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## Development and characterization of coloured wheat beverages

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### Abstract

Cereals are an important food source in the human diet, and the production process generates a huge variety of by-products. The germ and outer layers (bran) of grains obtained from dry and wet milling, brewers' residual grain derived from the brewing industry, and others derived from bread-making and starch production comprise the majority of these by-products. To prevent health issues caused by a high consumption of animal-based foods, the globe is emphasizing a well-balanced diet as well as vegan or plant-based diets. People who are gluten or lactose intolerant prefer fermented meals, with cereal-based fermented drinks topping the list. Many products are made from fermented or colored wheat varieties. Anthocyanins, present in colored wheat, help to regulate a variety of ailments such as cardiovascular disease, diabetes, and obesity, as well as working as an anti-inflammatory. Lactic acid bacteria (LAB) are the most often used microorganisms in fermentation. Colored wheat is used to make drinks with higher levels of anti-oxidants and proteins than white and red wheat, such as Boza, Rejuvelac, Anthograin liqueur, and Antho-beer. Fermentation using yeast, Lactic acid bacteria, and fungus was extensively employed to generate cereal-based meals with improved health qualities, and its application to cereal by-products might improve the system's overall eco-sustainability, giving a good option to reduce hunger and malnutrition.

**Keywords:** Anthocyanins, colored wheat, lactic acid bacteria, gluten and malnutrition

### Introduction

Massive changes in lifestyle, nutrition, and rural habitation are causing permanent change, resulting in a slew of health issues. Consumers desire meals that boost the immune system, reduce illness risk, and promote health and which they can self-prescribe for themselves and their families. As the notion of a healthy diet has become more obvious, many individuals throughout the globe have increased their hunt for functional foods to enhance their diets. Market research indicates that there is plenty of potential for value-added and health-promoting food items (Singh, 2007; Sharma *et al.*, 2013) <sup>[1, 80]</sup>. Foods containing probiotics and prebiotics, which increase health-promoting microbial flora in the gut, represent a significant improvement in functional foods. The bulk of a population's entire energy and nutritional needs are met by staple foods, which comprise the majority of their diet. Whole grains are also high in phytochemicals such as phytoestrogens, phenolic compounds, antioxidants, phytic acid, and sterols (Charalampopoulos *et al.*, 2002) <sup>[2]</sup>. Wheat is one of the world's most important food crops and a main source of energy in underdeveloped nations (Sharma *et al.*, 2020) <sup>[57]</sup>. Proteins, essential amino acids, carbohydrates, dietary fibers, chlorophyll, vitamins A, B, C, E, and minerals like iron, calcium, magnesium, and selenium are all plentiful (Sharma *et al.*, 2020; Braun *et al.*, 2010) <sup>[57, 12]</sup>.

Wheat grain processing characteristics vary based on color (red, purple, and black) and are controlled by pigments contained in the seed coat (carotene, xanthophylls, anthocyanin, and phenolic chemicals). The color of wheat grains is determined by the placement of pigments in the bran layers (Garg *et al.*, 2016) <sup>[25]</sup>. The most widely grown wheat (*T. aestivum*) is amber in color and has substantially less anthocyanins. Colored wheat varieties of *T. aestivum* (blue, black, purple, and red) are high in anthocyanins and other phytochemicals and are gaining popularity across the world (Syta *et al.*, 2018) <sup>[31]</sup>. Xanthophylls, carotenoids, and flavones are the principal pigments in red and amber durum wheats, but anthocyanins are the key pigments in blue and purple wheats. Purple color is restricted to the pericarp (Garg *et al.*, 2016) <sup>[25]</sup>, while blue color is restricted to the aleurone (Garg *et al.*, 2016; Abdel *et al.*, 2008) <sup>[25, 7]</sup>. Combining genes for both purple and blue descriptions resulted in black wheat.

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Normal wheat has 2.15 percent ash, 12.93 percent protein, 3.33 percent oil, 61.85 percent starch, and 2.29 percent cellulose, which are all much lower than the proportions seen in colored wheat, both qualitatively and statistically. Colored wheat had around 11.74 percent to 18.17 percent more protein, 7.31 percent to 18.13 percent more essential amino acids, and 8.88 percent to 18.91 percent more total amino acids than uncolored wheat (Tian *et al.*, 2018) <sup>[4]</sup>. Vitamins B1 (thiamine), B2 (riboflavin), B3 (niacin), B6 (pyridoxine), B9 (folate), and E (tocopherol/tocotrienol) are abundant in pigmented wheat. Provitamin A (carotene), D (calciferol), and K (phyloquinone) are also present in trace amounts (Balyan *et al.*, 2013) <sup>[80]</sup>. Separately, the Zn, Fe, and magnesium content of pigmented wheat is approximately 108.54 percent to 142.68 percent higher, 8.57 percent to 42.86 percent higher, and 5.31 percent to 40.63 percent higher, respectively, than that of regular wheat (Tian *et al.*, 2018) <sup>[4]</sup>.

Anthocyanins are essential components of the human diet, especially considering the growing body of research suggesting their antioxidant, anti-inflammatory, anti-diabetic, and anti-cancer properties (Shipp & Abdel-Aal, 2010;) <sup>[93]</sup>. Wheat anthocyanin pigments are aqueous; therefore, they may be employed as a natural food colorant. Depending on the pigmentation type, wheat pigments may be found in the aleurone or pericarp layers of the kernel. Wheat-colored grains include a high concentration of anthocyanins, which show potential for improving functional components (Abdel-Aal, Hucl, Shipp, & Rabalski, 2016) <sup>[85]</sup>.

Anthocyanins have anti-diabetic, anticancer, anti-inflammatory, antibacterial, and anti-obesity properties (Tsuda *et al.*, 2003) <sup>[64]</sup>, as well as the ability to protect cardiovascular diseases (CVDs) (He *et al.*, 2011; Khoo *et al.*, 2017) <sup>[30, 83]</sup>. (Patel *et al.*, 2013) <sup>[47]</sup>. For a healthy life, anthocyanin intake should range between 3-215 mg per day. According to Khoo *et al.* (2017) <sup>[83]</sup>, the most frequent anthocyanidins found in plants include cyanidin, delphinidin, pelargonidin, peonidin, malvidin, and petunidin.

Colored wheat products are rich in carotenoids, total dietary fibre (TDF), total phenolic compounds (TPCs), and total anthocyanin compounds (TACs) which have significant antioxidant potential (Ficco *et al.*, 2016) <sup>[84]</sup>. Anthocyanins (13.9 mg/100 g) found in colored wheat (blue or purple) release free radicals, protect human lipoprotein cholesterol from oxidation, and have anti-aging properties (Gebremariam *et al.*, 2014) <sup>[26]</sup>.

Fermentation may be used as an alternative approach to enhance the amounts of different organic components and improve product quality by adjusting the ratio of nutritious and anti-nutritive properties in plant meals. The kind of fermentation is without a doubt accountable for the grain's

bioactive potential (Tijana *et al.*, 2010) <sup>[63]</sup>. Lactobacillus plantarum is a typical probiotic used for fermentation in the medical and food industries because it is a safe and effective probiotic (Arsa *et al.*, 2019) <sup>[9]</sup>.

### Pigmented wheat types

#### Blue wheat

Blue wheat cultivars were created by the use of foreign chromosomal fragments and distant hybridization. Blue caryopses are distinguished by the presence of delphinidin-3-glycoside in the aleurone layer (Fig. 1). (Abdel *et al.*, 2003; Abdel *et al.*, 2018) <sup>[6, 85]</sup> Delphinidin is the most potent anthocyanin angiogenic inhibitor, with applications in cancer prevention and treatment. It may also inhibit tumor growth by blocking the activation of mitogen-activated kinase. The highest anthocyanin concentration was found in bran (460 mg/kg), followed by flour (200 mg/kg) and whole meal (160 mg/kg). Blue wheat surpasses white wheat in milling, with bran, grain, and flour yields of 7.5, 14.6, and 55.0 percent, respectively (Ficco *et al.*, 2016) <sup>[84]</sup> Blue wheat has been found as a possible source of natural anthocyanin pigments (Abdel, 2008) <sup>[7]</sup>. It has the potential to enhance bread, biscuits, muffins, and dairy goods such as yoghurt, ice cream, and frozen desserts.

#### Purple wheat

The purple tint is only present in the pericarp (Fig. 1). (Garg *et al.*, 2016) <sup>[25]</sup>. The anthocyanin Cyanidin-3-glucoside is responsible for the purple hue of wheat grain (Abdel *et al.*, 2003 and 2018; Li *et al.*, 2005) <sup>[6-7, 39]</sup>. Purple wheat contains 11.5 percent protein and 12.6 percent total dietary fibre content. Abdel and colleagues (2018) The high amounts of cyanidin 3-O-glucoside in Anthocyanin-3-O-glycoside-rich purple wheat, according to Pasqualone *et al.* (2015) <sup>[5]</sup>, have a significant cancer-prevention benefit. Certain kinds of pigmented wheat may protect against free radical-caused illnesses due to their intrinsic high antioxidant capacity, which may lead to their use as a dietary additive.

#### Black Wheat

The combined impact of blue and purple anthocyanin genes in both the pericarp and aleurone layer is assumed to be responsible for wheat's black grain color (see Fig. 1). (Li, 2005) <sup>[39]</sup>. When compared to other wheat grains, black wheat has the greatest free radical scavenging ability (Lachman *et al.*, 2017) <sup>[3]</sup>. Black wheat has greater protein, calcium, vitamin K, total flavonoid concentration, phenolic content, and antioxidant activity than other wheat cultivars (Richa, 2022) <sup>[69]</sup>.



Source: Sharma *et al.*, 2020 <sup>[57]</sup>

Fig 1: Different types of pigmented wheat

## Anthocyanins

Anthocyanins, also known as anthocyanidins, have both acidic and alkaline groups. It's a flavonoid containing phenolic components. They are the major plant colorant and may be found as water-soluble natural pigments in a broad variety of plants. Anthocyanins are water-soluble flavonoids pigments distinguished by the type, location, and hydroxyl number of their molecular glycosylation (Liu *et al.*, 2017) [41]. Anthocyanins are glycosylations of anthocyanidins. Plants with anthocyanin conjugated connections are red, blue, and purple in hue. The most prevalent anthocyanidins found in plants include cyanidin (50%), delphinidin (12%), pelargonidin (12%), peonidin (7%), malvidin (7%), and petunidin (7%) of fruits and vegetables, respectively (Castaneda *et al.*, 2009) [15].

Free radicals are natural metabolic products of an organism that play important roles in the redox process of substance metabolism in the body, such as energy transfer. In contrast, light, heat, radiation, and other factors may increase the formation of free radicals. Excess free radicals in the body are unstable, capable of absorbing electrons and showing significant oxidative activity, eventually causing damage to the cell membrane, proteins, DNA, RNA, and other components, resulting in aging and other illnesses (Kim *et al.*, 2014) [36].

When there is an abnormal increase in free radicals in the body for whatever reason, the body is unable to maintain its homeostasis. To augment and help in the preservation of the body's free radical balance, exogenous free radical scavengers are required. Several studies have revealed that anthocyanins operate as antioxidants in three ways: directly scavenging free radicals, modulating antioxidant enzyme activity, and chelating with metal ions (Jiang *et al.*, 2011; Yazhen *et al.*, 2020) [35, 78].

**Anti-cancer properties:** As antioxidants, anthocyanins have anticancer effects. Anthocyanins have been shown *in vitro* and *in vivo* to decrease tumour cell growth and development. Anthocyanins' anticancer action may be connected to their high antioxidant capacity and ability to inhibit cyclooxygenase (Yazhen *et al.*, 2020) [78].

### Anti-tumour effects

Anthocyanins have antitumor action as antioxidants. Anthocyanins have been proven *in vitro* and *in vivo* to decrease tumor cell growth and development. The anticancer mechanism of anthocyanins may be connected to their strong antioxidant properties and inhibitory effects of cyclooxygenase (Yazhen *et al.*, 2020) [78].

**Anti-dementia effects:** Many studies have shown that the cellular oxidative stress response is involved in the pathogenesis phase of Alzheimer's disease (AD), and that AD patients' brains create a considerable quantity of free radicals. (Wu *et al.*, 2017; Yazhen *et al.*, 2020) [77, 78].

### Anti-diabetic effects

Diabetes is a chronic disease that worsens with age and has a substantial impact on people's quality of life. Anthocyanins are antioxidants that may aid in the prevention and treatment of diabetes (Wang *et al.*, 2012) [74].

### Preventing cardiovascular diseases

The oxidative processes mediated by free radicals and their products are crucial role in the development and progression of cardiovascular disease. Anthocyanins found in red wine have been shown to effectively remove superoxide and hydroxyl free radicals (Yazhen *et al.*, 2020) [78].

## Anti-inflammatory effects

Inflammation is the body's response to stimuli, which may be beneficial or harmful depending on the situation. Anti-inflammatory properties of anthocyanins.

## Development of Pigmented Wheat Beverages

There are various unique products made from coloured wheat that provide a range of health benefits, and customers are increasingly substituting cereal-based beverages for less nutrient-dense solid meals. Fermentation is the major method for making wheat beverages or drinks. Fermented foods provide a number of advantages. They are used as a dairy alternative for those who are unable to eat dairy products owing to food allergies or intolerances (Turnbull *et al.*, 2014) [65]. People who like vegan cuisine or follow vegan diets, as well as gluten intolerant people, are interested in drinking healthy beverages. Gluten sensitivity may be managed by avoiding gluten in one's diet. Gluten levels that exceed 50-100 mg per day is thought to be hazardous, according to research (Hischenhuber *et al.*, 2006) [32].

**Fermentation:** Fermented foods have been a part of the human diet since the dawn of civilization, and despite people's ignorance at the time, these meals were beneficial to their health (Ibrahim, 2020; Dimidi *et al.*, 2019) [34, 88]. Fermented beverages may include probiotic microbes, which are microorganisms that provide consumers with health advantages when handled in appropriate concentrations in edible matrices. Fermentation uses a variety of bacteria, with Lactic Acid Bacteria being the most effective for fermenting wheat drinks (Ma *et al.*, 2021; Gobetti *et al.*, 2019; Wang *et al.*, 2021) [42, 28, 75]. Some food products get extra health benefits and qualities as a result of the fermentation process that the initial product lacked. The presence of beneficial bacteria, as well as the ability to limit the growth of pathogenic microflora, are both significant advantages (Mozaffarian *et al.*, 2011) [44].

Fermentation of lactic acid bacteria (LAB) may increase mineral availability, digestion, and the organoleptic quality of meals (Enujiugha & Badejo *et al.*, 2015) [23]. They are most often found in milk and dairy products, but they may also be derived from plants or animals such as leaves, fruits, roots, dung, and compost (Turpin *et al.*, 2011) [66]. Lactobacillus plantarum fermentation results in a low pH, which increases shelf life (Phiri *et al.*, 2019) [52]. Lactic acid (LA) fermentation is the most widely used method for improving grain taste, appearance, and safety (Anal *et al.*, 2019; Petrova *et al.*, 2020; Terpou *et al.*, 2019) [8, 50, 62]. The probiotic LAB improves human health by modifying the activity of the gut microbiota. They are used to boost immunity and keep gastrointestinal illnesses at bay. They have anti-cancer and anti-allergenic properties (Nowak *et al.*, 2010) [46].

Wheat bran and sprouting grain flour are utilized for fermentation in *T. aestivum*. Bran refers to the outer layers of wheat (the outer and inner pericarps, seed coat, and nucellar epidermis) (Delacour and Hosenev, 2010) [22]. Lactic acid bacteria are used to extract and ferment the colored bran. Sprouting colored wheat grains before drying and grinding them into flour is another approach. The flour is then fermented for 4 hours at 25-30 degrees Celsius. Lactobacillus bacteria hydrolyze wheat gluten, leaving it inaccessible to transglutaminase-2 enzyme (Savvateeva *et al.*, 2016) [55].

## Characterization of coloured wheat beverages

Coloured wheat drinks have been used to make a variety of alcoholic and non-alcoholic products. Among these are Antho-beer, Anthograin Liqueur, Rejuvelac, Cereal-based



Probiotic drinks, Boza, and Plant-based dairy products.

Beer is the world's second most popular beverage, after only soft drinks (Li *et al.*, 2007) <sup>[40]</sup>. Beer contains antioxidants such as volatile maltol and 2-furanmethanol, as well as polyphenols and ferulic acid, all of which lower blood cholesterol, triglycerides, and lipid peroxides while boosting HDL cholesterol levels.

Antho-grain, a kind of purple wheat grain, is used to make antho-beer. Purple wheats might be utilized to manufacture antho-beer, which could be a valuable commodity. Phenolic acids in packaged beer have high antioxidant activity and play an important role in taste and froth retention, as well as physical and chemical stability.

Boza is a thick, sweet-sour, low-alcohol beverage popular in Bulgaria, Albania, and Turkey. Eastern Europe and the Middle East generate it. It contains a lot of LAB and has a lot of probiotic qualities (Petrova *et al.*, 2010; Petrova *et al.*, 2017) <sup>[49, 51]</sup>.

Plant-based milks, often known as non-dairy milks, such as oat milk, wheat grain milk, and almond milk, are becoming more popular as functional and specialty drinks across the world. They might be used as a substitute for cow's milk at a time when lactose intolerance, cow milk allergy, calorie concerns, and hypercholesterolemia are common. Vegan diets are also growing increasingly popular (Sethi and Rahul, 2016) <sup>[56]</sup>. As a result, milk fermented from grains such as wheat is becoming more popular in markets.

A fermented anthograin beverage produced from colored wheat such as blue, purple, and black wheat. Anthograin liqueur contains between 20 and 35 percent alcohol by volume (v/v). It contains a lot of antioxidants like phenolics and anthocyanins. It's made of sprouted and colored wheat grains (Li *et al.*, 2011) <sup>[38]</sup>.

Rejuvelac is a popular fermented beverage made from sprouted grains (Penaranda *et al.*, 2021) <sup>[89]</sup>. This is often created from germinated quinoa or wheat grains that are immersed in water and anaerobically fermented at room temperature (Chavan *et al.*, 2018). It is utilized as a vegan cheese starter because it is thought to provide the lactic acid bacteria needed for fermentation in the food matrix (Chen *et al.*, 2020; Penaranda *et al.*, 2021) <sup>[18, 89]</sup>.

## Conclusion

The globe is stressing a well-balanced diet as well as vegan or plant-based diets to minimize health concerns caused by frequent animal-based meals. People who are gluten or lactose intolerant prefer fermented meals, with cereal-based fermented beverages topping the list. Many products are made from fermented coloured or coloured wheat varieties. Anthocyanins, present in coloured wheat, help to regulate a variety of ailments such as cardiovascular disease, diabetes, and obesity, as well as working as an anti-inflammatory. Lactic acid bacteria (LAB) are the most often used microorganisms in fermentation. Coloured wheat is utilized in the production of beverages that are higher in anti-oxidants and proteins than white and red wheat, such as Boza, Rejuvelac, Anthograin liqueur, and Antho-beer. As a result, shifting to plant-based or, more specifically, cereal-based foods are a step toward better health.

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