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A review on dietary fiber: definitions, classification, importance and advantages for human diet and guidelines to promote consumption

Diarra COMPAORE-SEREME[1,2*], Fidèle Wend-bénédo TAPSOBA[1], Douamba ZOÉNABO[1], Clarisse S COMPAORÉ[1] , Mamoudou H DICKO[2] and Hagrétou SAWADOGO-LINGANI[1]

[1]*Département Technologie Alimentaire (DTA)/Institut de Recherche en Sciences Appliquées et Technologies (IRSAT) /Centre National de la Recherche Scientifique et Technologique (CNRST), 03 BP 7047, Ouagadougou 03, Burkina Faso.*

[2]*Laboratoire de Biochimie, Biotechnologie, Technologie Alimentaire et Nutrition (LABIOTAN), UFR/SVT, Université Joseph KI-ZERBO, Ouagadougou 03, Burkina Faso.*

[*]*Corresponding author; E-mail: sdiarra6@yahoo.com, Telephone:+226 60 19 8908*

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ABSTRACT

The definitions of dietary fiber are based on scientific and regulatory purposes, mainly with emphasis on its functional impact and benefits to the organism. The aim of this review was to present dietary fiber classification, benefits and importance for human diet and recommendations to promote its consumption. The methodology used in this review is a drawn perspective from recently available classification and no attempt was made to make an exhaustive review of all articles related to dietary fiber. In the results, the structure, characteristics, the content of various food products on dietary fiber with a focus on cereal grains and benefits are presented; global guidelines and recommendations are included in this review. The link between dietary fiber intake and the prevention of various diseases such as cardio vascular disease, type 2 diabetes, digestive diseases, and some cancers, is plausible pertaining to the literature. Dietary guidelines in some countries recommend, on average, the consumption of 3 to 8 servings/day or 300 to 500 g/day of cereals and legumes in total (depending on age, gender or caloric needs) with at least half of your grain products as whole grains each day to meet daily dietary fibre requirements and reduce disease risk.

Keywords: dietary fiber, classification, resistant starch, gut health, guideline

INTRODUCTION

Emerging diet-related nutritional pathologies such as obesity, cancers, diabetes, cardiovascular diseases as well as respiratory diseases constitute a public health problem especially in cities (Bricas and Tchamba, 2017). They are known to be the consequence of a combination of factors, including genetic predisposition, environmental factors, lifestyle factors, and socioeconomic conditions (Alwan et al., 2010; IHME 2018). On the other hand, studies in nutritional epidemiology have shown the link between the consumption of dietary fiber from cereals and their potential beneficial effects in the prevention, control and reduction of cases of these diseases (Threapleton et al.,

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2013; Huang et al., 2015). With urbanization, lifestyle changes and refined grain consumption patterns result in a significant loss of nutrients and bioactive compounds from grains. Indeed, in the general process of cereal grains in cities, the bran is removed by dehulling, even though it is the part rich in dietary fiber and B vitamins. This dehulling operation, a common practice in food manufacturing, is linked to consumer preferences for refined flour products, especially for sensory attributes such as color and mouthfeel (Awika, 2011). Various chronic diseases such as obesity, cardiovascular disease and **some** cancers are growing exponentially worldwide and have been associated with a diet low in whole grains (Machado et al., 2022). Eating whole grain foods, which contain a certain amount of dietary fiber and micronutrients, may reduce the risk of these diseases. The beneficial effects of dietary fiber include lowering blood pressure, lowering blood lipids and glucose, improving insulin resistance, as well as effects on the composition of the gut microbiome (Franz and Sampson 2006; Ferruzzi et al., 2014). Guidelines have therefore been developed by many countries to increase the consumption of dietary fiber from various sources but mainly from cereals (Ferruzzi et al., 2014), the latter constituting the basis of the diet and contributing two-thirds of caloric intake in West Africa (Bricas and Tchamba, 2017). In view of the various recommendations aimed at promoting dietary fiber consumption, it is important to better understand dietary fiber through their definitions, classifications and potential beneficial effects in the diet of populations.

DEFINITION AND CLASSIFICATION OF DIETARY FIBER

Many scientific communities such as the American Association of Cereal Chemists (AACC) and the Institute of Medicine (IOM) of the U.S. National Academy, as well as food regulatory agencies including the U.S. Food and Drug Administration (FDA), the Food and Agriculture Organization of the United Nations (FAO/WHO), the Codex Alimentarius, and the European Food Safety Authority (EFSA), have attempted to define dietary fiber for scientific and/or regulatory purposes.

The term "dietary fiber" was used in reference to plant cell wall materials and has evolved to describe a class of plant-based polysaccharides that cannot be digested and absorbed in the human gastrointestinal tract (van der Kamp, 2004). Dietary fiber is defined as "the edible parts of plants or carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine". This scientific definition from the American Association of Cereal Chemists takes into account the origin, chemical and physiological aspects of fibers (van der Kamp, 2004; Sultan et al., 2022).

According to the regulations, dietary fiber in consumer foods can be classified into two categories: endogenous dietary fibers and added dietary fibers.

-Endogenous fibers refers to intrinsic and intact fibers present in the original food matrix. Endogenous dietary fiber is composed of non-digestible carbohydrates and lignin that are intrinsic and intact in plants (USDHH and USDA, 2015).

- Added fiber refers to a group of fibers that are either extracted from natural sources or synthetically produced and added to foods, beverages and supplements (USDHH and USDA, 2015). These are also called functional fibers (Institute of Medicine 2001). Added dietary fiber consists of isolated, non-digestible carbohydrates that have physiological effects in humans (Phillips and Cui, 2011).

A general classification of dietary fiber makes it possible to differentiate their components according to their solubility and/or their fermentation capacity. Thus, dietary fiber have been classified into two categories:

- non-hydrosoluble and less fermentable fibers which are plant polymers: cellulose, insoluble hemicelluloses, lignin and resistant starch (RS). The latter represents 0 to 5% of the starch in cereals and behaves like dietary fiber, and is presented in 5 distinct forms: RS1, RS2, RS3, RS4 et RS5 (Pierre 2002; Murphy et al., 2008; Maina et al., 2021);

- water-soluble and highly fermentable fibers: pectin, gums, inulin, galactomanans soluble hemicelluloses (arabinoxylans or pentosans) and mucilages (Dhingra et al. 2012).

The classification of fibers according to their solubility, their source and the main effects and related physiological mechanisms are presented in Table 1. Figure 1 provides an illustration of the nature of the fibers in the wheat grain.

The cereal grain contains three main components: the bran, the germ and the endosperm. Fiber is found in each component, although each component has a different composition of fiber types. The bran is included in the flour when the flour is from whole grain, but it is more often used for animal feed. The germ is usually separated during the refining process because of the presence of fat that can oxidize. The endosperm is the source of white flour (McWilliams, 2008). The bran and germ are rich in fiber and contain many micronutrients and phytochemicals, while the endosperm is mainly of starch (De Munter et al., 2007). The proteins are mainly found in the endosperm and the bran (McWilliams, 2008). The fibers found in these parts of the grain have different physical and chemical characteristics (Bernstein et al., 2013). Table 2 shows the classification of fibers according to the nature of the components.

SOURCE OF DIETARY FIBER

Insoluble fibers are found in wheat, whole grain foods such as whole wheat bread, whole wheat couscous, parboiled rice, vegetables, carrots, cucumbers and tomatoes.

Commonly consumed grains include rice, wheat, corn, barley, rye, oats, millet and sorghum; of these grains barley and rye contain the most fiber per gram of edible portion while rice and millet contain the least (Vincent et al., 2020). Generally, cereals are considered a good source of insoluble fiber. The soluble fiber content is relatively low in cereals, representing about 25% of total fiber, with the exception of oats which are a good source of soluble fiber and contain about 50%. Pulses are an important source of both types of fiber. Fruits and legumes contain less fiber than grains and legumes.

The composition and content of dietary fiber vary from one food to another. Fiber-rich foods contain different amounts of soluble and insoluble fiber. The dietary fiber content of various foods is shown in Table 3. From this table , the dietary fiber content varies from 0.5-17.7 g / 100 g respectively for watermelon and raw white beans.

BENEFITS AND IMPORTANCE OF DIETARY FIBER IN THE DIET

Physiological effects attributable to dietary fiber include: lowering of blood glucose and cholesterol levels, lowering of blood pressure, laxative effects and colonic motility, increased absorption of minerals in the intestinal tract, satiety and better control of eating (Vodouhe et al., 2013; Agbankpe et al., 2015; Nirmala Prasadi and Joye, 2020). Soluble fibers help lower glucose and serum cholesterol levels because they are soluble in water while insoluble fibers facilitate intestinal transit and thus contribute to reduce the risks of constipation because they are not soluble in water (Dhingra et al., 2012). Low dietary fiber intake is associated with an increased risk of cardiovascular disease. The relationship between whole grains and cardiovascular risk reduction has been well studied (Rimm et al., 1996; Mozaffarian et *al*., 2003). The cardiovascular benefits of fibers and, in particular, cereal fibers, have been well documented: cereal fibers are strongly associated with a reduced risk of myocardial infarctus, total and ischemic stroke, cardiovascular disease, and death from heart disease (Mozaffarian et al., 2003). These benefits are likely achieved through multiple metabolic pathways by reducing weight and waist circumference, body mass index (BMI), body fat percentage and waist fat percentage; improving glucose metabolism and insulin sensitivity; and decreasing the risk of metabolic syndrome and diabetes (Raninen et al., 2011; Satija and Hu, 2012). Fibers in millet have been shown to help reduce the risk of gallstones. Food rich in insoluble fibers can

speed up the transit of undigested food through the colon and also reduce the secretion of bile acids which prevents the formation of gall stones (Njeze 2013; Mounika and Sireesha, 2021)

The term whole grain may be used for a food if the weight of that food contains more than 30% whole grain or bran (Ross et al.,2017). Consuming whole grains in addition to the benefits of grain fibers confers a wide range of other so-called protective compounds, including vitamins, minerals, antioxidants (some of which are related to fiber), phytosterols, unsaturated fatty acids and lignins (Slavin, 2003) . The content of Table 4 presents the main dietary fiber from cereal grains that have been shown to have beneficial effects on cardiovascular health.

β-Glucan is a non-starch polysaccharide composed of linear glucose chains, found in cereals, such as oats and barley, which contain it in similar concentrations (Talati et al., 2009). Studies have examined the relationship between β-glucan and cardiovascular health. Results showed that 2-10 g/day of soluble fiber from oats (primarily β-glucan) resulted in a small but significant decrease in total cholesterol (Talati et al., 2009). Consumption of 3 g per day of soluble fiber from three bowls (28 g each) of oatmeal could reduce total cholesterol by about 2% and at the population level, such a reduction could reduce the incidence of coronary heart disease by about 4%. People with particularly high total cholesterol levels (≥ 229 mg/dL) may benefit from this cholesterol reduction (Ripsin et al., 2015).

Arabinoxylan is a polysaccharide fiber with a xylose backbone and arabinose side chains that constitutes nearly 70% of the non-starch polysaccharide in wheat bran and 90% in wheat endosperm (Lu et al., 2000). Its consumption has been associated with better blood sugar control.

Starch, which is found in abundance in the endosperm of cereal grains, is composed of amylose, a linear polymer of glucose, and amylopectin, a branched polymer of glucose. In many foods, a small proportion of the starch is resistant to the normal digestive process (typically 0-5% of the starch in grain products), although for some foods, such as legumes, this percentage is higher e.g. 10-20% for some beans (Englyst et al., 2007). This resistant starch behaves like a dietary fiber. Five main subtypes of resistant starch have been identified according to their structure or source:

- starch that is physically inaccessible to digestive enzymes, which is called type 1 resistant starch (RS1) and is found in whole or partially milled grains and whole grains foods;
- starch resistant to digestion due to the nature of the starch granules which is called type 2 resistant starch (RS2) and is found in raw potatoes, unripe bananas, some legumes and high amylose corn;
- starch that forms from amylose and amylopectin retrograded during food processing is called resistant starch type 3 (RS3) and is found in cooked and cooled foods such as potatoes, bread and cornflakes;
- resistant starch type 4 (RS4) is produced by chemical modification. Because each type has its own physical and chemical properties that influence the rate and site of fermentation in the human gut, the properties associated with one type cannot necessarily be extrapolated to other types (Englyst et al., 2007).
- Resistant starch type 5 (RS5) is a starch capable of forming complexes between amylose, long branched chains of amylopectin and lipids (Cione et al., 2021; Maina et al., 2021).

In view of their involvement and role in the diet and well-being of the population, strategies are developed and actions are undertaken to encourage dietary fiber consumption.

ACTIONS TO PROMOTE THE CONSUMPTION OF WHOLE GRAINS TO MEET DAILY DIETARY FIBER REQUIREMENTS

The consumption of whole grain foods makes a substantial contribution to total dietary fiber intake and is promoted to meet the various recommendations (Reicks et al. 2014).

Globally, many guidelines have been developed for the implementation of strategies to promote the consumption of whole grains with due regards to their potential beneficial effects. Indeed, in developed countries, considerable progress has been made in the research and development of whole grains. Whole grains in the U.S. market represent about 40% of all grain products and over 70% of premium products (Ferruzzi et al., 2014).

In Africa, diets are often not very diversified and the majority of cereal processing involves dehulling the raw grains . The impact of this technology is considerable in light of global recommendations and guidelines for increasing whole grains consumption to benefit from the effects of dietary fiber in reducing the prevalence of diet-related chronic diseases.

WHO and FAO recommend increasing whole grains consumption as a strategy to prevent diet-related chronic diseases. Globally, dietary recommendations encourage the consumption of at least 30 g of dietary fibers per day. The promotion of whole grains consumption specifically urges that at least half of all grains consumed be in the form of whole grains as a replacement for refined grains (Ferruzzi et al., 2014).

Some recommendations and guidelines for promoting whole grains consumption are presented in Table 5. From this table, it can be seen that country dietary guidelines generally recommend the consumption of 3 to 8 servings or 300 to 500 g/day (depending on age, gender or caloric needs) of whole grain or legume foods to meet daily dietary fiber requirements and reduce disease risk.

Table 1 : Classification of dietary fiber into soluble and insoluble fibers.

Type	**Chemical components of plant cell walls**	**Source**	**Main physiological effects and mechanisms**
Soluble/ highly fermentescible fiber	Mucilages: Non-cellulosic polysaccharides, oligosaccharides	Plant extracts (acacia gum, karaya gum, tragacanth gum	Delay gastric emptying; Regulate blood sugar, Lowering serum cholesterol levels, mainly due to the effects of increased viscosity of intestinal contents and colonic fermentation
	Pectins	Fruits, vegetables, sugar beet, potato	
	Gums	Leguminous seed plants (guar bean, carub), algae extract (carrageenan,alginates), gum of microbial origin (xanthan, gellan)	
Insoluble fiber / partialy fermentescibles	Cellulose	Plants (vegetables, sugar beet, various cereal bran)	Reduce the time of intestinal transit, laxative effect thanks to the capacity of swelling, promote the growth of intestinal microflora (especially probiotic species) through their fermentation in the large intestine
	Hemicellulose	Cereals	
	Lignin	Woody plants	

Source (Dhingra et al., 2012; Li et Komarek, 2017)

Table 2: Classification of fibers according to the nature of components.

Type	Origine	Fiber	Caracteristics
Resistant starch	Plant (cell)	Resistant starch type 1 (AR1)	α-glucan, physically inaccessible ; less fermentéscible
		Resistant starch type 2 (AR2)	α –glucan, natives granules resistants to &-amylase ; fermentescible soluble (gel)
		Resistant starch type 3 (AR3)	α -glucan, retrograded after heat treatment soluble (gel) fermentescible
	Synthesis	Resistant starch type 4 (AR4)	α -glucan, chemically modified; soluble (gel) fermentescible
		Resistant starch type 5 (AR5)	starches capable of forming complexes with lipids
Non-starch polysaccharides	Plant (cell wall)	Cellulose	(1-4) β-glucan ; high molecular weight, insoluble, linear glucose polymer , less fermentescible
		β-glucans	Low molecular weight linear glucose polymers, soluble, fermentescible
		Hemicelluloses	Various branched heteropolymers including xyloglycans (fruits, vegetables), arabinoxylans (cereals); partly soluble (gels) fermentescible
		Pectins	Branched complex heteropolymers containing galacturonic acid, rhamnose, arabinose, galactose, soluble (gels), highly fermentescible
	Plant (cell)	Gums (Guar, carub, etc.)	Complex heteropolymers: arabinogalactans, galactomannans; soluble (gels) fermentescible
		Mucilage (ispahule, psylium)	Complex heteropolymers; soluble (gels) fermentescible
		Inulin	Fructose polymer; soluble (gels), highly fermentescible
	Algea	Carrageenans, alginates, agar	Solubles (gels), fermentescible
	Animal (shells of crustaceans)	Chitin, chitosan	Structure similar to cellulose, insoluble or slightly soluble, not or slightly fermentescible
	Fungal, bacterial		β-glucan , galactomannans, xanthae, soluble (gels), fermentescibles
	Synthèse	Polydextrose	Branched glucose polymer, soluble (gels), fermentescible
Oligosaccharides indigestibles	Hydrolyse ou biosynthèse	Fructooligosaccharide, galactooligosaccharide, maltodextrins	Oligopolymers of fructose, galactose, glucose and other bones; soluble; highly fermentescibles
Other polymers	Plant (cell walls)	Lignin	Phenolic acid network polymers, insolubles, hydrophobic, non fermentescibles
		Subérine, cutine	hydrophobic, non-fermentescible

(Source : Pierre, 2002; O'Grady et al., 2019; Maina et al., 2021; Cione et al., 2021)

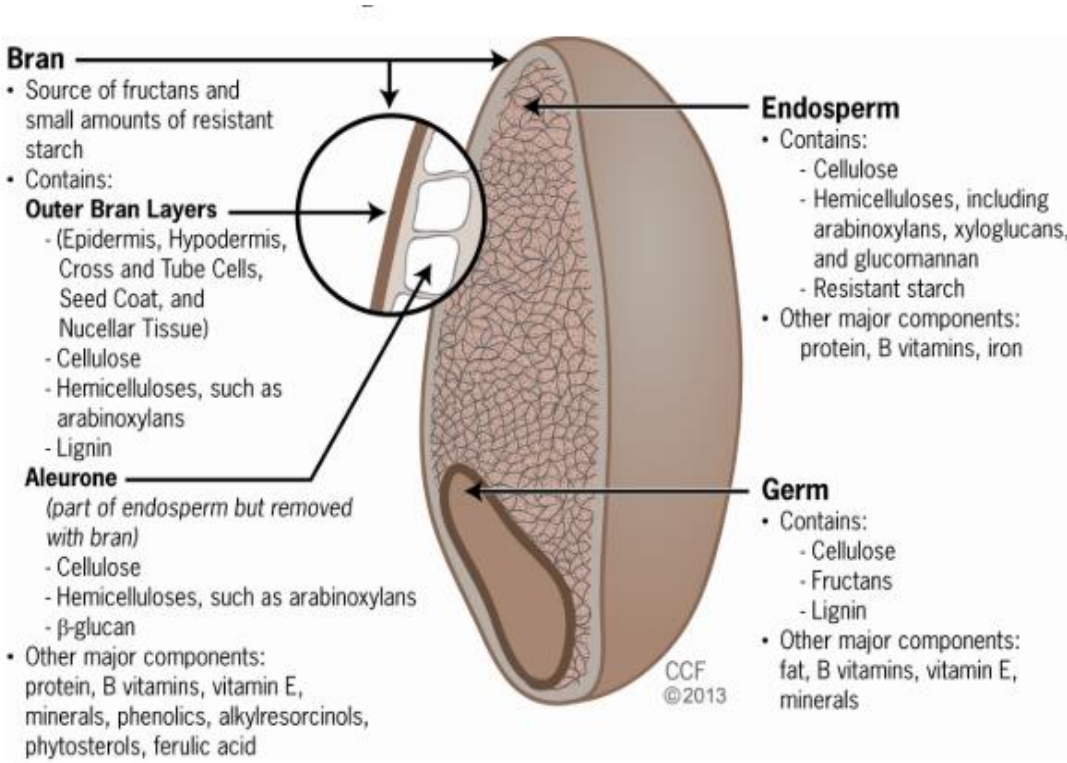

Figure 1 : The fibers in wheat grain (Bernstein et al., 2013).

Table 3 : Dietary fiber content of various foods.

Origin	Dietary fiber (average value in g/100 g edible portion)		
	Total	Insolubles	Solubles
Cereal			
Oats	10.3	6.5	3.8
Wheat (whole grain)	12.6	10.2	2.3
Wheat Germ	14	12.9	1.1
Maize	13.3	-	-
Pearl Millet	8.9	5	3
Pearl Millet , flour (without bran)	4.6	-	-
Barley	17.3	-	-
Rice (dry)	1.3	1.0	
Rice(coocked)	0.7	0.7	0.0
Sorghum	11.9	6.0	1.68
Pulses and legumes			
White beans. raw	17.7	13.4	4.3
Canned red beans	6.3	4.7	1.6
Green beans	1.90	1.40	0.50
Lentils. raw	11.4	10.3	1.1
Dry cowpeas, raw	12.8	-	-
Frozen green peas	3.5	3.2	0.3
Soybeans raw	15.0	-	-

Eggplant	6.6	5.3	1.3
Beet	7.8	5.4	2.4
Broccoli,	3.29	3.00	0.29
Carrot, raw	2.5	2.30	0.20
Raw celery	1.5	1.0	0.5
Bitter pumpkin	16.6	13.5	3.1
Cauliflower, raw	1.8	1.1	0.7
Cucumbers, peeled	0.6	0.5	0.1
Spinach , raw	2.6	2.1	0.5
Green onions, raw	2.2	2.2	0.0
Potato, peeled	1.30	1.0	0.3
Tomato, ,raw	1.2	0.8	0.4
Fruits			
Pineapple	1.2	1.1	0.10
Banana	1.7	1.2	0.5
Strawberry	2.2	1.3	0.9
Kiwi	3.39	2.61	0.80
Mango	1.8	1.06	0.74
Oranges	1.8	0.7	1.1
Watermelon	0.50	0.30	0.20
Pear	3.0	2.0	1.0
Apple , non peeled	2.0	1.8	0.2
Grapes	1.2	0.7	0.50
Nuts and seeds			
almond	11.2	10.10	1.10
peanut, dry	8.0	7.5	0.5
Sesame seeds, grilled	7.79	5.89	1.90
Cashew nuts , grilled	6.0	-	-
Coconut ,	9.0	8.5	0.5

-: data not available

(Source :Khanum et al., 2000; Nandini and Salimath, 2001; Krishnan and Meera, 2018; Vincent et al., 2020)

Table 4 : Major dietary fiber from cereals grains with established health benefits.

Fibers	**Water Soluble (S) or Insoluble (I)**	**Viscosity**	**Fermentability**	**Cereal Source**	**Properties that can help with incorporation into foods**	**Cardiovascular benefits**
β glucan	S	Very viscous	high	Oat, barley	Can be added to a variety of different products, including cereals, soups, drinks	≥3 g/day of β-glucan soluble fiber from whole oats or barley, or a combination of both, may reduce

						the risk of coronary heart disease
Arabinoxylans	I	viscous	High	Barley , wheat, rye, rice, sorghum, oat, maize, millet	Can lower the glycemic index of breads, while providing a pleasant mouth feel and tenderness	≥7 g/day of Arabinoxylans soluble fiber from whole oats or barley, or a combination of both, may reduce the risk of coronary heart disease
Inulin-Type Fructans	S	Mainly viscous	High	Wheat	Used to replace fats or carbohydrates without altering the taste or texture	Not yet determined
Resistant starch	S	Non - viscous	Variable (rate and degree depend on source and heat treatment)	RS : partially milled grains RS: cooled coocked rice, pasta	Used to improve the mouthfeel of refined grain-based foods	Not yet determined

(Source : Talati et al., 2009; O'Grady et al., 2019)

Table 5 : Global guidelines for whole grain diets.

Country/Organism	Recommandations/Guidelines
Australia	The Australian Dietary Guidelines for Healthy Eating recommend 3- 8 servings (depending on age, gender or caloric needs) of grain foods, mainly whole grains, whole grain breads, rice, pasta, noodles, polenta, couscous, oats, quinoa and barley.
Austria	The Austrian food pyramid (Die österreichische Ernährungspyramide) recommends 4 servings/day of cereals, bread, pasta, rice or potatoes (5 servings for active adults and children), preferably whole grain.
Canada	Canada's food guide recommends 3 to 8 servings/day (depending on age and gender) of grain products and advises choosing at least half of your grain products as whole grains each day. It also recommends eating a variety of whole grains such as barley, brown rice, oats, quinoa and wild rice.
Chili	The Chilean Pediatric Society recommends that half of the grains consumed be whole grains to meet the recommended amount of fiber.
China	Chinese dietary guidelines recommend that adults consume 300-500 g/d (depending on energy requirements) of cereals and legumes in total, with at least 50 g/d of coarse grains, including whole grains.

Danemark	The Danish Food Administration recommends 75 g/d of whole grain (for an energy requirement of 10 MJ/d). Bread, cereals, rice and pasta should be an essential part of the diet; for older children and adults, 500 g/d is recommended
France	The National Nutrition and Health Program's Food Guides recommend eating breads, cereals and starches at every meal, especially whole grain foods that provide significant amounts of fiber.
Greece	The dietary guidelines for adults in Greece suggest 8 servings of unrefined grains and products, preferably a variety of whole grains (whole grain bread, whole grain pasta, brown rice, etc.).
India	The dietary guidelines for India recommend increasing consumption of whole grains, legumes and nuts to maintain a balanced weight as needed.
Letonia	The Ministry of Health recommends the consumption of 4 to 6 servings/day of cereals, especially whole grains such as whole grain products rich in fiber (bread, pasta, oatmeal) to reduce the risk of diseases.
Mexico	The Mexican Ministry of Nutrition and Health Promotion recommends eating cereals, preferably whole grains with no added sugar. Their fiber and nutrients should be highlighted. Whole grains should be eaten at every meal, along with legume seeds.
Norway	The key tips for healthy eating "Nøkkelråd for et sunt kosthold" from the Norwegian Directorate of Health suggest increasing daily consumption of whole grain products and cereals. Whole grain products should together provide 70-90 g/d of wholemeal or whole grain flour.
Oman	The Omani Guide to Healthy Eating recommends choosing whole grains and cereals and eating potatoes with their skins. For an average diet of 2000 kcal, it is recommended to consume 2 to 3 servings/day of whole grains.
Singapour	Singapore's adult dietary guidelines and the Healthy Diet Pyramid recommend eating adequate amounts of grains, especially whole grains. Of the 5 to 7 servings of rice and rice alternatives, adults should eat 2 to 3 servings per day of whole grains.
Sweden	The Swiss Society of Nutrition recommends that each main meal be served with a starchy side dish [i.e., 3 servings/d, 1 serving = 75-125 g bread or 60-100 g pulses (gross weight)]; for example, lentils/chickpeas or 180-300 g potatoes or 45-75 g pasta/rice/flakes/corn/other cereals (gross weight), of which at least 2 servings should be whole-grain products
United Kingdom	Eatwell of the National Health Service recommends eating plenty of bread, rice, potatoes, pasta and other starchy foods (listed as one-third of the plate) and choosing whole grain varieties whenever possible
United States of America	The 2010 Dietary Guidelines for Americans suggest consuming at least 3 ounce-equivalents of whole grain products per day, with the remainder of the recommended grains coming from fortified or whole grain products (at the 2000 kcal intake level). Consume at least half of all grains as whole grains to increase whole grain intake.
OMS/FAO	WHO and FAO recommend increasing whole grain consumption as a strategy to prevent diet-related chronic diseases.

Source (Ferruzzi et al., 2014; FAO/WHO 2019)

Conclusion

Dietary fibers are considered functional nutrients, based on their effects on health, in relation to their structural properties and their classification. Their main effects include the protection against obesity and related metabolic diseases and gut health improvement. In developed countries, the beneficial effects of dietary fibers have been well understood and measures and directives are taken to promote their consumption by the populations. However, this is not the case in most developing countries where diet habits are not in favor of fiber-rich foods such as whole grains, vegetables, fruits. Efforts must therefore be made to meet this challenge. Promoting the consumption of whole grains is one of the approaches, but these grains must be of good sanitary quality so as not to compromise the health of consumers in view of the high risks of contamination by mycotoxins and pesticide residues. The double challenge to be faced remains the assurance of the sanitary quality of whole grains and the adoption of measures to promote their consumption, as cereals constitute one of the staple foods of the populations.The benefits associated with dietary fiber consumption should encourage the local food enterprises to develop and make available to consumers fiber-rich food products.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

DCS designed the manuscript. DCS, FWBT, DZ, CSC contributed to the writing of the manuscript. MHD and HS-L corrected and validated the submitted version of the manuscript.

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