and shows good repeatability and high precision (Redondo 1994). FT-IR spectroscopy can also be used to determine fruit dietary fiber composition (Chylinska 2016).

Mongeau and Brooks (2016), presented a brief overview and comparison of common methods for quantifying DF in food. Schweizer and Wursch (1979) employed GLC method for the characterization of gravimetrically determined soluble dietary fiber residues. Graham *et al*., (1988) examined the influence of extraction conditions on the solubility of dietary fiber in four cereals (wheat, rye, barley and oats) and four vegetables (potato, carrot, lettuce and peas). It was observed that the extraction at high temperature gave the highest values for soluble fiber, whereas the extraction in the acidic buffer gave the lowest value. Larrauri, (1999), described the procedure to obtain DF powders from fruit by-products. Ng, *et al*., (2010), extracted and characterized of DF from coconut residue. Vajiheh and Mania (2012), extracted DF from rice husk by the chemical and enzymatic methods. Dietary fibers were prepared as alkali- and acid-insoluble fractions with chemical phosphorylation from various foods. The dietary fiber fractions treated with alkaline solution and followed by phosphorylation with sodium metaphosphate had the lower protein content, higher total dietary fiber content and water holding capacity than those of the preparations without phosphorylation treatment.

The optimum extraction of banana peel cellulose (BPC) and bleaching conditions included using 90% ethanol for 16 h for fat removal, followed by sodium hydroxide pH 11.6 for 24 h for elimination of protein, and soaking in 15% hydrogen peroxide for 3 h for bleaching. The obtained BPC was washed and dried at 60 C for 10 h. (Singanusong**,** *et al***.,** 2013**).** Qi *et al*., (2011), studied the effect of cellulase on extraction rate of SDF and IDF, and optimize the effects of the cellulase that included four factors: the time, temperature, pH of cellulase action, and the rate of cellulase.

Effect of Food Processing on Dietary Fibers

Modification methods are used to transform IDF into SDF for better physicochemical and physiological properties (Feng *et al.,* 2017). Modification methods include mechanical degradation “extrusion cooking, high pressure, heating, or novel technology to mechanically disrupt the fiber”, chemical treatment use chemical reagents such as acid and alkali to break down dietary fiber, enzymatic, and microbiological fermentation methods. Typically, a combined method may have greater effects than any single approach. For example, chemical-enzymatic, ultrasound-enzymatic, and microwave enzymatic.

Extrusion cooking had a positive effect on total and soluble dietary fiber. The insoluble dietary fiber decreased appreciably with the varying processing parameters, probably due to disruption of covalent and non covalent bonds in the carbohydrate and protein moieties leading to smaller and more soluble molecular fragments. Additionally, the water solubility index was greatly enhanced by varying extrusion temperature and screw speed (Feng *et al.,* 2017).

Liu *et al.* studied the use of instantaneous high pressure for soybean dreg dietary fiber and found significantly increased soluble dietary fiber content after treatment. Additionally, the physical characteristics (expansibility, water holding capacity, water- binding ability, and specific surface area) of the modified dietary fiber were deferent from those of the unmodified dietary fiber (Huang and Ma 2016).

Carboxymethylation is also frequently used as a method of chemical modification and effects dietary fiber. A study reported improved SDF for dietary fiber extracted from whole grain barley by carboxymethylation (Park *et al.,* 2013).Enzymatic modification uses enzymes to degrade the dietary fiber, decreasing IDF and improving SDF. Microbial fermentation uses organic acids and enzymes produced naturally by microorganisms to reduce the molecular weight and improve the solubility of dietary fiber (Yang, *et al*., 2017).

The physico-chemical properties of fiber can be manipulated through treatments such as chemical, enzymatic, mechanical (grinding), thermal or thermo mechanical (extrusion, cooked-extrusion). Grinding may affect the hydration properties, in particular, the kinetics of water uptake as a result of the increase of surface area, the fibers hydrate more rapidly. Heating generally changes the ratio of soluble to insoluble fiber. Simple processes such as soaking and cooking tend to modify the composition and availability of nutrients**.** Processes, such as grinding, drying, heating or extrusion cooking for example, modifies the physical properties of the fiber matrix and also affect the hydration properties (Thibault, *et al*., 1992).

Honcu, *et al*., (2016) concluded that extrusion process is able to modify the physico-chemical properties of barley fiber components. Ng, *et al*., (1999) found that extrusion cooking increased the solubility of pectic polymers and hemicelluloses accompanied by an increase in swelling of the cell-wall material. Larrea, *et al*., (2005) modified the properties of fiber components in orange pulps using extrusion technology. They reported that extrusion conditions decreased IDF and increased SDF.

In wheat bran, it has been found that thermal treatments (boiling, cooking or roasting) originate an increase of total fiber that is not due to new synthesis, but rather to the formation of fiber-protein complexes that are resistant to heating and are quantified as dietary fiber (Caprez, *et al*., 1986). During cooking of lentils previously dipped, the quantity of fiber diminishes, fundamentally due to great decrease in hemicelluloses (Vidal-Valverde, *et al*., 1992).

The effects of thermal treatment (including extrusion cooking, boiling and frying) on the dietary fiber composition of cereals and potato samples were studied by Varo, *et al*., (1983), heat treated potato samples contained more water insoluble dietary fiber and less starch than raw samples. No changes were observed in the amounts of dietary fibers and starch in the extruded samples. The effects of domestic cooking on dietary fiber and starch composition of processed potato products were evaluated by Thed and Phillips (1995), they reported that microwave heating and deep fat frying significantly increases both the resistant starch (RS) and water-insoluble dietary fiber (IDF). Water-soluble dietary fiber content was not affected by any of the domestic cooking methods.

Chopra, *et al*., (2009) studied the effect of soaking on insoluble, soluble and total dietary fiber of Bengal gram, cow pea, dry pea, field bean and green gram. Samples were soaked in tap water (1:2) for 12 h at room temperature (29–31°C). Soaking increased total dietary fiber by 8.2% and a considerable increase in soluble dietary fiber was observed. Raghavendra, *et al*., (2006) evaluated the grinding characteristics of coconut residue and observed that the reduction in the particle size from 1,127–550 µm resulted in increased hydration properties, Beyond 550 µm, the hydration properties were found to decrease with decrease in particle size during grinding. The fat absorption capacity was also reported to increase with decrease in particle size.

Camire and Flint, (1991) observed an increase in total non-starch polysaccharides in oat meal and potato peels with extrusion and baking processes, but the ratio of soluble to insoluble non-starch polysaccharides was higher in the extruded samples. The process of extrusion increased the hydration capacity of corn meal and oat meal but the hydration capacity of processed potato peels was observed to be lower than raw peels.

The environmental conditions such as temperature, pH, ionic strength, dielectric constant of the surrounding solution and nature of the ions can also influence the hydration characteristics of fiber containing poly-electrolytes (charged groups such as carboxyl in fibers rich in pectin, carboxyl and sulfate groups in fibers from algae) (Fleury and Lahaye 1991 & Renard *et al*., 1994). Supercritical CO_2 affects pear pomace insoluble dietary fiber physicochemical properties, the glucose adsorption capacity and glucose retardation. Index of IDF were significantly higher after supercritical CO_2 treatment. (Chang, *et al.,* 2016).

Application of Dietary Fiber in Food Industry

Dietary fibers can provide a multitude of functional properties when incorporated in food systems. Thus, addition of fibers contributes to the modification and improvement of the texture, sensory characteristics and shelf-life of foods due to their water binding capacity, gel-forming ability, fat mimetic, antisticking, anticlumping, texturising and thickening effects (Dello Staffolo, *et al*., 2004; Gelroth and Ranhotra, 2001 & Thebaudin and Lefebvre 1997). Most commonly, dietary fibers are incorporated into bakery products to prolong freshness, thanks to their capacity to retain water, thereby reducing economic losses. Fibers can modify bread loaf volume, its springiness, the softness of the bread crumbs and the firmness of the loaf (Sangnark and Noomhorm, 2004 & Wang*, et al*., 2002). Dietary fibers from different sources have been used to replace wheat flour in the preparation of bakery products. Pomeranz*, et al*., (1977) used cellulose, wheat bran and oat bran in bread making. Potato peel, a by-product from potato industry, rich in dietary fiber, was used as a source of dietary fiber in bread making (Toma, *et al*., 1979 & Sudha *et al*., 2007).

Among foods enriched in fiber, the most known and consumed are breakfast cereal and bakery products such as integral breads and cookies (Cho and Prosky, 1999; Nelson, 2001 & Rodríguez, *et al*., 2006), as well as milk and meat derived products. The addition of DF to bakery products also improves their nutritional quality since it makes possible to decrease the fat content, by using DF as substitute of fat without loss of quality (Byrne, 1997; Martin, 1999 & Rodríguez, *et al.*, 2006). Isolated fiber components such as resistant starch and ß-glucans are also used for increasing fiber content in pastries, breakfast cereal,… etc. (Knuckles, *et al.*, 1997 & Rodríguez, *et al*., 2006). Comprehensive evaluation of potential applications of dietary fibers in flour products, addressing common problems such as dark color and rough texture and reviewing potential solutions (Wen Han *et al*., 2017).

Introduce of dietary fiber in meat products has been shown to improve cooking yield, water binding, fat binding, and texture (Cofrades, *et al*., 2000). Fiber addition in meat products may effectively increase acceptability by giving meat products higher quality, improving the processing characteristics, the yield and lengthening the shelf time of meat products, (Talukder, 2015). Dietary fiber and soy protein preparations due to their functional properties are extensively used in many branches of the food industry, including the meat sector (Bilska, *et al*., 2002; Hoogenkamp, 2007; Jiménez-Colmenero, *et al*., 2005; Makała and Olkiewicz, 2004; Pietrasik and Duda, 2000 & Waszkowiak and Szymandera-Buszka 2008). Dietary fber has been used as a fat substitute and added into sausages (Ham, *et al.,* 2016).

Citrus fiber may be incorporated into a broad range of products. For example meat products (Alesón-Carbonell, *et al*., 2005 & Fernández-López *et al*., 2007), fish (Sanchez-Zapata *et al.*, 2008 & Viuda-Martos *et al*., 2010). Viuda-Martos, *et al*., (2010), analyzed the effect of orange dietary fiber (ODF), oregano essential oil (OEO) and the storage conditions (vacuum, air and modified atmosphere) on the shelf-life of bologna sausage. ODF and OEO samples stored in vacuum packaging showed the lowest aerobic and lactic acid bacteria count. The sensory evaluation scores were similar for samples with ODF and OEO, and stored either in air or vacuum packaging. Orange dietary fiber, cellulose, soy, wheat, maize or rice isolates and beet fiber can be used for improving the texture of meat products, such as sausages, salami. At the same time, they are adequate to prepare low-fat products, such as 'Dietetic hamburgers'. Since they have the ability of increasing the water retention capacity, their inclusion in the meat matrix contributes to maintain its juiciness (Chevance, *et al*., 2000 & Mansour and Khalil 1999).

Oat bran or oat fiber appears to be suitable fat replacement in ground beef and pork sausage products due to its ability to retain water and emulate particle definition in ground meat in terms of both color and texture (Verma and Banerjee, 2010). In an attempt to develop low salt, low fat and high fiber functional chicken nuggets, Verma, *et al*., (2009) incorporated various fiber sources like, pea hull flour, grain hull flour and apple pulp at 10% level.

The use of fibers in dairy products is also widespread, e.g., inulin introduces numerous improvements into dairy products. It improves body and mouth feel in cheese analogues or ice-cream, and reduces syneresis in yoghurt and other fermented milk products (Blecker, *et al*., 2001). Soukoulis, *et al*., (2009), investigated the effects of four dietary fiber sources (oat, wheat, apple and inulin) on the rheological and thermal properties of model sucrose polysaccharides solutions and ice cream mixes. The content of fiber in insoluble compounds, significantly increased the viscosity and the shear thinning behavior of the model solutions and ice creams, due to the increase of total solids and the formation of networks comprised of hydrated cellulose and hemicellulose. The increase of soluble material did not significantly alter the rheology of the samples but limited the freezing point depression and elevated the glass transition temperatures, indicating a potential cryoprotective action. The use of oat and wheat fiber favored viscosity development due to water-binding. Whereas inulin caused a remarkable increase of glass transition temperature (Tg) in model solutions and ice cream mixes, indicating the reduction of water mobility from the bulk aqueous phase to the ice crystals' surface. Apple fiber addition greatly increased viscosity and elevated the Tg values, particularly in the presence of proteins. Results suggested that the potential use of dietary fibers as crystallization and recrystallization phenomena controllers in frozen dairy products.

Fagan, *et al*., (2006), studied the effects of soluble dietary fiber inclusion on milk coagulation kinetics. Addition of 2% (w/w) inulin was required to decrease gel time and coagulum firming time and no discernible difference was observed between the inulin enriched and control gels. Pectin (0.2-0.4% (w/w)) significantly reduced gel times. Above 0.2% (w/w), added pectin increased coagulum firming times and resulted in a limited casein network developing. Dietary fiber (DF) extracted from date flesh showed a high water-holding capacity (~15.5 g water/g sample) and oil-holding capacity (~9.7 g oil/g sample) and pseudo plasticity behavior of their suspensions. Thus, date DF concentrates may not only be an excellent source of DF but an ingredient for the food industry (Elleuch*, et al*., (2008).

Garcia-Perez, *et al*. (2005) reported that yogurt containing 1% orange fiber had a lighter, more red and yellow color and showed lower syneresis than the control and yogurt containing 0.6% and 0.8% orange fiber. Addition of 0.5% barley β- glucan or inulin and guar gum (>2%) were effective in improving serum retention and viscoelastic properties of low-fat yogurt (Brennan and Tudorica 2008). Incorporation of fiber obtained from asparagus shoots, increased yogurt consistency and imparted a yellowish greenish color to the yogurt (Sanz, *et al.*, 2008). Some types of soluble fibers, such as pectin, inulin, guar gum and carboxymethyl-cellulose, are utilized as functional ingredients in the milk products (Nelson, 2001). Fermented milk enriched with citrus fiber (orange and lemon) had good acceptability (Sendra, *et al*., 2008). Dello Staffolo, *et al*., (2004) observed the yogurt fortified with 1.3% wheat, bamboo, inulin and apple fibers appeared to be promising avenue for increased fiber intake, with higher consumer acceptability. Hashim, *et al*., (2009) studied the effect of fortification with date fiber, a by-product of date syrup production, on fresh yogurt. Yogurt fortified with 3% date fiber resulted in similar sourness, sweetness, firmness, smoothness and overall acceptability as the control yogurt.

Sharif, *et al*., (2009) concluded that replacement of wheat flour with defatted rice bran could be used without adversely affecting physical and sensory characteristics of cookies. Rice bran supplementation significantly improved the dietary fiber, mineral and protein content of the cookies. Addition of fiber ingredients such as alginates, guar gums and cellulose gels not only replaces fat but also serves to provide viscosity, improve emulsion, foam, freeze/thaw stability, control melting properties, reduce syneresis, promotes formation of smaller ice crystals and facilitate extrusion (Alexander, 1997). Coffee grounds were added to cookies for increased dietary fiber source, resulting in more nutritious and more flavorful cookies with potential value in the prevention of diabetes (Martinez-Saez et al., 2017).

In case of beverages and drinks, the addition of dietary fiber increases their viscosity and stability, soluble fiber being the most used because it is more dispersible in water than insoluble fiber. Oat fiber can be incorporated into milk shakes, instant type-breakfast drinks, fruit and vegetable juices, ice tea, sports drinks, cappuccino and wine. Other beverages that can benefit from the addition of fiber include liquid diet beverages- both those created for people with special dietary needs as well as weight loss or meal replacement beverages (Hegenbart, 1995). Larrauri, *et al*., (1995) described the manufacture of powdered drink containing dietary fiber from pineapple peel. The product, called FIBRALAX, contained 25% dietary fiber and 66.2% digestible carbohydrates, and provided a mild laxative effect.

Conclusions

Dietary fiber is primarily derived from plant material and is composed of complex, non starch carbohydrates and lignin that are not digestible within the small intestine. Fiber is commonly classified as soluble or insoluble. Each fraction has different physiological effects. Dietary fiber plays an important role in human health; it is showing protective effects toward cardiovascular disease, diverticulosis, constipation, irritable colon, colon cancer, obesity, and diabetes. DF also prevents the absorption of proteins, inorganic salt and some minerals in food, which is a problem for people who need more of these nutrients, such as actively growing teenagers. Dietary fibers from cereals are more frequently used than those from fruits; however, fruit fiber have better quality due to higher total and soluble fiber content, water and oil holding capacity and colonic fermentability, as well as lower phytic acid content and caloric value. It is recommend that fiber be obtained through the consumption of foods, because this form allows consumption of many micronutrients and bioactive compounds. Daily intake of total fiber for adults has been set at 38 g for men and 25 g for women. Adding too much fiber can quickly promote intestinal gas, abdominal bloating and cramping. Fiber increase in diet should be gradual over a period of few weeks with drinking plenty of water. This allows the natural bacteria in digestive system to get adjusted to the change. Also, fiber works best when it absorbs water, making stool soft and bulky. To avoid intolerance to grain and legume we should look for other fiber sources such as vegetables, fruits and other seeds/nuts. Fiber supplements don’t provide the micronutrients, phytochemicals, and water found in whole plant foods.

Dietary fiber analysis methodology has adopted two general approaches, enzyme-gravimetric and enzyme-chemical methods. The physico-chemical properties of fiber can be manipulated through treatments such as chemical, enzymatic, mechanical (grinding), thermal or thermo mechanical (extrusion). Dietary fibers can provide a multitude of functional properties when incorporated in food systems, contributing to the improvement of food texture, sensory characteristics and shelf-life of foods, due to their water binding capacity, gel-forming and fat mimetic ability, anti-sticking, and thickening effects. Addition of fiber ingredients such as alginates, guar gums and cellulose gels not only replaces fat, but also serves to provide viscosity, improve emulsion, foam, freeze/thaw stability, control melting properties, reduce syneresis, promotes formation of smaller ice crystals and facilitate extrusion.

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الفوائد الصحية وإستخلاص وإستخدام الألياف الغذائية: بحث مرجعي

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الملخص العربى

الألياف الغذائية هي عبارة عن الجزء النباتي في الوجبة الغذائية والتي لا تهضم بواسطة أنزيمات القناة الهضمية. وتشتمل الألياف الغذائية علي كل من السليلوز والمواد البكتينية والصموغ والميسيلاج والمادة الغير كربوهيدراتية (اللجنين).

تقسم الألياف الغذائية إلي نوعين تبعا للذوبان في الماء وهما الألياف الغذائية الذائبة والغير ذائبة وكلاهما له تأثير فسيولوجي مختلف.

الوجبات الغذائية ذات المحتوي المرتفع من الألياف تشترك في الحماية ومعالجة بعض الأمراض مثل الإمساك ، أمراض إلتهاب الأمعاء ، السرطان ، أمراض القلب ومرض السكر. الإحتياج اليومي من الألياف للبالغين هو 38 جرام للرجال و25 جرام للسيدات.

يتم الحصول علي الألياف الغذائية من مصادر مختلفة بواسطة طرق مختلفة. كمية وتركيب الألياف تختلف من غذاء إلي آخر. تعتبر الحبوب من أعلي الأغذية إحتواء علي الألياف علي الرغم من إنخفاض محتواها من الألياف الذائبة في حين تحتوي الفاكهة علي نسبة من الألياف الذائبة والغير ذائبة أكثر توازنا.

كثير من المعاملات وطرق التصنيع مثل الطبخ مع البثق الحراري – التعليب – الطحن – الغلي – التجميد يؤثر علي الخواص الفيزيوكيميائية للألياف الغذائية وتحسن من خواصها الوظيفية.

إضافة الألياف الغذائية في الأنظمة الغذائية تعمل علي تحسين القوام والخواص العضوية الحسية وزمن الحفظ للأغذية وهذا راجع إلي ثدرة الألساف علي ربط الماء وتكوين جل وإستبدال الدهن كما تساعد في إنتفاخ القوام وعدم الإلتصاق.

يمكن إستخدام الألياف الغذائية في العديد من الأغذية الوظيفية مثل منتجات المخابز ، المشروبات ومنتجات اللحوم. يتم تقدير الألياف الغذائية بواسطة العديد من الطرق وخاصة طريقة enzymatic gravimetric وطريقة enzymatic chemical methods .

الكلمات الإرشادية : الألياف الغذائية – تقسيمها – مصادرها – الفوائد الصحية – طرق التقدير والإستخلاص – تطبيقات في الصناعة.