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Wheat Antioxidants, Their Role in Bakery Industry, and Health Perspective

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Abstract

Wheat grains and its fractions contain significant level of antioxidant activity and many phytochemicals, such as phenolic acids (ferulic and vanillic acids), carotenoids, and tocopherol are beneficial in curing many disorders. The beneficial phytochemicals are mostly present in aleurone fraction of wheat bran. The phytochemicals and antioxidants present in wheat have several health benefits, such as their ability to act as antioxidants, immunoenhancers, and inhibitors of certain lesions, which have been demonstrated for phenolic. Many wheat antioxidants are similar to the antioxidants present in wheat, but their characteristics are also unique in nature. The regular consumption of these antioxidant compounds in whole grains is associated with a reduced risk of many heart diseases and several forms of cancers and improves the regulation of blood glucose. Wheat antioxidants play a vital role in bakery industry mostly in bread industry. People are getting aware to use the bakery products that are prepared from the white flour due to proper nutrition, healthy lifestyle, improved nutritional composition, and functional properties. In nutshell, wheat antioxidants including phytochemicals synergistically improve the health status of consumers by consuming the products having complete nutrition.

Keywords: wheat antioxidants, phytochemicals, bakery products, health perspectives

1. Introduction

Wheat (*Triticum aestivum* L.) is used as a staple food by human since the late Stone Age (ca. 6700 BC) [1]. It is also a promising source of bioactive compounds such as phenolic acids, tocotrienols, tocopherols, carotenoids, phytosterols, and flavonoids and antinutritional factors, such as phytic acids and oxalates. Wheat cultivars exert antioxidant activity due to the presence of phytochemicals, such as phenolic acids, carotenoids, anthocyanins, and tocopherols [2]. They are also enriched with basic nutrients, i.e., proteins, vitamins, and minerals including calcium, iron, zinc, phosphorous, etc. The percentages of the phytochemicals are greatly influenced by multiple factors, such as soil type, cultivar type, topography, temperature, and humidity [3].

The population is more diverting toward the consumption of natural antioxidants due to their safe status and effectiveness in the physiological system when compared to synthetic antioxidants. They neutralize the effects of free radicals, act as metal chelators, and terminate the oxidative enzyme inhibitors and reactive oxygen species (ROS) reactions [4]. These free radicals enhance the uncontrolled growth of cells, produce the genetic defects in DNA, and leak the antioxidant enzyme concentration from the cells [5]. Similarly, low-density lipoprotein (LDL) is responsible for the development of coronary diseases [6]. The polyphenols from the wheat have preventive role against reactive oxygen species through neutralizing the hydroxyl and peroxy radicals, thereby suppressing the lipid peroxidation [7]. The human body contains two antioxidant systems: enzymatic including glutathione peroxidase and superoxide dismutase (SOD) and nonenzymatic, i.e., vitamin C, β -carotene, vitamin E, and selenium [8]. Extraction is a process which is used for the recovery and isolation of phytochemicals from wheat cultivars. The quantification of phytochemicals from wheat is affected by multiple factors, i.e., extraction time, solvent, solute/solvent ratio, efficiency of mass transfer, temperature, and particle size [9]. There are frequently methods which are used to determine the antioxidant potential of wheat such as DPPH, ORAC, and FRAP. High-performance liquid chromatography and gas chromatography are direct indicators of antioxidant capacity [10].

2. Antioxidant potential of wheat grain

Rising investigations have proved that certain types of cancer, coronary heart disease, and potential health benefits are reduced by the intake of whole wheat. Phytochemicals and nondigestible carbohydrates are the beneficial bioactive factors present in whole wheat grain [11–14]. In wheat grain there are small molecular weight phytochemicals known as bioactive molecules. They consist of but they are not inadequate to carotenoids, phenolic acids, tocopherols, and lignans. Oxidative damage to the most important compounds such as enzymes and DNA by different mechanisms is prevented by these bioactive molecules. To dismiss the attack of reactive oxygen species (ROS) such as singlet oxygen molecule or hydroxyl radicals on biological molecules, bioactive molecules directly react with these ROS molecules [15].

There are an adequate number of bioactive compounds present in the wheat grains instead of aleurone which is mainly consist of protein granules. The wheat bran also contained

the major proteins in the wheat grain [16]. The above investigation indicates the utilization and production of “super bran” and other wheat-based food and components rich in bioactive molecule present in wheat. Other bioactive factors and bioactive molecule-rich wheat grain should be produced after studying the results of old investigations [17]. The bioactive compounds particularly the phenolics are found in the bran portion of the cereal grains and occur in different forms mainly free, soluble conjugated, as well as insoluble-bound forms [18].

In wheat bran, the availability of bioactive molecule potential can be influenced by postharvest treatment, milling practice, and storage conditions investigated in few investigations. The outcomes of the above investigations showed that yeast treatment and postharvest enzymatic particle size of bran and storing practices can considerably change bioactive molecule accessibility in food products containing wheat [19].

Remarkably, the bioactive molecules of selected food have been investigated in food products and the properties of processed food atmosphere on bioactive molecule accessibility in food products containing wheat. To have little health support, bioactive foods are dynamic and are well acknowledged in Ref. [15]. The accessibility and bioavailability of various ingredients from wheat are very beneficial regarding health perspective in targeting specific body organs. Collaboration of wheat bioactive molecule with different food compounds and also the end merchandise to process food environments such as thermal treatment on the universal bioactive molecular properties of wheat products are not understood. Lignans and phenolic acids present as wheat phenolics are known as bioactive molecules [20].

The bioavailability and availability of bioactives can be altered by food matrix. The bioavailability of bioactive molecules presents in wheat such as lignans and phenolic acids from different wheat-based food products and ingredients has been investigated in pilot human and animal investigations. The natural bioactive molecule rich in wheat-based functional food is very important to augment human benefits [21].

There are number of analytical techniques has been established for the determination of phytochemical composition, bioactive molecular properties of wheat grain and their fractions. Among different fluorometric and spectrophotometric methods, electron spin resonance (ESR) spectroscopy considered a better approach because it deals with the presence of free radicals and considered a better analytical method for wheat bioactive molecules. These analytical methods can be used on different botanicals and cereal grains [22].

2.1. Phenolic compounds present in wheat

Cereals are used as staple foods due to a promising source of nutrients including carbohydrates, vitamins, proteins, and minerals. They are also consisting of a wide range of bioactive compounds and exert health-promoting effects such as anticancer, cardio-prevention, diabetes, and aging [23]. These bioactive compounds exhibited multiple physiological mechanisms including antioxidant activity, enhancement of immune system, mediation of hormones and facilitation of substance transit via digestive tract, production of butyric acid in the colon, and assimilation of substances in the gut [24, 25].

Among these cereals, wheat (*T. aestivum* L.) is a significant source of minerals, proteins, water-soluble vitamins, and dietary fibers. The wheat grain is divided into three parts such as endosperm (80–85%), bran (13–17%), and germ (2–3%) and comprises all essential nutrients. Generally, wheat grain kernel contains carbohydrates (70%), protein (12%), water (12%), fat (2%), crude fiber (2.2%), and minerals (1.8%), respectively. Moreover, wheat grain kernel is a potential source of minerals, including magnesium, phosphorus, zinc, manganese, iron, selenium, copper, and potassium [26]. Likewise, wheat is also enriched with a wide range of bioactive compounds, including phenolic acids (136.8–233.9 $\mu\text{g/g}$), alkylresorcinols (AR) (99.9–316.0 $\mu\text{g/g}$), phytosterols (562.6–1035.5 $\mu\text{g/g}$), and tocopherols (19.3–292.7 $\mu\text{g/g}$) [27, 28]. Phenolic acids are widely distributed in different parts of grains, i.e., testa, pericarp, and aleurone [29]. In wheat, several phenolic acids are present such as chlorogenic acid, ferulic acid, caffeic acid, *p*-coumaric, and sinapic acid, respectively. These compounds are present as bound forms, respectively, as phenolic acids (85%) in maize, wheat and maize (75%), and rice (62%). Cinnamic acids have been categorized as bioactive ingredients of the diet because they are bound to structural compounds of the cell wall [30, 31]. The schematic representation of wheat grain fractions is shown in **Figure 1**.

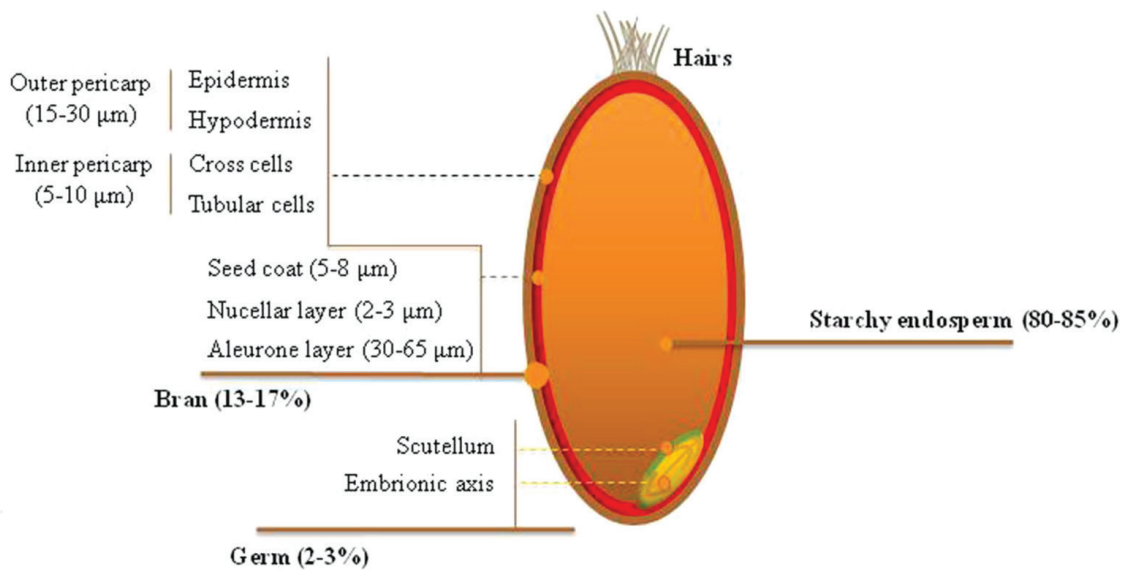


Figure 1. Schematic representation of wheat grain fractions.

Ferulic acid (4-hydroxy-3-methoxycinnamic acid) is present in different parts of vegetables, fruits, and grains as well as also endorses the health-promoting perspectives [29, 32]. Wheat flour is the prime ingredient, which is used to prepare different products of bread industry such as pasta. Wheat is also a promising source of dietary fibers along with preventing and curing some digestive disorders [33]. Endosperm is separated from the bran and germ through grinding, sieving, and purifying steps in conventional wheat roller milling. Furthermore, endosperm is also grounded to wheat flour on the basis of refinement and then used to prepare the bread, whereas bran, aleurone layer, starchy endosperm, and germ are used as milling by-products. Similarly, wheat bran is used by animals due to higher nutritional profile which exerts beneficial physiological effects. The bran-based products are shown with more health perspectives when

compared to refined flour. Consumers are more interested to utilize the bran-based products, such as cookies, bread, pasta, breakfast cereals, cakes, snacks, and more [34].

3. Chemistry of wheat polyphenols

Wheat polyphenols are generally involved in defense mechanism against biotic and abiotic stresses which are secondary metabolites [35]. The first substrate of the phenyl propanoid pathway is phenylalanine, which initiates the biosynthesis of phenolic acids and then produces the different phenolic acids and flavonoids [36]. Similarly, wheat phenolic compounds are categorized into derivatives of hydroxybenzoic acid or hydroxycinnamic acid. In hydroxybenzoic acid derivatives, different compounds are present like gallic, vanillic, *p*-coumaric, hydroxybenzoic, and syringic acids, whereas hydroxycinnamic acids contain different derivatives, such as ferulic acid, dehydrotrimers of ferulic acid, *p*-coumaric acids, and dehydrodimers [37, 38].

Wheat antioxidants are located in wheat grain compartments such as the endosperm, bran, and germ [37]. The intermediate layer of wheat grain mostly composed of arabinoxylan and high amounts of ferulic acid monomers, whereas aleurone layer has lower content of ferulic acid dimers and trimers [39]. The phenolic contents present in bran/germ have 15–18 folds higher than that of endosperm, whereas only 17% of the total phenolic content is present in starchy endosperm [40, 41]. The phenolic compounds and antioxidant in wheat grain are shown in **Figure 2**.

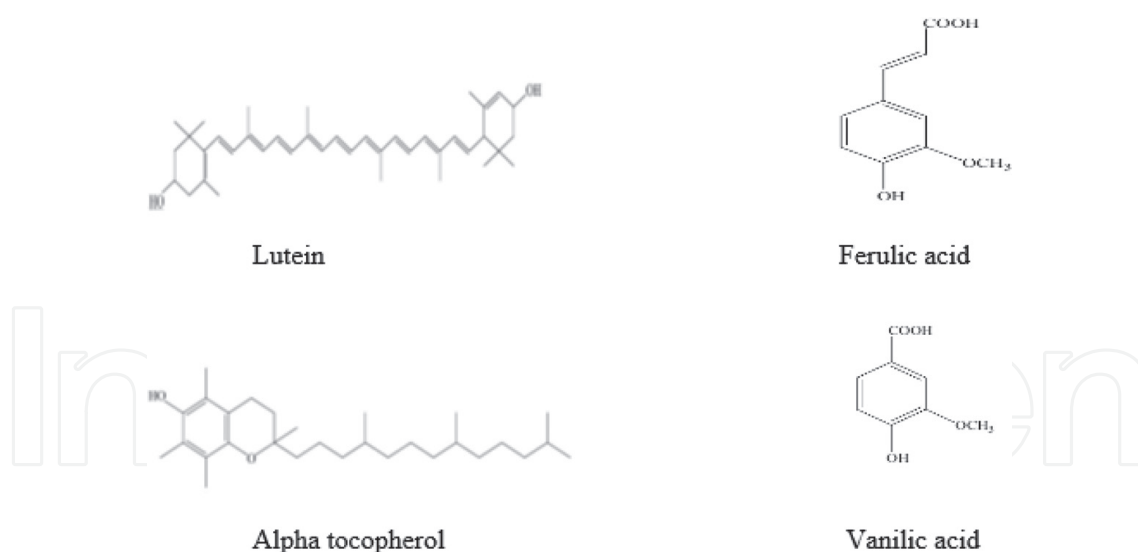


Figure 2. Phenolic compounds and antioxidant in wheat grain.

4. Wheat antioxidants in bread industry

Bread and bakery products have significant importance in human nutrition through preventing from the human disorders. These products are obtained from the white flour and a promising source of irreplaceable nutrients. People are getting aware to use the bakery products which are

prepared from the white flour due to proper nutrition, healthy lifestyle, improved nutritional composition, and functional properties [42]. The prepared bread is a significant source of dietary fibers, minerals, inulin, vitamins, omega-3 fatty acids, oligosaccharides, β -glucans, and flax seeds. Gluten is a protein which is not present in pseudocereal (buckwheat) [43]. Buckwheat is enriched with carbohydrates, proteins, fiber, and minerals along with reducing the blood pressure, cholesterol levels, blood glucose level, and prevention of cancer [44]. It is also a prominent source of balanced amino acid composition and essential amino acids [45]. Furthermore, buckwheat phenolic compounds comprise significant quantity of rutin, ferulic, and quercetin along with preventing from the lipid peroxidation and activity of free radicals [46]. They also show higher antioxidant activity mainly due to high rutin content [47]. The total phenolic contents of whole wheat and refined flour were reported as 1.58 and 0.87 mg FAE/g, respectively [48]. On baking and phenolic conditions, total phenolic contents were decreased to about 72% and 67% of the average content found in whole wheat and refined flour [49, 50]. The antioxidant activity of bakery products is mainly affected by processing conditions, mixing, fermentation time, baking temperature, and formulations [51]. Phenolic acid recovery after baking was 74–80%. In comparison to baker's yeast wheat bread, sourdough wheat (durum and kamut) offered more antioxidant protection [52].

5. Wheat antioxidants in breakfast foods

Wheat-based breakfast is proven effective by promoting the health-endorsing perspectives due to higher concentration of phenolic bioactive moieties. The acid and enzymatic hydrolysis increase the solubility of wheat bioactive compounds. Similarly, food processing conditions mainly affect the stability, distribution, and activity of wheat-based compounds [53]. The resultant breakfast of wheat has been used to prevent from the proliferation of type 2 diabetes mellitus through lowering the glycemic level in the postprandial phase [54]. The utilization of wheat in breakfast foods prevented the individuals from many disorders like obesity, hypertension, oxidative stress, diabetes complications, mental disorders, digestive ailments, and cognition due to the presence of diets higher in minerals and vitamins and lower in fat. These breakfasts are also used to reduce the body mass index and incidences of obesity and overweight [55, 56]. Similarly, wheat antioxidant-based breakfast significantly decreased hunger [57]. They also protect from the bowel disorder due to dietary fiber. They enhanced the hydrated fecal weight between 10 and 20 g/100 g diet from a baseline of 21 ± 1.5 g/100 g diet [58].

6. Absorption and bioavailability of wheat antioxidants

6.1. Syringic acid, sinapic acid, vanillic acid, and *p*-hydroxybenzoic acid

The information regarding pharmacokinetic parameters or the absorption characteristics of syringic acid, sinapic acid, *p*-hydroxybenzoic acid, and vanillic acid is less. Therefore, it is need of the time to conduct some studies regarding the absorption of these particular acids. Moreover, these compound bioavailability is unknown. Which based on the derived innovative principle of bioavailability and absorption for phenolic acid, nevertheless, we can now assess their bioavailability and absorption effectiveness. The substrate of monocarboxylic acid transporter meets

the structural standards of all these compounds, that is, group of mono-anionic carboxyl and a component of aromatic hydrophobic. Each phenolic acid inhibits the transport of fluorescein, and they increased by the following order: syringic acid (105.9%)<sinapic acid (75.0%)<vanillic acid (56.2%)<*p*-hydroxybenzoic acid (35.5%) [59]. Compared to fluorescein transport inhibition by *p*-coumaric acid (85.2%), ferulic acid (52.4%), and caffeic acid (116.2%), each phenolic acid monocarboxylic acid transporter affinity increased by the following order: *p*-hydroxybenzoic acid>vanillic acid $\frac{1}{4}$ ferulic acid>*p*-coumaric acid, sinapic acid>syringic acid>caffeic acid. Hence, monocarboxylic acid transporter vigorously absorbed the *p*-hydroxybenzoic acid, vanillic acid, and sinapic acid through a mediated transport system.

Syringic acid absorption is particularly absorbed through paracellular diffusion; lesser amount is absorbed by monocarboxylic acid transporter, same in the case with caffeic acid [60]. Conjugating enzyme susceptibility, for instance, sulfotransferase and glucuronosyltransferase, bioavailability also affects by that enzyme. Vanillic acid, having a group of hydroxymethoxy aromatic ring, may be a good aim for conjugation [61]. The ferulic acid and vanillic acid affinities for monocarboxylic acid transporter, their conjugation susceptibility together, show that these two compounds have similar bioavailability. While the caffeic acid absorption efficiency is alike to the syringic acid, conjugation susceptibility is different. Component of catechol lacks in syringic acid and therefore unlikely to be conjugation [62]. These results propose a syringic acid has a greater bioavailability over caffeic acid. The understood fact, that is, syringic acid, *p*-hydroxybenzoic acid, and sinapic acid bioavailability, is alike to that of *p*-coumaric acid, while the vanillic acid bioavailability is alike to that of ferulic acid. Germano et al. stated that after hydrolyzed extraction from the root of *Trichilia emetica* including numerous phenolic acids which is orally ingested in rats such as free caffeic acid, syringic acid, *p*-coumaric acid, vanillic acid, and gallic acid, free vanillic acid absorption was comparatively efficient and fast [63].

The bran of oat powder rich in phenol-fed hamsters to find the total bioavailability of vanillic acid, sinapic acid, syringic acid, *p*-coumaric acid, *p*-hydroxybenzoic acid, and ferulic acid, including each phenolic acid, is present in conjugated and free forms, calculated by plasma C_{max} /oral dose ratio [64]. The expected bioavailability and absorption of these phenolic acids, depend on our new protocol of fluorescein assay, are generally constant with these two reports. Nevertheless, a number of factors influenced by the bioavailability and absorption came from these studies (i.e., impacts of numerous phenolic acid medicated concurrently and considerable differences of bioavailability between intact and total phenolic acid). Both in vivo and in vitro studies must be done for accurate determination of engagement and bioavailability of these phenolic acids. It has already been performed for caffeic acid and *p*-coumaric acid [30, 65, 66].

6.2. Soluble, insoluble, and free conjugate-bound phenolic acid present in wheat

In grains, phenolic acid contributes the major portion, for instance, corn, wheat, and rice, which are typically esterified with arabinose or galactose in pectic and hemicellulosis residues in cell wall as well as occur as insoluble fraction (corn 85%, wheat 75%, and rice 62%) [67]. The major phenolic compounds present in grains is ferulic acid with free, soluble conjugated and bound form present in 0.1:1:100 ratios [67]. Furthermore, the major contributors to the total antioxidant activity are the bound phytochemicals e.g. 71% in rice, 90% in wheat, 58% in oats and 87% in corn. The health consequences of dietary phenolic acid in wheat based food

materials depends mainly on the bioavailability and absorption of soluble/ insoluble and free/ conjugate phenolic acids.

In case of insoluble fiber, the greater number of bound ferulic acid, for example, wheat bran, is believed to evade from the stomach or intestinal digestion or absorption to hold out the colon. Microbial enzymes of the colon, for instance, esterase and xylanase, release and solubilize feruloylated oligosaccharides (FOs) (i.e., feruloyl-arabinoxylan, 5-o-feruloyl-arabinofuranose) or free ferulic acid, just after reaching the colon. An esterase from mucosa acts on a part of bound ferulic acid during the flow within the gastrointestinal tract leading to the colon, and feruloylated oligosaccharides or free ferulic acid is released [68, 69]. The newly emancipated phenolic acid is absorbed through the gastrointestinal epithelium into the bloodstream jointly with ingested free phenolic acid and delivered to various tissues. The microbial esterases and mucosal substrates like 5-o-feruloyl-arabinofuranose are examples of soluble free and conjugate phenolic acids which are used for absorption of nutrients [70].

In short, phenolic acid in wheat which is of various forms (i.e., insoluble, soluble, and free conjugated bound forms) is converted by the breakdown reaction of free phenolic acid involving colonial and mucosal enzymes. These free phenolic acids destined to blood stream after distribution and metabolized into the body by the action of different enzymes. Wheat phenolic acids have different stages where various factors affects absorption and bioavailability. These factors include (a) the absorption of phenolic acids in the lumen of digestive system and capacity of the biomembrane and monocarboxylic acid transporter; (b) conjugating enzyme susceptibility, tissue having free phenolic acid metabolism, and transporter of monocarboxylic acid affinity; (c) ingestion of wheat phenolic acid, phenolic acid-bound content in conjugated, free, insoluble, and soluble; and (d) discharge of free phenolic content and soluble and insoluble bound of phenolic acid which are attacked by enzymes and the area of GI tract. In recent studies the effect of ingested food components having phenolic acid has been discussed in Ref. [71]. The health benefits of whole grain such as rice and wheat should be studied in detail to find the effect of different aspects on bioavailability and absorption of phenolic acid present in wheat.

7. Health perspectives of wheat antioxidants

There are multiple evidences which prove that utilization of wheat antioxidants is linked with the lower incidence of oxidative stress-related chronic diseases and age-related disorders, such as carcinogenesis, cardiovascular diseases, type II diabetes, and obesity. They perform health-endorsing perspectives due to the presence of vitamin C, vitamin E, carotenoids, phenolic acids, and flavonoids [25, 26]. They also facilitate digestion in human body by allowing the bound phenolics in the colon [67]. Similarly, they improve insulin and inhibit the tumor necrosis factor (TNF) alpha serum levels, lowering the serum cholesterol, fasting glucose, and triglyceride. They also exert anticancer effects on cell growth and apoptosis of human breast cancer cells such as MCF-7 and MDA-MB-231 [72].

The fact is that diet can completely change the life quality and human health. Wheat has numerous essential nutrients, which are important part of diet. It is one of the most dominating nutritious crops. Intake of whole grain or wheat reduces the cardiovascular risk and

diabetes [73]. The antioxidants of wheat and the insoluble fibers impart the valuable properties. Nevertheless, metabolism and cholesterol biosynthesis are directly standardized through wheat antioxidants as compares to antioxidative agents, which are acting simply. The productive impacts are examined regarding the effect of antioxidants present in wheat on the enzymes which participate in cholesterol biosynthesis.

The expression of genes involved in metabolism and cholesterol biosynthesis are examined by the wheat antioxidants. Wheat antioxidants at a concentration of 0.12 mg/mL are treated with the rat hepatocytes which is equivalent to 2 mg of wheat grain /mL of medium for 24 hours. Ribonuclease protection assay (RPA) are used for the examination of mRNA levels of HMG-CoA reductase (HMG-CoA-R), LDL receptor (LDLR) and cholesterol 7 α -hydroxylase (CYP7A1). CYP7A1 and HMG-CoA-R are rate limiting enzymes for the conversion of cholesterol to bile acids and cholesterol biosynthesis respectively. It is precisely evident that wheat antioxidants considerably boosted the breakdown of HMG-CoA-R mRNA due to the progressive studies of impacts of wheat antioxidants on the mRNA stabilities of HMG-CoA-R and CYP7A1 but rise the CYP7A1 mRNA stability. Wheat antioxidants also participate in continuous boosting of bile synthesis. The data concludes that the control of the important genetic factors participating in metabolism and biosynthesis may be illustrated as among basic and important mechanism on molecular/cellular bases due to which the dangers of heart-related disorders are reduced by wheat antioxidants [74].

The polyphenols from wheat have been proven effective against cervical cancer cells (HeLa) and colon cancer cells (HT-29 and Caco-2) due to their antioxidant potential and induction of apoptosis and inhibit the proliferation of uncontrolled growth of cell lines [75]. Similarly, in human neuroblastoma cells (SH-SY5Y), they enhanced the viable cell numbers by 37%, lowered the release of lactate dehydrogenase, suppressed the H₂O₂-induced formation of reactive oxygen species, and maintained the mitochondrial transmembrane potential. They also enhanced the Bcl-2/Bax ratio and blocked cleavage poly(ADP-ribose) polymerase by inhibiting caspase-3 activation [76]. They also exert anticancer effects on cell growth and apoptosis of human breast cancer cells such as MCF-7 and MDA-MB-231. Wheat bran is rich in alkylresorcinols (ARs), and having colon cancer cell lines (HT-29 and HCT-116) through increasing or decreasing the side-chain lengths, it diminished the activities. On the aromatic ring of the AR analogue, there are two hydroxyl groups at C-1 and C-3, greatly contributed to their antitumor activity. There is no significant enhancement in activity against HCT-116 cells on the third hydroxyl group at C-2 into the aromatic ring of the AR analogues [77]. Moreover, wheat bioactive compounds caused significant reduction in lipid peroxidation (LPO) and enhancement in glutathione (GSH), superoxide dismutase (SOD), and catalase (CAT) in Swiss albino mice [78]. Similarly, the administration of 2,6-dimethoxy-1,4-benzoquinone (DMBQ) (24 μ mol/l) from fermented wheat germ extract (FWGE) exhibited the antiproliferative properties in vitro in nine human cancer cell lines after 24 h of culture by causing cell cycle arrest, inducing apoptotic cell death and neutralizing the effect of reactive oxygen species [79]. Ferulic acid is another promising antioxidant of wheat that induced the apoptotic cell death in human breast cancer cells such as MCF-7, MDA-MB-231, osteosarcoma 143B, and MG63 cells lines in dose-dependent fashion through multiple mechanisms such as (1) induction of apoptosis; (2) caused G₀/G₁ phase arrest, enhancement of caspase-3 activity; (3) downregulation of

the expression of cell cycle-related protein, CDK 2, CDK 4, and CDK 6; (4) downregulation of Bcl-2 expressions, upregulation of Bax, and inhibition of PI3K/Akt activation [80, 81]. In another study conducted by [82], wheat ethanolic extracts provide protection to hepatic microsomes through reducing the proliferation of the HCT 116 and A549 cancer cell lines. The *in vivo* inclusion of β -Glucans has a great potential against number of conditions like tumor development and infections caused by fungal, viral, protozoal and bacterial pathogens [83]. It also activates the T-helper and natural killer (NK) cells, cytotoxic macrophages, and promotion of T-lymphocyte differentiation and activation [84]. Wheat polyphenols are used to resolve the problem of septic discharge from the ear, relieve ear pain, and eliminate scars [85]. These polyphenols also prevented from the oxidative damage of DNA, proteins, and membrane lipids as well as also protected from the incidence of cardiovascular and cancer [86]. They also suppress the LDL oxidation through binding with apolipoprotein B [87]. Alkylresorcinol from wheat bran suppresses the platelet binding to fibrinogen, stimulates the thromboxane production, and inhibits triglyceride accumulation. In human erythrocytes, they also prevent from the free radical-induced oxidative damage [88, 89]. Wheat antioxidants are also effective to reduce the accumulation of triglycerides, low-density lipoprotein, reactive oxygen species, and concentration of thiobarbituric acid-reactive substances (TBARS) and enhance the high-density lipoprotein, vitamin E, and vitamin A [90]. They also improved insulin, suppressed the tumor necrosis factor (TNF) alpha serum levels, and lowered the serum cholesterol, triglyceride, and blood sugar [72]. The bioactive compounds, such as ferulic acid, tocopherols, and carotenoids, significantly increased the liver glycogen and lowered the glycosylated hemoglobin levels and blood glucose [76, 91, 92].

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