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Research Article

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Overview of the Methods for Seaweed Polysaccharide Extraction and Derivatization

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Abstract With the increasing development and utilization of marine biological resources, the development of marine algae resources has also been developed to a certain extent, with abundant seaweed resources, which is the most important part of marine biological resources. The molecular structures of different alginpolysaccharides is significantly different, and the alteration of polysaccharide structure may have a decisive effect on their biological activity. Therefore, it is necessary to extract seaweed polysaccharide, study its derivatives deeply, select different derivative methods, and compare the structure and activity differences between different polysaccharides for marine drug screening. The text systematically summarizes the derivation of polysaccharides and various extraction methods of polysaccharides.

Keywords Algal Accharides; Derivation; Extraction of Polysaccharides

Introduction

Seaweed polysaccharides are the general names of polysaccharides contained in seaweed. They are mixtures of a class of multi -component with water -soluble, high viscosity, coagulation and so on [1]. The number and variety of seaweed in marine creatures are the largest, and polysaccharides account for about 20% to 70% of the dried seaweed weight. It is connected by different monosaccharides through the glycoside bond, most of which are acidic polysaccharides containing sulfate bases [2]. Compared with other important organisms such as protein, fat, and nucleic acids, seaweed polysaccharides have stronger hydroponics. Seaweed can maintain the moisture required for life activities in the body by synthetic polysaccharides to adapt to the living environment of the ocean [3]. Depending on the types of seaweed, the types of polysaccharides contained in are also different, and the type of sugar -based monogether and structure of polysaccharides are also different [4]. There are many types of seaweed polysaccharides. Depending on their sources, they can be divided into red algae polysaccharides, green algae polysaccharides, brown algae polysaccharides and so on.

Red algae polysaccharide

Red algae sulfuric acid polysaccharides are mainly composed of galactose with sulfuric acid root, which are mainly divided into Kara gums containing D-galactose and 3,6-ether l-hyparthamium lactose, and agar gum composed of L-galactose and its derivatives Species [5]. At the same time, red algae sulfate may contain a small amount of

mannose, galactose, and hypoglycemia [6]. Due to its gel characteristics, red algae polysaccharides are widely used in the food industry as an emulsifier, gelgling agent, thickener and stabilizer [3].

Green algae polysaccharide

Green algal polysaccharide is mainly located in cell stroma, mostly water-soluble polysaccharide; also found in cell wall. Unlike other algae and land plants, the cell wall of green algae is not composed of cellulose, but mainly mannan and xylan, which are not soluble in water, and a small amount of glucan is found in the cytoplasm [7,8]. Green algae, like other Marine algae, are rich in non-starch polysaccharides, minerals and vitamins. In addition, the green algae sulfate polysaccharide molecules are highly branched and have a complex structure, and may not have a simple repeat unit [2]. Green algae is considered to be the source of a large amount of sulfate polysaccharide, and ulvan is an important water-soluble sulfate polysaccharide in green algae, containing rhamnose, xylose, glucuronic acid and enduronic acid. These sulfated polysaccharides exhibit many beneficial biological activities, such as the anticoagulant, antiviral, antioxidant, anti-tumor, immune regulation, antihyperlipidemic and antihepatotoxic activity [9].

Brown algae polysaccharide

Brown algae polysaccharides mainly include three types of briginate, brown algae polysaccharides, and latoolin (*Laminarin*).

Brown algae is a water-soluble acidic polysaccharide in the wall of brown algae cells. It is a linear long chain formed by β-1,4-D-man-1,4-L-Guluo glycogenic acid that is irregularly connected. The molecule, unique structure, is the only natural marine biological polysaccharide that contains carboxyl groups in each sugar ring [10]. The use of brown algae glue in the food industry, textile industry, and pharmaceutical industry is very wide. It can be used as viscose, emulsifier, stabilizer, etc., and is a type of natural biomolecules with extensive activity [11].

Brown algae polysaccharide is a viscosity miscellaneous polysaccharide produced by brown algae cells. It is a water-soluble polysaccharide. Most of them have high viscosity and high solidification capacity. Semiose, glucose, mannose, xylose is an important part of brown algae [12]. Brown algae polysaccharides are one of the richest sulfate polysaccharides in nature [13]. Because of its extensive biological activity, such as anticoagulation, anti -tumor, immune regulation, antioxidant, etc., in recent years Follow and research [14-17].

Brown algae starch is an intracellular polysaccharide of brown algae, which is mainly composed of β-1,3-polysaccharides. Animal tests have proved that sodium kelpylid sodium sodium sulfate has the effect of anticoagulation and prevent thrombosis [18]. Brown algae starch is used as long -term carbon storage compounds in brown algae.

Structural modification of seaweed accharides

The molecular modification of seaweed polysaccharide is a method of structural modification of compound molecules through chemical, physical and biological means to obtain derivatives of many structural types [20]. Molecular modification can affect the biological activity of polysaccharides by changing the spatial structure, molecular weight and the species, number and position of the substituents. Choosing the appropriate method to obtain different derivatives can reduce the toxic side effects of polysaccharides and improve the bioactive [21]. Therefore, the molecular modification of polysaccharides has become an important means for the research and development of polysaccharide drugs.

Sulfation derivation of polysaccharides

Sulfation is a very simple and effective tool to enhance the biological activity of polysaccharides, a class of polysaccharides formed by the replacement of the hydroxyl group on the polysaccharide chain by sulfate. Numerous studies have shown that the content and distribution of the sulfate groups have a very important impact on their activity. Sulfation is one of the most important modification means to improve the biological activity of sulfpolysaccharide. Studies on a variety of natural sulfate polysaccharides confirmed their outstanding antiviral

activity. The sulfation of polysaccharide is to introduce the hydroxyl group on the polysaccharide chain, make it change the conformation, easy and protein specific domain combination, thus has stronger biological activity compared with non-sulfated polysaccharide, including stronger anticoagulant, antiviral, immune enhancement, hypoglycemia, antitumor and antioxidant activity [22]. Bao et al. reported that sulfation can enhance the solubility of α -D-glucan in the same binding site as the enzymes of some RNA template primers, so sulfate polysaccharide can competitively inhibit HIV retroenzyme. Sulfate polysaccharides can also achieve antiviral action by inhibiting the binding of the virus and the cell [23]. Furthermore, sulfated polysaccharides can also inhibit HIV active by preventing cytopathic cells and the expression of specific viral antigens caused by HIV [24]. Shao et al. found that the sulfate content may be the main factor affecting the antitumor activity. After derivatization of the polysaccharides extracted from copper algae, the samples with the highest sulfate content (51.92%) showed the best antitumor activity (gastric cancer MKN45 cells) [25].

For polysaccharide acetylation modification

Acetylation of polysaccharides is an important chemical modification method, mainly performed on branches of polysaccharide molecules. The introduction of acetyl group has a great effect on the polysaccharide activity. On the one hand, the acetyl group can make the glycan extension, change direction, lead to the exposure of the hydroxyl group, increase the solubility of the polysaccharide in water, and facilitates the play of its activity [26]. In addition, it can change the orientation and lateral order of polysaccharide molecules, thus changing the spatial arrangement of glycan chains, changing the physical properties of polysaccharides, and then have an effect on polysaccharide activity [27,28]. Acetylation can greatly affect the removal of hydroxyl radicals of polysaccharides. Proper acetylation effectively reduces the hydrogen bond and activates the hydrogen atom of the heterocarbon [29]. The introduction of acetyl groups significantly increased the activity of Ganoderma (*Ganoderma. atrum*), with 71.36% and 47.64% [30]. The immunomodulatory activity of polysaccharide acetylated derivatives of G. lucidum (*G. atrum*) was significantly increased. The possible mechanism is that the introduction of the polysaccharide into the acetyl group may have caused a change in its structure and orientation and caused different exposure of the hydroxyl group, which enhancing its interaction with the specific receptor and stimulate active in macrophages.

For the phosphorylation modification of polysaccharides

The synthesis of phosphorylated derivatives of polysaccharides, especially glucosyl phosphoesters, and their bioactivity have been reported earlier. Phosphorylated polysaccharides have biological activities against tumor, antiviral, antibacterial and immunomodulatory agents. Monosaccharides such as fructose and glucose themselves do not have anti-tumor or antiviral biological activities, but they have these activities after phosphorylation. The introduction of phosphate root on the sugar base enables some inactive sugar compounds with activity, and can improve the biological activity of some polysaccharides and oligosaccharides. As electron receivers, phosphate groups can enhance antioxidant activity and significantly increase the ability to scavenge free radicals. Furthermore, phosphorylation modification can strongly affect the ability to scavenge the hydroxyl radical [29]. Deng et al showed that the solubility of phosphoryl polysaccharide derivatives, antioxidant activity and anti-tumor activity were improved in compared with common polysaccharides [31]. Chen et al. reported that phosphorylation could improve the anti-tumor activity of Poria cocos (1→3)-β-D-glucan by increasing the interaction between polysaccharides and the immune system [32]. Huang et al showed that phosphorylated polysaccharides showed significantly enhanced antitumor activity than unmodified polysaccharides, suggesting that expanded glycans may contribute to enhancing the antiviral capacity in vivo and in vitro [33].

Benzoylation modification of the polysaccharide

The introduction of formyl group can improve the activity of raw materials. Benzoylation of polysaccharide can introduce acyl group, change the spatial extension direction of the glycan chain, expose the active group and site of action, and the introduction of phenyl group can change the oil-water distribution coefficient, so that the water-soluble polysaccharide can more easily pass through the membrane structure into cells to play a role [34]. At the

same time, the activity of polymer derivatives is higher than that of low derivatives, and the reason may be the same mechanism as the acetyl group. The introduction of benzoyl group can effectively improve the activity of hydroxyl radical scavenging, and the final active concentration of high and low molecular weight derivatives can reach more than 90%, indicating that the two functional groups have strong activity for the removal of hydroxyl radical[35].

Carboxymethylation modification of polysaccharides

Carboxymethylation is also a common method for chemical modification of polysaccharides, which introduces carboxymethyl groups into the polysaccharide chain, which can improve the water solubility of the polysaccharide and thus facilitate its activity. Carboxymethyl group has an extremely important role for the biological activity of polysaccharides [36]. Carboxymethylated derivatives of Ganoderma lucidum polysaccharides showed stronger in vitro antioxidant activity in superoxide anion radical strong scavenging activity experiments. Due to the strong electron tolerance of the carboxyl group in the polysaccharides, the superoxide scavenging activity of the related carboxypolysaccharides enhanced [37]. In addition, Takahashi et al. found that the antioxidant activity of the carboxymethylated black fungus (Auricularia auricular) polysaccharide was close to twice the of the raw material polysaccharide [38].

Extraction of the seaweed polysaccharide

The main seaweed polysaccharide extraction methods include solvent extraction method (water formulation, alkali formulation, acid formulation and so on), physical extraction method (ultrasonic extraction method, microwave extraction method, etc.) and other extraction methods (enzyme formulation, freeze-thaw method, etc.). Among them, the solvent extraction method is the most common method for extracting seaweed polysaccharide.

Solvent extraction method

The solvent extraction of polysaccharide extraction includes water extraction, alkali extraction and acid extraction, among which the hot water extraction method is widely used due to the ease of operation. The characteristics of several solvent extraction methods are briefly introduced.

1. Water immersion formulation

Water immersion formulation is one of the most commonly used methods in polysaccharide extraction. Because of the large solubility in hot water, it can be dissolved in hot water and extracted. The hot water formulation is easy to operate, high extraction rate, the least damage to the polysaccharide, and has the highest acidic and neutral polysaccharide content [39]. The polysaccharides extracted in hot water are mainly water-soluble sulfate polysaccharide. Hot water immersion formulation does not require special equipment, is cheap, and is widely used. However, there are a large amount of cell debris, proteins and other gelatin like impurities in the polysaccharide solution extracted by hot water immersion, which increases the viscosity of the extract, and it needs to be continued after separation and purification.

2. Alkali formulation

Acidic polysaccharides or polysaccharides with large molecular weight have little solubility in hot water, so 5-15% NaOH or Na_2CO_3 aqueous solution is commonly used for extraction. Animal polysaccharides are generally acidic polysaccharides, usually extracted with alkaline solution. In addition, cellulose, hemicellulose and lignin can be precipitated in an alkaline environment, so this method can improve the yield of polysaccharide to a certain extent [40,41]. Zeng et al. used alkali liquor to extract the polysaccharide material ratio of 1:41, the extraction temperature was 89℃, the NaOH concentration of 0.05 mol/L, the extraction time was 3.5 h, the extraction times were 3 times, the rate of polysaccharide (8.56 ± 0.23)% was 3.73 times higher than the traditional thermal water immersion method.

3. Acid formulation

Some polysaccharides extracted with dilute acid can obtain high extraction efficiency. However, under acidic conditions, the glycosidic bonds may break to form monosaccharides and oligosaccharides. At present, hydrochloric acid extraction method is commonly used, but the use of weak acid extraction can promote the dissolution of polysaccharide, improve the rate of polysaccharide, and reduce the degradation of polysaccharide, which has a certain advantage [42]. Hao et al. extracted fucose from jiang vegetables. The liquid ratio was 1:40, the concentration of hydrochloric acid was 0.17 mol/L, the temperature was 90℃, the time was 2.5 h, and the extraction rate was 9.54% [43].

The above three solvent extraction methods are widely used in seaweed polysaccharide extraction, they have the advantages of simple process and low cost; but low extraction efficiency and long cycle. In addition, in the extraction of acid and base, the existence of acid and base may cause polysaccharide breakdown, glycosidic bond destruction and other conditions, affecting the product [44].

Physical extraction method

Physical extraction method is commonly used by ultrasonic extraction method, microwave extraction method and so on. The advantages of short physical extraction time, high efficiency and simple operation make them more and more popular, but they need additional experimental instruments, which increases the experimental cost.

1. Ultrasonic extraction

Ultrasonic extraction method is a method of crushing cell wall by ultrasonic dissolution. It is a physical extraction method with short extraction time, which greatly reduces the extraction temperature and can greatly improve the extraction efficiency [45]. Ultrasonic extraction method is easy to operate and has a high degree of automation for mass production. However, ultrasound may destroy the chemical structure of the extract, making the extracted material components more complex and causing difficulties for subsequent separation [46]. Tan extracted fucose sulfate from cabbage (Undaria pinnatifida) by ultrasound-assisted extraction, with a ratio of 1:100 and 20 min at 1000 W to obtain the maximum polysaccharide extraction rate. It was 16.87%, 23.59% higher than the traditional water formulation [47].

2. Microwave extraction

Microwave extraction method uses the powerful penetration ability of microwave to promote cells to quickly absorb energy and impact the cell wall to break, and the content is logistics out, so as to improve the polysaccharide extraction rate. This method is fast, energy saving, simple operation and high extraction rate [48]. Liu et al. used microwave-assisted method to extract laver polysaccharide. Under the optimal conditions, the liquid ratio was 1:40, the microwave power was 200 W, the extraction time was 8 min, the extraction rate was 7.45%, and the extraction rate of hot water extraction method was 2.05% [49].

Enzyme extraction

Within the optimal temperature and optimal pH range, a single enzyme or complex enzyme reaction is added to destroy the cell wall to separate the intracellular polysaccharides. The commonly used enzymes are cellulase, pectinase, protease and other [50]. Enzymatic extraction does not destroy the polysaccharide structure, the extraction efficiency is high, the action conditions are mild, but the cost is relatively high, and the conditions are demanding.

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