# Therapeutic and Functional Properties of Beta-Glucan and Its Effects on Health

**Memnune SENGÜL[1*], Seda UFUK[2]**

[1]*Ataturk University Faculty of Agriculture Department of Food Engineering, Erzurum/Turkey*

[2]*Ataturk University Graduate School of Natural and Applied Sciences Department of Food Engineering, Erzurum/Turkey*

*Corresponding author: memnune@atauni.edu.tr*

*ORCID: 0000-0003-3909-2523*

**Abstract**

Among the dietary fibers, β-glucan is naturally occurring non-starch polysaccharide formed by β-glycoside bonds of D-glucose monomers. Beta-glucan can be present in abundance in cereals, fruits, fungi, algae, yeast and bacteria. Beta-glucan has recently attracted attention with its positive effects on human health. It has effects on many systems in the body containing the immune system and cardiovascular system. Due to the positive effects of beta-glucan, it has been the subject of many studies and its effects in different fields have been demonstrated by these studies. The aim of this review is to evaluate not only the general properties of beta-glucan, but also its effects on the immune system, blood sugar, cholesterol and insulin, anticarcinogenic effect, obesity, antihyperactive effect, prebiotic and antioxidant properties, antimicrobial and antiviral effects. On the other hand, another aim is to demonstrate the purposes of the use of beta-glucan in the food industry. The application of beta-glucan is agreeable for a wide range of food materials, because of the combination of both, health-beneficial properties and technological features.

**Keywords:** Beta-Glucan, Dietary fiber, Disease, Functional Foods, Health

*Review article*
*Received Date: 18 February 2022*
*Accepted Date: 4 June 2022*

## INTRODUCTION

All over the world, the attention in functional foods increases because people understand the significance of health and balanced nutrition to prevent diseases and also the life expectancy increase. Functional foods, which are nutrients or nutritional components, have important roles in organisms. They support the body's primary food elements, regulate physiological and metabolic functions, to prevent the risk of illnesses and protect from diseases and provide a healthier life.

Recently, at the beginning of functional foods, the production of products rich in dietary fiber has started to gain importance because of its benefits to human health. For several decades, it has been observed that β-glucan not only contributes to the functional properties of food but also has important positive effects on human health, and many studies have been carried out to evaluate these effects.

According to studies about the health effects of β-glucan, consumption of β-glucan controls the glycemic response and reduce the total serum cholesterol levels in the blood so it has hypocholesterolemic effect and hypoglycemic activities (Mishra, 2020; Dhewantara 2016; Bulam 2019). Also, it can decrease the risk of coronary heart diseases (Nishantha et al., 2018), moreover it can prevent the risk of obesity and oxidative stress thanks to its prebiotic properties (Kanagasabapathy et al., 2013; Karaçil and Akbulut, 2013). In addition, it improves and modulates the immune system (Silva et al., 2017) and lower the risks of cancer like colorectal cancer (Ciecierska et al., 2019). Moreover, β-glucan shows not only anti-allergic effects (Vlassopoulou et al., 2021), but also it is an effective immune adjuvant for a vaccine (Liu et al., 2021).

Beta-glucan is considered a functional component with positive effects on health and disease prevention. In addition to its health effects, it is also used in developing innovative nutraceutical foodstuffs due to its rheological properties such as gel formation, emulsification and thickening in foods (Mishra, 2020). Furthermore, beta-glucan has abilities to change functional properties such as sensory features, rheology, texture and viscosity of food products (Kaur et al., 2020).

The mechanisms of action and receptors of beta-glucan have been demonstrated by many recent in vivo and in vitro animal experiments and studies. Beta-glucan is preferred because of its cheapness, easy accessibility, reliable consumption based on historical records, its therapeutic and functional effects (Chan et al., 2009). Therefore, it is necessary to demonstrate its benefits and properties with more studies and experiments to utilize in health and food industries.

## DIETARY FIBERS

Dietary fiber is mainly plant-derived edible carbohydrate that is not digestible in the small intestines of people because mammals are not able to secrete enzymes that hydrolyze dietary fiber into its monomers (Turner and Lupton, 2011). It can ferment completely or partially in the colons of human. Dietary fiber consists of a special blend of bioactive units such as resistant starches, phytochemicals, minerals, vitamins and antioxidants (Lattimer and Haub, 2010).

Dietary fiber can be put into two main groups as soluble fiber including pectin, guar gum, psyllium, beta-glucan and insoluble fiber such as cellulose, hemicellulose and lignin. Soluble fiber can dissolve in water, however, insoluble fiber cannot dissolve in water. Foods can contain both soluble and insoluble fiber. Therefore, the food that is a good source of soluble fiber may also include some insoluble fiber (Karaçil and Akbulut, 2013). For instance, both fruits and vegetables include pectin (soluble fiber) and cellulose (insoluble fiber). However, fruits contain more pectin and vegetables contain cellulose (Samur and Mercanlıgil, 2008).

The importance of dietary fiber consumption has increased after studies have shown that dietary fiber has positive influences on particular diseases like colon cancer, obesity, and cardiovascular diseases. Moreover, it is stated that dietary fibers have impacts on obesity, blood pressure, hemorrhoids, diarrhea, some intestinal disorders, hypertension, vascular and immune diseases (Dülger and Gahan, 2011). Both soluble and insoluble fibers have various therapeutic impacts on health (Ege and Köseoğlu, 2021). Soluble fibers, form a viscous gel in nature, increase transit time, delay gastric emptying and reduce nutrient absorption. They are smoothly fermented by the gut bacteria in the large intestine and therefore have some prebiotic activities (Mudgil, 2017; Chakrabarty and Chakrabarty, 2019). On the other hand, insoluble fibers, are non-viscous in nature, have fast gastric emptying, reduce the intestinal transit time, and commonly escalate the fecal bulk that can help to lessen constipation (Chakrabarty and Chakrabarty, 2019).

The recommended dietary fiber requirement is 25-30 g per day for adults or 10-13 g per 1000 kcalorie of the daily diet (Samur and Mercanlıgil, 2008). Table-1 shows the recommended daily intake levels for the dietary fibers according to age and gender.

**Table 1.** Recommended daily intake levels for dietary fibers (Turner and Lupton, 2011)

| Age, y | Male (g/day) | Female (g/day) |
|---|---|---|
| 1-3 | 19 | 19 |
| 4-8 | 25 | 25 |
| 9-13 | 31 | 26 |
| 14-18 | 38 | 26 |
| 19-50* | 38 | 25 |
| >51 | 30 | 21 |

**Intakes for females rise to 28 g/day during pregnancy and to 29 g/day for lactation.*

## β-GLUCAN

β-glucan, one of the most significant dietary fibers, are natural and non-starch polysaccharides composed of D-glucose monomers linked by β-glycoside bonds (İşsever et al., 2018). They are hydrosoluble and viscous at low concentrates (Lattimer and Haub, 2010). They can be commonly found in fruits, algae, yeast, some bacteria, cereals (wheat, oat and barley), seaweeds and fungi (Ege and Köseoğlu, 2021; Du et al., 2019; Şimşekli and Doğan, 2015).

β-glucan can be divided into two categories as cereal or non-cereal derived depending on their origin. Cereal sources of β-glucans are oat, rice and barley, besides non-cereal sources are mushrooms, bacteria, algae and seaweed (Murphy et al., 2021).

Differences in molecular weight, degree of branching, compatibility, and intermolecular combination are the factors that can affect the biological activity of β-glucan. Differences in the way glucose molecules bind to each other give each β-glucan unique structural differences (Keser and Bilal, 2008). Beta-glucan's structures and features can also differ according to the isolation source. For instance, the structure of the beta-glucan isolated from the bacteria of *Euglena gracilis* has a linear β 1,3-glucan. In turn, the structure of the fungal type of beta-glucan (*Schizophyllum commune)* has a short β 1,6 branched β 1,3-glucan. Also, the structure of β-glucan isolated from cereal such as Barley has a linear unit-linked via a mixture of β-(1→3) and β-(1→4) bonds (Seo et al., 2019). Briefly, Figure-1 demonstrates that there are different types of beta glucan depending on their structures, respectively.

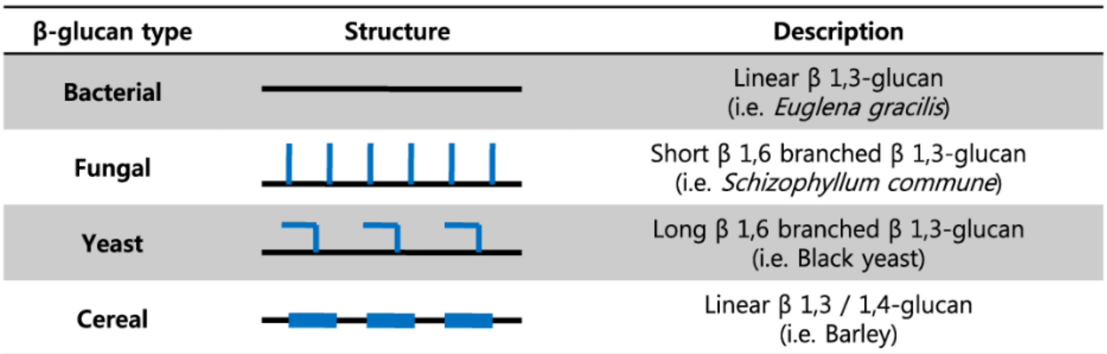


**Figure 1.** Structures and description of different types of beta-glucan (Seo et al., 2019)

Beta-glucans can have different types of linkage, the charge of polymers, molecular weight, viscosity, the degree of branching, solution conformation as well as chain length. Therefore, these various types of beta-glucans can have different physical roles and biological effects (Khorshidian et al., 2018).

The viscosity of beta-glucan is positively related to the health-benefiting effects as well as preventing diseases such as diabetes mellitus, cardiovascular diseases, colon dysfunction and cancer (Mishra, 2020). The viscosity changes with the concentration and molecular weight of beta-glucan. At low concentration under the 0,2% , beta-glucan becomes a Newtonian solution and viscosity is not affected by increasing shear rate. On the other hand, if the concentration is above the 0,2% with high molecular weight, the solution becomes more viscous and pseudoplastic form, i.e. Pseudoplastic form is associated with both high molecular weight and high concentration (Anttila et al., 2004). In general, beta-glucan with high molecular weight is more effective in biologically in comparison to beta-glucan with low molecular weight (Mishra, 2020). Although, beta-glucan with high molecular weight shows more biological activity, according to Lei et al. (2015), stated that β-glucan derived from yeast with low molecular weight is better candidate as an immunostimulant and antioxidant as comparison with the high molecular weight of beta-glucan. Another factor is the degree of branching of beta-glucan that affects the biological activities of beta-glucan. If the degree of branching frequencies of beta-glucan are between 0,2-0,33, they show positively more biological activity. For instance, it is known that beta-glucan with the branching ratio between 0,2-0,33 are more powerful immunomodulators (Han et al., 2020). Additionally, branched beta-glucan is more biologically active in comparison with unbranched beta-glucan (Mishra, 2020). Beta-glucan can exist in three different conformation which are single helix, triple helix and random coil, respectively. According to studies, it is declared that beta-glucan with triple helix shows more biological activity (Han et al., 2020). Another study shows that single helix beta-glucan is less able to control growth of tumours as compared to beta glucan with triple helix (Falch et al., 2000). Other feature of beta-glucan is chain length. Beta-glucan with short chain has more mobility and is more able to form junctions with near chains and then easily rearranging itself. With this property, beta-glucan with short chains extensively used to prepare pseudoplastic solution in food industries (Mishra, 2020).

The content of the beta-glucan changes according to environmental factors, cultivators and sources (Mishra, 2020). Table-2 shows the various sources of beta-glucans below. According to this table, the highest content of β-glucan is barley as 2-20 g per 100g dry weight.

**Table 2.** β-glucan Content (g per 100g dry weight) of some types of cereals (El Khoury et al., 2012)

| **Type of Cereal** | **β-glucan Content (g per 100g dry weight)** |
|---|---|
| Barley | 2-20 |
| Oat | 3–8 |
| Sorghum | 1.1–6.2 |
| Rye | 1.3–2.7 |
| Maize | 0.8–1.7 |
| Triticale | 0.3–1.2 |
| Wheat | 0.5–1.0 |
| Durum Wheat | 0.5-0.6 |
| Rice | 0.13 |

Beta-glucan, has an important place in human nutrition, provides favourable effects on hypertension, total and low-density lipoprotein content, blood sugar, insulin level and gastrointestinal health (Yuca et al., 2019). β-glucan has several effects, containing immunomodulatory effects, anticarcinogenic activities, lipid-lowering effects, as well as the ability to decrease blood sugar levels and control weight (Kim et al., 2006).

Therefore, beta-glucans have a wide application area, particularly in medicine and pharmaceutical, food industries, cosmetics and chemical sectors, as well as in veterinary medicine and feed production because of their properties (Ciecierska et al., 2019).

According to The US Food and Drug Administration (FDA), it is suggested that it is required to consume 3 g or more oat's b-glucan intake per day to get health benefits.

## THE EFFECTS OF β-GLUCAN ON HEALTH

β-glucan shows several beneficial effects on human health because of its physicochemical properties. It can be active in all living species from earthworms to people and is able to induce humoral and cellular immunity, regulate diabetes metabolically, urge wound healing, decrease psycho-physical stress, reduce chronic fatigue syndrome and hinder the development of cancer (Sima et al., 2018).

Consumption of β-glucan and dietary fiber, which has been shown and is being proven to have an impact on many different health problems, has an important role in promoting health and preventing diseases (İşsever et al., 2018). Figure-2 below, a summary of the health benefits of beta-glucan is shown. According to this figure, beta-glucan has various properties on health. They are prebiotic properties, hypocholesterolemic properties, immunomodulatory and anti-tumour properties, antioxidant properties and hypoglycemic properties, respectively.

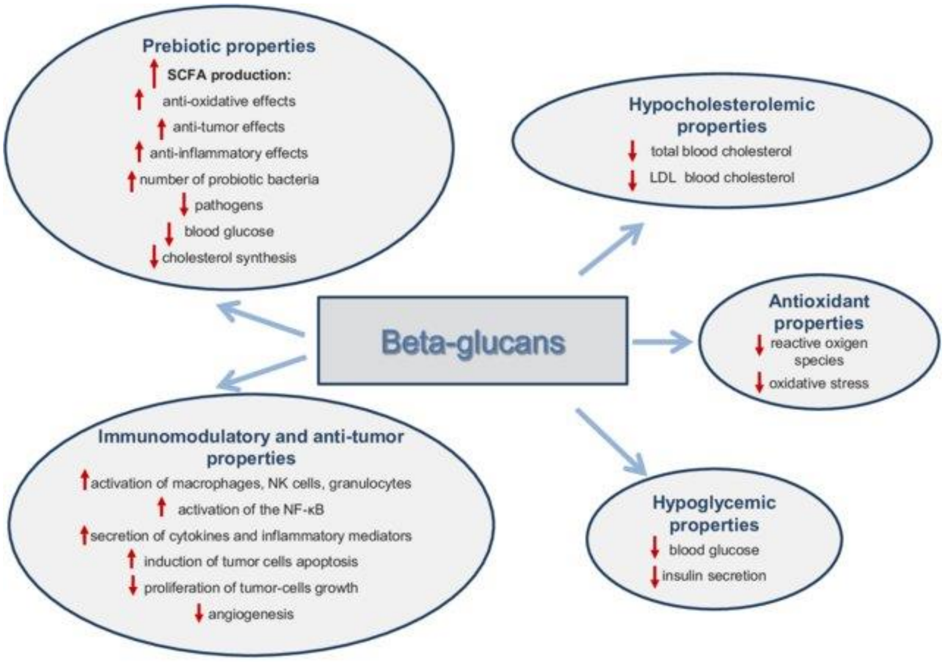


**Figure 2.** Summary of the health effects of Beta-glucan (Ciecierska et al., 2019)

## IMMUNE ENHANCEMENT

β-glucan can be effective in strengthening the response of the fight against microorganisms such as viruses, bacteria, parasites and fungal pathogens in living things (İşsever et al., 2018). It has been shown by many studies that beta-glucan has a stimulating and regulating effect on the immune system in humans, and these effects are stated in much relevant literature. It is known that beta-glucan shows this effect by increasing the functional effects of macrophages, natural killer cells (NK cells) and neutrophils that affect the immune system (Keser and Bilal, 2008).

Additionally, beta-glucan increases the secretion of both cytokines and inflammatory mediators in the immune system (Chan et al., 2009). In addition, beta-glucan can bind to macrophages and white blood cells on the binding system and activate them. Furthermore, the studies demonstrate that beta-glucan increases phagocytosis, lysosomal enzyme activity, IL-1 (interleukin) production function and accelerates macrophage studies (Şöhretoğlu and Uz, 2015).

It has been shown by studies that zymosan, which is obtained from the yeast cell wall and known to contain high amounts of beta-glucan, activates the body's immune system (Ciecierska et al., 2019). According to another study, it was observed that the frequency of catching colds decreased with the use of β-glucan in healthy people (Şöhretoğlu and Uz, 2015). In their study, Talbott and Talbott (2019) showed that the use of β-glucan in marathon runners reduced the symptoms of upper respiratory tract infection and also improve the mood states of runners. Moreover, in in vitro studies on animals and humans, it has been stated that beta-glucan stimulates humoral and cellular immunity, thereby increasing the effect and activity of immune cells (El Khoury et al., 2021).

## ANTITUMOR EFFECTS

Another important feature of β-glucan is its anti-cancer effect. Beta-glucan is an important compound used in cancer prevention and cancer treatment such as lung, breast, ovarian and prostate cancer. For example, a beta-glucan known as Lentinan has long been used in the treatment of stomach and colorectal cancer in Japan (İşsever et al., 2018). In studies conducted on cancer patients, it has been shown that with β-glucan therapy tumor size is reduced, infiltration and metastasis are stopped, thus with β-glucan therapy, life expectancy increases (Şöhretoğlu and Uz, 2015). According to Louie et al. (2010), when 200 µg/ml beta-glucan was applied together with 10000 IU/ml IFN-α2b, the development of pancreatic cancer cell T24 in vitro was reduced by 75% and more successful results were obtained compared to IFN-α2b application alone.

Nowadays, one of the new trends in cancer treatment is monoclonal antibody therapy targeting tumor tissue. In studies where monoclonal antibodies and β-glucans were used in combination, these combinations were found to be more advantageous in terms of tumor regression in the short term and survival in the long term compared to the use of monoclonal antibodies alone (Driscoll et al., 2009).

Recent studies in China and Japan has been concentrated on the anti-cancer properties of beta-glucan, also the studies demonstrated that the activities of beta-glucan to be similar to radiation and chemotheraphy without the side effects (Lam and Cheung, 2013).

## ANTIOXIDANT ACTIVITY

Oxidative stress, which is caused due to imbalance between the production of free radicals and antioxidant defenses, is one of the main reasons for aging and some serious diseases such as cardiovascular disease, diabetes, inflammatory disease, cerebral disease and also cancer (Kofuji et al., 2012; Betteridge, 2000). Beta-glucan has many biological effects, including antioxidant effects, anticancer and scavenging of free radicals in the body. Beta-glucan can prevent the chain reaction caused by reactive oxygen species (ROS) by capturing reactive oxygen by donating hydrogen, thus reducing the damage to the body by ROS (Maheshwari et al., 2019).

(2012) show that β-glucan has a scavenging ability against the hydroxyl radicals that cause various diseases and aging. In an experiment conducted on rats to demonstrate the antioxidant property of beta-glucan, it was determined that orally administered beta-glucan prevented oxidative stress in important internal organs such as the liver and kidneys in rats. As a result of this experiment, it was understood that beta-glucan showed antioxidant properties and prevented the negative effects of free radicals formed in the body (Bayrak et al., 2008).

## ANTIMICROBIAL AND ANTIVIRAL EFFECTS

One of the biological effects of beta-glucan is its antimicrobial and antiviral properties. Studies have shown that beta-glucan protects against infections caused by both bacteria and protozoa. In studies on mice, it has been reported that treated with beta-glucan, mice are extra resistant to infections caused by bacteria like Staphylococcus aureus and parasites like Leishmania braziliensis (Geller and Yan, 2020). In addition, it has been reported that beta-glucan has antibiotic properties especially against infections caused by bacteria resistant to antibiotics. Beta-glucan also has a protective effect against microorganisms such as Candida albicans, Streptococcus suis, Plasmodium berghei, Staphylococcus aureus, and Escherichia coli (Vetvicka and Fernandez-Botran, 2018).

Geller and Yan (2020) have shown that beta-glucan can protect against infections caused by SARS-CoV-2 and prevent serious clinical symptoms, thanks to its anti-viral properties. Although there is no definitive treatment method for COVID-19 yet and there are authorized/approved vaccine candidates, there are significant obstacles in finding an ideal treatment method without side effects. It is thought that oral beta-glucan can be used as a COVID-19 β-WIFE vaccine adjuvant (Ikewaki et al., 2021).

## ANTIHYPOCHOLESTEROLEMIC EFFECT

There are several cholesterol-lowering mechanisms of β-glucans, which ought to be included in the diet in the prevention of cardiovascular disease (CVD) and the treatment of the disease. It is known that β-glucans can form a gel on the mucosal surface of the gut, like a pulp. This gel structure hinders the absorption of bile salts and stimulates bile salt synthesis in the liver. Increasing bile salts, on the other hand, activate the use of circulating cholesterol and lower its levels in the blood (Ege and Köseoğlu, 2021). Since β-glucan has soluble and insoluble forms, which interact with lipids and bile acids in the intestine, and as a result of this interaction, they lower the cholesterol level in the blood (Sima et al., 2018). Othman et al., (2019) indicated that beta-glucan derived from oat has the ability to reduce low-density lipoprotein (LDL) cholesterol and total blood cholesterol levels. According to the rule of the US Department of Health and Human Services (1997), consumption of at least 3 g/day of beta-glucan obtained from oats is recommended for a significant reduction in cholesterol levels and to reduce the risks of coronary heart diseases.

In a study of 2 men with diabetes, patients were given a low glycemic index breakfast for 4 weeks, containing 3 g beta-glucan derived from oat. After comparison with the control group, a 12% decrease was observed in plasma cholesterol levels of this group (Kabir et al., 2002). Another study showed that 0.5 g of concentrated beta-glucan significantly increased the production of short-chain fatty acids. Short-chain fatty acids are effective in preventing hepatic cholesterol synthesis. In this way, it contributes to lowering the level of LDL cholesterol (Queenan et al., 2007).

## ANTIHYPERGLYCEMIC EFFECTS

Another important effect of beta-glucan is its antihyperglycemic effect. The molecular weight of β-glucan adjusts the glycemia status. In one study, a beverage containing oat β-glucan (5 g) with a molecular weight of 70000 Daltons (Da) provided lower postprandial glucose and insulin levels than a beverage containing barley β-glucan (5 g) with a molecular weight of 40000.

In research with beta-glucan obtained from Saccharomyces cerevisiae, it has been shown that this product can be used as a nutraceutical as well as to lower blood sugar and reduce pain in diabetic patients (Morshed et al., 2013). Kim et al. (2009), showed that regularly consumed barley grains containing beta-glucan reduced insulin response. In addition, it has been stated that obese women at high risk of developing insulin resistance should consume 10 g of beta-glucan per serving. It has been reported that it would be beneficial to add whole-grain foods containing high amounts of beta-glucan to the diets of obese women with hyperglycemia. Additionally, as in the case of glycemia, the amount of β-glucan is crucial in insulin responses. It has been observed that there is a continuous decrease in insulin secretion depending on the amount of β-glucan in oats in overweight individuals, and daily consumption of 3.8 g of β-glucan has significant effects (Beck et al., 2009).

## OBESITY

Obesity is defined as the abnormal accumulation of body fat and is associated with increasing serious illness, disability and finally death. Obesity is a condition that should be treated because it is an important risk factor for chronic diseases and its negative effects on quality of life, and the basis of treatment is adequate and balanced nutrition and lifestyle changes (Şahin, 2018). Obese people have excessive adipose tissue and dyslipidemia. Therefore these conditions can cause many chronic diseases, such as metabolic syndrome, hypercholesterolemia, hypertension as well as diabetes, and these diseases are serious risk factors for CVD (Sima et al., 2018).

Beta-glucan from barley and oat has been known to decrease appetite and also lose weight in humans. Oat, which is a functional food, gives satiation along with nutrition thanks to its dietary fiber content of β-Glucan (Maheshwari et al., 2019). In Japan 100 subjects consumed a mixture of rice and barley with high β-glucan (test group, 4.4 g β-glucan per day) and barley without β-glucan (placebo group, 0.0 g β-glucan per day). As a result of the study, it was determined that the group consuming β-glucan barley significantly reduced body weights, waist circumference and body mass index (Aoe et al., 2017). Another study conducted on the mice shows that diet with oat beta-glucan decrease not only fatty liver but also adipocyte size in mice. As a result of this study, beta-glucan inhibits high fat diet caused obesity (Xin-Zhong et al., 2015).

## PREBIOTIC ACTIVITY

Beta-glucan shows prebiotic activity with various ways. Thanks to beta-glucan, there is an increase of production of short chain fatty acids (SCFA). Moreover, it can help to increase the growth of health-beneficial probiotic microorganism populations and restrict the development of pathogenic microorganisms (Schmidt, 2020). With these biological effects, beta-glucan acts as prebiotic material. According to Chaikliang et al. (2015), beta-glucan derived from Auricularia auricula Judae and Schizophylum commune Fr are possible prebiotics. Another study implies that beta-glucan derived from barley is possible prebiotic material into the manufacturing of beer as well as baked food (Ren et al., 2018).

## β-GLUCAN IN THE FOOD INDUSTRY

Nowadays, functional foods have been rapidly growing day to day to respond to the needs of consumers and growing populations all across the world. Apart from the benefits of the field of health and nutrition, beta-glucan has many different functional properties. These properties include thickening, emulsification, stabilization and gelling in the foods (Ahmad et al., 2012). With the aim of developing functional foods, the use of grains in various food formulations and the development of grain-based foods have been the subject of much research in recent years (Özcan et al., 2013). Beta-glucan is used in the food industry as an important ingredient in the content of many food products such as breakfast cereals, sports nutrition products, bakery products, and fat replacers (Bulam et al., 2019).

In a study conducted with yogurt to demonstrate the functional effects of beta-glucan on foods, it was determined that the sensory properties of yogurt with beta-glucan added were improved. For example, Sahan et al., (2008) investigated the possibility of using β-glucan as a hydrocolloid fat replacer in the production of nonfat yogurt. In the study, an increase in the viscosity of yogurt occurred with the addition of β-glucan during 15 days of storage. It has been determined that β-glucan is suitable for use, especially at 0.25-0.50%, with its dietary fiber properties and positive effects on the physical and sensory properties of non-fat yogurts (Sahan et al., 2008). As a result of this study, the storage quality of yogurt increased by decreasing the separation of whey and increasing its water-binding capacity (Kearney et al., 2011).

The potential use of β-glucan as a hydrocolloid is determined by considering its rheological properties. For this reason, it is stated that β-glucan can be used as a thickening agent in ice cream formulations, meal and salad dressings. In addition, it is seen that β-glucan is used in grain-based pasta and various bakery products (Lazaridou et al., 2003). Moreover, thanks to its properties, beta-glucan can be used as an alternative thickener in traditional beverages instead of alginates, pectin, gum arabic, carboxymethyl-cellulose (Giese, 1992). Beta-glucan is applied in different types of food products such as meat products, dairy products and cereal products. In meat industry, beta-glucan can be added to produce low-fat meat, meatballs, prebiotic sausages and reduced-fat sausages. In cereal industry, it can be added to bread, noodles, low-fat cakes, muffins, pastas and gluten-free bread. Also, there are applications of beta-glucan in dairy industry. It can be ingredient in cheese, yogurt, milk and probiotic drink. On the other hand, there are other types of applications such as functional beverages, soups and chocolates that beta-glucan is added in (Kaur et al., 2020).

## CONCLUSION

Overall, the therapeutic and functional properties of beta-glucan have been investigated through existing studies and literature. Thanks to these properties, it has many effects on human and animal health. In general, it has properties such as reducing total cholesterol and LDL cholesterol levels, acting as anti-cancer, stimulating the immune system, stimulating the glycemic response, preventing obesity, preventing cardiovascular diseases, anti-inflammatory and antioxidant properties. In addition, due to its functional and rheological properties, it is used to improve the sensory properties of products produced in the food industry.

**REFERENCES**

Ahmad A., Anjum F.M., Zahoor T., Nawaz H. & Dilshad S.M.R. 2012. Beta glucan: a valuable functional ingredient in foods. Critical reviews in food science and nutrition, 52(3), 201-212.

Anttila H., Sontag-Strohm T. & Salovaara H. 2004. Viscosity of beta-glucan in oat products.

Aoe S., Ichinose Y., Kohyama N., Komae K., Takahashi A., Abe D. & Yanagisawa T. 2017. Effects of high β-glucan barley on visceral fat obesity in Japanese individuals: a randomized, double-blind study. *Nutrition*, 42, 1-6.

Bayrak O., Turgut F., Karatas O.F., Cimentepe E., Bayrak R., Catal F. & Unal D. 2008. Oral β-glucan protects kidney against ischemia/reperfusion injury in rats. *American Journal of Nephrology*, 28(2), 190-196.

Beck E.J., Tosh S.M., Batterham M.J., Tapsell L.C. & Huang X.F. 2009. Oat β-glucan increases postprandial cholecystokinin levels, decreases insulin response and extends subjective satiety in overweight subjects. *Molecular nutrition & food research,* 53(10), 1343-1351.

Betteridge D.J. 2000. What is oxidative stress?. Metabolism, 49(2), 3-8.

Bulam S., Pekşen A. & Üstün N.Ş. 2019. Use Potential of Edible and Medicinal Mushrooms in Food Products. *Journal of Fungus*, 10(3), 137-151.

Chaikliang C., Wichienchot S., Youravoug W. & Graidist P. 2015. Evaluation on prebiotic properties of β-glucan and oligo-β-glucan from mushrooms by human fecal microbiota in fecal batch culture. *Functional Foods in Health and Disease*, 5(11), 395-405.

Chakrabarty K. & Chakrabarty A.S. 2019. Textbook of Nutrition in Health and Disease. Springer Nature.

Chan G.C.F., Chan W.K. & Sze D.M.Y. 2009. The effects of β-glucan on human immune and cancer cells. *Journal of hematology & oncology,* 2(1), 1-11.

Ciecierska A., Drywie E., Hamulka J., Sadkowski T. 2019. Nutraceutical functions of beta-glucans. Rocz. Panstw. Zakl. Hig, 70, 315-324.

Dhewantara F.X. 2016. Cholesterol-lowering effect of beta glucan extracted from Saccharomyces cerevisiae in rats. *Scientia pharmaceutica*, 84(1), 153-165.

Driscoll M., Hansen R., Ding C., Cramer D.E. & Yan J. 2009. Therapeutic potential of various β-glucan sources in conjunction with anti-tumor monoclonal antibody in cancer therapy. *Cancer biology & therapy,* 8(3), 218-225.

Du B., Meenu M., Liu H. & Xu B. 2019. A concise review on the molecular structure and function relationship of β-glucan. *International Journal of Molecular Sciences*, 20(16), 4032. https://doi.org/10.3390/ijms20164032

Dülger D. & Gahan Y. 2011. Properties of dietary fiber and its effects on health. *Journal of Uludag University Faculty of Agriculture*, 25(2), 147-158.

Ege R. & Köseoğlu S.Z. 2021. Beta Glukanın Kardiyovasküler Sağlık Üzerine Etkisi. *İstanbul Sabahattin Zaim Üniversitesi Fen Bilimleri Enstitüsü Dergisi.* https://doi.org/10.47769/izufbed.915997

El Khoury D., Cuda C., Luhovyy B.L. & Anderson G.H. 2012. Beta glucan: health benefits in obesity and metabolic syndrome. *Journal of nutrition and metabolism,*

Falch B.H., Espevik T., Ryan L. & Stokke B.T. 2000. The cytokine stimulating activity of (1→ 3)-β-D-glucans is dependent on the triple helix conformation. *Carbohydrate Research,* 329(3), 587-596.

Geller A. & Yan J. 2020. Could the induction of trained immunity by β-glucan serve as a defense against COVID-19?. *Frontiers in Immunology*, 11, 1782.

Giese J.H. 1992. Hitting the spot: Beverages and beverage technology. *Food technology* (USA).

Han B., Baruah K., Cox E., Vanrompay D. & Bossier P. 2020. Structure-functional activity relationship of β-glucans from the perspective of immunomodulation: a mini-review. *Frontiers in immunology,* 11, 658.

Ikewaki N., Iwasaki M., Kurosawa G., Rao K.S., Lakey-Beitia J., Preethy S. & Abraham S.J. 2021. β-glucans: wide-spectrum immune-balancing food-supplement-based enteric (β-WIFE) vaccine adjuvant approach to COVID-19. *Human vaccines & immunotherapeutics,* 1-6.

Kabir M., Oppert J.M., Vidal H., Bruzzo F., Fiquet C., Wursch P. & Rizkalla S.W. 2002. Four-week low-glycemic index breakfast with a modest amount of soluble fibers in type 2 diabetic men. *Metabolism-Clinical and Experimental,* 51(7), 819-826.

Kanagasabapathy G., Malek S.N.A., Mahmood A.A., Chua K.H., Vikineswary S. & Kuppusamy U.R. 2013. Beta-glucan-rich extract from Pleurotus sajor-caju (Fr.) singer prevents obesity and oxidative stress in C57BL/6J mice fed on a high-fat diet. *Evidence-Based Complementary and Alternative Medicine.*

Karaçil M.Ş. & Akbulut G. 2013. Tip 2 Diabetes Mellitus ve Beta Glukan. *Beslenme ve Diyet Dergisi,* 41(3), 242-246.

Kaur R., Sharma M., Ji D., Xu M. & Agyei D. 2020. Structural features, modification, and functionalities of beta-glucan. *Fibers,* 8(1), 1.

Kearney N., Stack H.M., Tobin J.T., Chaurin V., Fenelon M.A., Fitzgerald G.F. & Stanton C. 2011. Lactobacillus paracasei NFBC 338 producing recombinant beta-glucan positively influences the functional properties of yoghurt. *International Dairy Journal,* 21(8), 561-567.

Keser O. & Bilal T. 2008. Effect of beta-glucan on immune system and performance in animal nutrition. *Journal of Erciyes University Faculty of Veterinary Medicine,* 5(2), 107-119.

Khorshidian N., Yousefi M., Shadnoush M. & Mortazavian A.M. 2018. An overview of β-Glucan functionality in dairy products. *Current Nutrition & Food Science,* 14(4), 280-292.

Kim S.Y., Song H.J., Lee Y.Y., Cho K.H. & Roh Y.K. 2006. Biomedical issues of dietary fiber β-glucan. *Journal of Korean Medical Science,* 21(5), 781-789.

Kim H., Stote K.S., Behall K.M., Spears K., Vinyard B. & Conway J.M. 2009. Glucose and insulin responses to whole grain breakfasts varying in soluble fiber, β-glucan. *European Journal of Nutrition,* 48(3), 170.

Kofuji K., Aoki A., Tsubaki K., Konishi M., Isobe T. & Murata Y. 2012. Antioxidant activity of β-glucan. International Scholarly Research Notices.

Lam K.L. & Cheung P.C.K. 2013. Non-digestible long chain beta-glucans as novel prebiotics. Bioactive carbohydrates and dietary fibre, 2(1), 45-64.

Lattimer J.M. & Haub M.D. 2010. Effects of Dietary Fiber and Its Components on Metabolic Health. *Nutrients,* 2(12), 1266–1289. https://doi.org/10.3390/nu2121266

Lazaridou A., Biliaderis C.G. & Izydorczyk M.S. 2003. Molecular size effects on rheological properties of oat β-glucans in solution and gels. *Food Hydrocolloids,* 17(5), 693-712.

Lei N., Wang M., Zhang L., Xiao S., Fei C., Wang X. & Xue F. 2015. Effects of low molecular weight yeast β-glucan on antioxidant and immunological activities in mice. *International Journal of Molecular Sciences, 16*(9), 21575-21590.

Liu Y., Liu X., Yang L., Qiu Y., Pang J., Hu X. & Jin X. 2021. Adjuvanticity of β-Glucan for Vaccine against Trichinella spiralis. Frontiers in Cell and Developmental Biology, 1803.

Louie B., Rajamahanty S., Won J., Choudhury M. & Konno S. 2010. Synergistic potentiation of interferon activity with maitake mushroom d-fraction on bladder cancer cells. BJU international, 105(7), 1011-1015.

Maheshwari G., Sowrirajan S. & Joseph B. 2019. β-Glucan, a dietary fiber in effective prevention of lifestyle diseases–An insight. *Bioactive Carbohydrates and Dietary Fiber,* 19, 100187.

Mishra N. 2020. Cereal β Glucan as a Functional Ingredient. *In Innovations in Food Technology* (pp. 109-122). Springer, Singapore.

Mohebbi Z., Homayouni A., Azizi M.H. & Hosseini S.J. 2018. Effects of beta-glucan and resistant starch on wheat dough and prebiotic bread properties. *Journal of food science and technology,* 55(1), 101-110.

Morshed M.T., Rahman S., Rahman S., Jahan S., Mukti M. & Taznin I. 2013. Antihyperglycemic and antinociceptive effects of a commercially produced beta-glucan from Saccharomyces cerevisiae in Swiss albino mice. A*dvances in Natural and Applied Sciences,* 7(3), 260-263.

Mudgil D. 2017. The interaction between insoluble and soluble fiber. In Dietary fiber for the prevention of cardiovascular disease (pp. 35-59). Academic Press.

Murphy E.J., Rezoagli E., Major I., Rowan N. & Laffey J.G. 2021. β-Glucans. Encyclopedia, 1(3), 831-847.

Nishantha M.D.L.C., Jeewani D.C., Xiaojun N. & Weining S. 2018. Beta-Glucan: An Overview of its Properties, Health Benefits, Genetic Background and Practical Applications. *Scholars Journal of Agriculture and Veterinary Sciences* (SJAVS) e-ISSN 2348–1854.

Özcan T., Kurtuldu O. & Delikanlı B. 2013. Use of β-glucan in the development of cereal-containing dairy products. *Journal of Uludag University Faculty of Agriculture,* 27(1), 87-96.

Ren Y., Xie H., Liu L., Jia D., Yao K. & Chi Y. 2018. Processing and prebiotics characteristics of β-glucan extract from highland barley. *Applied Sciences,* 8(9), 1481.

Queenan K.M., Stewart M.L., Smith K.N., Thomas W., Fulcher R.G. & Slavin J.L. 2007. Concentrated oat β-glucan, a fermentable fiber, lowers serum cholesterol in hypercholesterolemic adults in a randomized controlled trial. *Nutrition Journal,* 6(1), 1-8.

Sahan N., Yasar K. & Hayaloglu A.A. 2008. Physical, chemical and flavour quality of non-fat yogurt as affected by a β-glucan hydrocolloidal composite during storage. *Food Hydrocolloids,* 22(7), 1291-1297.

Samur G. & Mercanlıgil S.M. 2008. Dietary fiber and nutrition. The Ministry of Health of Turkey, the General Directorate of Primary Health Care.

Schmidt M. 2020. Cereal beta-glucans: an underutilized health endorsing food ingredient. *Critical Reviews in Food Science and Nutrition, 1*-20.

Seo G., Hyun C., Choi S., Kim Y.M., Cho M. 2019. The wound healing effect of four types of beta-glucan. *Applied Biological Chemistry,* 62(1). https://doi.org/10.1186/s13765-019-0428-2

Silva V.D.O., De Moura N.O., De Oliveira L.J.R, Peconick A.P. & Pereira L.J. 2017. Promising effects of beta-glucans on metabolism and on the immune responses. *American Journal of Immunology,* 13(1), 62-72.

Sima P., Vannucci L. & Vetvicka V. 2018. β-glucans and cholesterol. *International journal of molecular medicine,* 41(4), 1799-1808.

Şahin G. 2018. The effect of oat flakes added to the diet on body weight loss and some biochemical parameters in obese women.

Şimşekli N. & Doğan S.İ. 2015. The Effect of Grain Based Beta-Glucan Addition on the Technological and Functional Properties of Foods. *Turkish Journal of Agriculture-Food Science and Technology,* 190-195.

Şöhretoğlu D. & Uz A.K. 2015. β-Glucan and the Immune System. Hacettepe University *Journal of the Faculty of Pharmacy*, (2), 103-115.

Talbott S. & Talbott J. 2009. Effect of Beta 1, 3/1, 6 Glucan on upper respiratory tract infection symptoms and mood state in marathon athletes. *Journal of sports science & medicine, 8(4), 509.*

Turner N.D. & Lupton J.R. 2011. Dietary Fiber. Advances in Nutrition, 2(2), 151–152. https://doi.org/10.3945/an.110.000281

US Department of Health and Human Services. 1997. Food labeling: health claims; oats and coronary heart disease: final rule. *Federal register*, 62(15), 3583-3601.

Vlassopoulou M., Yannakoulia M., Pletsa V., Zervakis G.I. & Kyriacou A. 2021. Effects of fungal beta-glucans on health–a systematic review of randomized controlled trials. *Food & Function.*

Vetvicka V. & Fernandez-Botran R. 2018. β-Glucan and parasites. Helminthologia, 55(3), 177.

Xin-Zhong H., Xia-lu S., Xiao-ping L., Liu L., Jian-mei Z. & Xing-yun C. 2015. Effect of dietary oat β-glucan on high-fat diet induced obesity in HFA mice. *Bioactive Carbohydrates and Dietary Fibre,* 5(1), 79-85.

Yuca B., Topçu İ., Yağcılar-Aydemir H., Özer C.O., Kılıç B. & Başyiğit-Kılıç G. 2019. Effects of beta-glucan addition on the physicochemical and microbiological characteristics of fermented sausage. *Journal of food science and technology*, 56(7), 3439-3448.