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Review paper

Beta-glucans: Structure and Utilization in Fermented Milk: A Mini Review

Hency Rose*, Aparnna, V.P. and Ridhi Pandey

Department of Dairy Science and Food Technology, Banaras Hindu University, Uttar Pradesh, India

*Corresponding author: hencyrose1@gmail.com

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ABSTRACT

β-glucan is a naturally occurring non-starch polysaccharide formed by β-glycoside linkages between D-glucose monomers. Beta-glucan is found in significant quantities in various sources such as grains, fruits, fungi, algae, yeast, and bacteria. The recent emergence of beta-glucan has garnered considerable interest due to its beneficial impact on human health. This article provides a systematic overview of the sources, structure, technological functions, and practical applications of β-glucan in fermented dairy products. Gel formation, high moisture-binding capacity, enhanced yield of completed goods, texture formation, and original sensory indicators are just some of its pronounced technological roles in the composition of dairy products. The utilization of β-glucan derived from yeast and mushrooms has been found to be advantageous in providing biologically active compounds that contribute to the functional properties of the final product.

Keywords: Polysaccharides, β-glucan, microalgae, mushrooms, yeast,fermented milk products

Over the past three decades, a notable shift in dietary habits has taken place in developing nations. This transformation can be attributed primarily to alterations in consumer preferences, nutritional ideologies, and eating behaviors. Notably, there has been a surge in the consumption of food items that are lower in calories, fat, and cholesterol. This trend can be attributed to the influence of dietary guidelines and the conscious food choices made by consumers, driven by their perception of these options as being conducive to maintaining good health. Functional foods added with bioactive components to improve health or lower chronic disease risk have been popular in the recent two decades. The functional food industry has grown due to consumer health awareness, new bioactive sources, and process technologies that safely incorporate them into food formulations (Yegin *et al.* 2020). At the advent of functional foods, dietary fiber-rich products have gained relevance due to their health benefits (Sengul and Seda, 2022).

Dietary fiber, a crucial component of functional food, has been the subject of comprehensive research and validation for numerous years, as highlighted by the extensive investigation conducted by Lee *et al.* (2009). Within the realm of dietary fiber, it is worth noting that β-glucan stands out prominently. This particular type of fiber can be found in both plant-based and microbial sources, and it has a range of functional properties that make it highly desirable for various industrial applications. Moreover, β-glucan has been linked to numerous health benefits, further emphasizing its significance in the realm of

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nutrition and well-being. β-glucans, as explained by Wolever *et al.* (2020), have been observed to exert a beneficial influence on the healthy balance of blood glucose levels and reduce the risk of cardiovascular disorders. Furthermore, the immunomodulatory potential of these compounds, as highlighted by Akramiene *et al.* (2007), has been found to enhance the functionality of the immune system. Additionally, Abedini *et al.* (2022) have reported on the wound healing properties exhibited by β-glucans. Moreover, these compounds have demonstrated noteworthy antimicrobial attributes, encompassing antibacterial and antiviral activities. The rheological properties of this particular ingredient, such as its ability to form gels, emulsify, and thicken foods, make it a valuable component in the development of innovative nutraceutical food products (Mishra, 2020). Moreover, it has been observed that beta-glucan exhibits remarkable potential in modulating various functional characteristics of food items, including sensory attributes, rheological properties, texture, and viscosity (Kaur *et al.* 2020). This comprehensive review looks into the various sources of beta glucans and thoroughly explores their therapeutic effects.

1. Dietary Fiber

Dietary fibers are complex substances characterized by their polysaccharide structure, consisting of 10 or more monosaccharide units. These unique compounds resist enzymatic breakdown by the endogenous enzymes found in the small intestine of humans. The subject matter encompasses the presence of food-grade carbohydrate polymers in their unprocessed state, as well as naturally occurring carbohydrate polymers that undergo modifications through physical, enzymatic, or chemical processes, resulting in notable physiological advantages. The aforementioned description encompasses synthetic carbohydrate polymers that have been scientifically proven to possess notable physiological advantages (CAC, 2008).

Dietary fibers can be classified into different categories based on their functional properties. These categories encompass total dietary fiber, soluble dietary fiber (SDF), insoluble dietary fiber (IDF), viscous dietary fibers, non-viscous dietary fibers, fermentable fibers, nonfermentable fibers, and functional fiber (Ahmad and Khalid, 2018).

β-Glucan

β-Glucan, a non-starch polysaccharide, is a member of the carbohydrate's family. It is characterized by its composition of elongated chains of glucose units, which can be arranged either in a branched or unbranched manner. The cohesive mechanism for these elongated molecular structures is facilitated through glycosidic linkages between β-d-glucopyranose molecules. The glycosidic linkages among glucose molecules exhibit variations that are contingent upon the origin of β-glucan, as elucidated by Ahmad and Khalid (2018). β-glucans, which are found in various food sources such as yeast, fungi (including mushrooms), certain bacteria, seaweeds, and cereals (specifically oat and barley), are polysaccharides composed of D-glucose monomers connected by β-glycosidic linkages (Mikkelsen *et al.* 2013; Volman *et al.* 2010). Table 1, shows a comprehensive compilation of various sources that contain β-glucans.

1. Significance of β-Glucan

The study conducted by Kuge *et al.* (2015) provided evidence for the presence of β-glucans in various glycosidic linkages, including β (1,3), (1,4), and (1,6), which can be found in both unbranched and branched configurations. The presence of numerous hydroxyl groups within the molecular structure facilitates the formation of hydrogen bonds with water molecules. This unique characteristic enables the molecule to possess the ability to retain water in both soluble and insoluble forms, thereby exhibiting a pronounced hydrophilic nature. The molecular weight (MW) of β-glucans is based upon the specific source from which they are derived, resulting in a range of values between 102 and 106Da, as reported by Kim and White (2013). The presence of high molecular weight (MW) and elevated viscosity in β-glucan has been observed to exhibit notable effects on human health, specifically in relation to hypocholesterolaemiaand hypoglycaemia (Wolever *et al.* 2020). **β-**glucans, known for their versatile properties, find extensive utilization in the realm of food. Their remarkable ability to modulate various functional attributes of food products, such as viscosity, texture, rheology, and sensory characteristics, has been widely acknowledged by researchers (Ahmad *et al.* 2012).

2. Importance of β-Glucan in diet

In 1997, the US Food and Drug Administration made a significant decision regarding oat bran, which is known for its high content of β-glucan. This ruling designated oat bran as the first cholesterol-reducing food and outlined a recommended daily intake of 3 g of β-glucan. To achieve this dosage, one could consume up to 40 g of oat bran or up to 60 g of oatmeal, as suggested by Vetvicka *et al.* (2018). The soluble fermentable fiber known as β-glucan, derived from oats and barley, is recognized for its ability to exhibit increased viscosity inside the small intestine and undergo fermentation within the large intestine. The β-glucans undergo a process of fermentation, resulting in the production of short-chain fatty acids. These valuable compounds are then efficiently absorbed by the intestinal walls and transported into the portal blood circulation. The majority of β-glucan ingested undergoes fermentation within the cecum and colon, resulting in the production of short-chain fatty acids, as observed in the study conducted by Juvonen *et al.* (2009). In addition to β-glucan, it is worth noting that various other polysaccharides have the potential to undergo the intricate process of fermentation. These include pectin, resistant starches, gums, and inulin. The health-promoting effects of these short-chain fatty acids on the body are noteworthy. Several physiological effects have been observed in relation to the consumption of certain food components. These effects encompass an increase in insulin secretion, regulation of glycogen breakdown, a decrease in colonic pH leading to enhanced mineral absorption, inhibition of cholesterol synthesis in the liver, and promotion of T cell, leukocyte, and antibody production (El Khoury *et al.* 2012).

Table 1: Comprehensive compilation of various sources that contain β-glucans

Names of the sources		**β-Glucan Content (%)**
Cereal crops	Oat	4.5–5.5
	Wheat	< 1
	Rice	0.4–0.9
	Sorghum	0.07–0.2
Bacteria	Lactic acid bacteria	1.9–14.9
	Paenibacillus polymyxa	1.06
	Agrobacterium sp. ZX09 (Salecan®)	> 90
Fungi	*Saccharomyces cerevisiae*	55–65
	Aspergillus niger mycelium	50.9
	Gyrophora esculenta	22.7
	Ganoderma lucidum	45.1
Microalgae	*Euglena*	20-70
	Durvillaea antarctica	5-33
	Scenedesmus obtusiusculus A 189	6.4–19.5

Source: Mykhalevych et al. 2019.

3. Structure of β-Glucan

In terms of their composition, β-glucans consist of glucose units that are interconnected through various types of beta-glycosidic linkages (as depicted in Fig. 1). The molecular composition of this particular entity can be described as a polymer consisting of multiple monosaccharide residues, as elucidated by Murphy *et al.* (2020) in their comprehensive study. **β-**glucans, fascinating polysaccharides, consist of β-D-glucose monomer units that are intricately connected through glycosidic linkages at various positions, namely (1,3), (1,4), or (1,6). The architectural composition of this particular structure exhibits the potential to manifest in either a branched or unbranched configuration, as elucidated by the research conducted by Yang *et al.* (2019). The structural characteristics of β-glucans are contingent upon the source from which they are derived, specifically influencing the presence and degree of branching within the molecule. The interconnection of monosaccharide units occurs at multiple locations, resulting in a diverse array of both branched and linear structures (Kaur *et al.* 2019).

The complex composition of β-glucans exhibits notable variations that highly influence their impacts and modes of operation. According to the findings of Kaur *et al.* (2019), it has been observed that there are variations in glycosidic linkages, molecular weight, branching, degree of polymerization, and solubility. According to Bae *et al.* (2013), it has been noticed that β-glucans derived from various sources exhibit distinct effects or functions. In contrast to other biopolymers, such as proteins, β-glucans exhibit a remarkable degree of structural diversity, which consequently provides them with an enhanced potential for conveying biological information. Because of their adaptability and diversity, **β**-glucans have the potential to affect a wide range of cellular pathways, functions, and signaling processes (Murphy *et al.* 2020).

4. Potential sources and methods of extraction

β-Glucan, a prominent non-starch polysaccharide, can be found abundantly in the cell walls of cereal grains, particularly in barley and oats (Buckeridge *et al.* 2004). Cereal grains, from a structural point of view, are composed of elongated linear chains of glucose molecules that are connected through β-(1→3) and β-(1→4) linkages. However, it is important to note that these linkages do not occur in a random or repetitive manner, as stated by Demirbas, (2005). The β-glucan derived from baker's yeast exhibits a distinct linkage pattern, characterized by the presence of both β-(1→3) and (1→6) linkages (Gardiner, 2004). In the field of cereals, it is worth noting that β-glucan exhibits a fascinating pattern of (1→4)-linkages, which tend to occur in clusters of two to four. However, (1→3)-linkages, on the other hand, are observed individually. In cereals, it is observed that β-glucan molecules exhibit (1→4)-linkages in clusters of two to four, whereas (1→3)-linkages are found individually. The observed structure is primarily characterized by the prevalence of β-(1→3)-linked cellotriosyl and cellotetraosyl units (Wood, 2000). The remaining composition of the structure is primarily comprised of elongated segments containing 4-15 (1→4)-linked β-D-glucopyranosyl units, as reported by Wood *et al.* (1994). The primary chain of β-glucan exhibits a structural similarity to cellulose, although with a notable deviation in the β-(1→3) linkage position. This deviation leads to the disruption of the strong hydrogen bonds found in cellulose, as stated by Okobira *et al.* (2008). This explains the water solubility of β-glucan derived from various cereal sources.

The scientific literature currently lacks significant empirical evidence about the extraction of β-glucan from bacterial cell walls (Tupe *et al.* 2022). According to the research conducted by Utama *et al.* (2020), it has been observed that the β-(1→3)-glucan component found in the cell walls of yeasts and bacteria, specifically *Xanthomonas campertris* and *Bacillus* sp., is comparatively smaller in size when compared to that of fungi. Consequently, this difference in size leads to a lower yield of β-glucan obtained from these particular sources. Nevertheless, these bacterial representatives typically possess the capacity to synthesize homo- or heteropolysaccharides with structuring properties that have the ability to form gels within food matrices (Zhu *et al.* 2016). Bacterial β-glucan is characterized by its linear and unbranched structure consisting of β-(1→3)-D-glucan residues. On the other hand, β-glucan derived from seaweed exhibits two possible configurations: a linear chain of β-(1→3) residues or a linear chain with β-(1→6)-linked glucosyl side branches. This information has been documented by Suzuki *et al.* in 2021. In a study conducted by Miyamoto *et al.* (2018), the researchers examined various aspects related to food.

The presence of β-glucan, a polysaccharide with potential health benefits, has been observed in certain microalgae species, including *Euglena.* Studies have reported that the β-glucan content in *Euglena* can reach as high as 90%, although it is important to consider that this value may vary depending on factors such as the quality of the raw material and the extraction method employed (Barsanti *et al.* 2001).By subjecting Euglena microalgae to excessive irradiation (Schulze *et al.* 2016) or cultivating cells under specific growth medium and conditions (Tuse *et al.* 1992), researchers have discovered a fascinating possibility: achieving a remarkable 90% yield of β-glucan. In contrast, traditional extraction methods yield a range of 20-70%, dependent upon the specific morphological component of the microalgae utilized. The β-glucan content in yeast, specifically Saccharomyces cerevisiae, has been found to be significantly higher compared to cereal crops, with a range of 55-65% (Aboushanab *et al.* 2019). The chemical composition of this particular substance is characterized by an intricate arrangement of linear β-(1→3) chains, accompanied by residual straight chains that are linked to them via elongated branches connected through β-(1→6) bonds, as described in the study conducted by Suzuki *et al.* (2021).

β-glucan can also be derived from edible mushrooms. Nevertheless, the majority of mushrooms exhibit a relatively low polysaccharide content, typically not exceeding 1%. However, several species, such as *Gyrophora esculenta*, have been found to possess significantly higher β-glucan content, exceeding 40%. The remaining fungal species exhibit a range of β-glucan concentration, with some species holding levels comparable to wheat, while others contain as much as 20% or more. **β-**glucans are predominantly regarded as a valuable source in the biomedical and pharmaceutical sectors.

The study conducted by Krzysztof Sobieralski *et al.* (2012) shown the high potential of mushrooms in producing a physiologically active form of β-glucan. This particular form of β-glucan holds promise as an ingredient in functional food items, specifically in the formulation of dairy products (Camilli *et al.* 2018). The therapeutic activities of these compounds can be attributed to their distinct structural characteristics, solubility in water, and molecular mass.

β-glucans derived from mushrooms have a diverse array of health-promoting properties. Fungal-derived β-glucans consist of β-(1→6)-linked chains that are attached to a β-(1→3) backbone. It is important to acknowledge that the fundamental composition of β-glucans is dependent upon the specific fungal origin. Fungal β-glucans consist of abbreviated β-(1→6)-linked chains, whereas yeast β-glucans possess β-(1→6) side chains accompanied by supplementary β-(1→3) chains (Synytsya, 2014). The aforementioned variations influence the characteristics of β-glucan as an immunoprotective agent and additionally ascertain its capacity to inhibit the growth of harmful microorganisms (Camilli *et al.* 2018). Nevertheless, it should be noted that β-glucans derived from mushrooms have not yet been officially approved for medical applications. Consequently, continuing research endeavors are being conducted to ascertain their potential for future utilization.

Table 2: β-glucans and its different linkages depending on the source

β-glucans	**Linkages**
Cereal	Linear β-(1→3) and β-(1→4) glucans
Bacterial	Linear β-(1→3) glucans
Fungal	Short β-(1→6)- branched β-(1→3) glucans
Yeast	Long β-(1→6)- branched β-(1→3) glucans

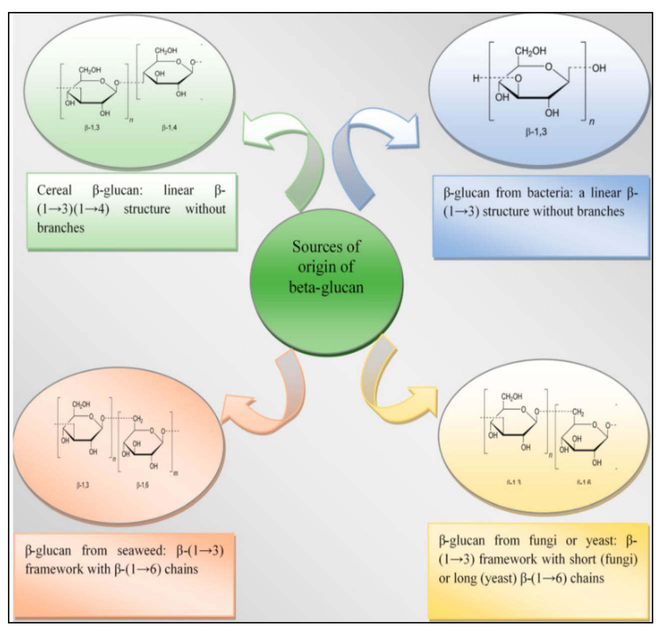

Fig. 1: The chemical composition of β-glucan in its many forms (adopted from Mykhalevych *et al.* 2019)

Utilization of β-Glucan in Fermented Dairy Products

According to the research conducted by Xiaoqing Qu *et al.* (2021), the incorporation of oat β-glucan in fermented milk beverages such as kefir, yogurt, *rhazhenka*, acidophilic milk, and others shows great potential. This is because oat β-glucan has the ability to enhance various physicochemical aspects of these products. Notably, it can contribute to increased viscosity, decreased acidity, prevention of consistency issues such as water separation and product delamination, and the provision of unique taste characteristics. Additionally, the author states that the addition of oat β-glucan at a concentration of 0.3% induces alterations in the chemical composition of the three-dimensional mesh structure of yogurt. This is attributed to the ability of oat β-glucan hinder the interaction with casein, resulting in a reduction of the fermentation process duration by 16 minutes. Furthermore, the incorporation of oat β-glucan enhances the sensory attributes of the final product. According to Liutkeviˇcius *et al.* (2015), the addition of oat β-glucan at a concentration of 0.6% in kefir, yogurt, and fermented milk beverages made from buttermilk and skimmed milk leads to a considerable increase in viscosity, particularly in yogurt. Additionally, the study revealed that kefir drink and fermented milk had superior taste characteristics, but yogurt displayed a noticeable secondary flavour similar to rice porridge. The addition of a 0.6% concentration of oat β-glucan to the drink results in an excessive rise in viscosity, hence hindering the effectiveness of the fermentation process.

Simultaneously, a recent investigation conducted by esteemed researchers (Jaworska *et al.* 2020) has shed light on the impact of oat β-glucan, specifically at a concentration of 1.4%, on the structural properties of yogurt. The findings suggest that this particular dosage fails to confer the desired textural attributes to the yogurt, resulting in a more liquid consistency. This outcome can be attributed to a unique interaction between the lactic acid cultures employed, a lower fermentation temperature of 36^0C, and an enhanced quantity of polysaccharide. Moreover, the enhanced concentration of oat β-glucan exhibits a favourable impact on the proliferation and maturation of microorganisms, specifically *L. Paracasei.*

In a study conducted by Lyly *et al.* (2003), it was observed that the incorporation of oat β-glucan into milk prior to the fermentation process exhibited a notable effect on protein aggregation. This effect was attributed to the occurrence of phase separation between milk proteins and β-glucan, resulting in a deceleration of gelation. Hence, it is recommended to incorporate probiotic strains of microorganisms alongside cereal β-glucan, particularly those with a relatively high content. This combination will facilitate the desired gel formation process.

Other researchers have also observed the impact of cereal β-glucan on the growth and metabolic functions of probiotic microorganisms within fermented milk and milk-based beverages. In a study conducted by de la Vega *et al.* (2021), it was observed that the presence of oat β-glucan had an impact on the proteolytic activity of *Lb. Rhamnosus* GG during the fermentation process of milk. To optimize the growth and potential benefits of *Lb. Rhamnosus* GG, it is recommended that the β-glucan content in the milk substrate reaches a concentration of 22.46 grams per liter. In their study, de la Vega *et al.* (2021) observed a notable increase in the population of bacterial cells belonging to Lactobacillus acidophilus and *Lactobacillus bulgaricus* strains during the fermentation process of mixtures containing whey protein concentrate (70%) and oat β-glucan. This increase was found to be particularly prominent within the initial 10-hour period of the fermentation process. The findings from Sharma et al. (2017) indicate that oat β-glucan has a noteworthy impact on the metabolic functions of Lactobacillus plantarum B28 within the formulation of an oat-based probiotic beverage.

According to Aboushanab *et al.* (2019), numerous scientists have verified that the utilization of cereal β-glucans in fermented milk products offers a significant benefit in terms of syneresis. This advantage has particular importance in the manufacturing of low-fat or skimmed fermented milk products. From the findings of Angelov *et al.*

(2006) and Kaur *et al.* (2020), the variation in the impact of oat or barley β-glucan on the viscosity of yogurts can be attributed to the specific composition of their respective formulations. Based on established research, it has been observed that the presence of starch can influence the hydrophobicity of the hydrogen bonds found in amylose and β-glucan. This phenomenon ultimately leads to the destabilization of the spatial network and consequently contributes to the liquid consistency of the beverage. This further underscores the necessity for scientific substantiation of the ingredients found in products containing β-glucan.

The addition of β-glucan derived from Saccharomyces cerevisiae, commonly known as baker's yeast, in the formulation of milk-based beverages has been found to yield nutritious and health-promoting products. In a recent study conducted by Mah *et al.* (2020), a novel milk beverage was formulated, incorporating 0.1% β-glucan derived from dispersed yeast. This innovative formulation was then administered to a group of marathon runners as part of their dietary regimen. Research findings have indicated that the ingestion of this particular beverage on the 91st day has shown potential in mitigating the symptoms associated with a common cold, particularly in the aftermath of difficult physical activity. This promising outcome holds a guarantee for minimizing post-marathon recovery time and expediting the restoration of physical vigor. In their study, Mah *et al.* (2020) conducted research on the effects of incorporating soluble and insoluble β-glucan derived from Wellmune® brand yeast into a milk-based beverage at a concentration of 0.1%. The objective of their investigation was to assess the impact of this formulation on symptom improvement among marathon runners.

Table 3: Utilization of β-glucanin various dairy products and its functional properties

Product	**Source of β-glucan**	**Dose of β-glucan**	**Functional properties**	**References**
Kefir, yogurts, rhazhenka, acidophilic milk	Oat	0.3%	Increase viscosity, reduce acidity, prevent consistency defects	Xiaoqing Qu *et al.* (2021)
Kefir drink and fermented milk	Oat	0.6%	Excessively increases the viscosity of the drink	Liutkeviˇcius *et al.* (2015)
Fermented milk	Cereal		Effect on syneresis	Aboushanab *et al.* (2019)
Milk drinks	Yeast	0.1%	Reduces the symptoms of a cold	Mah *et al.* (2020)
Skimmed milk yoghurt	Brewer's yeast	1.5%	Improves rheological properties	Mejri *et al.* (2014)
Yoghurt	Brewer's yeast	0.3%	Milk fat replacer	Piotrowska *et al.* (2009)
Low fat yoghurt	Yeast	0.8%	Effective thickener and reduces fermentation time by 25%,	Avramia *et al.* (2021)
Low fat yoghurt	Yeast from Viorica wine	0.2–0.5%	Reduction in fermentation process by 1 hour	Chirsanova *et al.* 2021
Yoghurt	*Ganoderma lucidum* mushrooms	1%	Immune modulation	Henao *et al.* (2018)
Low fat yoghurt	*Pleurotus citrinopileatus* mushrooms	1%	Possess anti-allergic properties and exhibit antioxidant effects	Pappa *et al.* (2018)
yoghurt	*Lactobacillus paracasei* NFBC 338		Reduce the syneresis, improves texture	Kearney *et al.* (2021),

The utilization of brewer's yeast, a by-product derived from the production of beer, as a source of β-glucan is not only an rational decision for enhancing the physicochemical characteristics of the product, but also aligns with the principles of sustainable development within the brewing industry (McFarlin *et al.* 2013). In their research, Mejri *et al.* (2014) conducted a study on the incorporation of β-glucan derived from brewer's yeast into skimmed milk yogurt. The study focused on evaluating the effects of varying concentrations of β-glucan, ranging from 0% to 2%, on the composition of the yogurt. The research findings have indicated that when the dose is set at 1.5%, it has a positive impact on the rheological properties. Specifically, it enables the achievement of desirable viscosity and consistency, reminiscent of yogurt with a high-fat content.

The investigation conducted by Piotrowska *et al.* (2009) explored the potential utilization of β-glucan derived from brewer's yeast as a substitute for milk fat in the development of yogurt with a fat content of 3%. Within the spectrum of β-glucan concentrations (ranging from 0.15% to 0.9%) that were thoughtfully selected for the investigation, it was determined that the optimal dosage of 0.3% yielded an appealing creamy flavor profile, a pleasantly thick texture, and an attracting milky aroma. The obtained outcome of the sensory evaluation can be attributed to the absence of low-fat content in the yogurt.

In another investigation, it has been discovered that the inclusion of yeast β-glucan in low-fat yogurt exhibits notable thickening capabilities while concurrently reducing the duration of fermentation by a noteworthy 25%. This phenomenon can be attributed to the inherent characteristic of β-glucan derived from brewer's yeast, which facilitates the formation of small clusters within the yogurt matrix (Avramia *et al.* 2021). By elevating the dosage to 0.8%, a notable enhancement in the sensory attributes of the product can be observed, while the physicochemical properties, including syneresis, titrated acidity, and viscosity, remain largely unaffected.

Yeast sediment, such as that derived from the production of wines, specifically Viorica wine from Moldova (Chirsanova *et al.* 2021), serves as a notable source of β-glucan. The incorporation of β-glucan into low-fat yogurt at a concentration of 0.2–0.5% has been observed to result in a decrease in the fermentation time by 1 hour. This reduction can be attributed to the gel-forming properties exhibited by β-glucan, as reported in the study.

The exploration of β-glucan extraction from edible mushrooms and its application in the food industry represents a highly encouraging avenue in the advancement of technologies for the creation of nutritious food products that encompass biologically active compounds, vitamins, and mineral complexes within their chemical composition. The study conducted by Cerletti *et al.* (2021) highlights the potential of β-glucans derived from edible mushrooms as a means to inhibit the proliferation of pathogenic microorganisms. Additionally, these β-glucans have been found to possess anti-allergic properties and exhibit antioxidant effects. The investigation conducted by Pappa *et al.* (2018) delved into the extraction of β-glucan from *Pleurotus citrinopileatus* mushrooms within the context of low-fat yogurt technology.

In a study conducted by Henao *et al.* (2018), the researchers investigated the potential benefits of incorporating β-glucan from Ganoderma lucidum mushrooms into therapeutic yogurt. The aim was to explore its ability to enhance the immune system and protect children aged 3-5 years from infectious diseases. Interestingly, the researchers found that when the yogurt was supplemented with 1% of β-glucan and *Plukenetiavolubilis* seeds, derived from the Sacha Inchi plant, it not only improved the sensory properties of the yogurt but also exhibited potential therapeutic effects. However, it is worth noting that there was a slight decrease in the yogurt's rheological characteristics. This formulation enables the replication of the lipid content in yogurt, thereby enhancing its resemblance to the control sample in terms of sensory perception.

The utilization of β-glucan derived from edible mushrooms in dairy beverage applications is currently constrained by the limited understanding of its characteristics within dairy-based food systems, as well as the intricate production process involved in achieving a paste- or gel-like consistency. The exploration of β-glucan derived from microalgae in the context of food technology remains relatively limited in terms of research and investigation.

The evaluation of the efficacy of bacterial β-glucan in yogurt was conducted by Kearney *et al.* (2021), wherein they employed the utilization *of Lactobacillus paracasei* NFBC 338 strain containing the *Pediococcusparvulus* glycosyltransferase gene, which is accountable for the production of β-glucan. The utilization of this cutting-edge technology enables the mitigation of syneresis in the fermented clot, owing to the remarkable moisture binding capabilities of β-glucan. Furthermore, it facilitates the enhancement of yogurt's texture by strengthening its viscosity.

The enhancement in the composition of yogurts through the utilization of various strains of lactic acid bacteria as a β-glucan source can be described by their ability to synthesize exopolysaccharides, specifically β-glucan, which exhibits inhibitory properties towards casein aggregation. This phenomenon contributes to the overall stability and viscosity of the end product (Kearney *et al.* 2011).

CONCLUSION

β-glucan is an esteemed functional component that exhibits the potential to cause enhanced physiological responses and possesses numerous uses for enhancing health. The favorable physiochemical features of this substance make it a good candidate for utilization in a variety of food systems. The primary roles of β-glucans found in oats and barley encompass both technological and biological functions. Technologically, these β-glucans contribute to the formation of texture, simulate the taste of milk fat, enhance the viscosity of beverages, and improve rheological characteristics. Biologically, they are associated with reducing cholesterol levels, positively impacting the intestinal tract, and other related effects. In contrast, β-glucans derived from yeast and edible mushrooms exhibit notable biological functions, such as positively influencing the immune system. The characteristics and functions of β-glucan derived from bacterial sources have received relatively limited attention in academic research. Hence, it is imperative for future studies to prioritize the advancement and comprehensive analysis of β-glucan derived from bacterial sources. In order to fully realize the advantages of this significant functional component, it is crucial that the next investigations should focus on the application of β-glucan in the creation of novel commodities. Special emphasis should be given to unexplored areas in the field of health applications. Further investigation is necessary to have a comprehensive understanding of the underlying mechanism through which β-glucan exerts its immunomodulatory effects.

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