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The Nutraceutical Role of Wheat Grains

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Abstract: Wheat is one of the most important food crops worldwide due to its wide use. Often, it is perceived only as a food instrument, but the biochemical properties of the wheat grain recommend it as a nutraceutical tool. Starting from the morphology and structure of the wheat grain, in addition to the major composition of the endosperm which is rich in protein and starch, the outer layers of the grain represent a rich variety of biochemical constituents that can have beneficial effects on health. The outer pericarp consists mainly of cellulose, arabinoxylan and lignin with carbohydrate and phenolic acid compositions, a high concentration of ferulic acid has antioxidant and anti-inflammatory properties. On the other hands, at the test level there is a significant source of lignin that has both an antioxidant role and a protective role against the development of various diseases and viral infections. Aleurone layer, as the main wheat bran contains a wide variety of biochemical compounds and vitamins with a role in the biofortification of the human body. The wheat embryo contains a good level of tocopherols, phytosterols, policosanols, thiamin, riboflavin and other bioactive compounds with significant role in prevention of diseases such as colon and breast cancers, cardiovascular disease, obesity and gastrointestinal diseases.

Keywords: cereal, grain, human health, nutritional, quality, wheat.

Introduction

Wheat (*Triticum aestivum* L.) is an important agricultural commodity and a primary food ingredient worldwide which contains important beneficial nutritional components (Vaher et al., 2010). The widespread use of this crop and its accessibility make it one of the most consumed nutritional raw materials. Wheat quality has traditionally been judged on the basis of functionality, mostly on gluten content and colour, and, to a lesser extent, nutritional value (Marconi and Carcea, 2001).

There is growing evidence that wheat whole grain composition plays an important role in the prevention against chronic diseases (Brouns et al., 2012). Whole grains of cereals, especially raw flour which contains outer layers are rich sources of bioactive phytochemicals (associated with high antioxidant activity), tocopherols, carotenoids, vitamin E, lignans, β-glucans, inulin, resistant starch, sterols, and phytates. These bioactive compounds determine furthermore health benefits also for plant, as well as for food (Žilić, 2016).

Polyphenols are important antioxidants with antibacterial, anti-allergic, antiviral, and anti-cancer properties, and ameliorate the effects of immunological inflammatory diseases. Ferulic acid (FA) is a dietary polyphenol and is abundant in the cell walls of plants such as wheat, oats, coffee beans, apples, oranges, peanuts, pineapples, and artichokes (Zhao and Moghadasian, 2008). Many studies have found that the FA has diverse pharmacological effects such as anti-diabetic (Srinivasan, 2007), and anti-bacterial effects (Lee et al., 2006), neuroprotective effects (Turkez et al., 2022; Wang et al., 2021), a brightening effect on skin (Pueknang and Saewan, 2022), and anti-cancer effects (Chang et al., 2006; Fong et al., 2016; Janicke et al., 2011).

Arabinoxylan (AX) is a major component of cell walls being also a main component of dietary fiber, it is found in many cereal grains, wheat being a rich source of AX. The extraction of AX is difficult to achieve from wheat bran but can be produced from wheat endosperm during the commercial processing of wheat flour. When starch and gluten are processed from wheat flour, the fiber component, which is primarily AX, remains in the byproduct (Barr, 1989).

Xylose is an essential component of plant hemicellulose, after glucose, being the second most abundant carbohydrate on the earth. The majority of the hemicellulose backbone, known as arabinoxylan in the cell walls of cereal grains, is made up of the pentose sugars xylose and arabinose (Huntley and Patience, 2018).

Knowing, using, and improving the quality of nutrients in foods offers a complementary intervention strategy for alleviating the burden of diet-related chronic disease. Due to daily use in food wholegrain cereals, such as wheat, are prime targets. Their nutritional credentials and health-promoting potential are well established. Wheat is the major source of protein, minerals and vitamins, and dietary fiber for most people, being also a versatile ingredient for producing foods that have high consumer appeal (Barron et al., 2007; Kamal-Eldin et al., 2009; Bird and Regina, 2018). These health advantages are partly attributed to the distinctive phytochemical composition of grains (Adom et al., 2003).

Cereal-based fiber includes non-starch polysaccharides such as arabinoxylans (AX), β-glucans, fructans, and cellulose, as well as resistant starch and lignin (Kamal-Eldin et al., 2009). AX, β-glucans, fructans, and resistant starch are often considered prebiotics because of their beneficial effects on the microbiota of the colon. In human health arabinoxylans are responsible for the modulation of SCFAs in the colon, improved antioxidant capacity, reduced glucose blood response via different mechanisms (Zannini et al., 2022) prevent of heart disease (Jin et al., 2010) reduces the risk of certain types of cancer. These beneficial effects are attributed to the bioactive factors in wheat grain such as non-digestible carbohydrates and phytochemicals.

The morphological and structure of wheat grains are the result of plant generative stages which involve the genetic dowry and environment effects. From floral initiation to physiological maturity, the maternal tissues of wheat grains show a complex development and growth (Ghiglione et al., 2008; Ferrante et al., 2010). The pericarp is the centre of hydration and nutrition both the embryo and endosperm especially during early grain filling (Herrera and Calderini, 2020). On the other hands, wheat bran is a protective covering material which envelopes the starchy endosperm and grain germ of different mechanical shocks (Parker et al., 2005).

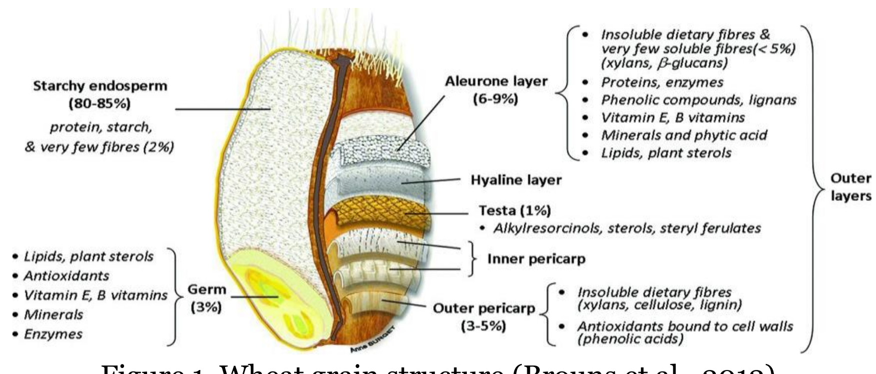

Figure 1. Wheat grain structure (Brouns et al., 2012).

Outer pericarp (3-5 %) has its cellular organization and chemical composition (Barron et al., 2007). The outer pericarp of the wheat grain has an intermediate thickness (15–30 mm), comprising about 45–50% cell wall material (Tosi et al., 2018) which consists mainly of cellulose (30%), arabinoxylan (60%) and lignin (12%) (Stone and Morell, 2009), with carbohydrate and phenolic acid compositions (Antoine et al., 2003; Rhodes et al., 2002) indicating the presence of high amounts of cell wall polysaccharides, especially highly feruloylated arabinoxylans showing different structural features. A high concentration of ferulic acid (FA) was observed in cell walls of intact wheat bran (Antoine et al., 2003; Parker et al., 2005). Alongside by other proprieties, FA has antioxidant and anti-inflammatory properties, but it is unclear what effects it has on the intestine. The structure and composition of outer pericarp and **inner pericarp** are simple these being composed of empty cells, mostly made of branched heteroxylans, cellulose and lignin.

Testa or **seed coat** (1%) is a protective grain layer rich in lignin, characterized by the presence of lipid compounds such as alkylresorcinol located on the outer face of this tissue (Evers and Reed, 1988; Landberg et al., 2008). The albumins and globulins have a high concentration in testa, these fractions cover about 25% of the total grain proteins (Belderok et al., 2000). Also, the testa layer contains proanthocyanidins (PAs), polymeric flavonoids also known as condensed tannins that acquire a reddish colour on oxidation, which may contribute just as other polyphenols to prevent oxidative stress and reduce the risk of various chronic diseases (Scalbert et al., 2000). Proanthocyanidins play several important roles in maintaining good health, including preventing sun damage to the skin and retina, enhancing flexibility in joints, arteries, and body tissues like the heart, and enhancing blood flow by fortifying capillaries, arteries, and veins (Hemmati et al., 2015; Shi et al., 2003).

Hyaline layer known as the nucellar tissue is an intermediate layer, which contains more than 90% poorly cross-linked arabinoxylans (Barron et al., 2007). Hyaline layer contains a good level of Ferulic acid compared to other grain components, as well as coumaric acid and sinapic acid (Călinoiu and Vodnar, 2018).

Aleurone layer (6-9%) is a simple cell layer (20–75 μm) at the inner site of the bran, representing ~50% of wheat bran. It is a good source of the minerals, vitamins, phenolic antioxidants, and lignans of the wheat grain, phytates, B vitamins such as niacin and folates, and lipidic compounds such as plant sterols (Buri et al., 2004; Hemery et al., 2011; Brouns et al., 2012; Antoine et al., 2002; Fardet et al., 2010) being rich in proteins and enzymes, with a vital role in the germination process (Šramková et al., 2009). The aleurone layer is the thickest (up to 65 mm) bound to the seed coats, it is rather difficult to separate this fraction from the rest of the bran (Brouns et al., 2012) The aleurone cell is composed of the cytoplasm or intracellular medium, surrounded by thick nonlignified cell walls, which represent ~35% of the cell volume, and more than 40% of the layer in mass (Hemery et al., 2009a). Aleurone cell walls contain 29% β-glucans, few type of proteins, and 65% relatively linear arabinoxylan with a low arabinose-to-xylose ratio, and high amounts of esterified FA monomer (Rhodes et al., 2002a; 2002b; Saulnier et al., 2007). The intracellular medium of aleurone cells contain aleurone granules (2–4 μm diameter), which are either phytate inclusions (composed of phytic acid minerals), or niacin inclusions (composed of niacin and proteins), each granule being surrounded by a fine layer of lipidic droplets (Brouns et al., 2012).

The presence of ferulic acid esters in wheat bran has been known for some time (Brett and Waldron, 1996; Sanchez et al., 1991; Lequart et al., 1999). Ferulic acid (FA) is esterified to arabinose units of cell wall arabinoxylans, and is prominent in aleurone, pericarp and embryo cell walls.

Ferulic acid (hydroxycynnamic acid derivative) is the most abundant phenolic compound in wheat grain. Compared to other structure-related antioxidants, its ability to inhibit lipid peroxidation by superoxide scavenging is of greater magnitude than that of cinnamic acid but less than that of caffeic acid (Toda et al., 1991), whereas its ability to inhibit oxidation of low-density lipoprotein (LDL), the main cholesterol carrier in blood, is greater than that of ascorbic acid (Castellucio et al., 1996).

The aleurone layer content significant level of dietary fiber which has been estimated to be 44–50 g/100 g DM (Amrein et al., 2003), this quantity may vary depending on the wheat variety and purity of the aleurone fraction. The major polysaccharides present in the fiber fraction are arabinoxylan (65%) and β-glucans (29%), while cellulose plays a more minor role.

Aleurone layer can content a significant level of phosphorus, magnesium, manganese, and iron. In aleurone- 80% of phosphorus is in phytate form, the wheat grain being a great reserve for this element. Indeed, the phytate inclusions from aleurone granules are composed of phytic acid (1160 mg/100 g) or myo-inositol phosphate, which forms complexes with calcium, magnesium, or trace elements (particularly zinc). Whole grains are very often blamed for decreasing mineral bioavailability due to the strong mineral chelating properties of its dietary fibers and phytic acid.

Also, the wheat aleurone layer is an important source of B-group vitamin- B_1 (1.6 mg/100 g), vitamin B_3 (32.9 mg/100 g), and folic acid (0.8 mg). It can be estimated that 100 g of aleurone may provide the recommended daily allowances of these vitamins (Brouns et al., 2012). Thiamin (B_1) and riboflavin (B_2) contents are higher in the aleurone than in other bran layers, being essential micronutrients that are mainly involved in energy metabolism; being essential for body mobility, also they may prevent the occurrence of developmental abnormalities and chronic degenerative and neoplastic diseases (Mielgo-Ayuso et al., 2018).

Starchy endosperm (80-85%) is rich in starch and gluten proteins (Barron et al., 2007). The starch is a main component in wheat grain, which accounts for 60–70% of its dry weight (Wang et al., 2012), followed by protein, the two being known as wheat quality indicators (Zhang et al., 2016). The wheat endosperm contains about 70% starch, so differences in the quality and quantity of starch affect the milling and dough process and the flour characteristics (Kim and Kim, 2021). The wheat kernel starch in the endosperm has three types (A-, B-, and C-type) of starch granules, each distinguished by its properties (Zhang et al., 2016). Each type has a unique physico-chemical property that determines the quality of starch.

The milling process are focused to separates the starchy endosperm cells form the other grain tissues, in order to give the white flour fraction suitable for bread making industry and other baked goods, pasta and noodles. A major aim of milling is therefore to maximize the recovery of white flour (Tosi et al., 2018). Although the starchy endosperm is usually treated as a single homogeneous tissue, even if this one contains several types of cells whit differ size and composition what determines the different behaviour in dough process.

Wheat starch is a major storage carbohydrate and contains about 60~75% grain and 70~80% flour (Shevkani et al., 2017). Starch granules located in starchy endosperm cells are composed of two polymers called amylose (~25%) respectively amylopectin (~75%) with role in water absorption, stability, and altered starch pasting properties. Starch plays a significant role in the texture of many kinds of food and serves as a major source of energy for humans (Hung et al., 2006).

Starch granules are composed of two types of α-glucans, amylose and amylopectin, and make up about 98-99% of the dry weight (Tester et al., 2004). Amylose and amylopectin differ in structure and properties and can determine the nutritional and biochemical properties of starch (Lv et al., 2021). These starches are rapidly digested and absorbed as glucose. In the process of digestion, the human body responds to hyperglycemia causing obesity and diabetes. Recently, many studies conducted on resistant starch (RS), a type of starch, proved that it is not easily decomposed by digestive enzymes in the body. Resistant starch acts similar to dietary fiber, providing nutrients to intestinal bacteria. Grains high in RS are reported to help improve human health and reduce the risk of serious non-infectious diseases. Currently, there is an increasing need for developing crops with high RS to address the rapidly growing nutritional challenges for public health (Regina et al., 2006).

Germ /the embryo accounts for about 3% of the mature grain and comprises the embryonic axis, which forms the seeding during germination, and a single cotyledon (scutellum), which is a storage tissue.

The wheat germ (embryonic axis and scutellum) represents about 2.5–3.8% of total seed weight and is an important by-product of the flour milling industry. The germ contains about 10–15% lipids, 26–35% proteins, 17% sugars, 1.5–4.5% fibre and 4% minerals, as well as significant quantities of bioactive compounds such as tocopherols (300–740 mg/kg dry matter (DM)), phytosterols (24–50 mg/kg), policosanols (10 mg/kg), carotenoids (4–38 mg/kg), thiamin (15–23 mg/kg) and riboflavin (6–10 mg/kg) (Brandolini and Hidalgo, 2011).

Wheat germ has excellent nutritional value, as a food supplement being a concentrated source of dietary fiber and essential fatty acids, but its incorporation into the diet has been rare up to now (Moreira-Rosario et al., 2016). Also, the embryo represents the main by-product of the flour milling industry, and although it is considered an excellent source of minerals, vitamins, fiber and essential fatty acids, it has been underused (Moreira-Rosario et al., 2016). Ingestion of raw wheat germ seems to reduce cholesterol and triglycerides and maintaining normal cholesterol levels (Cara et al., 1992) and in decreasing potentially pathogenic gastrointestinal microorganisms (Matteuzzi et al., 2004).

Conclusion

➢ The wheat grain is an important source of valuable bioactive compounds with a role in combating and preventing various disorders or diseases of the body.

➢ The integration and use of the various component parts of the grain in the daily diet can have a favourable effect in ensuring the daily requirement of essential bioactive compounds.

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