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Review

Preparation and modification of high dietary fiber flour: A review

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A B S T R A C T

Dietary fiber, consisting of soluble dietary fiber and insoluble dietary fiber, has beneficial functional effects on the human body that are receiving increasingly attention. Refined flour lacks dietary fiber and poses potential risks to human health. Therefore, improving the nutritional value and processing performance of flour in the preparation and modification of high dietary fiber flour is of great importance. Whole-wheat flour, a high dietary fiber flour obtained by crushing whole-wheat grains, is rich in nutritional value. High dietary fiber flour obtained by adding bran back into the flour makes full use of the bran, which increases the utilization of wheat-milling byproducts. The addition of dietary fiber to flour is a direct method for obtaining high dietary fiber flour, and which has evolved with the development of the dietary fiber extraction industry. Further modifications of whole-wheat flour, bran, and dietary fiber, such as milling, extrusion, heat treatment, and biological treatment, can diminish the effect that bran materials on the quality of flour and flour products. This review summarizes methods used for the preparation and modification of three kinds of high dietary fiber flour and the effects of these different methods on the quality of flour and flour products, with the aim to provide guidance for the industrial preparation of high dietary fiber flour.

1. Introduction

Dietary fiber is defined as non-digestible carbohydrates of ≥3 monomeric units found inherently in foods, and also includes isolated or synthetic fibers with demonstrated physiologic benefits, such as resistant starches (Anderson et al., 2009; Jones, Lineback, & Levine, 2010). Dietary fiber can be classified according to its solubility in water as soluble dietary fiber including inulin, β-glucans, and other non-starch polysaccharides (Khan, Alam, Ali, Bibi, & Khalil, 2007; Yangilar, 2013) and insoluble dietary fiber typically including lignin, cellulose, and some hemicelluloses (Prakongpan, Nitithamyong, & Luangpituksa, 2010). As "the seventh nutrient", dietary fiber is gaining increasing research attention. Dietary fiber with strong water-absorption capacity can increase satiety and accelerate intestinal peristalsis, resulting in the elimination of intestinal toxins and controlling body weight (Cook, Rains, Maki, & Chu, 2014; Karl & Saltzman, 2012). Dietary fiber can absorb free estrogen, reducing the risk of breast cancer (Tousen, Uehara, Abe, Kimira, & Ishimi, 2013). Simultaneously, as a substrate for fermentation, dietary fiber can be fermented by microorganisms in the colon, resulting in the production of various metabolites including short chain fatty acids, which confers host health benefits (Flint, Duncan, & Louis, 2017; Holscher, 2017; J, R, CW, A, & DJ, 2006). Diets rich in high dietary fiber foods, such as vegetables, fruits, and whole grains, are associated with a decreased risk of various chronic diseases (Steffen Jr et al., 2003). Studies have shown that the intake of dietary fiber can reduce the risk of type II diabetes, and cardiovascular disease (Rodríguez, Jiménez, Fernández-Bolaños, Guillén, & Heredia, 2006; Silva et al., 2013). Increased consumption of dietary fiber has been shown to improve serum lipid levels, and lower blood pressure (Aleixandre & Miguel, 2016; Birketvedt, Shimshi, Erling, & Florholmen, 2005). High dietary fiber foods could offer important health benefits for human health sustainability.

Wheat grain, including endosperm, germ, pericarp, testa and aleurone layer, *etc.* is rich in nutrients (Fig. 1). Wheat flour is produced by milling wheat grain and provides daily energy requirements to people worldwide in the form of different products. As a by-product of flour processing, wheat bran consistes of a lot of nutritional compontens, such as protein, dietary fiber, phenolic compounds, vitamins, and other phytochemicals (Table 1) (Brouns, Hemery, Price, & Anson, 2012; Apprich et al., 2014; Yan, Ye, and Chen (2015); Mateo, Hemery, Bast, & Haenen, 2012). As processing technology has progressed, the precision of flour processing has equally improved (Ka, 2015). Although various types of refined flour products are popular, refined flour essentially contains only the endosperm after whole grain processing, resulting in a loss of dietary fiber (Barros, Alviola, & Rooney, 2010), which is largely in the wheat bran. Therefore, producing high dietary fiber flour is

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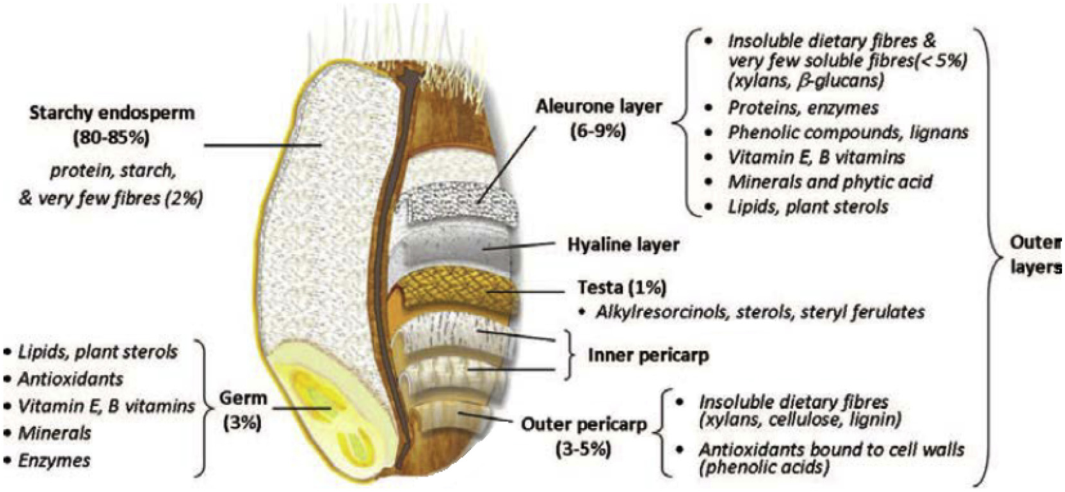

Fig. 1. Histological structure and nutrient distribution of wheat grain from Brouns et al. (2012) and Surget and Barron (2005).

Table 1
Content of compounds of per 100 g wheat bran.

Category	Compounds	Content
General compositions	Water[1]	12.1 g
	Protein[1]	13.2–18.4 g
	Fat[1]	3.5–3.9 g
	Starch[1]	13.8–24.9 g
	Ash[1]	3.4–8.1 g
	Soluble dietary fiber[2]	9.82 g
	Insoluble dietary fiber[2]	33.38 g
Bioactive compounds	Phytic acid[3]	2180–5220 mg
	Ferulic acid[3]	500–1500 mg
	Alkylesorcinols[3]	220–400 mg
	Vitamin E[3]	1.4 mg
	Betaine[3]	1000–1300 mg
	Choline[3]	47–100 mg
	Niacin[3]	14–18 mg
	Pantothenic acid[3]	2.2–3.9 mg
	Riboflavin[3]	0.39–0.75 mg
	Biotin[3]	0.048 mg
	Thiamin[3]	0.54 mg
	Pyridoxine[3]	1–1.3 mg
	Folate[3]	79–200 mg
	Lutein[3]	97–140 mg
	Iron[3]	11 mg
	Manganese[3]	12 mg
	Zinc[3]	7.3 mg
	Selenium[3]	78 mg

Note: The data in this table came from the work of Apprich et al. (2014)[1], Yan et al. (2015)[2], and Mateo et al. (2012)[3].

important for increasing dietary fiber intake in the daily diet for good health. In contrast to refined flour, which contains only the endosperm, whole-wheat flour contains the bran, germ, and endosperm, resulting in dietary fiber retention. Furthermore, whole-wheat flour is an important source of several vitamins, minerals, and phytochemicals with anticancer properties that could affect the risk of colorectal cancer through several potential mechanisms (Slavin, Martini, Jacobs, & Marquart, 1999). Adding bran and dietary fiber to flour is another effective method for the preparation of high dietary fiber flour. Using high dietary fiber flour can meet human requirements for healthy foods. However, bran or dietary fiber can also affect flour quality, dough rheology and high dietary fiber flour products. A lower shelf life appeared in whole-wheat flour compared to white flour due to the release of enzymes in bran during whole-wheat milling (Dobladomaldonado, Pike, Sweley, & Rose, 2012). The peak viscosity, final viscosity, breakdown value, and setback value of bran flour decreased with the increasing of bran content (Chen et al., 2011). The addition of wheat bran influenced dough rheology, with the increased water absorption, decreased development time and stability (Wang, Liu, & Wen, 2016). Resistance to extension and extensibility of the dough decreased with the increasing of bran addition (Boita et al., 2016). Bleis, Chaunier, Chiron, Valle, and Saulnier (2015) found that the solid particle effect of bran caused insufficient formation of the gluten network in the dough and the loss of dough stability was attributed to the destabilizing effect of bran particles on the films separating gas bubbles. The growth and size of bubbles in bread dough during the fermentation and proofing was limited, which ultimately led to a reduction in the volume of the high dietary fiber bread (Ishwarya, Desai, Naladala, & Anandharamakrishnan, 2017). Andrzej, Jarosław, Sabina, Magdalena, and Agnieszka (2017) also reported that high dietary fiber bread had a lower specific volume compared to white bread. The chewiness and gumminess of high dietary fiber bread noodles decreased with the increasing of bran addition (Song, Zhu, Pei, Ai, & Chen, 2013). The color of high dietary fiber noodles was deepened (Song et al., 2013) and total sensory scores were significantly lower than those of white noodles (Chen et al., 2011). Considering sensory, a reduced brightness appeared in high dietary fiber steamed bread (Wang et al., 2016). The above-mentioned influence adversely affected the processing of high dietary fiber flour and consumer choice to a certain extent. Consequently, further modification of high dietary fiber flour for food applications is needed to expand its use and consumption.

This review summarizes preparation and modification methods for high dietary fiber flour and its effect on flour and flour products, with the aim to provide guidance for the production of high dietary fiber flour for food applications.

2. Preparation of high dietary fiber flour by whole-wheat milling

2.1. Preparation of whole-wheat flour

High dietary fiber flour obtained by directly crushing whole wheat, is called whole wheat flour. The whole wheat comminution process is simple because the separation of flour from bran is not required. Stone milling, roller milling, and jet milling can be used to obtain whole-wheat flour (Dobladomaldonado et al., 2012; Protonotariou, Mandala, & Rosell, 2015). Whole-wheat milling not only produces whole-wheat flour high in dietary fiber, but also preserves other nutrients from the whole-wheat grain. However, these ingredients also have two main adverse effects. First, dietary fiber affects the physicochemical properties of whole-wheat flour and its dough, owing to whole-wheat flour being dark and leading to products with a rough texture limiting sensory appeal. Second, microorganisms and highly active enzymes, such