UDC 664.6/7
DOI https://doi.org/10.15673/gpmf.v23i2.2707

R. Kosiv, PhD, Associate Professor, *E-mail: ruslana.b.kosiv@lpnu.ua*
Scopus ID 57194159234, ORCID 0000-0001-6357-0316, Researcher ID: R-1853-2017,
Department of Organic Products Technology,
Lviv Polytechnic National University, Stepan Bandera Str., 12, Lviv, 79013, Ukraine

OAT GUM: STRUCTURE, PROPERTIES, PRODUCTION, APPLICATION IN THE FOOD INDUSTRY

Abstract
Oat gum (β-glucan, glycan) belongs to the group of soluble dietary fibers. Due to their important functional properties, cereal β-glucans are used to reduce the level of cholesterol in the blood, alleviate the symptoms of diabetes, lower blood pressure, and prevent cardiovascular and oncological diseases. Sources of β-glucans are yeast, mushrooms, bacteria, barley, oats. The use of secondary resources of barley and oat processing as a source of β-glucans has both economic and environmental significance. Cereal β-glucans consist of β-D-glucose monomers connected by (1,3)- and (1,4)-glycosidic bonds. β-Glucan dissolves well in cold water and is insoluble in ethyl alcohol. It is able to form very viscous solutions at low concentrations. The viscosity of solutions depends on the concentration and molecular weight of β-glucan. The rheological properties of aqueous gum solutions do not depend on the pH of the medium. The presence of NaCl in concentrations of more than 0.5% leads to a decrease in the viscosity of solutions, and the addition of sucrose in the amount of 20-45% increases the viscosity. The technological features of obtaining β-glucans are related to the method of their extraction from natural sources. Extraction of oat gum from oat bran or rolled oats involves alkaline treatment of flour at 50-70 °C and pH 8.0-10.5, removal of starch and proteins, precipitation of oat gum with alcohol and separation by centrifugation. Solubility, degree of extraction, and yield of β-glucan from oats depend on particle size, pretreatment of grain raw materials, and extraction conditions (temperature, pH, extractants). β-Glucan is isolated from the extract by dialysis, ultrafiltration or alcohol precipitation. When using dialysis, highly viscous β-glucan is obtained, but with a lower yield; ultrafiltration and alcohol precipitation allow a higher yield of β-glucan with lower viscosity. Oat gum can be introduced into a wide range of food products to provide new functional properties and improve nutritional quality, including wheat bread, bakery products, cookies, pasta, soft drinks, as a fat substitute in dairy and meat products. It performs the technological functions of a thickener, gelling agent, stabilizer or coating in food systems.

Keywords: β-glucan, glycan, functional ingredient, functional food products.

Introduction

Recently, there has been a growing interest in functional foods, which are obtained by adding physiologically functional ingredients to their composition. Such ingredients include dietary fibre, which has a positive effect on physiological and biochemical processes in the human body [1].

Oat gum (β-glucan, glycan) performs the technological functions of thickener, gelling agent, stabiliser or coating in food systems. Due to its important functional properties, cereal β-glucans are used to lower blood cholesterol levels, alleviate the symptoms of diabetes mellitus, lower blood pressure, and prevent cardiovascular and oncological diseases. [2]. According to experts, from 2023 to 2029, the global oat gum market will grow steadily, with an increase of approximately 6.5% over this period [3].

The purpose of this review is to summarize the data from the current scientific literature on the structure and physicochemical properties of oat gum, technological aspects of its production and use in food production.

Literary review

Sources

β-Glucan is present in various natural sources: cereal grains (oats, barley), yeast (in particular *Sacchromyces cerevisiae*), and some molds [4]. However, the main sources of this valuable functional ingredient are cereals. Among cereals, oats and barley have the highest β-glucan content: 2-11% in barley and 2-7.5% in oats. For wheat and rye, β-glucan is a less common component, with a content ranging from 0.5-1% and 1.4-2.6%, respectively. Sorghum, rice and millet contain less β-glucan.

Oats are the most widely available source of cereal β-glucan. The content of β-glucan in grain is largely influenced by the genotypic characteristics of the oat variety and its growing conditions [5]. Hulled oats contain more β-glucan than filmy oats. High temperatures and excessive irrigation during grain cultivation cause a decrease in the content of β-glucan in grain.

β-Glucans predominate among the cell wall components of cereals.

Structure

β-D-Glucans are a group of structurally diverse carbohydrate polymers composed of β-D-glucopyranose residues. To date, five common natural structures of β-D-glucans are known [6]:

- cellulose or (1-4)-β-D-glucan, the most common polysaccharide in nature, which is formed in higher plants, seaweeds, some invertebrates and microorganisms;
- unbranched (1-3), (1-4)-β-D-glucans from lichens and higher plants, in which both types of bonds are distributed randomly along the chain;
- (1-3)-β-D-glucans produced by fungi and microorganisms;
- (1-6)-β-D-glucans from lichens and some fungi;
- branched (1-3), (1-6)-β-D-glucans from fungi and algae.

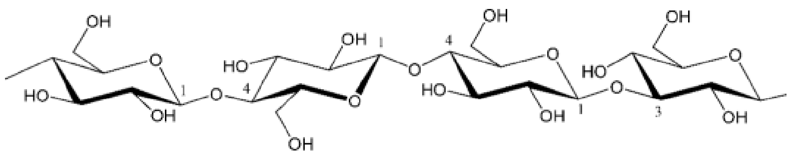

Fig. 1. Structure of cereal β-D-glucan [6]

Oats and barley contain unique metabolites - hydrocolloidal polysaccharides with mixed bonds - (1-3), (1-4)-β-D-glucans. Their primary structure is a linear chain of glucopyranose monomers linked by single β-(1-3)- and consecutive β-(1-4)-glycosidic bonds (Fig. 1). The structure of β-D-glucans determines their solubility in water.

Physical and chemical properties

β-Glucan is highly soluble in cold water and insoluble in ethyl alcohol. It is capable of forming very viscous solutions at low concentrations. The viscosity of the solutions depends on the concentration and molecular weight of β-glucan. At low concentrations (less than 0.2%), a β-glucan solution behaves as a Newtonian fluid, i.e., an increase in the shear rate does not affect the viscosity. However, at higher concentrations (more than 0.2%), β-glucan molecules with a high molecular weight form viscous and pseudoplastic solutions. The pseudoplastic behavior increases with increasing concentration and molecular weight. β-Glucans with high molecular weight form viscous and pseudoplastic solutions, while β-glucans with low molecular weight can form soft gels at higher concentrations. An increase in the concentration of the dissolved polymer usually leads to an increase in viscosity, as does an increase in the molecular weight of the dissolved substance [7].

The rheological properties of aqueous solutions of oat gum do not depend on the pH of the medium. The presence of NaCl in concentrations of more than 0.5 % leads to a decrease in the viscosity of solutions, and the addition of sucrose in the amount of 20-45 % increases the viscosity, while a higher concentration of sucrose negatively affects the rheological properties [8].

Production

Oat gum is produced from oat or other cereal grains containing β-glucan. In the process of production, the grain endosperm is subjected to extraction, followed by fermentation and purification of oat gum from raw material residues.

The extraction of oat gum from oat bran or flattened oats involves several stages: alkaline treatment of flour at a temperature of +50-70°C and pH 8.0-10.5, starch removal, isoelectric precipitation of proteins, precipitation of oat gum with alcohol and separation by centrifugation [9]. The content of oat gum varies in the range of 3.0-6.3 % for oat bran and 1.8-5.2 % for flattened oats, while the content of β-glucan in the gum varies in the range of 70-89 % and 50-68 %, respectively. Oat gum extracted at a temperature of +50-55°C and pH 9.2-10.5 is characterized by little or no starch contamination.

The solubility, degree of extraction and yield of β-glucan from oats depend on the particle size, pretreatment of the grain raw material and extraction conditions (temperature, pH, extractants).

To increase the yield of β-glucan, dry fractionation methods are used, including sequential grinding using a roller and hammer mill with oat groats sieved or classified in the air. Furthermore, the yield of β-glucan is increased by heating the oats at 12% moisture for 20 minutes. Fine grinding leads to a decrease in the yield of β-glucan, but with an increase in particle size, the degree of its extraction decreases. The distribution of β-glucan in cereals varies, and therefore the respective fractions may differ in its content.

Other cereal components may limit the extraction of β-glucan. Enzymatic processing of raw materials with subsequent inactivation of enzymes allows to obtain a product with a higher β-glucan content and solution viscosity, but its yield is reduced [10, 11].

The enzymatic conversion of oat flour starch and bran to maltooligosaccharides is carried out with the participation of thermostable α-amylase at a temperature of +95°C for 10-60 minutes. After that, α-amylase is inactivated by passing the mixture through a jet ejector at +140°C. The soluble β-glucan fibers and maltooligosaccharides are extracted by centrifugation [12].

Protein degradation under the influence of proteolytic enzymes added before heating leads to an increase in β-glucan yield, although it has been found that this reduces both the molecular weight and viscosity of barley and oat β-glucans. Trypsin, which does not have β-glucanase activity, unlike other proteases, is used as a proteolytic enzyme [13].

To enrich cereal β-glucans, acidic or alkaline conditions can be used in combination with elevated temperature, dry fractionation, enzymes and extractants. Using a slightly alkaline solution with a pH of 7.0-8.0 at +55°C, 87 % of β-glucan is extracted from barley flour with a purity of 89 %. The extraction of β-glucan is more efficient at +55°C than at +40°C, and increasing the pH has no effect. In another method, to obtain a highly concentrated β-glucan solution, milled barley is treated in 70 % ethanol, washed in 96 % ethanol or extracted with hexane, and then treated with hot water and thermostable α-amylase.

From untreated or enzyme-treated oat bran, β-glucan can be extracted with aqueous sodium carbonate at +40 °C and pH 10.0, after which β-glucan is separated from the extract by dialysis, ultrafiltration or alcohol precipitation. These methods make it possible to obtain products from oats with a β-glucan content of 60-65%, but the viscosity and molecular weight vary depending on the processing conditions. Dialysis produces a highly viscous β-glucan, but with a lower yield; ultrafiltration and alcohol precipitation allow for a higher yield of β-glucan with a lower viscosity [14].

Application in the food industry

Cereal β-glucans can be added to a wide range of food products to impart new functional properties and improve nutritional quality.

One of the most common foods enriched with β-glucan is bakery products and other wheat flour-based products. However, β-glucan added to wheat bread in the amount of 2.5 to 5.0% significantly reduces the volume and height of the bread. β-Glucans with a high molecular weight undergo degradation during bread baking, which leads to the greatest loss of dough and bread quality. In contrast, low-molecular-weight β-glucans do not degrade during baking. Freezing and thawing bakery products reduces the solubility of oat β-glucans and weakens the hypoglycaemic effect. Adding β-glucan to biscuits increases their elasticity and water content. Oat β-glucan has been successfully added to Asian noodles, which allows reducing the use of rice flour by 50%, while maintaining the quality of the noodles, their taste and without culinary losses during cooking. The addition of β-glucans to pasta leads to an increase in the water absorption index, water solubility index, and viscosity of products [15].

Cereal β-glucans have been successfully incorporated into some dairy products. It has been found that β-glucan from oats is better than barley at supporting the viability and stability of probiotics, and increases the content of lactic and propionic acid in yoghurt. A probiotic low-fat dairy product enriched with β-glucan resembles yoghurt. Recently, there has been a growing interest in the development of dairy desserts with good nutritional and rheological properties, in particular, using carrageenan and oat gum [16].

β-Glucan is used as a fat substitute in cheeses. The resulting cheeses have a lower hardness, desirable taste and melt duration, and similar elasticity and cohesion. However, when using cereal β-glucans as fat substitutes in cheese, difficulties arise in creating a product with unchanged sensory properties.

β-Glucans are used as fat substitutes in meat products. Sausages with a fat content of 12% and 0.3% β-glucan met the requirements, but with 0.8% β-glucan in the sausages, tasters did not rate them positively. Replacing 50 to 90 % of the fat in hamburger beef with cereal β-glucans did not reduce the product yield, maintained a high moisture content, and slightly reduced the size of the product.

Soft drinks prepared with the addition of 0.3-0.7% barley β-glucan did not differ in color intensity from drinks in which pectin was added. Beverages containing 0.7 % β-glucan were more acidic than those with 0.3 % pectin. At the same time, the viscosity of the drinks increased. With an increase in the concentration of β-glucan, the beverages became lighter and flocs formed, while the organoleptic properties of beverages with pectin did not change [14]. When studying the effect of hydrocolloids - oat gum, guar gum and carboxymethyl cellulose - on the sensory perception of sweetness and aroma, it was found that the sweetness of drinks was best perceived in oat gum solutions and the weakest in guar gum solutions. The effect of thickener composition on sweetness perception was greater than that of viscosity. The reduction of sweetness by hydrocolloids was weaker for aspartame than for fructose or sucrose [17].

Oat gum is authorized for use in Ukraine and Europe. There is no daily allowable intake, although its metabolism and toxicity have not been determined. Taking into account the possible harm of oat gum, a daily intake dose has been established that should not exceed 20 mg/kg body weight.

Conclusions and prospects for further research

Oat gum (β-glucan) is a valuable physiologically functional ingredient used to lower blood cholesterol levels, alleviate the symptoms of diabetes mellitus, lower blood pressure, and prevent cardiovascular and oncological diseases. The data of modern scientific literature on the structure and physicochemical properties of oat gum, as well as the technological aspects of its production and use in food production, are summarized. Further research aimed at fortification of soft drinks with cereal β-glucans as a convenient basis for the creation of functional food products is promising. The development of products enriched with cereal β-glucan will help to provide the population with food products with a sufficient amount of dietary fiber.

REFERENCES

1. Kosiv, R. (2023). Dietary fibers: structure, properties, application in soft drink technology. Science, technology and innovation in the modern world: Scientific monograph. Riga, Latvia, Baltija Publishing (in Ukrainian).
2. Yueyue Y., Sen M., Xiao-xi W. et al. (2017). Modification and Application of Dietary Fi-ber in Foods. Journal of Chemistry, 10, 1-8.
3. https://www.maximizemarketresearch.com/market-report/global-oat-gum-market/96142/
4. Ahmad, A., Munir, B., Abrar, M., Bashir, S., Adnan, M., & Tabassum, T.M. (2012). Perspective of β-Glucan as Functional Ingredient for Food Industry. Journal of Nutrition and Food Sciences, 2, 1-9.
5. Havrlentova, M., Petrulakova, Z., Burgarova, A., Gago, F., Hlinkova, A. Šturdík, E. (2011). Cereal β-glucans and their significance for the preparation of functional foods - A review. Czech Journal of Food Sciences, 29 (1), 1-14.
6. Sushytskyi L, Synytsya A, Čopíková J, Lukáč P, Rajsiglová L, Tenti P, Vannucci LE. (2023). Perspectives in the Application of High, Medium, and Low Molecular Weight Oat β-d-Glucans in Dietary Nutrition and Food Technology – A Short Overview. Food, 12(6):1121. https://doi.org/10.3390/foods12061121
7. Anttila, H., Sontag-Strohm, T., & Salovaara, H. (2004). Viscosity of beta-glucan in oat products. Agricultural and Food Science, 13(1-2), 80-87. https://doi.org/10.2137/1239099041838012
8. Gustaw, W., Achremowicz, B., Glibowski, P., Mleko, S. (2001). Otrzymywanie i właściwości reologiczne gumy owsianej. Żywność: nauka - technologia - jakość, 8, 4(29), 46-56.
9. Dawkins, N.L., & Nnanna, I.A. (1993). Oat Gum and β-Glucan Extraction from Oat Bran and Rolled Oats: Temperature and pH Effects. Journal of Food Science, 58, 562-566.
10. Beer M.U. Arrigoni E., Amado R. (1996). Extraction of oat gum from oat bran: effects of process on yield, molecular weight distribution, viscosity and (1-3)-β-D-glucan content of the gum. Cereal Chem, 73, 58-62.
11. Gajdosova A., Petrulakova Z., Havrlentova M. et al. (2007).The content of water-soluble and waterinsoluble β-D-glucans in selected oats and barley varieties. Carbohydr Polym, 70, 46-52.

12. Polonski V.I., Sumina A.V. (2013). β-glucans content as a perspective trait in the barley breeding for foodstuff use (review). Agricultural Biology, 5, 30-43.
13. Stephen C.F., Bertram H.W., Nesselrode A. et al. (2008). Mixed-linkage (1-3,1-4)--β-D-glucan is a major hemicellulose of Equisetum (horsetail) cell walls. New Phytologist, 179, 104-115.
14. Beer M.U. Arrigoni E., Amado R. (1996). Extraction of oat gum from oat bran: effects of process on yield, molecular weight distribution, viscosity and (1-3)-β-D-glucan content of the gum. Cereal Chem, 73, 58-62.
15. Krawęcka A, Sobota A, Sykut-Domańska E. (2020). Physicochemical, Sensory, and Cooking Qualities of Pasta Enriched with Oat β-Glucans, Xanthan Gum, and Vital Gluten. Foods, 9(10), 1412. https://doi.org/10.3390/ foods9101412
16. Zarzycki, P., Ciołkowska, A.E., Jabłońska-Ryś, E. et al. (2019). Rheological properties of milk-based desserts with the addition of oat gum and κ-carrageenan. J Food Sci Technol, 56, 5107-5115. https://doi.org/10.1007/s13197-019-03983-4
17. Mälkki, Y., Heiniö, R-L., & Autio, K. (1993). Influence of oat gum, guar gum and carboxymethyl cellulose on the perception of sweetness and flavour. Food Hydrocolloids, 6(6), 525-532. https://doi.org/10.1016/S0268-005X(09)80076-3

УДК 664.6/7

Р.Б. Косів, канд. техн. наук, доцент, доцент, *E-mail: ruslana.b.kosiv@lpnu.ua*
Кафедра технології органічних продуктів
Національний університет «Львівська політехніка», вул. Степана Бандери, 12, м. Львів, 79013, Україна

ВІВСЯНА КАМЕДЬ: БУДОВА, ВЛАСТИВОСТІ, ОТРИМАННЯ, ЗАСТОСУВАННЯ В ХАРЧОВІЙ ПРОМИСЛОВОСТІ

Анотація

Вівсяна камедь (β-глюкан, глікан) належить до групи розчинних харчових волокон. Завдяки важливим функціональним властивостям зернові β-глюкани застосовують для зниження рівня холестерину в крові, ослаблення симптомів цукрового діабету, зниження артеріального тиску, профілактики серцево-судинних і онкологічних захворювань. Джерелами β-глюканів є дріжджі, гриби, бактерії, ячмінь, овес. Використання вторинних ресурсів перероблення ячменю та вівса як джерела β-глюканів має як економічне, так і екологічне значення. Зернові β-глюкани складаються з мономерів β-D-глюкози, зв'язаних (1,3)- і (1,4)-глікозидними зв'язками. β-Глюкан добре розчиняється в холодній воді й не розчиняється в етиловому спирті. Він здатний утворювати дуже в'язкі розчини за низьких концентрацій. В'язкість розчинів залежить від концентрації та молекулярної маси β-глюкану. Реологічні властивості водних розчинів камеді не залежать від pH середовища. Наявність NaCl у концентраціях більш як 0,5 % призводить до зниження в'язкості розчинів, а додавання сахарози в кількості 20-45 % підвищує в'язкість. Технологічні особливості отримання β-глюканів пов'язані зі способом їх добування з природних джерел. Екстрагування вівсяної камеді з вівсяних висівок або плющеного вівса включає лужне оброблення борошна за температури +50-70 °C та pH 8,0-10,5, видалення крохмалю й білків, осадження вівсяної камеді спиртом і відокремлення центрифугуванням. Розчинність, ступінь екстрагування та вихід з вівса β-глюкану залежать від розміру частинок, попереднього оброблення зернової сировини й умов екстрагування (температури, pH, екстрагентів). β-Глюкан виділяють з екстракту діалізом, ультрафільтрацією або спиртовим осадженням. При застосуванні діалізу отримують високов'язкий β-глюкан, проте з нижчим виходом; ультрафільтрація й осадження спиртом дають змогу отримати вищий вихід β-глюкану з нижчою в'язкістю. Вівсяна камедь може бути введена в широкий спектр харчових продуктів для надання нових функціональних властивостей і покращення якості харчування, зокрема в пшеничний хліб, хлібобулочні вироби, печиво, макаронні вироби, безалкогольні напої, як замінники жиру – в молочні й м'ясні продукти. Вона виконує в харчових системах технологічні функції загусника, гелеутворювача, стабілізатора або покриття.

Ключові слова: β-глюкан, глікан, функціональний інгредієнт, функціональні харчові продукти

Received 26.05.2023 **Revised 25.06.2023**
Reviewed 07.06.2023 **Approved 29.06.2023**

Cite as Vancouver Citation Style
Kosiv, R. Oat gum: structure, properties, production, application in the food industry. Grain Products and Mixed Fodder's, 2023; 23 (2, 90): 16-19. **DOI** https://doi.org/10.15673/gpmf.v23i2.2707

Cite as State Standard of Ukraine 8302:2015
Oat gum: structure, properties, production, application in the food industry. / Kosiv, R. // Grain Products and Mixed Fodder's. 2023. Vol. 23, Issue 2 (90). P. 16-19. **DOI** https://doi.org/10.15673/gpmf.v23i2.2707