Extraction, Separation and Purification of Seaweed Polysaccharide and its Application in Food Industry

Yunlong Pang[1,4,*], Lin Fan[1,4], Wentao Song[1,4], Xiaoyong Liu[2], Haiyi Zhang[1,4], Hongfang Du[3]

[1]Weihai Vocational College, Weihai 264200, China
[2]Shandong Haizhibao Marine Technology Co., LTD, Weihai 264200, China
[3]Weihai Rensheng Pharmaceutical Group Co., LTD, Weihai 264200, China
[4]New Technology Research and Development Center of Marine Resources Exploitation and Ecological Protection of Shandong Colleges and Universities, Weihai 264200, China
Correspondence Author

Abstract: ***Seaweed polysaccharide has good physical and chemical properties such as moisturizing, gelling, film forming, thickening and stability, and has biological activities such as antioxidant, antibacterial, immunomodulatory, anti-tumor, anti-inflammatory, anti-aging and lowering blood glucose and lipids. It has been widely used in the food industry. In this paper, the extraction, separation and purification methods of seaweed polysaccharides were reviewed, and their applications in beverage, food packaging, meat products, confectionery and baked goods were also reviewed.***

Keywords: seaweed polysaccharide, biological activity, food industry.

1. INTRODUCTION

Algae is a general term for algae in the ocean, and there are a wide variety of species, about more than 30,000 species, mainly divided into blue algae, green algae, red algae and brown algae four species. Seaweed contains a lot of polysaccharides, dietary fiber, protein, trace elements and minerals and other nutrients, edible value is very high. Polysaccharide is the main component of seaweed, accounting for up to 76% of the dry weight of seaweed. Seaweed polysaccharide has good biological activity, and has the advantages of wide sources, no residue and no biological tolerance. It has become a research hotspot in the field of food science, especially in the application of green food, functional food and health food. In order to better develop and utilize seaweed polysaccharides, the extraction and purification of seaweed polysaccharides and its value in food industry were briefly summarized in this paper, in order to provide some references for the rational application of seaweed polysaccharides.

2. OVERVIEW OF SEAWEED POLYSACCHARIDES

2.1 Structure of seaweed polysaccharide

Seaweed polysaccharide is a kind of multi-component mixture. It is a kind of macromolecular carbohydrate which is connected by different monosaccharides through glucoside bond. Its molecular weight is large and its chemical structure is complex. According to its source, it can be roughly divided into four kinds: brown algae polysaccharide, red algae polysaccharide, green algae polysaccharide and cyanobacteria polysaccharide [1].

2.2 Extraction of polysaccharides from seaweed

Studies have found that the human digestive system lacks enzymes that break down the tissue structure of seaweed, so when eaten directly, the human body can ingest very few nutrients and polysaccharides. The extraction and utilization of seaweed polysaccharide is more conducive to human absorption. There are many kinds of extraction methods for seaweed polysaccharides. At present, solvent extraction, enzyme extraction and auxiliary extraction methods are commonly used at home and abroad. In recent years, there have been some new extraction methods, such as ultrafiltration, synthetic extraction, repeated freeze-thaw and high voltage pulsed electric field extraction, but they have not been widely used because of the high technical requirements.

2.3 Separation of polysaccharides from seaweed

The polysaccharide extracted from seaweed contains impurities such as protein, pigment and small molecules, which have great influence on the extraction rate and biological activity of polysaccharide. There are a variety of methods to remove protein, mainly Sevag method, trifluorotrichloroethane method, trichloroacetic acid method, hydrochloric acid method, sodium hydroxide method, tannic acid method, lead acetate method, salting out method, repeated freeze-thaw method, anion exchange resin method, enzyme hydrolysis method and saccharyeast fermentation method, which are divided into three categories: chemical method, physical method and biological method. The main methods of pigment removal are adsorption, hydrogen peroxide oxidation, macroporous resin adsorption and metal complex method. The removal of small molecular impurities is relatively simple, and there are two main methods: dialysis and ultrafiltration.

2.4 Purification of seaweed polysaccharides

The polysaccharides after separation and impurity removal are macromolecular compounds with different molecular weights, which need to be purified to obtain a single polysaccharide substance. The common purification methods include fractional precipitation, column chromatography, ultrafiltration, quaternary ammonium salt precipitation, salting out, metal complex and electrophoresis.

3. APPLICATION OF SEAWEED POLYSACCHARIDES IN FOOD INDUSTRY

3.1 Application in drinks

3.1.1 Beverage making

Seaweed polysaccharide has various physiological activities, such as lowering blood sugar, lowering blood lipids, regulating immunity, anti-tumor, anti-mutation, anti-virus, etc. In addition, seaweed polysaccharide contains alginans, alginic acid and other substances, which can cover gastric mucosa and reduce the damage of alkaloids in tea to stomach. Therefore, adding it to the beverage formula can play a good health role. Chen Damiao [2] developed an energy drink with Enterorpha polysaccharides as the main raw material, supplemented by hawthorn, wolfberry and other auxiliary materials, which has the effect of lowering blood sugar and blood lipid. Wu Xiaoqing et al. [3] mixed kelp polysaccharide concentrate extracted by complex enzyme method with Tieguanyin tea powder and licorice, determined the best seaweed tea formula, and made tea bags by spray kneading method.

3.1.2 Clarifying agent

Clarification treatment is an important part of wine production process, mainly to remove the unstable colloidal impurities precipitated in wine to ensure the quality of wine. As a natural polymer compound, seaweed polysaccharide is a good clarifying agent with its characteristics of hydrophilicity, high viscosity and flocculation. Sun Yonglin et al. [4] used homemade mushroom wine as raw material to study the clarifying effect of different plant-based clarifying agents, and the results showed that sodium alginate could be used as clarifying agent for mushroom wine. Huang Daming et al. [5] found that sodium alginate could stabilize the foam in beer, thereby increasing the light transmission and stability of beer and extending the shelf life. In addition, sodium alginate as a clarifying agent added to juice, champagne and other wine can effectively remove nitrogen in wine.

3.2 Application in food packaging

3.2.1 Edible film

Edible film is a film formed by intermolecular force through natural polymer material as the main material. Edible film can not only protect food, but also extend the shelf life of food, reduce food loss, and may replace plastic film in the future. Algal polysaccharide has good film forming property and can be used to make edible film. Jia Xiaoyun et al. [6] prepared a Pullulan polysaccharide-sodium alginate composite antibacterial film with antibacterial ability, which could effectively extend the shelf life of fresh meat to 16d. Algal polysaccharide edible film can also reduce the oil content of fried food, making it healthier. Wan Juan et al. coated salted fish with AGAR and found that AGAR could reduce the oil content of salted fish by 12%. Wu Huiling et al. [7] found that adding nanomaterials to edible films could enhance the bonding degree between the film and the substrate, improve the sealing property of the film, and thus improve the antibacterial and antioxidant properties of the film.

3.2.2 Film preservation

Film preservation is a new efficient and environmentally friendly chemical preservation method, which can form a film on the surface of the product, inhibit microbial infection, effectively reduce oxygen content to prevent oxidative Browning, and extend the shelf life. Algal polysaccharide is a hydrophilic colloid, but it can crosslink with metal ions to form a network structure, restrict the free movement of polymer structure and inhibit the flow of water, thus reducing the water solubility of algal film, and is widely used in film preservation. Zhao Shan et al. [8] found that using phenyllactic acid-sodium alginate food coating as the packaging material for sweet cherry preservation could reduce the loss of water and nutrients and extend the storage time of sweet cherry. LAN Yuan Yuan et al. [9] used sodium alginate/nano-silver coating to keep bananas fresh, and the fresh-keeping effect was good. The transparency, permeability and water retention of different polysaccharide composite coatings can be improved through the action of polymers, which is more conducive to the preservation of the coatings.

3.2.3 Food microcapsule

Encapsulation technology involves embedding the desired substance into microcapsules and converting it into solid particles. The required substance is embedded in the microcapsule, which does not affect the use effect but also enhances its resistance to the external environment. Seaweed polysaccharide has been widely used in food microencapsulation and sustained-release

preparation because of its good biocompatibility and biodegradability. The formation of gel microspheres or microcapsules with sodium alginate is an effective way to protect the vitality of probiotics [10]. He Yating et al. [11] used sodium alginate and sodium caseinate as wall materials to prepare microcapsules of iron pyrophosphate by secondary emulsification method, which effectively improved the oxidation stability of nutrition packages, thus improving the quality of nutrition packages and extending the shelf life.

3.3 Application in meat products

3.3.1 Water retaining agent

The retention power of meat products is an important factor affecting meat products, which not only affects the quality, taste and flavor of meat products, but also plays an important role in economic benefits. The results show that seaweed polysaccharide can be used as water retaining agent in meat products, which can effectively prevent water loss, reduce cost and improve economic benefit. Song Lei et al. [12] found that trehalose compound antifreeze could effectively improve the water retention of frozen chicken meatballs. Adding metal ions to seaweed polysaccharide can effectively improve its gel performance, and the calcium alginate gel formed by combining with meat protein can form a dense three-dimensional network structure, which can better prevent water loss in meat. Wang Qidong et al.[13] used copper algae as the main raw material combined with phosphate to produce a water retaining agent for mackerel surimi, which had better texture properties than the traditional sodium kelp alginate water retaining agent for mackerel surimi.

3.3.2 Fat substitute

Meat is an important food for people to take in nutrients, but its high fat and high cholesterol are harmful to health. Seaweed polysaccharide has good biological activities such as lowering blood sugar and blood lipids, which can hinder the absorption of cholesterol by the human body, so it can be used to make healthy and low-fat fat substitutes. Fan Suqin et al. [14] studied the influence of different sodium alginate compound gels on the quality structure of fat substitution, determined the best formula of the production process through experiments, and developed a fat substitution with simple process and good effect. Tan Wenying et al. [15] used sucrose polyester and sodium alginate as main raw materials to prepare a functional composite fat substitute with excellent properties such as water retention, oil retention and emulsifying stability.

3.3.3 Binding agent

Binders are widely used in meat products, which can effectively improve the quality and taste of meat products and extend the shelf life. Algal polysaccharide gels have good properties. Adding algal polysaccharide to meat products can change its structure, increase viscosity and improve the taste of meat products. Algal polysaccharide was added in the process of recombinant meat production, and the gel structure was formed to connect the ground meat, so as to change the distribution of muscle tissue, adipose tissue and connective tissue of meat and make it taste better. In addition, seaweed polysaccharide also has a bonding effect on canned meat, which can enhance the molding ability of meat in the can and maintain a stable curing ability after high temperature sterilization, so as to improve the quality of canned food.

3.4 Applications in the confectionery industry

3.4.1 Gel jelly

Gelatin gummies are mainly made from food glue and starch syrup through a specific process. Algal polysaccharide can be used to make gel jelly because of its gel properties, and is one of the main excipients of jelly. The performance of gel gummy mainly depends on the type of colloid. The gummy gummy with seaweed polysaccharide as the excipient is brittle and transparent, has high water content and long shelf life, which is superior to starch gummy gummy. Tian Qiying [16] added agarose powder to the fudge formula with AGAR as coagulant to develop a new fudge product with moderate taste and better chewability. But at high temperature, algal polysaccharide is easily destroyed in acidic environment. In actual production, various colloid can be mixed to improve the quality and taste of soft candy. Bai Xu [17] uses AGAR and carrageenan to make ginger-orange peel jelly, which has a unique flavor and smooth taste.

3.4.2 Confectionery additive

Candy is a kind of daily consumer goods, but a large amount of sugar is easy to cause the rise of blood sugar. Adding seaweed polysaccharide with hypoglycemic effect to the ingredients of candy can prevent the rise of blood sugar to a certain extent. Seaweed polysaccharide has good gel properties. When it is added to agarose, FIG sugar, cotton candy and other products, it can also play the role of stabilizer and effectively enhance the gel properties of products. Chen Xiangzhi [18] used compound glue and gelatin to manufacture milk candies respectively, and studied their properties respectively, and the results showed that the deformation resistance of the compound glue candy was better. In addition, seaweed polysaccharide added to the general hard candy, can make the candy evenly smooth, increase its taste.

3.5 Application in baked goods

3.5.1 Nutritional fortifier

Baked food is an important type of leisure food, with the advantages of convenient consumption, good taste, storage, etc., by people's love, but because of the high glycemic index of baked food, many people are discouraged. Seaweed polysaccharide has good hypoglycemic activity, adding it to the production industry of baked goods can change the structure of starch particles and reduce the glycemic index. Seaweed polysaccharides can also be used as fillers and leavening agents to produce low-heat energy foods, which are used to replace starch in the manufacture of cereal paste, starch-free bread and snacks. Wang Qingjia [19] used kelp powder as raw material to develop and export crisp kelp cookies with excellent feeling and attractive color, which effectively reduced the glycemic index of the cookies. Wang Fen et al. [20] determined the best formula of trehalose purple rice cake through single-factor experiment, and developed purple rice cake with excellent quality and higher nutritional value.

3.5.2 Quality improvers

In addition to nutritional value and product appearance, the intrinsic quality of baked goods is also an important content of research by scholars today. Seaweed polysaccharide can significantly improve the texture of bread, increase the elasticity and reduce the hardness and adhesiveness, and effectively improve the quality of bread. Huang Linqing et al. [21] combined carrageenan with konjac flying powder to develop konjac fruit cake with excellent appearance, fragrance and taste. Seaweed polysaccharide also has significant fresh-keeping, moisturizing and anti-aging effects on baked products, which can keep the moisture of products to a certain extent and extend the shelf life. Adding metal ions to seaweed polysaccharide can enhance its gel properties, which can be used as a binder for baking food in the production of biscuits, egg rolls and other foods, which can effectively reduce its crushing rate and improve its quality.

4. CONCLUSION

Seaweed polysaccharide is widely used in food industry because of its unique physical and chemical properties and biological activity, and is one of the research hotspots in food industry. In recent years, the research on seaweed polysaccharides in food industry has achieved rich results. In addition, the research on seaweed polysaccharides can be strengthened in the following aspects: the structural differences of several kinds of seaweed polysaccharides and their effects on activity; The specific mechanism of algal polysaccharide action on human body; The influence of seaweed polysaccharides on human body when they interact with other plasticizers, antibacterial agents and preservatives in food industry; To develop a new type of algal polysaccharide bio-based composite which is more suitable for food industry. It is believed that seaweed polysaccharides will be more widely used in the food industry in the future.

ACKNOWLEDGMENTS

This work was supported by Key Technology Research and Development and Industrialization Project of Natural Antimicrobial Agent Based on Chitosan (2022TSGC1304), Research on Key Technology of Comprehensive Utilization of Laminaria polysaccharide and its Derivatives with high Value (2019TSLH0501) and Development of Functional Health Food of Weihai Branch of Jinan Fruit Research Institute (WHFY-2022-06).

REFERENCES

[1] Z.X. Liu, J.F. Liu, F. Xu, et al. (2013). Technique Optimization for Extracting Laminaria japonica Polysaccharide by Ultrasonic Compound Enzyme Method. Journal of Anhui Agricultural, vol.41, no.20, p.8467-8469.
[2] D.M. Chen (2012). Beverage of Enteromorpha prolifera and its hyperglycemic and hypolipemic effects. Fujian Medical University.
[3] X.Q. Wu, W.Q. Cheng, D.X. Guo (2017). Study on the development of laminaria polysaccharide lipid-reducing tea bags. Journal of Anhui Agricultural, vol.45, no.5, p.70-72.
[4] Y.L. Sun, S.W. Tang, Y.Q. Li, et al. (2017). Effects of Vegetable Clarifing Agents on Clarification and Stability of Lentinula edodes-grape Wine. Storage and Process, vol.17, no.3, p.64-68.
[5] D.M. Huang, C. Li, Z.C. Zhang, et al. (2013). Application of immobilized Saccharomyces cerevisiae by sodium alginate. FOOD SCIENCE AND TECHNOLOGY, vol.38, no.3, p.31-34.
[6] X.Y. Jia, S.L. Zhang, W.Y. Liu, et al .(2013). Development and Application of Nisin-Pullulan-Sodium Alginate Composite Edible Film in Preserving the Quality of Fresh Pork during Chilled Storage. MEAT RESEARCH, vol.31, no.4, p.17-22.
[7] H.L. Wu, S.P. Zhang (2014). Progress in the application of sodium alginate/nanomaterial composites. CHEMICAL INDUSTRY AND ENGINEERING PROGRESS, vol.33, no.4, p.954-959.
[8] S. Zhao, H.S. Gong, Y.C. Tian, et al. (2018). Preparation of PLA/SA Composite Coating and Its Application in Quality Preservation of Sweet Cherries. Food Science, vol.39, no.11, p.221-226.

[9] Y.Y. Lan, L. Wei, L.W. Du, et al. (2020). Preservation effect of sodium alginate-silver nanoparticles composite coating on banana. Journal of Southern Agriculture, vol.51, no.7, p.1584-1590.
[10] W.J. Cai, J.L. Sun, X. Han (2022). Research Progress of Probiotics Microcapsule. FOOD SCIENCE AND TECHNOLOGY, vol.47, no.2, p.36-42.
[11] Y.T. He, X.L. Yao, S. Li, et al. (2018). Effect on the stability of nutrition pack and preparation of microencapsulated ferric pyrophosphate. FOOD SCIENCE AND TECHNOLOGY, vol.43, no.12, p.287-292.
[12] L. Song, T. Gao, R.X. Ma, et al. (2016). Optimization of the Formulation of Composite Cryoprotectant to Improve the Eating Quality of Frozen Chicken Meatballs. FOOD SCIENCE AND TECHNOLOGY, vol.37, no.8, p.13-17.
[13] Q.D. Wang, X.T. Fu, J.C. Xu, et al. (2018). Optimization of the water holding capacity of Spanish mackerel surimi by anovel Sargassum horneri sodium alginate compound additive. Chinese Fishery Quality and Standards, vol.8, no.2, p.9-16.
[14] S.Q. Fan, H.Y. Huang, X.M. Wang, et al. (2011). Influence of Different Commercial Compound Sodium Alginate Products on Texture of Fat Substitute. MEAT RESEARCH, vol.25, no.9, p.5-7.
[15] W.Y. Tan, Y. Wu, Y. Hu (2018). Preparation and physicochemical properties of composite fat substitute. CHINA OILS AND FATS, vol.43, no.2, p.150-153.
[16] Q.Y. Tian (2018). Study on Extraction and Properties of Hesperidin from Orange Peel. Jiangsu Condiment and Subsidiary Food, no.1, p.18-22.
[17] X. Bai (2015). Study on the Processing Technology of Ginger and Citrus Peel Soft Candy. Farm Products Processing, no.11, p.6-8.
[18] X.Z. Chen (2009). Formula and Key Technologies for Improving Quality and Function ofMild Candy and Gum-sweets. Jiangnan University.
[19] G.Q. Wang, Z. Li, B.D. Zheng, et al. (2016). A Method for Creating Kelp Crispy Biscuit and Evaluation of the Glycemic Index. Food Research And Development, vol.37, no.7, p.184-188.
[20] F. Wang, Z.S. Zhang, D. Qiao (2018). Development of trehalose purple rice cake. Cereal & Feed Industry, no.10, p.33-36.
[21] L.Q. Huang, Y.Xu, C.F. She, et al. (2017). Study on the Gel Properties of Konjac Gum, Xanthan Gum and Carrageenan. Modern Food, no.15, p.123-124.