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Wheat Bran-Composition and Nutritional Quality: A Review

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Abstract

Wheat bran is considered as one of the most abundant and economically cheap source of dietary fibre, vitamins, minerals, bioactive compounds and is considered as an excellent ingredient in food. Consumption of wheat bran improves the health and prevents some diseases including colon cancer, cardiovascular diseases. This review article discusses the importance of wheat bran, its composition, extraction methods and its health benefits.

Keywords: Wheat bran; Extraction methods; Composition; Economic importance; Health benefits; Diseases

Abbreviations: CVD: Cardio Vascular Diseases; IBS: Irritable Bowel Syndrome; SCFA: Short Chain Fatty Acids

Introduction

Wheat is the second most consumed cereal for human food after rice. It is one of the most staple food crops consumed by more than one third of the world population due to the presence of high calories. Wheat is not only a nutritious grain, but is also a rich source of proteins, minerals, B vitamins and dietary fiber [1]. Wheat is primarily cultivated in China, India, Russia, USA, France, Canada, Germany, Pakistan, Australia and Ukraine, responsible for a production of 760 million tons in 2017 [2]. India is the second largest wheat producer in the world. It produces around 95 million metric tons to 100 million metric tons. Wheat produced from two species *Triticum aestivum* vulgare and *Triticum turgidum* durum (hard wheat) are of most importance in preparation of bread, production of biscuits, confectionary products, noodles and vital wheat gluten. Wheat is also used in brewing for the production of ethanol and wheat beer, as a raw material for cosmetics, wheat protein as a substitute for meat, to make wheat straw composites and also as fodder for domestic animals [3]. Wheat grain also called caryopsis, harvested for the human food is usually 5-9mm in length, weighs between 35 and 50mg is composed of a number of different tissues divided into three principal parts.

A. Bran

B. Germ

C. Endosperm

Grain consists of13-17% bran, 2-3% germ or embryo and 80-85% endosperm rich in starch. A thick cell walled aleurone layer, encasing the endosperm is found along with the bran composed of a fractions of pericarp, test a, hyaline and aleurone layers [4]. A wheat kernel comprises three principal fractions-bran, germ and endosperm. A wheat kernel comprises three principal fractions bran, germ and endosperm

Wheat Bran

The bran fraction is a by-product of milling and has food and nonfood applications [5]. The use of wheat bran (WB) for human consumption has increased gradually over the years. Globally, the number of WB-incorporated food products increased from 52 in 2001 to approximately 800 in2011 [6]. WB is rich in minerals, fibre, B vitamins and bioactive compounds which are known to possess health-promoting properties [7]. Treatment processes to asses s the functional ingredients from WB have been studied Rosa et al. (2013). The awareness of consumers and their demand for healthier foods led to the exploration and incorporation of ingredients from natural sources in food production. As indicated by Preuckler et al. [7] of all bran-incorporated food groups categorized, bakery and cereals topped the chart with approximately 60% market share. Over the years, WB has received more attention in baked foods and recently in fried cereal foods. This article examines the

nutritional composition of WB, effects of WB inclusion on quality and sensory properties of cereal foods, and possible application of WB in fried cereal snacks as a potential functional ingredient that can serve as a barrier layer which could reduce oil migration into food during frying.

Wheat bran is a fraction of the outer pericarp layer, left as by-product after milling with food and non-food applications [5]. The human consumption of the wheat bran has increased gradually over the years along with the number of products isolated from wheat bran increased from 52 in 2001 to 800 by 2011 [6]. Wheat bran is rich in minerals, fibre, B vitamins and lot of bioactive and volatile compounds with health benefits [7]. Increased awareness of consumers and their demand for healthier foods have led to the exploration and incorporation of ingredients from natural sources in the food production and wheat brans have been very well exploited for the isolation of the compounds with increased health benefits.

Extraction of wheat bran

Wheat bran makes up about 13-17% of total wheat grain weight and its extraction is divided into two types depending on the process of milling.

1. Dry milling and
2. Roller milling

1. Dry milling: Involves the separation of bran from the endosperm, which is further ground into fine flour.
2. Roller milling: Separation of bran from wheat grain is achieved efficiently using a roller mill.

Before the grains are subjected to milling, they are first tempered by spraying of water to regain the moisture and are transferred into a tempering bin for conditioning. During this process, the pericarp and germ layer of the grain absorbs water, which will soften the endosperm for the extraction process. It also prevents the bran from breaking during separation. In the roller mill, the conditioned grains are passed through metal rolls rotating in opposite direction. Here, the grain is cracked open removing the endosperm and germ from the bran and gets separated into these three fractions [8]. Bran is a major by-product of flour milling. Wheat bran is also extracted by using other processes such as pearling (removal of outer layers by friction implemented for Durum wheat), peeling and bran fractionation, which yield bran with enhanced nutritional quality [9].

Composition of wheat bran

Composition of wheat bran is purely based on the variety, cultivation conditions and the methods employed for its separation, which determines the amount of starch attached to the aleurone layer after the separation. The bran composition vary widely among different crops, majorly contains dietary fibre (xylans, lignin, cellulose, and galactan, fructans), vitamins and minerals [10]. Germ can also be added up to the bran depending on the milling process enriching the bran with lipids. Bran is rich in minerals such as iron, zinc, manganese, magnesium and phosphorus. 80% of Phosphorous in wheat bran is stored in the form of phytates, forming complexes with Fe, Zn and Mg, which will drastically reduce their bioavailability. 34-63% of the wheat bran is occupied by the rich stock of soluble and insoluble dietary fibre, a complex compound made of edible plant polysaccharides (cellulose, hemicelluloses and pentosan polymers) attached to proteins, lignin and other substances which escape hydrolytic enzymatic digestion in the upper gastrointestinal tract. Soluble dietary fibre comprises of 5% of total dietary fibre, consisting of glucan and xylans [11]. Dietary fibre enhances the gut health, appetite regulation and prolonged satiety. Increased satiety can be attributed to large water absorption of dietary fibre, reduced gut transit time, increased digest a viscosity in the small intestine, and increased stool bulk and short-chain fatty acid production, in the colon, due to fermentation of the fibre [12]. Dietary fiber helps in the prevention of colon diseases (including cancer), preventing gastric cancer, treating Irritable Bowel Syndrome (IBS), reducing the risk of hemorrhoids and hiatal hernia, hypercholesterolemia, hypertension, reducing the risk of breast cancer and gallbladder disease, and type 2 diabetes [13]. Although there have been some work exploring the role of wheat bran dietary fibre in human weight regulation, not much evidence is available for establishing its role as weight regulator.

Further, wheat bran is subdivided into distinct layers pericarp, test a, hyline and aleuronelayers. Pericarp is having outer and inner epidermal layers, composed of three different types of cells, intermediate cells, cross cells and tube cells with high levels of branched hetrocyclans. The total pericarp comprises about 5 % of the grain, consisting of 20% cellulose, 6% protein, 2% ash and 0.5% fat. It is also rich in xylans and insoluble fibre. Most of the pericarp's tissues comprises of lignified walls. Testa contains almost all of the grain's alkylresorcinols, a class of phenolic lipids reported to exhibit antioxidant properties and anticancer activities [14]. Hyaline layer (nucellar tissue) is the intermediate layer of the bran consisting of arabinoxylan and monomers of ferulic acid. The aleurone layer is the innermost layer of the wheat bran, partly shared by its endosperm. 80 % of the all niacin, 60% of the all vitamin B6 and 32% of all thiamine in whole wheat grain are provided by aleurone layer [15]. Wheat aleurone has arich stock of lignans and proteins with balanced amino acid content (particularly high levels of lysine), bioactive compounds, phytic acid, antioxidants, vitamins and minerals, because of which it has gained the attention of many researchers as functional ingredient in many cereal based foods [16]. High levels of antioxidants, lignans and phenolic acids in the wheat aleurone are involved in the prevention of diseases, adding the additional values to wheat bran. The outer seed coat comprises about 1% of the grain and is composed of mainly arabinoxylan, lipids, alky resorcinols and lignin, which gets separated at the first stage of milling. Bran also comprises water-insoluble

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fiber involved in the protection of grain and endosperm. This fiber is made of Arabinoxylan (19-25%), Starch(17-29%), protein(14-18%), Lignin(~3%), β-glucans (1-3%), Phytic acid(3-5%), Feluric acid(0.3-5%).

Nutritional Quality of Wheat Bran

Carbohydrates

The major components of the wheat bran are carbohydrates, especially arabinoxylan. Due to its partial water-extractability, gelation, viscosity and water- binding capacity, Arabinoxylan has important functional properties in bread making [17]. The dietary fibre content in those two brans varied from 40 to 53% of the dry matter, and starch content from 9 to 25%. Around 55% of the dietary fibre in wheat bran was arabinoxylan, while the remaining was cellulose (9-12%), lignin (3-5%), fructan (3-4%) and mixed linked β-glucan (2.2-2.6%). The ash content of wheat bran samples was 5.5-6.5%. Wheat bran also contains about 4-6% di- and trisaccharides such as sucrose and raffinose. Cellulose makes up 30 % of wheat bran's cell wall, and corresponds about 9.3-12.1% of the dry weight of wheat bran. Cellulose is insoluble and resistant to many microorganisms and enzymes. Celluloses are often associated with lignin and other non-starchy polysaccharides. Together with lignin and other fibres, cellulose forms a lignocellulose, which is highly resistant towards degradation [18].

Arabinoxylans

Arabinoxylan is a fibre composed of a β -D-xylan backbone with arabinose side chains linked by α-1, 2 and α-1, 3 glycosidic linkages. Around 64% of wheat bran cell walls consist of Arabinoxylans. Arabinoxylans corresponds about 22.4-29.8% of the wheat bran dry weight. Arabinoxylan has some antioxidative properties might be due to the phenolic compounds that are covalently attached to arabinoxylans [19]. Arabinoxylans may also reduce postprandial glycemic response by maintaining viscosity in the gut, thereby reducing the risk of developing type II diabetes, [20]. When bran is used as an additive, it plays an important role in the preparation of dough and also in bread baking performance [21]. Arabinoxylans can be water-soluble or water-in soluble, flexibility of the Arabinoxylan molecules is extremely dependent on xylose and arabinose subunits ratio. Only some portion of the Arabinoxylans is soluble and majority of the Arabinoxylans is insoluble.

β-glucans and proteins

β- glucan soluble in water and highly viscous. β-Glucans correspond about 2.2-2.7% of the dry weight of wheat bran. Protein content of the wheat bran is approximately 15.2-16.9%. This is around 14% of all the proteins in wheat kernel. Wheat bran mostly consists of glutamic acid (18.6%) and aspartic acid (7.2%) [22].

Lipids

Wheat bran contains 5.5-5.6% of lipids and wheat germ approximately contains 28.5% of lipids: 10.0-16.3% in embryonic axis and 12.6-32.1% in scutellum. Most of these are phospholipids, but there are some glycolipids. In bran, 50% of the lipids are unsaturated lipids with 18 carbons and two double bonds [23].

Phenolic acids

On the wet basis the total phenolic acid content in the wheat bran is around 4.5μg/g bran Ferulic acid is an example of the hydroxycinnamic acids. These phenolic compounds are found richly in wheat bran. Usually about 80% of ferulic acid is ester-linked to other constitutive elements of the cell wall, namely arabinoxylans [24]. Flavour, texture, colour and the nutritional properties of foods can be greatly influenced by the phenolic acids.

Bioactive potential of wheat bran

The bioactive compounds present in wheat bran are reviewed in relation to their antioxidant and anti-inflammatory activities. The content of bioactive compounds in wheat grain and bran are given in Table 1. The wide ranges found in the contents of some compounds are the result of a difference in environmental conditions, areas of cultivation, genetic factors and evolution, varieties or extraction.

Table 1: Bioactive compounds per 100g of wheat bran.

S No	Bio active Component	Quantity per 100g of Wheat Bran
1	Phytic acid	2180-5220mg
2	Ferulic acid	500-1500mg
3	Alkylresorcinols	220-400mg
4	Lutein	97-140μg
5	Iron	11mg
6	Manganese	12mg
7	Zinc	7.3mg
8	Selenium	78μg
9	Vitamin E	1.4mg
10	Betaine	1000-1300mg
11	Choline	47-100mg
12	Niacin	14-18mg
13	Panthothenic acid	2.2-3.9mg
14	Riboflavin	0.39-0.75mg
15	Biotin	0.048mg
16	Thiamin	0.54mg
17	Pyridoxin	1-1.3mg
18	Folate	79-200μg

Health Benefits of Wheat Bran

Studies have shown that the consumption of wheat bran and its products will have a beneficial effect on the prevention of diseases such as cancer, cardiovascular disorders, obesity and some gastrointestinal diseases including diverticular disease, constipation and irritable bowel syndrome [25].

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In the prevention of cancer

Increased consumption of fiber diet will reduce the risk of Bowel cancer and Colorectal cancer in humans by 40%. Similarly, the consumption of wheat bran with and without the ascorbic acid and α-tocopherol supplements for 4 years has reduced the number of polyps and the risk of cancer [26]. Found that the diet supplemented with wheat bran of 13.5g/day had significantly reduced faecal bile acid concentration, which plays a pivotal role in the colorectal cancer risk. These studies gave some experimental support that diet comprising the wheat bran supplementation may protect against cancer.

The protective mechanisms of wheat bran against colon cancer fall into three categories.

1. Effect on dilution of potential carcinogens and promoters of carcinogens

2. Wheat bran accelerates transit of faecal material through the colon, such that rapid transit reduces access of the colonic epithelial cells to faecal constituents.

3. Effect of fermentation of wheat bran to Short chain fatty acids such as butyric acid throughout the colon.

Short chain fatty acids modulates carcinogenesis by their effects on proliferation, differentiation and apoptosis of colonocytes, as well as stimulation of the immune system have shown that Wheat bran doubles the production of Short Chain Fatty Acids (SCFA) and in vitro fermentation, resulting in reduced production of butyrate in subjects with colonic adenomas or suffering from colon cancers [26]. Wheat bran reduces colon carcinogenesis and minimizes the incidence of tumors. Wheat bran fibre supplementation can inhibit DNA synthesis and epithelial cell proliferation within rectal mucosa crypts of patients at high risk for colon cancer. Phyticacid of wheat bran may block PI-3 kinase activation, which accelerates apoptosis and may be protective against colorectal cancer [27] and breast cancer development [28].

Cardio vascular diseases (CVD)

Consumption of wheat bran will lead to a reduction in the total serum cholesterol [29]. After the consumption of wheat bran-based breakfast for 3 weeks, serum cholesterol was reduced from 5.576 to 4.385mmol/l in those participants with the highest quintile of serum cholesterol, without any reduction in beneficial HDL-C, suggests the benefits of wheat bran on CVD risk [30] has examined the effect of wheat bran in the diet of 42,850 males on risk of coronary heart disease [31] has compared the women lowest intake of bran with highest intake on the cardio vascular disease-specific mortality of 7822 women with type 2 diabetes. Women with the highest intake have all-cause mortality risk of 0.72 and cardio vascular disease-specific mortality risk was 0.65.

Wheat bran and irritable bowel syndrome (IBS)

Irritable Bowel Syndrome is oriented with a pain or discomfort in the stomach with either diarrhea or constipation along with a different kind of stool. Increased fibre intake is suggested as an initial treatment for this syndrome. Wheat bran is reported to be associated with reducing the symptoms of Irritable Bowel Syndrome [32]. Reported that an increase in the insoluble fibre in the form of wheat bran (20g a day), for the patients with Irritable Bowel Syndrome. Wheat bran also has increased stool weight and decreased transit time in healthy controls and patients with IBS and chronic constipation [33]. Consumption of 45g raw unprocessed wheat bran has provided a marked relief from the symptoms of diverticular disease [34]. Increased consumption of wheat bran will alleviate the constipation during pregnancy and increases the frequency of defaecation [35].

Antioxidant properties

Wheat brans also have rich antioxidant properties [36]. Wheat brans are the rich sources of flavonoids, phenolic acids, tocopherols, lignans, phytosterols and carotenoids, which provides many health benefits [37]. Free-radical inhibiting capacity of wheat bran has been can be measured through ferric reducing antioxidant power, diphenylpicryl hydrazyl and oxygen radical absorbance capacity assays [38]. Antioxidant properties of wheat brans are mainly determined by their phenolic acid contents. Phenolic acids such as ferulic acidare found abundantly in the wheat bran in insoluble bound state [39]. Phenolic compounds have been extracted from wheat brans both by conventional methods (Soxhlet extraction) and through advanced micro-fluidisation, ultrasonic-assisted extraction and pressurised liquid extraction [40]. Various processing methods such as milling, electrostatic separation, ultrafine grinding will not only enhance the bio-accessibility of phenolic acid and other bioactive compounds in wheat bran, but also increases surface area and its antioxidant capacity. This increase of antioxidant capacity might be due to increased accessibility phenolic acid, carotenoids, anthocyanin, and flavonoids in the aleurone cell wall due to mechanical extraction, which in turn contributes to increased antioxidant activity. From these results, wheat bran can be suggested as an important functional food ingredient with many positive health implications.

Wheat bran and pre-biotics

Colonic microflora has profound effects on the human health. Prebiotics are defined as non-digestible food ingredients that are beneficial to the host by selectively stimulating the growth or activity of one or a limited number of bacteria in the colon [41]. There is a growing body of evidence which supports the role of prebiotics on bowel health and colon cancer. Consumption of wheat bran will be fermented into form short chain fatty acids by the microflora in the intestine, resulting in physiological changes

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to the colonic contents, affecting bulking, water retention capacity and viscosity [42].

Influence of Milling on Antioxidants and Secondary Metabolites

Phenolics were concentrated in debraned fractions representing ≤20% of the outer layers of wheat. Total phenolics and antioxidant activity were highly correlated. In between red and white wheat varities there was no significant difference in total phenolics or antioxidants. The physical structure of the wheat bran influences its antioxidant capacity [43].The recent studies showed that the parameters such as the granulometric distribution of particles, the particle size reduction speed, and the dissociation of the different bran layers during grinding were greatly influenced by temperature. When the temperature is decreased below the 'brittle point' of a material, its fragmentation into ultrafine particles is made easier and this behaviour is associated with the composition of the materials and to their related thermo-mechanical properties. The study of the thermo-mechanical properties of wheat bran and wheat bran layers has shown that, due to the presence of lipidic compounds in the cuticles of test a and hyaline layer, a glass transition can be detected at 46 °C within the intermediate layers. At ambient and cryogenic temperatures this glass transition explains the observed difference of grinding behaviour of bran.

In cryogenic conditions (below 46 °C), the intermediate layers become brittle, and all the bran constituent layers display increased stiffness and similarly low extensibilities. As the bran became brittle, it was easily fragmented, leading to a fast particle size reduction. On the other hand, the dissociation of the bran layers is limited at low temperature leads to the simultaneous fracture of the tissues. Cryogenic grinding results in a faster fragmentation of bran into fine particles, and a higher proportion of composite particles. At ambient temperatures, due to the exhibition of a high plasticity and extensibility by the intermediate layers of bran, wheat bran acts is an elastoplastic material. At ambient temperature, the diverse bran layers exhibit highly different extensibilities. The different extensibilities of the bran layers will lead to their dissociation from each other during ambient grinding, generating a wide range of particle sizes. The increased wheat bran's antioxidant capacity was linked neither with the release of aleurone intracellular compounds nor with the release of phenolic acids in their conjugated or free forms. It was rather linked with the phenolic moieties exposition.

Food Products Utilizing Wheat Bran

In food industry wheat bran is used as emulsifier. Usage of modified wheat bran can add several properties to the final food product and can impart functional properties to it. It increases water and oil holding capacity which helps in reduction of cooking time. Thermal treatment like extrusion cooking has been reported to soften the bran, inactivate Wheat bran endogenous enzymes and increase the extractability of bioactive compounds such as sterols and ferulic acid. In baking it is used as an additive in dough, wheat bran is known to reduce the quality of bread resulting in a lower specific volume and denser crumb texture [44]. Added wheat bran also causes changes in the flavour and colour, and reduces the shelf-life. Arabionxylans obtained from the fibre components of wheat bran can be used in food formulations as gelling agents, cryostabilizers, and as a source of prebiotics and also in beverages to increase the amount of dietary fibre wheat bran can be used as an additive [45].

Other than the food products and beverages modified wheat bran fractions, such as polymers and fibres can be used in paper and bioplastic applications as filler to improve the quality of the product. In paper industry, the particles can be used to decrease the weight of paper. As functional paper additives, the filler particles could be used to improve the retention, i.e. how well the filler materials are bound to the cellulose network, and thus increase the strength of paper [46]. In paper applications, fillers could be used as edible packaging material or for eco- friendly products. Previous studies have shown that wheat bran can be modified in several operations to edible packaging material used as an inner or outer package. Edible packaging material could be used, for example, as packaging papers for burgers and sandwiches [47].

Conclusion

Wheat bran contains various compounds which have potential nutraceutical functions. This wheat bran can be exploited in various countries to prevent malnutrition and deadly diseases. Utilization of this wheat bran for various food and drug applications has to be improved for obtaining its full potential health benefits.

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