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Review of Nutraceuticals and Functional Properties of Whole Wheat

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Abstract

Wheat (Triticum aestivum L.) is one of the most commonly cultivated and consumed cereals throughout the world. Though phytochemicals and antioxidants in the cereal grains have not been studied as in fruits and vegetables, given the role of wheat in our diet plate, it is a given of primary importance to understand the chemistry of our major food, wheat. The presence of diverse polyphenols and their action against leading cause of death, including heart diseases, cancer, obesity, and diabetes, widens the scope of wheat. Phytochemicals such as phenolic acids, alkylresorcinols, flavonoids, phytosterols, and carotenoids are present in whole wheat. The majority of phytochemicals are located in the wheat bran/germ fraction, and they are the leading contributors to the health promoting activities. However, the presence of anti-nutrients and binding of phenolic acids with protein may have adverse effect on health. This review mainly focuses on studies that have been carried out in the past decade to present, emphasizing the importance of whole wheat and whole wheat based products in preventing major diseases and disease conditions, potentials threats, current lacks, and future prospects.

Keywords: Phytochemicals; Wheat; Polyphenols; Antioxidants; Anti-nutrients

Introduction

Wheat (Triticum spp.) is an ancient grain and also one of the leading cereal crops, ranking third, in the world [1]. The centre of origin of wheat is South-western Asia. Hybridization of diploid and tetraploid wheat occurred several thousand years ago resulting in the production of hexaploid wheat (common wheat: T. aestivum L.) [2]. Common wheat has been consumed as a food for more than 12,000 years. It was believed that Greek, Roman, Sumerian, and Finnish mythology had god and goddesses of wheat. In the United States, wheat was introduced in the early colonial years. However, it was not until 19th century that wheat cultivation flourished, which was brought by the Russian immigrants who settled in the Kansas [2]. At present, the largest commercial producers of wheat include China, India, United States, Russian Federation, and France [1].

The unique viscoelastic properties of wheat, which allow the formation of a number of products, make it leading choice on our diet plate [3]. The ability of wheat to be well suited for a wide range of agro-climatic zones make it the most cultivated crop throughout the world and in the United States. These two reasons make wheat the largest produced and consumed cereals throughout the world. In the U.S., wheat is grown as winter and spring wheat: winter wheat accounts for 70-80% of total production in the U.S. [4]. The United States Department of Agriculture (USDA) classified wheat as hard red winter wheat, hard red spring wheat, soft red winter wheat, white wheat, and Durum wheat, the use of which may be different depending upon the final product. The composition of wheat varies among genotypes, environment and their interactions, classes of wheat [5], and parts of a wheat grain [6]. A wheat grain is divided into three main parts, the bran, endosperm, and germ. The bran, the outer layer, is composed of fibres (50%), antioxidants, B vitamins, and 50-80% of minerals are composed of iron, copper, zinc and magnesium [7]. Wheat is also a rich source of protein, carbohydrates and fibres as mentioned in several previous studies [3]. The protein content in the germ and aleurone layer is 30%, whereas the pericarp layer contains 10% of the total protein [6]. Though protein contents in wheat aleurone and germ layer are high, the contribution of endosperm to total kernel protein content is relatively higher; about 74% [6].

The health promoting effects of whole wheat or whole wheat based products are mainly due to the presence of phytochemicals in wheat, including phenolic, carotenoids, lignans and vitamin E [8]. Each of these phytochemicals in combination or alone accelerates health-promoting events. Several past studies have shown the effectiveness of polyphenols against oxidative stress and dietary fibre against cancer [9]. The amount of these phytochemicals varies depending upon the fraction of wheat grain and the processing conditions. In a study, environment influences on the total phytochemical concentrations were pronounced more significant than production system [9]. In the recent years, several studies on health benefits of whole wheat are increasing the perception of people and inclination towards whole wheat/whole wheat based products. Due to the association of whole wheat in preventing several diseases, numerous studies have been carried out to date with no sign of decreasing. In future, oxidative stress-related diseases, obesity, cancer, and diabetes are likely to cause large number of deaths. Though several studies have been conducted and much is known about benefits of whole wheat, there remains a lack of information about the phytochemicals present in whole wheat to their possible association with different diseases. This paper reviews phytochemicals present in whole wheat and studies of several health benefits and the health promoting action of whole wheat with special emphasis on oxidative stress, heart diseases, cancer, inflammation, obesity, and immunology carried out in the last decade.

Composition of Whole Wheat

Wheat grain is comprised mainly of starch, proteins, and cell wall polysaccharides (dietary fibre) [5]. These components in combination
account for 90% of the grain composition on dry weight basis. The minor components present in wheat are lipids, terpenoids, phenolics, minerals, and vitamins. The fat soluble nutrients that include vitamin E (tocopherols and tocotrienols, collectively called as tocols) and the carotenoids are located in wheat flour. In the wheat kernel, tocols are unevenly distributed as the activity of methyltransferases is crucial in determining the relative proportion of vitamins in grains [6]. Toccols scavenge peroxy radicals, singlet oxygen and nitrogen oxide, which are responsible for the oxidative stress-mediated diseases, such as cancer and coronary heart diseases. However, the bran matrix formed in whole wheat flour may decrease the bioavailability of tocols [7]. According to the U.S. Department of Agriculture’s National Nutrient Database, whole-grain wheat flour has 0.71-0.85 mg/g of vitamin E (α-tocopherol). Processing of the whole wheat causes loss of tocols, as they are subjected to oxidation in the presence of heat, light or alkali. During extrusion, around 85% losses of tocols have been reported [9]. Carotenoids are not active as alone but contribute to antioxidant property of wheat [10]. Lutein, β-cryptoxanthin, zeaxanthin (xanthophyll: hydroxylated carbons) and β-carotene (hydrocarbon) is the carotenoids present in wheat [9]. Though wheat flour is not a rich source of carotenoids, it is still an important nutrient considering the amount of whole wheat consumed.

The phytosterols are mainly located in the wheat kernel [9]. The total phytosterols in winter wheat grain range from 0.62-0.96 mg/g dry weight basis [7]. The predominant phytosterol in wheat is the desmethyl sterols (no methyl group at C-4). Campesterol, sitosterol, stigmasterol, avenasterols (desmethyl sterols) and the stanols (saturated sterols) are different phytosterols that have been reported in wheat grains. Phytosterols have been shown to reduce low-density lipoprotein cholesterol and may have a promising effect against cancer [8].

Phenolics, compounds containing a phenol ring and at least one hydroxyl substituent, are the main constituents of wheat. Phenolic compounds are located mainly in the outer barn layers of kernels [7]. Wheat phenolics include the phenolic acids, flavonoids, and alkaliresorcinols. Ferulic acid (main phenolic acid in wheat), caffic acid, sinapic acid, protocatechuic acid, vanillic acid, p-hydroxybenzoic acids, p-coumaric acid, and syringic acid are some phenolic acids present in wheat bran and whole wheat flour [9]. Phenolic acids are mainly known for their antioxidative properties. However, the antioxidative properties of phenolic acids have been reported to decrease when they bind to the protein. The flavonoids are mainly located in the wheat germ (0.09 µmol/g of grain) [11]. Flavonoids have both anti-oxidative and anti-inflammatory activities [12]. Lastly, lignans are the phytoestrogens, which are found in the wheat bran. Though studies remain limited on wheat lignans, their association has been reported against cancer [13].

Oxidative Stress

High reactive molecules, known as free radicals, are produced in our body that causes oxidative stress (imbalance between oxidants and antioxidants) due to the hyper oxidation nature of oxygen [14]. When our body can’t cope with the oxidative stress, oxidative damage occurs in the form of many diseases, including but not limited to Coronary Heart Diseases (CHD), cancer and diabetes [14]. However, the regular intake of whole wheat in our diet has been associated with the reduced risk of chronic diseases and oxidative stress related disorders [11]. Several mechanisms that include termination of free radical-mediated oxidative reactions, stimulation of antioxidant enzymes, reduction of peroxides, and chelation of transition metals, are exhibited by dietary antioxidants/polyphenols against the oxidative stress [15].
The immune system is a complex web of cellular interactions, which is influenced by health, genetics, and consumption of the foods [44]. Whole wheat contains a plethora of bioactive components, the consumption of which influences biochemical reactions in our body. Ferulic acid, the major bioactive component in whole wheat, contributes the functional immunity mostly by improving gamma delta T (γδ T) cell proliferation and function in the body [29]. γδ T cells are important immune cells that have the properties of innate and acquired immune systems [45]. Ferulic acid acted as a pathogen-
associated molecular pattern (PAMP) for the γδ T cells [29]. The γδ T cells lysed cells via perforin of Fas-ligand-dependent pathways. These cells also secreted cytokines and chemokines in order to recruit monocytes and neutrophils to the site of inflammation. γδ T cells either recognize PAMPs, phosphor antigens or non-peptide, lipid antigens, and respond directly to Toll-like receptor (TLR) ligands without the presence of antigen presenting cells. In a recent study in mice, feralic acid modulated the function of dendritic cells (antigen presenting cells) to promote interferon (IFN)-gamma production by activated T cells. Further it was explained that feralic acids affected the Th2 based immune response. In addition, feralic acid was determined to act as an antiallergic in treating Th2 mediated allergenic response [46].

Studies using dietary fibres present in whole wheat were able to stimulate the immune function via production of short-chain fatty acids (SCFAs) [47]. The addition of SCFAs to parenteral feeding has shown to increase T helper cells, macrophages, neutrophils, and cytotoxic activity of natural killer cells in animal studies [48]. Celiac disease (caused due to dietary intolerance of wheat), a chronic inflammation of the bowel, results from an autoimmune response due to the binding of gluten peptides to T cells of the immune system (only to those people who are allergic to wheat) with the human leucocyte antigens (HLA) DQ2 and DQ8 [7]. These bound peptides are recognized by specific CD+ T cells and then releases inflammatory cytokines, which flattens the intestinal epithelium [7].

Gastrointestinal Microbiota

Arabinoxylan and cellulose (important components in whole wheat) are poorly fermented in the gut [49] and have high potential to improve/maintain a healthy gut. Consumption of whole grain was shown to increase bifidogenic effect: some strains of Bifidobacterium are markers of healthy gut [15]. An increase in butyrate-producing bacteria, Roseburia, Eubacterium rectale and the Clostridium leptum, contributed to host colonic epithelial cell energy during the fermentation of carbohydrates from the whole wheat [50]. A study has shown that dietary fibers provided significant health benefits by increasing viscosity, which delays gastric emptying and limits glucose diffusion towards the enterocytes for absorption [15]. Dietary fibre intake has also been associated with an increase in satiety thus help to control body weight [51]. The mechanism for this may be due to the hormonal effects mediated by the reduction of insulin secretion, the metabolic effect mediated by increased fat oxidation and colonic effects via SCFA production [22]. Decrease in the diversity of the microbiota are associated with increased risk of obesity and disease [43]. Whole wheat consumption increased the microbiota. Another compound, lignan in whole wheat was able to protect against hormonally mediated diseases [22]. Plants lignans are converted by gut bacteria to the mammalian lignans enterolactone and enterodiol. Saturated fat exhibits an antimicrobial effect and consequently reduced diversity [49]. Considering that whole wheat is lower in the total fat content but high in high unsaturated fat, these fats have been shown to produce a healthy microbial effect [48]. An increase in the Bifidobacteria and decrease in Coriobacteriaceae resulted when whole wheat was incorporated in diet. Bifidobacteria was correlated with plasma HDL-concentration, while Coriobacteriaceae was correlated with non-HDL cholesterol [48].

Metabolic Syndrome

Metabolic syndrome is a pattern of metabolic disturbances associated with increased risk of type 2 diabetes, raised blood pressure, dyslipidemia, and obesity [52]. Several studies on intake of whole grains have been reported that consumption of wheat was negatively associated with metabolic syndrome [35,53]. Whole wheat flour has been able to improve glycaemic control and insulin sensitivity, decrease blood pressure and produce a healthy body mass index (BMI) as discussed in reference [22]. The mechanism for the above response was due to the presence of bran, which decreased glucose absorption and produced SCFA from the fermentation of resistant carbohydrates, which in turn improved insulin sensitivity [53].

Yet another study, tocotrienols in whole wheat decreased the risk of heart disease whereas β-sito sterol was associated with a decrease in cholesterol [34]. A study with feralic acid, which is the major component in whole wheat, showed that feralic acid converted into DHFA by microbiota in gut resulting an increase in Bacteroidetes and Firmicutes [54]. γ–oryzanol (γ–oryzanol content in wheat bran ranged from 300-390 mg/kg) observed in wheat bran showed to lower serum cholesterol effectively than tocopherols and tocotrienols [55]. Low-density cholesterol (LDL) was shown to be reduced by 12% and ratio of LDL to HDL (high-density lipoprotein) cholesterol was decreased by 19% when diets containing γ–oryzanol were fed to rats (Mitchell et al., 1996). That arabinoxylan reduced the postprandial glucose level due to its high viscosity [56]. As a result, arabinoxylan reduced small intestinal motility resulting in delayed glucose absorption; hence a flat postprandial glucose response was observed.

Whole Wheat Prospects and Lacks

The diversity of the nutraceuticals present in whole wheat makes this bran an excellent commodity on our diet plates. Several studies have been carried out over a decade, to identify its multiple health benefits including cellular oxidation mediated diseases, cancer, atherosclerosis, inflammation, obesity, and diabetes [5,22] as described throughout this documents. The presence of polyphenols in whole wheat was correlated with the reduced risk of the diseases. However, most of the studies were focused either on the individual action of the polyphenols, supplementation of the wheat/wheat extract in vitro. Only very few studies reported the effect on health due to the overabundance of specific phytochemicals. Will the effect be beneficial or detrimental? Also, the bioavailability of the proposed phytochemicals in presence of anti-nutritional factors is another crucial concern. Several studies have reported the binding of polyphenols with trypsin inhibitors during digestion [57]. The fact that humans may have other diseases and allergic response, the beneficial effects of polyphenols on these groups of people is not yet known. Will the unhealthy people have a similar effect or a new health complication may take place? Moreover, the analytical method used can vary the amount of polyphenols [58]. A unique and consistent approach to quantify compounds may give a reliable results considering their chemical diversity and their interactions with a given food matrix. Besides above-mentioned questions, a number of phytochemicals in wheat are largely depended on the growing conditions of wheat and therefore, probably each food type will have to be optimized on its own merit.

Given the fact that polyphenols are produced in plants to protect them against stresses (biotic and abiotic), how relevant it is in terms of total production of wheat. There lacks the specification in the classes of wheat that were being used in the study. Compared to white wheat, red wheat contains higher levels of polyphenols, but what about the bioavailability of those compounds. An abundance of polyphenols does not really assure higher bioavailability. Studies on diverse group of the population also may help to pronounce effect of phytochemicals on wheat. In presence of stresses, the total production decreases, but polyphenols may increase in those grains. Will the phytochemicals derived from unhealthy grains be useful to us?
In the recent years, besides health benefits from whole wheat several studies have shown the negative or possible problems due to the consumption of whole grains. Given the possibility of contamination of heavy metals on whole wheat and their possible adverse effects on human health, it is important to study if whole wheat is actually beneficial or not. Also, the contamination of whole wheat by nanoparticles such as zinc oxide and titanium dioxide [59,60] and their potential effects to health has been a major concern regarding the use of whole wheat in our diet. The ability of nanoparticles to cross the blood-brain barrier, move to other vital organs, and possible damage of DNA [61] makes whole wheat questionable in its potential benefits. The contamination of nanoparticles from the different sources in an environment to plant and finally to grains [59] is the serious issue and more studies need to be carried out. The amount of heavy metals that reaches on our diet plate, their potential to exacerbate other benefits more studies need to be carried out. The amount of heavy metals that reaches on our diet plate, their potential to exacerbate other benefits either by binding with phenols or by acting as inhibitory agent: these all areas need to be addressed.

Concluding Remarks

Although presence of anti-nutrients and binding of phenolic acids with protein may have adverse effect on health, whole wheat and whole wheat based products played a great role to improve health by preventing major diseases and disease conditions. However, thorough study on the types of wheat, interaction of the phytochemicals with other proteins, heavy metal accumulation in wheat bran, bioavailability of compounds in different wheat products need to be addressed in future, which will give us a big picture of the beneficial effects of one of the largely consumed products in world.

References