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Mini Review

Unlocking the Potential of Brewer's Spent Grains: A Mini Review on Health and Nutritional Benefits

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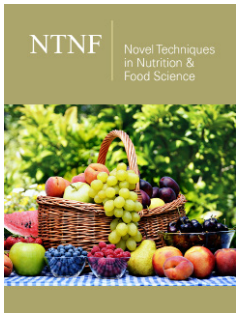

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Abstract

The untapped potential of Brewer's Spent Grains (BSG) has been explored. It is a by-product of the brewing process and a significant resource for human nutrition, health, food safety and the circular economy. Despite being rich in fiber, protein, vitamins and antioxidants, BSG has been traditionally underutilized. The review illuminates the nutritional profile of BSG and its prospective applications in the human diet, particularly its role in modulating Glycaemic Response (GR) and fostering gut health. The antioxidant properties of BSG are underscored, with a focus on their potential in mitigating oxidative stress. The review also emphasizes the role of BSG in bolstering food safety and advocating for a circular economy, highlighting the necessity for innovative approaches to optimize diminishing natural resources and enhance food security. The valorization of BSG is presented as a process for minimizing resource Wasting, reducing the carbon footprint of the brewing process, and creation of new markets.

Keywords: Brewer's spent grains; Prebiotics; Glycaemic response; Human health; Human nutrition

Introduction

The BSG, a by-product of the brewing process, is rich in fiber and protein. In 2023, the total volume of alcoholic beverages available for consumption reached 477 million liters [1]. The global malt beverage market, valued at US$ 6.5 billion in 2022, is projected to reach US$ 13.7 billion by 2030, growing at a CAGR of 9.8% during the forecast period of 2023-2030 [2]. Despite its nutritional value, BSG has been underutilized for years, often being recycled into animal feed, compost, baking ingredients and substrates for mushroom cultivation [3]. However, the BSG is not only cost-effective but also a nutritious by-product that can enhance the nutritional values of foods and find applications in various industries [4]. BSG is a rich source of functional compounds such as Arabinoxylans (AX), cellulose (β-glucan), hemicellulose, lignin, proteins and phenolic acids [3], all of which hold immense potential to be incorporated into functional foods for human nutrition and health.

Health Benefits of BSG

Nutritional profile of BSG

BSG is produced after the brewing process, specifically the mashing stage where starch is broken down into fermentable sugars. The solid residue left behind, primarily composed of barley grain husks, is known as BSG. This underutilized resource boasts a rich nutritional profile, including proteins, fibers, vitamins and antioxidants [3]. Incorporating BSG into one's diet can potentially enhance overall health and well-being. BSG contains 15-30% of total protein, with major protein fractions including prolamins [5]. Essential amino acids such as methionine, phenylalanine, tryptophan, histidine and lysine are present, along with nonessential amino acids like serine, alanine and glycine, with proline being the most abundant [5]. Dietary fiber, a complex group of compounds, is classified according to its solubility. Soluble dietary fibers in BSG include β-glucans, pectic polysaccharides, arabinogalactans, highly-branched AX and xyloglucans [6]. In contrast, the insoluble dietary fiber consists of lignin, cellulose, low-branched AX, xyloglucans and galactomannans [6]. BSG is also rich in vitamins, including folic

acid, niacin, biotin, thiamine, choline, pantothenic acid, riboflavin, pyridoxine and vitamin E [7]. It contains a significant amount of minerals, with calcium (3600mg/kg), magnesium (1900mg/kg), phosphorus (6000mg/kg) and sodium (137mg/kg) being the most abundant [8]. Other minerals found in BSG include iron, copper, potassium and manganese [9].

Application of BSG in human diet

BSG holds immense potential for utilization in food applications, thanks to its rich nutritional composition and unique functional properties. BSG's excellent water and oil retention capabilities can be leveraged to enhance the texture and sensory attributes of various food products [10]. A range of existing food items, including noodles, bread, pasta, cookies and snacks, have been successfully enriched with BSG, thereby improving both their functional and nutritional values [10,11].

GR modulation

GR refers to the impact of food or a meal on blood sugar levels post-consumption. The GR can be influenced by various factors including the type of food consumed, preparation methods and individual metabolic differences [12]. Research has shown that diets with low or zero GR can favourably improve control over overweight, obesity, diabetes mellitus and the risk of coronary heart disease [13]. For individuals with fasting blood glucose concentration exceeding 5mmol/L, consumption of such diets could reduce levels of fasting blood glucose, glycated proteins and fasting insulin [12]. It has been reported that biscuits containing BSG have a higher nutritive value compared to commercial wheat-based biscuits, which can help regulate postprandial glycemic response in individuals with metabolic syndrome [14]. Furthermore, food supplements based on BSG extract have been found to restore blood glucose and insulin levels to baseline values within 120 minutes, reducing postprandial glucose and insulin increases in normoglycemic subjects exhibiting mild insulin resistance [15]. BSG has been incorporated into functional noodles, providing a almost zero-carb, dietary fiber and plant protein-enriched staple food that does not induce a GR post-consumption [13].

Prebiotics for better gut health

Prebiotics, a distinct type of dietary fiber, act as nourishment for the beneficial bacteria inhabiting the human gut. This fiber assists the gut microbiota in executing crucial functions that contribute to overall health, such as nutrient metabolism and immune system regulation [16]. The BSG is composed of up to 80% fiber, with cellulose and AX making up approximately 25% and 28% (w/w) of BSG, respectively [16,17]. The presence of glucan and starch is notably lower, around 1% (w/w) [16]. The AX, a segment of the indigestible carbohydrates, reaches the large intestine in an unaltered state. A significant proportion of water-extractable AX that enters the large intestine undergoes fermentation by the natural colonic microflora, predominantly consisting of bifidobacteria [16]. A demonstrated cause-and-effect relationship exists between the consumption of AX and the reduction of postprandial glycaemic and insulinemic responses [18,19]. Soluble β-glucan, a vital nutrient, has the ability to lower plasma cholesterol, a primary risk factor for cardiovascular diseases [20]. Moreover, the BSG contains mannan oligosaccharides, which promote the growth of beneficial gut bacteria, particularly those from the Bifidobacteria and Lactobacillus genera [21]. This supports a healthy gut microbiome, potentially restraining the proliferation of certain gram-negative bacteria. Gram-negative bacterial lipopolysaccharides can induce insulin resistance and neurodegenerative diseases [22,23]. Additionally, bioactive compounds in BSG, such as AX and polyphenols, exhibit antimicrobial activity against Gram-positive bacteria like Staphylococcus aureus and Gram-negative bacteria like Escherichia coli, as well as antifungal properties [24]. Therefore, BSG acts as a prebiotic by fostering the growth of probiotic bacteria.

Antioxidants

BSG is a rich source of phenolics, predominantly hydroxycinnamic acids [4,7]. These phenolics exhibit antioxidant, antiradical, anti-carcinogenic and anti-apoptotic properties [4]. Compounds like ferulic, p-coumaric (which generates resveratrol) and caffeic acids, all of which are hydroxycinnamic acids, activate Sirtuin 1 [25]. The Sirtuin 1 (SIRT1) protein, known for its anti-aging properties, plays a vital role in reversing insulin resistance and a variety of chronic diseases [25,26]. These activators are essential in preventing insulin resistance and chronic diseases. Water/salt soluble extracts derived from BSG demonstrate significant radical scavenging activity [27]. Bioprocessed BSG has been utilized as an ingredient to produce fortified semolina pasta. This product has been shown to significantly reduce the intensity of intracellular reactive oxygen species in human colon carcinoma cells (Caco-2) [28]. Additionally, AX and β-glucan present in BSG contribute to its antioxidant properties, aiding in the reduction of postprandial glucose and insulin increases, which are responsible for oxidative stress and β cell damage, factors linked to serious chronic diseases [15].

Food Safety and Circular Economy

Food safety is emerging as a critical concern in the face of increasing population, climate change, pandemic lockdowns, regional conflicts and trade embargoes [13]. With the world population projected to reach 9.7 billion by 2050, the challenge of boosting crop yields is compounded by the shrinking arable land due to rapid industrialization and urbanization [29]. This necessitates the adoption of more innovative and technologically advanced methods to maximize the use of valuable natural resources. The Food and Agricultural Organization (FAO) estimates that annually, 1.3 billion tons of food produced for human consumption are wasted [30]. Constant innovation is required to transform such food waste into consumable food, providing an additional food source to enhance food security and create new jobs, thereby promoting a circular economy. The valorization of BSG can contribute to reducing resource wastage, including water, labor, land, capital and greenhouse gas emissions. Valorizing BSG from a circular economy perspective not only contributes to resource conservation, land use reduction and carbon footprint decrease of the brewing process, but also aids in establishing novel waste processing streams, thereby encouraging the development of societal changes and new markets.

Conclusion

BSG presents substantial potential in the realms of food safety, the circular economy and human health and nutrition. With its high protein and fiber content, BSG serves as an appealing source for value-added products. As a by-product of the brewing industry, BSG is predictably available in large quantities worldwide. The presence of β-glucan and AX in BSG has been linked to numerous health benefits, including anti-aging, gut health support and reduction of blood sugar and cholesterol levels. The incorporation of BSG into food products, such as noodles, bread and pasta, is gaining popularity, with these functional foods showing promising results. However, further research is necessary to fully comprehend the potential of BSG in human nutrition and to devise effective methods for its integration into a broader range of food products. Moreover, the potential of BSG extends beyond its nutritional value, playing a significant role in promoting a sustainable and circular economy. It offers a sustainable solution for waste reduction, resource efficiency, and economic growth.

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