International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2025; 9(1): 730-735
www.biochemjournal.com
Received: 20-11-2024
Accepted: 24-12-2024

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Health promoting properties of bioactive dietary beta-glucan: A review

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DOI: https://doi.org/10.33545/26174693.2025.v9.i1i.3617

Abstract
Cereal beta glucan refers to a category of soluble dietary fibers predominantly found in barley and oats. The primary biological effects of beta glucan encompass its ability to lower cholesterol levels, antihyperglycemic properties, anticancer potential, and immunomodulatory effects. Despite the potential of beta glucan as a nutraceutical food ingredient, its applications remain infrequently employed. Currently, there is a growing interest in functional foods, as individuals recognize the importance of health and balanced nutrition in disease prevention and the enhancement of life expectancy. The aim of this review is to discuss the current knowledge of this field.

Keywords: Beta glucan, biological effects, disease, health

Introduction

β-glucans are non-digestible polysaccharides that are found naturally in corn grains, yeasts, bacteria, and algae. They are significant constituents of dietary fibers, comprising unbranched polysaccharides made up of β-d-glucopyranose units connected by (1→4) and (1→3) glycosidic bonds in cereal sources, and by (1→6) glycosidic bonds in fungal sources [1]. Barley and oat grains contain the highest concentrations of beta glucans among cereals [2]. Numerous biological activities associated with beta glucans have been documented, including anticancer, antidiabetic, anti-inflammatory, and immune-modulating effects. The specific structure and characteristics of beta glucans play a crucial role in determining their effects and mechanisms of action. Variations may arise among different sources of β-glucans, influenced by factors such as molecular weight, glycosidic linkages, the presence of branching, degree of polymerization, and solubility [3]. The European Food Safety Authority (EFSA) has issued a favorable assessment regarding health claims associated with the cholesterol-lowering and hypoglycemic effects of beta glucans found in oats and barley [4]. This review discusses the various bioloigical effects of beta glucan and its health benefits.

Cholesterol lowering effects

Cardiovascular disease ranks among the foremost contributors to illness and death worldwide [5]. National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults advised Lifestyle changes to decrease the risk of cardiovascular disease involve the daily intake of 5 to 10 grams of viscous soluble dietary fiber, which can help in lowering LDL cholesterol levels [6]. Research indicates that the intake of a beverage containing 1 g of high-molecular-weight oat beta glucan three times a day for a duration of four weeks led to a significant reduction in LDL cholesterol levels by approximately 6% and a decrease in cardiovascular disease risk by around 8% among healthy adults with LDL cholesterol levels ranging from 3 to 5 mmol/L [7]. Oat beta glucan is believed to lower serum cholesterol levels by modifying the metabolism of cholesterol and bile acids. This occurs through its capacity to bind bile acids and cholesterol within the small intestine, as well as by influencing the colonic microbiome and the production of short-chain fatty acids [8]. Similar to these findings, it was concluded that the intake of oat beta-glucan in the diet may considerably lower total cholesterol and LDL cholesterol levels in individuals suffering from hypercholesterolemia [9]. There exist two types of β glucans: insoluble and soluble.

These forms can engage with lipids and biliary salts within the intestines, leading to a reduction in cholesterol levels. Consequently, they hold potential as a viable therapeutic alternative for managing dyslipidemia in patients, given that they are natural compounds with minimal risk of significant side effects [10]. Research has shown that beta glucans influence the composition of gut microbiota, resulting in enhanced benefits for cardiovascular disease. Elevated serum cholesterol and blood pressure are significant modifiable risk factors associated with the onset of cardiovascular disease, and recent findings emphasize the importance of gut microbiota in improving these biomarkers and the clinical features of the condition [11].

Antihyperglycemic effects

The findings indicate that the viscosity of oat beta glucan plays a crucial role in influencing postprandial responses related to glucose, insulin, and gastric emptying [12]. A research study involving adults diagnosed with pre-diabetes aimed to examine the impact of incorporating oat-derived beta-glucan-enriched bread into a regular diet on glycated hemoglobin levels. This was compared to the effects of consuming whole-grain wheat bread. The findings suggest that beta glucan enriched bread may be beneficial in lowering postprandial glycemic responses in individuals with pre-diabetes [13]. The impact of combining white rice with barley that has a high β-glucan content at a ratio of 50% on postprandial blood glucose levels was evaluated through a meal tolerance test and continuous glucose monitoring in a cohort of 15 healthy individuals with normal glucose tolerance. The findings indicated that the reduction of the glycemic index of white rice mitigates fluctuations in blood glucose levels among those with normal glucose tolerance, potentially contributing to a decrease in obesity and delaying the onset of diabetes, particularly for Asians who primarily consume white rice as a staple food [14]. Similarly, it was indicated that incorporating oat beta-glucan into meals that contain carbohydrates leads to a decrease in both glycaemic and insulinaemic responses [15].

Anticancer effect

Research has indicated that beta glucans possess certain anti-cancer characteristics, attributed to their effects on both adaptive and innate immune responses. The utilization of beta glucans presents a promising therapeutic avenue for the prevention and treatment of cancer, particularly in the context of cervical cancer [16]. Research studies have shown that the intake of nutraceuticals high in beta glucans can positively influence both the prevention and management of breast cancer. This effect is linked to the ability of beta glucans to enhance the activity of immune system cells and to modulate tumor cells [17]. A study has demonstrated that bioactive compounds derived from mushrooms exhibit immunomodulatory properties. *In vitro* research indicates that these compounds can promote the maturation and activation of immune cells, leading to an enhanced release of pro-inflammatory cytokines and chemokines, as well as an increase in the antibacterial activity of macrophages and neutrophils. Consequently, beta glucans may be utilized as an adjunctive treatment in cancer therapy, particularly in conjunction with chemotherapy or immunotherapy [18]. Furthermore, beta glucans may serve as an adjunct in mitigating the negative effects associated with chemotherapy for mammary tumors [19]. Five distinct glucans derived from algae, yeast, bacteria, oats, and mushrooms were evaluated for their impact on the stimulation of phagocytosis in blood cells, the secretion of IL-2, and the inhibition of melanoma, as well as breast and lung cancers. The findings indicated that the majority of the glucans tested enhanced phagocytosis and IL-2 secretion, inhibited cancer proliferation, and alleviated certain effects associated with experimental infections [20]. Furthermore, studies have shown that beta glucan nanoparticles can be engineered as a new form of nanomedicine for cancer therapy [21].

Immunomodulating effects

Beta glucans exhibit a diverse array of immunological functions, such as the activation of macrophages, dendritic cells, and monocytes, the induction of nitric oxide synthesis, the regulation of cellular signaling pathways associated with immune responses, the mitigation of damage inflicted by ionizing radiation on the immune system, and the enhancement of immunoglobulin production. The modulation of the immune response in the human body through (1→3)-beta-glucans holds significant potential for enhancing immune status and may open new pathways for clinical applications in anti-tumor, anti-infection, and anti-inflammatory therapies [22]. Beta glucans trigger immune responses through immune cells that are activated when the polymer binds to particular receptors [23]. The supplementation of glucan significantly enhanced the impaired phagocytosis and the alterations in cytokine levels and oxidative stress markers induced by fatigue. Furthermore, glucan supplementation also contributed to the improvement of motor function in the tested animals. A research finding indicate that the anti-fatigue effects of glucan are associated with its recognized role as a stimulator of immune responses [24]. Beta-glucan is a natural substance recognized for its immune-stimulatory and immunomodulatory properties, which has been regarded as a significant therapeutic agent in the fight against cancer. It has been proposed that beta-glucan could be crucial in developing future approaches aimed at preventing and suppressing tumor growth [25].

Wound healing property

Researchers demonstrated the wound healing properties of four distinct types of beta glucans sourced from barley, yeast, mushrooms, and euglena. Their findings indicate that beta glucan derived from S. commune is particularly effective in facilitating wound repair, as it enhances re-epithelialization and dermal contraction. This suggests that beta glucan from S. commune may serve as a promising therapeutic agent for skin injuries [26]. Beta glucans may engage with the innate immune system by modulating macrophage activity and facilitating the release of cytokines, which in turn promote the production of growth factors and receptors. This process contributes to the formation of a temporary extracellular matrix essential for the healing of chronic wounds [27]. In a similar study, the results indicate that the application of a yeast beta glucan ointment at a concentration of 5% (m/m) demonstrates effectiveness in the healing of burn wounds, with a significant difference observed in the levels of IL-4 [28]. In another study the results revealed that beta glucans may serve as an active component possessing UV light-protective and soothing characteristics following UV exposure, applicable in both the cosmetic and pharmaceutical sectors [29]. In addition, the integration of collagen and beta glucan demonstrated enhanced effectiveness in the healing of wounds, resulting in a more rapid closure of the affected areas [30].

Gut health

Recent research in food science has highlighted the crucial role of gut microbiota, which has been extensively studied for its intermediary function in health regulation. Numerous studies indicate that beta glucans may significantly influence changes in gut microbiota, thereby affecting human health [31]. A clinical trial involving 52 healthy participants was carried out to investigate the impact of low-dose barley beta glucans, which resulted in a significant increase in the population of bifidobacteria. Similarly, another clinical study indicated that durum wheat flour rich in beta glucans and whole-grain barley pasta led to elevated levels of Roseburia hominis, Clostridiaceae (including Clostridium orbiscindens and Clostridium sp.), and Ruminococcus sp., while simultaneously reducing the levels of Firmicutes and Fusobacteria. Accordingly, the findings also demonstrated a notable rise in the concentrations of 2-methyl-propanoic, acetic, butyric, and propionic acids [32]. In addition, a research investigation has recognized oat beta glucan as a promising new therapeutic agent for the prevention of metabolic dysfunction-associated steatotic liver disease and fibrosis in a mouse model, achieved through the modification of gut microbiota [33]. It was supported by another findings which indicated that both the Barlet BARLEYmax and the high beta glucan barley line resulted in elevated levels of acetate and n-butyrate in the cecal digesta, as well as an increased abundance of bifidobacterium in both cecal and distal colonic digesta. These alterations were attributed to the fermentation of beta glucan [34].

Prebiotic activity

A research demonstrated the impact of steaming and microwave processing on the physicochemical characteristics, microbiota composition, and production of short-chain fatty acids from oat beta glucan during fermentation. The findings indicated that microwave processing led to the degradation of oat beta glucan, while steaming resulted in its aggregation. These outcomes imply that thermal processing did not markedly diminish its prebiotic potential [35]. It was stated that beta-glucans are particularly notable among prebiotics for their role in modulating the host's immune response. In addition to this immunomodulatory effect, beta glucans may also influence metabolic parameters, including blood glucose and cholesterol levels. These effects are attributed to the creation of a gelatinous layer in the intestine, which hinders the absorption of glucose and lipids [36]. In the human diet, mixed linkage glucans [MLG - β-(1,3/4)-glucans] play a significant role in shaping the gut microbiome and modulating the host immune response. Understanding the ability of B. producta to utilize beta glucans offers a logical foundation for evaluating the probiotic potential of this group of organisms [37]. In a related investigation, beta-glucan extract demonstrated significant resistance to α-amylase and simulated gastric acid, while also promoting the growth of Lactobacillus bulgaricus and Bifidobacterium adolescentis, approaching the levels seen with fructooligosaccharide. Consequently, the beta glucan extract derived from highland barley may serve as a promising prebiotic ingredient in the production of baked goods, beer, and other applications [38].

Antitumor effects

It was reported that the enhancement of immune system activity through beta-glucans may facilitate the prevention of cancer progression. Beta glucans, belonging to a category of naturally occurring compounds referred to as biological response modifiers, have demonstrated potential anti-tumor, anti-cytotoxic, and anti-mutagenic properties [39]. The findings demonstrate significant anti-tumor effects of the novel beta glucan derived from oats, while simultaneously exhibiting no toxicity towards normal cells [40].

Antioxidant activity

Glucans act as potent antioxidative agents that reduce oxidative stress, particularly in the endothelium. Studies indicate that glucans extracted from the mushroom Ganoderma lucidum, which has been used for millennia in China (commonly called lingzhi) and Japan (known as reishi), notably alleviated pro-oxidative states in both high-risk individuals and patients with stable angina pectoris, while simultaneously improving endothelial function [41]. In other study, beta glucan has been observed to significantly decrease DNA damage in patients with colorectal cancer and exhibit antimutagenic properties. This effect is attributed to the antioxidant capabilities of beta-glucan in mitigating oxidative DNA damage [42]. It was stated that the primary physicochemical characteristics of beta glucans have been identified to include their antioxidant properties, which may help mitigate damage to the gut caused by reactive oxygen species produced in that environment [43].

Genoprotective properties

It was reported that the results offer significant evidence that edible mushrooms may possess components that safeguard genome integrity, a crucial factor particularly for promoting healthy aging [44].

Human appetite control

A research investigation assessed the impact of instant oatmeal (IO), old-fashioned oatmeal (SO), and an oat-based ready-to-eat breakfast cereal (RTEC) on appetite regulation. The findings indicated that both IO and SO enhanced appetite control over a four-hour period in comparison to RTEC. This effect was linked to the superior levels of beta glucan, molecular weight, gastric viscosity, and larger hydration spheres present in IO and SO relative to RTEC. Additionally, IO exhibited a higher viscosity following oral and initial gastric digestion (initial viscosity) than RTEC [45].

Immunostimulation

It was observed that the beta glucans play a significant role in modulating both the gut microbiota and the immune system. It is possible that immunostimulation serves as the primary mechanism underlying the activity of beta glucans. The principal approach to preventing the proliferation of cancer cells and infectious microorganisms within the host may be through systemic immunostimulation [46].

Antifungal properties

Researchers have introduced the development of novel cationic beta glucan derivatives that exhibit targeted antifungal properties while demonstrating minimal toxicity to both animal and human cells [47].

Anti-obesity effect

Research has demonstrated that the consumption of barley leads to a significant and safe reduction in visceral fat area (VFA), body weight, Body Mass Index (BMI), and waist circumference among Japanese participants suffering from metabolic syndrome, specifically those with a VFA of 100 cm^2 or greater. It was attributed to barley, which is rich in beta glucan, may play a role in preventing visceral fat obesity. Furthermore, it has been proposed that the regular intake of a rice-based dish enhanced with high beta glucan barley could assist in managing weight [48].

Conclusion

In summary, beta glucan, a complex polysaccharide presents in a range of natural sources such as cereals, mushrooms, and algae, demonstrates considerable potential in the fields of nutrition, health, and industry. This compound is likely to be instrumental in improving human health and supporting sustainable practices in agriculture, food production, and healthcare. Continued and forthcoming research in this field is expected to reveal the significant role of beta-glucan in fostering a healthier and more sustainable future. Modifications in lifestyle, particularly through a nutritious and balanced diet abundant in dietary fibers, have been shown to effectively prevent numerous chronic diseases without adverse effects. Beta glucans, which are naturally occurring polysaccharides, have demonstrated their efficacy in the treatment of various health conditions.

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