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Bioactive Carbohydrates – Health benefits and its Utilization in Food Preparations

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Abstract

Carbohydrates play an important role in human health because they are rich sources of bioactive compounds which can be used as functional foods. Category of carbohydrates with a well- defined target are often referred to as bioactive substances. Bioactive carbohydrates can be derived from plants, animals and microorganisms. Aiming to achieve nutritional security has always been an important area for research. Diet related diseases are the serious problem faced by the mankind. The consumption of high amount of rapidly digestible, refined starches, has led to increased demand for low glycemic index foods. Since polysaccharides have a significant role in human health, it is very important to explicit the varying alterations and nutrient loss during the processing of plant material. It can be concluded that increasing the amount of whole grain products in our diet can help in maintaining health. It is suggested to consume food products made from wholegrain cereals or fractions of whole grains and fruits and vegetables as it provide health benefits.

Keywords: Bioactive carbohydrates, biological activities, healthy food, processing effects

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Introduction

Almost all living things, particularly lower and higher plants, naturally contain carbohydrates. Polysaccharides can be divided into plant polysaccharides, animal-derived polysaccharides and microorganism polysaccharides based on the dietary sources [1]. Polysaccharides are an essential dietary component that have been shown to have numerous biological activities. Plants, are a valuable source of polysaccharides that make a large portion of our daily diet and provide valuable nutrition that aids the immune system, improves digestion, and assists in eliminating toxic by-products from the human body [2]. On account of the high level of consumption of processed foods by the consumers, there is inadequacy of fiber in their diet which made food fortifications with bioactive carbohydrates an important area of research in nutrition. The Sustainable Food Systems EAT-Lancet Commission on Healthy Diets estimates that over 820 million people worldwide do not now have enough access to food, and many more consuming low-quality diets resulting in under nutrition, micronutrient deficiencies, and heightening of diet-related diseases. The survey also came to the conclusion that there must be a minimum 50% reduction in the consumption of harmful foods, such as sugar and red meat, worldwide. An increase in the consumption of fruits, vegetables, nuts, and legumes is essential, necessitating a doubling of the current intake by the year 2050 in order to meet healthy dietary standards [3]. This review describes the sources of bioactive carbohydrates, their applications in food industry and effects on processing and significance of consumption of healthy foods.

Bioactive carbohydrates

Cellulose

Cellulose is present in fruit, grains, nuts, vegetables. The beneficial health effects are increased stool bulk and bowel movement regulation [4]. It aids in decreasing the duration of intestinal transit and promotes the removal of potential carcinogens, thereby helping to lower the risk of colon cancer development.

Hemicelluloses

Hemicellulose is advantageous for use in the food, medicine, and energy industries [5]. Vegetative and storage tissues of annual/ perennial plants, fruit, legumes, and nuts are the sources of hemicelluloses. Antioxidant activity,

antithrombotic activity, immunomodulating activity, cholesterol lowering, free radical elimination and bowel movements regulation are the health effects reported [6].

β-Glucans

A water-soluble dietary fiber, β-glucan is found in barley, oats, algae, yeast, bacteria, and mushrooms. Glucans are usually concentrated in the internal aleurone and sub-aleurone endosperm cells walls [7]. The FDA determined that an effective daily intake of β-glucan is 3 g, but there have been few attempts to establish a dose response which may differ among different subject groups and depend upon baseline level. The primary sources of β-glucan in the human diet from cereals are oats, barley, rye and wheat. The largest amounts of β-glucan are found in barley (3-11%) and oats (3-7%), with lesser amounts reported in rye (1-2%) and wheat (<1%) [8]. Only trace amount has been reported in corn, sorghum, rice and other cereals of importance as food. Oat-based breakfast cereals have also gained considerable attention in recent years as they are rich in β-glucan. It has positive effects on human health, such as cancer prevention, anti-inflammatory activity, skin protection, antioxidant, immune modulation and reduction of glycaemia and serum cholesterol. Anti-angiogenesis is a possible pathway by which β-glucans can decrease tumor proliferation and prevent tumor metastasis [9]. Despite this, β-Glucan has been demonstrated to increase resistance to infectious challenge [10] by eliciting broad anti-infective effects.

Resistant starch

Cooked and cooled potatoes, rice, green bananas, legumes are the sources of resistant starch. The hypoglycemic activities, hypocholesterolemic effects, prevention of colonic cancer, prebiotic roles, inhibition of fat accumulation, enhanced absorption of minerals are the health benefits documented [11]. The resistant starch content of different pulses (beans, chickpeas, lentils, and peas) ranged from 3.95 to 5.09 % against 1.42–2.85 %, respectively for cereals like wheat, rice and barley [12].

Arabinoxylan

Arabinoxylans can also act as a bioactive agent due to their immunomodulatory, antioxidant, antimicrobial and prebiotic properties. The structural characteristics of this polysaccharide have given rise to its interesting functional properties and potential industrial applications as an emulsifier, stabilizer, suspending agent, binder, disintegrant, a film-forming agent and a gelling agent. [13]. In addition, many studies utilized arabinoxylan from rice bran to reveal its effects on some diseases, such as cancer [14] and also revealed that its interaction with gut microbiota is beneficial to human health [15].

Pectin

Pectins, mainly from citrus peel and apple pomace, are widely used in the food industry as gelling or thickening agents [16].

Oligosaccharides

Functional oligosaccharides are non-digestible by human gut enzymes and providing health benefits as fibers and prebiotics [17]. In higher plants, functional oligosaccharides are present in some plants tissue with large amounts such as, in Jerusalem artichokes from where commercial inulin is extracted [18]. Onions, garlic, legumes, wheat, asparagus, and other plants are also a source of functional oligosaccharides, present in trace amounts. The major known functional oligosaccharides are fructooligosaccharides, galacto-oligosaccharides, lacto-sucrose, isomalto-oligosaccharides, malto-oligosaccharides. trehalose, cyclodextrins, xylo-oligosaccharides, and soy-oligosaccharides [19]. They have mildly sweet taste with mouthfeel and texture characteristic that interest food industries in utilizing these oligosaccharides to improve food texture, and as, partial replacement for fats and sugars [20] in healthy foods. Besides this, they have been used extensively in foods, and as dietary supplements for health benefits to regulate and control blood glucose for diabetes, reduce lipid level for patients with symptoms of hyperlipidemia, for a healthy colon, and to regulate body weight. In addition, functional oligosaccharides have applications in pharmaceuticals, cosmetics, agrichemical formulations, and in encapsulation technology [21]. Apart from this, galacto-oligosaccharides are used in wide varieties of adult foods such as, backed goods, beverages, and in infant formula [22]. It is well known that of all the crops, pulses have the highest concentrations of certain oligosaccharides. Total oligosaccharides in different pulses, such as lentils, chickpeas and peas were observed to range between 70.7 mg/g DW in yellow peas and 144.9 mg/g DW in chickpeas [23].

Inulin

Inulin can be found in onions (*Allium cepa*), Jerusalem artichoke (*Helianthus tuberosus*), asparagus (*Asparagus officianalis*), leeks (*Allium ampeloprasum*), wheat, garlic and chicory (*Cichorium intybus*) root. It is a prebiotic carbohydrate, which possesses many positive health effects [24]. The health beneficial properties of inulin were attributed to its numerous effects such as antibacterial effects against pathogenic bacteria, anticancer effects, lowering blood serum lipids, blood urea, and uric acid levels, increasing the absorption of calcium, magnesium, copper, iron, and zinc, decreasing the risk of cardiovascular diseases, and atherosclerosis and so forth [25]. Inulin is widely used in food industry due to its nutritional and technological properties and utilised as a sugar replacer, fat replacer and texture modifier in food applications. Moreover, inulin exhibits wider applications in dairy and bakery products, beverages, cereals and cereal bars, low-fat spreads, ice cream and confectionary products [26].

Dietary Fibers include Bioactive Polysaccharides

The Food-and-Agriculture-Organization (FAO) characterizes dietary fiber as a combination of inedible plant - polysaccharides like cellulose, hemi-celluloses, gelatins, oligosaccharides, latexes, and other lignified complexes. [27]. Generally, the dietary fibre content of pulses (either raw or cooked) is in the range of 13–35 g per 100 g of edible portion [28] with SDF and IDF ranging from 0–9 and 10–28 %, respectively against 3.00–15.02, 0.86–4.33, and 2.14–10.79 %, respectively for cereals like wheat, rice and barley [29]. The role of cereal fibers in the prevention of many chronic diseases is well documented, which has led to dietary recommendations that emphasize for increased intake of whole grain products or products rich in cereal fibers. In response, food manufacturers are tailoring processing conditions to develop food structures that deliver the desired physiological functionality while maintaining good sensory properties [30].

Effect of processing on bioactive carbohydrates

Different researchers have reported that an increase in enzyme-resistant starch content in wheat, maize [31], and barley (2–3%) after extrusion [32]. Cereal grains and wholegrain cereal products are the excellent sources biologically active compounds includes arabinoxylans, beta-glucans, cellulose, lignin and lignans [33]. When wheat flour is refined, practically all of its nutrients are reduced. As observed by the decrease in soluble and insoluble dietary fiber was found to be significant after refining. The nutritional quality of grains must be retained by processing and consumption of highly refined products should be avoided [34]. In general, promoting wholegrain cereal grain consumption over refined ones to prevent non-communicable diseases is extensively followed. However, due to poor keeping qualities, different processing methods are being adopted to produce refined products for consumption. As a consequence, we lose the nutritional density found in grains, such as rice bran [35]. Polished rice has a poor dietary content because rice bran is discarded. Rice bran's dietary fiber is dominated by insoluble dietary fiber and consists of cellulose, hemicellulose, and lignin with low solubility [36]. Rice bran also contains arabinoxylan, which is a non-starch polysaccharide derived from cereals and has many functions that are related to health [15]. It is also reported that there are emerging applications for the use of pulse bioactives such as bioactive proteins, dietary fibre, resistant starch, polyphenols, and oligosaccharides extracted from pulses for nutraceuticals, functional foods production [37].

The high content of dietary fibre, minerals and potential health promoting phytochemicals in the seed coats indicate their great potential to be used as a natural "nutritious dietary fibre". The main method for producing dehulled splits, ground flours, and other fractionated pulse ingredients is the removal of the pulses' seed coat, or dehulling. However, the high content of dietary fibre in pulse seed coats, along with considerable amounts of minerals, phytochemicals suggest they could be more widely utilized as novel functional dietary fibre ingredients [38].

When comparing the glycemic index of different potato cooking methods, it was discovered that boiled and mashed potatoes have a high glycemic index, whereas fried and baked potatoes have a low glycemic index, which is thought to be due to the gelatinization effect. Domestic heating affects the physico-chemical properties of starch in two ways: one, it induces gelatinization, which leads to the formation of resistant starch, and second, it alters the microstructure of potatoes, which alters enzyme interactions with starch [39]. Retrogradation is another effect of the processing. Low-temperature storage causes the starch to retrograde, resulting in the formation of resistant starch [40]. Nowadays, food industries are focusing their efforts on increasing the resistant starch fraction in processed foods to improve nutritional quality [41]. Autoclaving or hydrothermal processing raises the amount of resistant starch in starchy foods compared to uncooked ones. Pre-cooking or parboiling rice produces a significant amount of retrograded starch because of the leaching of amylose. Glycemic index of rice is reduced by parboiling, resulting in a significant positive relationship between resistant starch content and amylose content [42]. Fermentation lowers the amount of resistant starch while increasing starch digestibility. Baking also encourages the use of retrograded starchy foods [41]. Furthermore, it is reported that polysaccharides extracted from tropical fruits and sub-products have gained interest due to their numerous biological activities such as antioxidant, antifatigue, antiinflammatory, anticoagulant, hepatoprotective,

immunomodulatory, antidiabetic and anticancer [43]. These fruits produce a remarkably high number of byproducts, and the seeds and skins have been shown to be a significant source of bioactive substances. Consequently, polysaccharides offer a substitute for novel functional foods.

Conclusion

Bioactive carbohydrates are found to possess health-promoting properties. Natural compounds of bioactive carbohydrates from foods mostly have a safe profile due to their origin and can be applied quickly and more widely in health conditions. If they are used effectively, they can confer the health benefits to the mankind by protecting from non-communicable diseases. These unique bioactive compounds in whole grains and fruits and vegetables are proposed to be responsible for the reduced risk of several developing chronic diseases. Since the dietary fiber intake of many people is below their suggested adequate intake values, strategies to successfully fortify foods with fiber must be focuses much in food research. The preservation and incorporation of plant derived polysaccharides during processing may be a promising approach to achieve food and nutritional security.

References

[1] Liu, S.Z. Zhou, W.G. Chen, Y. Research progress on bioactivity and structure-activity relationship of active polysaccharides. Food R.D, 2017,38: 211-218.

[2] Singh, D. Rajpu, A. Bhatia, A. Kumar, A. Kaur, H. Sharma *et al.*, Plant-based polysaccharides and their health functions. Functional Foods in Health and Disease, 2021, 11(4): 179-200.

[3] Willett, W. Rockström, J. Loken, B. Springmann, M. Lang, T, Vermeulen, S. Food in the anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. Lancet, 2019,393, 447–492.

[4] Wang, H. Liu, Y.M. Qi, Z.M. Wang, S.Y. Liu, S.X. Li, X. Wang, H.J. Xia, X.C. An overview on natural polysaccharides with antioxidant properties. Curr Med Chem, 2013, 20(23):2899–2913.

[5] Luo, Y. P. Li, Z. Li, X. L. Liu, X. F. Fan, J. J. Clark, J. H. The production of furfural directly from hemicellulose in lignocellulosic biomass: a review. *Catal. Today, 2019,* 319 14–24.

[6] Wang, H. Tao, H. Na, L. Zang, B. Wu, X. Soluble dietary fiber improves energy homeostasis in obese mice by remodeling the gut microbiota. Biochem Biophys Res Commun, 2018, 498:146–151.

[7] Holtekjolen, A.K. Uhlen, A.K. Brathen, E.S. Sahlstrom, S. Knutsen, S.H. Food Chemistry. 2006, 94: 348—358.

[8] Antognoni, F. Mandrioli, R. Potente, G. Saa, D.L.T. Gianotti, A. Changes in carotenoids, phenolic acids and antioxidant capacity in bread wheat doughs fermented with different lactic acid bacteria strains. Food Chem, 2019; 292: 211-216.

[9] Moreno-Mendieta, S. Guillen, D. Hernandez-Pando, R. Sanchez, S. Rodriguez-Sanoja, R. Potential of glucans as vaccine adjuvants: a review of the α-glucans case. Carbohydr Polym, 2017, 165:103–114.

[10] Friedman, M. Mushroom polysaccharides: chemistry and antiobesity, antidiabetes, anticancer, and antibiotic properties in cells, rodents, and humans. Foods, 5(4):80.

[11] Toivonen, R.K. Emani, R. Munukka, E. Rintala, A. Laiho, A. Pietilä, S. Pursiheimo J.P. Soidinsalo, P. Linhala, M. Eerola, E. Huovinen, P. Hänninen, A. Fermentable fibres condition colon microbiota and promote diabetogenesis in NOD mice. Diabetologia, 2014, 57(10):2183–2192.

[12] Yadav, B.S. Sharma, A. Yadav, R.B. Effect of storage on resistant starch content and in vitro starch digestibility of some pressure-cooked cereals and legumes commonly used in India. Int J Food Sci Technol, 2010.

[13] Morales-Burgos, A. M. Carvajal-Millan, E.López-Franco, Y. L. Sotelo-Cruz, N. Rascón-Chu, A. Lizardi-Mendoza, J. ampa-Mada, A. C. Cereal arabinoxylans: Bioactive polysaccharides and potential additives in foods and pharmaceutical products. *En Agricultural Research Updates, 2017.*

[14] Ooi, S.L. Pak, S.C. Micalos, P.S. Schupfer, E. Zielinski, R. Jeffries, T. Harris, G. Golombick, T. McKinnon, D. Rice bran arabinoxylan compound and quality of life of cancer patients (RBAC-QoL): Study protocol for a randomized pilot feasibility trial. Contemporary Clinical Trials Communications, 2020, 19:1–9.

[15] Chen, H. Chen, Z. Fu, Y. Liu, J. Lin, S. Zhang, Q. Liu, Y. Wu, D. Lin, D. Han, G. Wang, L. Qin, W. Structure, antioxidant, and hypoglycemic activities of arabinoxylans extracted by multiple methods from triticale. Antioxidants, 2019,8(584): 1–15.

[16] Liu,L. Fishman, M.L. Kost, J. Hicks, K.B. A Pectin-based systems for colon-specific drug delivery via oral route. Biomaterials, 2003, 24(19): 3333-3343

[17] Cheng, W. Lu, J. Li, B. Lin, W. Zhang, Z. Effect of functional oligosaccharides and ordinary dietary fibers on intestinal microbiota diversity. Front Microbiol, 2017, 8: 1750.

[18] Lingyun, W. Jianhua, W. Xiaodong, Z. Da, T. Yalin, Y. Studies on the extracting technical conditions of inulin from Jerusalem artichoke tubers. J Food Eng, 2007, 79(3): 1087-1093.
[19] Ibrahim, O.O. Functional Oligosaccharide: Chemicals Structure, Manufacturing, Health Benefits, Applications and Regulations. J Food Chem Nanotechnol, 2018, 4(4): 65-76.
[20] Morris, C.Morris, G.A. The effect of inulin and fructooligosaccharides supplementation on the textural rheological and sensory properties of bread and their role in weight management: a review. Food Chem, 2012, 133(2): 237-248.
[21] Loftsson, T. Duchêne, D. Cyclodextrins and their pharmaceutical applications. Int J Pharm, 2007, 329(1-2): 1-11.
[22] Bakker-Zierikzee, A.M, Alles, M.S, Knol, J. Kok, F.J. Tolboom, J.J. Effect of infant formula containing a mixture of galactooligosaccharides and fructo-oligosaccharides or viable Bifidobacterium animalis on the intestinal microflora during the first 4 months of life. Br J Nutr, 2005, 94(5): 783-790.
[23] Han, I.H. Baik, B.K. Oligosaccharide content and composition of legumes and their reduction by soaking, cooking, ultrasound, and high hydrostatic pressure. Cereal Chem, 2006. 83:428–433.
[24] Glibowski, P. Effect of thermal and mechanical factors on rheological properties of high performance inulin gels and spreads. Journal of Food Engineering, 2010, 99 (1):106–113.
[25] Karimi, R. Azizi, M.H. Ghasemlou, M. Vaziri,M. Application of inulin in cheese as prebiotic, fat replacer and texturizer: A review. Carbohydrate polymers, 2015. 119:85–100.
[26] Meyer, D. Bayarri, S. Tárrega, A. Costell, E. Inulin as texture modifier in dairy products. Food Hydrocoll, 2011, 25:1881–1890.
[27] Jain, D. Mohan, R. and Singh, V.D. Comparison of microsurgical and macrosurgical technique using bioactive synthetic bone graft and collagen membrane for an implant site development: A randomized controlled clinical trial. J. Indian Soc. Periodontol, 2019.
[28] Rawal, V. Navarro, D. K. The Global Economy of Pulses. Rome: Food and Agriculture Organization.2019.
[29] Duen˜as, M. Sarmento, T. Aguilera, Y. Benitez, V. Molla, E. Esteban, R.M. Martı´n-Cabrejas, M.A. Impact of cooking and germination on phenolic composition and dietary fibre fractions in dark beans (Phaseolus vulgaris L.) and lentils (Lens culinaris L.). LWT Food Sci Technol, 2016, 66:72–78.
[30] Maina, N.H. Katina, K. Effects of Processing on the Functionality of Cereal Polysaccharides. 2018. Cereal Foods World, 63 (3).
[31] Chanvrier, H. Uthayakumaran, S. Appelqvist, I.A. Gidley, M.J. Gilbert, E.P, López-Rubio, A. Influence of storage conditions on the structure, thermal behavior, and formation of enzyme-resistant starch in extruded starches. Journal of Agricultural and Food Chemistry, 2007, 55(24):9883-9890.
[32] Huth, M. Dongowski, G. Gebhardt, E. Flamme, W. Functional properties of dietary fibre enriched extrudates from barley. Journal of Cereal Science, 2000, 32(2):115-128.
[33] Sofi, S.A. Nazir, A. Ashraf, U. Cereal Bioactive Compounds: A Review. International Journal of Agriculture, Environment and Biotechnology, 2019, 12(2): 107-113.
[34] Oghbaei, M. Prakash, J. Effect of fractional milling of wheat on nutritional quality of milled fractions. Trends in Carbohydrate Research, 2013, 5:53–58.
[35] Kasote, D. Tiozon, R.N Jr. Sartagoda, K.J.D. Itagi, H. Roy, P. Kohli, A. Regina, A. Sreenivasulu, N. Food Processing Technologies to Develop Functional Foods with Enriched Bioactive Phenolic Compounds in Cereals. Front. Plant Sci, 2021, 12:771276.
[36] Liu, R. Xu, Y. Chang, M. Tang, L. Lu, M. Liu. Ruijie. Jin, Q. Wang, X. Antioxidant interaction of α-tocopherol, γ-oryzanol and phytosterol in rice bran oil. Food Chemistry, 2021, 343:1–8.
[37] Acquah, C. Ohemeng-Boahen, G. Power, K.A. Tosh, S.M. The Effect of Processing on Bioactive Compounds and Nutritional Qualities of Pulses in Meeting the Sustainable Development Goal 2. Front. Sustain. Food Syst, 2021, 5:1-16.
[38] Macagnan, F. T. da Silva, L. P. Hecktheuer, L. H. Dietary fibre: The scientific search for an ideal definition and methodology of analysis, and its physiological importance as a carrier of bioactive compounds. Food Research International, 2016, 85:144-154.
[39] Tian, J. Chen, J. Ye, X. Chen, S. Health benefits of the potato affected by domestic cooking: A review. Food Chemistry, 2016, 202:165-175.
[40] Zhang, G. Ao, Z. Hamaker, B.R. Slow digestion property of native cereal starches. Biomacromolecule, 2006, 7:3252–3258.
[41] Perin, D. Murano, E. Starch Polysaccharides in the Human Diet: Effect of the Different Source and Processing on its Absorption. Natural Product Communications, 2017, 12:837-853.

[42] Zhua, L. Liua, Q. Wilson, J.D. Gu, M. Shi, Y. Digestibility and physicochemical properties of rice (*Oryza sativa* L.) flours and starches differing in amylose content. Carbohydrate Polymers, 2011, 86:1751-1759.
[43] Sousa, S.G. Oliveira, L.A. de Aguiar Magalhães, D. de Brito, T.V. Batista, J.A. Pereira, C.M.C. *et al* Extraction and enzymatic hydrolysis of inulin from Jerusalem artichoke and their effects on textural and sensorial characteristics of yogurt. Food and bioprocess technology, 2010, 3 (2):315–319.

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