Fractionation of Dietary Fiber

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Contributor: Gita Nevara

Dietary fiber (DF) has wide applications, especially in the food and pharmaceutical industries due to its health-promoting effects and potential techno-functional properties in developing functional food products. There is a growing interest in studies related to DF; nevertheless, there is less focus on the fractionation and characterization of DF. The characteristics of DF fractions explain their functionality in food products and provide clues to their physiological effects in food and pharmaceutical industrial applications. The review focuses on a brief introduction to DF, fractionation and characterization methods of DF, and the potential sources of DF from selected defatted oilseeds for future studies.

Keywords: dietary fiber ; fractionation ; functional ; oilseed by-product

1. Introduction

Dietary fiber (DF) is an essential nutrient that is resistant to the digestive enzymes in the small intestine. However, it can be partially or fully fermented in the large bowel [1]. Fractionation of DF aims to isolate and quantify fractions and eliminate undesirable compounds. The relative number of individual fiber constituents, especially in relation to soluble and insoluble fractions, affects the physicochemical and physiological attributes of DF [2].

A study on the structural characterization of polysaccharides is necessary to provide a better understanding of their function as DF. The different methods used in the fractionation resulted in different structural characteristics of the compound. Moreover, DF has essential functional properties such as water- and oil-holding capacity, emulsification and gel formation, and rheological properties that are required in developing novel food products [3]. These properties may explain its role in food products and provide clues to its physiological effects when extended to industrial applications. Furthermore, analyzing the rheological behavior of DF is crucial specifically in food product development, storage stability, sensory evaluation, quality control, food structure and design of food processing equipment [2][3].

Even though there is a growing number of studies on DF, limited literature about the fractionation and characterization of DF, and potential sources of DF from defatted oilseeds are available. The fractionation of DFs into their constituents with specific physical characteristics and chemical contents may improve their functionality. Furthermore, the utilization of the by-products of oilseeds such as oilseed meal or cake into high value-added food ingredients with health-promoting properties will benefit mankind. Therefore, this review focuses on a brief introduction to DF and its fractionation and characterization methods, and information on some potential defatted oilseeds as a source of DF.

2. Fractionation of DF

Fractionation of DF can be conducted using dry or wet processes to isolate starch and protein, and a fiber fraction is obtained as an end product [4]. There are several fractionation processes, differing by the method applied, separation techniques, and pretreatment practices. The parameters, such as the cost, time, yield, technological characteristics, and the functionality lost during the fractionation, change considerably according to the fractionation process applied [5]. Fractionation of DF isolates the interested fractions, quantify those constituents, and eliminate unfavorable components. There are limited methods for the fractionation of DF into their constituents. It is recognized that the physicochemical and physiological effects of DF depend on its individual components, especially in relation to insoluble and soluble fractions [6].

Southgate [7] was the first to fractionate the unavailable carbohydrates in foods, which include the extraction and fractionation procedure for crude lignin, cellulose, and lignocellulose fractions [8]. Also, wheat bran was fractionated using a hot and cold water extraction to isolate the water-soluble polymers and enzymatic and acid treatments to fractionate the insoluble fibers [9]. Furthermore, combined fractionation methodologies using heat resulted in the modified insoluble fiber fraction levels [10]. Graham et al. [11] found that high-temperature extraction contributed to the highest yield of soluble fibers, and acidic extraction yielded the lowest. Czuchajowska and Pomeranz [12] patented the wet fractionation method to isolate starch, protein, and DF, requiring no chemicals and much less water than other standard methods. DF is a significant component of both water-soluble and tailings starch fractions and large amounts of protein and starch [13].

Alternatively, Wang et al. [14] employed a dry fractionation that is water- and energy efficient and does not need any solvents to produce enriched DF from defatted rice bran. Also, the dry fractionation technique creates fractions with different particle sizes and densities that affect their fiber content [15]. Yáñez et al. [16] applied dry fractionation on distillers dried grains with solubles (DDGS) using a vibratory sifter and gravity separator and found that this technique was more effective than wet fractionation due to its cost effective, environmental-friendly method and high yield. Therefore, dry fractionation could be conducted as a tail-end method at ethanol plants to separate DDGS into fragments [17].

The various fractionation methods are developed based on the material evaluated; thus, a global fractionation procedure is unavailable [6]. The aforementioned techniques only describe universal fractionation methods. Hence, each researcher should modify previous procedures to develop an optimum method for a specific sample [6]. Several methods enable a more refined separation of constituents, allowing the evaluation of molecular structure, e.g., pectin [18]. Following the extraction, isolation, and purification using chromatographic techniques, the molecular weight of polysaccharides can be evaluated by high-performance liquid chromatography (HPLC), and the structure is confirmed by nuclear magnetic resonance (NMR) [19]. Recently, Alba et al. [20] developed a sequential fractionation procedure of blackcurrant pomace into five insoluble and soluble DF fractions. In commercial applications, dry fractionation uses pin milling and air classification, which is repeated to obtain a high recovery level of the protein fraction [4]. The efficiency of milling and air classification varies considerably due to differences in structural thickness and hardness of cell walls and seeds and binding strength between starch granules and protein [21].

The variation in starch, protein, and minor component levels in the fractions will influence functionality [4], thus, affecting the overall product quality produced from the fraction. Food product development can be successfully achieved by understanding the particular functional attributes of the constituents and their performance under different treatments such as temperature and pH [22][23].

3. Characterization of DF

There is a considerable variation in the DF amounts and insoluble to soluble DF ratios [24]. The characteristics of plant varieties are required to interpret the physiological function of the fibers better. There are several types of DF, including long-chain insoluble and soluble polysaccharides, galactooligosaccharides, and resistant starch. While insoluble DF is commonly associated with laxation, soluble DF reduces cholesterol levels and ameliorates postprandial blood glucose levels. All DF can serve as prebiotics, which provides food for gut microbiota [25][26].

The efficacy of DF in promoting health benefits depends on its intake, source, and structural and chemical composition. Moreover, a substantial understanding of the chemical structure of DF is required when incorporating DF into food products as DF will interact with other ingredients that can remarkably modify the microstructure and characteristics of the final food product [20]. The basic composition of DF has been determined; however, the study on the full characterization of the non-starch polysaccharides is limited. This knowledge is important for learning the effects of structure on the functionality of these DFs and how the physicochemical properties of DF fractions can affect the final processed foods [24].

The characteristics of the cell wall polysaccharides in cotyledons and seed hulls are essential for understanding their function as DF. The forms of sugars exist and the physical properties of materials are less important than the linkage of constituent monosaccharides in polysaccharides [27]; different monosaccharides linked in the same manner can give similar physical attributes to materials. In contrast, the same monosaccharide linked in different manners can provide polysaccharides with completely different attributes [24].

The profiles of small molecular weight carbohydrates i.e., galactooligosaccharides of cooked seeds are also of interest. These molecules were previously considered undesirable due to their flatulence effect [25]. However, there is increasing recognition of their prebiotic effect, which stimulates the growth of probiotic bacteria to produce beneficial short-chain fatty acids [23].

For the carbohydrate characterization, resonances 1H NMR and 13C NMR are the most appropriate spectra for analyzing monosaccharides [28]. In this regard, the 1HNMR (<1 ppm) detects CH3-groups, while the 1HNMR (>2 ppm) are suitable to detect *O*-acetyl and *N*-acetyl groups [29]. NMR spectroscopy is a potent analytical method for analyzing the structure, type, and several glycosidic linkages of carbohydrates and α- and β-anomeric configurations in the molecules [30]. NMR is considered as a non-destructive rapid technique to obtain the structural information of molecules [28]. For example, the chemical structure of multiple carbohydrates such as macroalgae gums (i.e., carrageenan and alginates) has recently been analyzed using NMR methods [31].

The soluble and insoluble nature of DF involves variations in their technological functionality and physiological properties [32][33]. Soluble DFs are characterized by their ability to increase the viscosity and decrease glycemic response and plasma cholesterol [33][34]. Insoluble DFs are characterized by their low density, porosity, and capacity to increase fecal bulk and reduce intestinal transit [33][35]. Compared with insoluble DF, the soluble fraction exhibits a better capacity to form gels, provide viscosity, act as emulsifiers, has neither unpleasant taste nor undesirable texture, and is simpler to incorporate into convenience food and beverage. Fruit by-products and marine algae seem to be excellent sources of soluble DFs, followed by vegetables, fruit, and cereals [6].

4. Potential Sources of DF from Defatted Oilseeds

Defatted seed cakes are seed flours in which their fat content have been removed partially or fully, which subsequently improved the protein content of the resultant seed cake. The exploitation of by-products generated from food processing as a source of functional ingredients and their application in other foods is necessary as part of a waste management system [36]. The by-product of oilseeds such as defatted cakes from kenaf, hemp and sesame seeds are some of the potential low-cost sources for DF extraction.

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