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Polysaccharides of Crude Herbal Drugs as a Group of Biologically Active Compounds in the Field of Modern Pharmacognosy: Physicochemical Properties, Classification, Pharmacopoeial Analysis

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ABSTRACT

This review provides an overview of polysaccharides as a multifaceted group of biologically active compounds; they are discussed in the framework of modern pharmacognostic analysis. Data on chemical classification, component composition, physicochemical properties, and the content of polysaccharides in crude herbal drugs in the Russian Federation are consistently presented and analyzed. Some general groups and major compounds are characterized taking into account the use in pharmaceutical practice. Polysaccharides are the products of secondary metabolism; some of them can be used in pharmacy as excipients, while others have pronounced pharmacological effects and are active pharmaceutical ingredients. Improvement and development of procedures for the pharmacopoeial analysis of crude herbal drugs containing polysaccharides and preparations based on are important tasks of modern pharmacognosy

Keywords: polysaccharides, crude herbal drugs, pharmacopoeial analysis, pharmacognosy.

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INTRODUCTION

Polysaccharides (PSHs) are high-molecular compounds formed by the condensation of more than 5 monosaccharides and their derivatives. Monosaccharides are interconnected by O-glycosidic bonds, forming linear or branched chains [1]. There are 2 types of PSHs: homopolysaccharides (homopolymers) and heteropolysaccharides (heteropolymers); this classification depends on the nature of the monosaccharides and their derivatives. Homopolysaccharides consist of monosaccharide moieties (monomers) of the same structure (starch, fiber, glycogen, chitin), and heteropolysaccharides consist of residues of various monosaccharides and their derivatives (hemicelluloses, inulin, pectin, mucilages, and gums) [2, 3]. PSHs can also be classified by function in plant organisms (reserve, structural, protective), origin (phytopolysaccharides, zoopolysaccharides, polysaccharides of microorganisms), acidity (neutral and acidic), and chain structure (linear and branched). The molecular weight of PSHs ranges from several thousand to several million moieties. Over 20 different types of monosaccharides and their derivatives were found in the PSHs. The most common are: hexoses – D-glucose, D-galactose, L-fructose, D-mannose; pentoses – D-xylose, L-arabinose, etc.; deoxysaccharides – L-rhamnose, D-fucose; D-mannose reduction products – mannitol; monosaccharide oxidation products – D-glucuronic, D-mannuronic, D-galacturonic, and other acids. Monosaccharides and their derivatives are presented in PSHs in pyranose, less often in furanose form. The O-glycosidic bond is formed due to the semi-acetal (glycosidic) hydroxyl of one monosaccharide and the hydrogen of the hydroxyl group of another monosaccharide, forming $1 \rightarrow 2$, $1 \rightarrow 3$, $1 \rightarrow 4$, $1 \rightarrow 6$ bonds [4-7].

All world state pharmacopoeias include monographs on crude herbal drugs containing PSHs. This group of compounds exhibits different pharmacological effects. In this review, we will try to briefly characterize such an important group of substances as polysaccharides of crude herbal drugs.

MATERIALS AND METHODS

We searched for the necessary data in various sources of scientific literature – electronic databases: PubMed, Google Scholar, Scopus, Web of Science, e-Library, normative documentation.

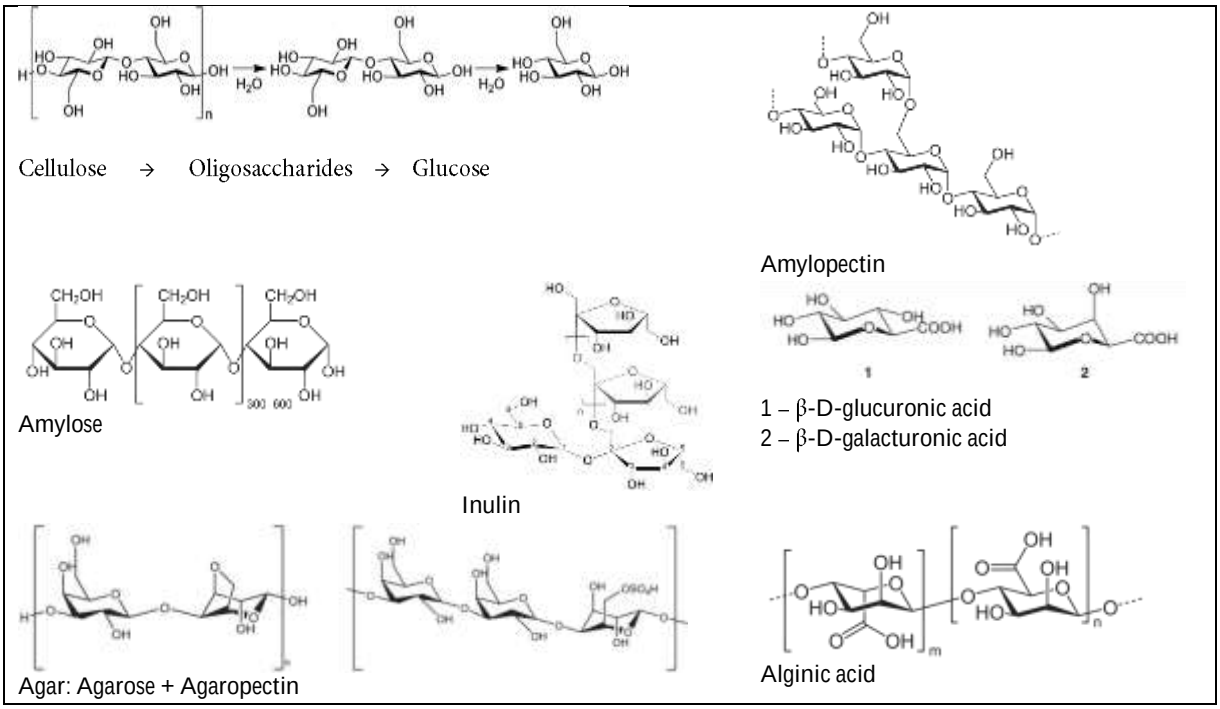
RESULTS AND DISCUSSION

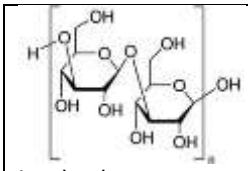
The diversity of the PSHs structure can be associated with different factors (not only with the nature of the monosaccharides and the type of their binding to each other). In addition, the hydroxyl and carboxyl groups of monosaccharides and their derivatives can be methylated, esterified with organic and inorganic acids (for example, sulfuric acid – agar-agar). Also, hydrogen atoms of carboxyl groups can be substituted by metal ions (in pectins, gums). PSHs are amorphous substances, insoluble in non-polar solvents, and alcohol. Solubility in water varies significantly. For example, some linear homoglycans (cellulose, chitin,

xylans, mannans) do not dissolve in water due to strong intermolecular bonds. And complex and branched PSHs both dissolve in water (glycogen, dextrans, etc.) and form jellies (pectin, agar-agar, alginic acids, etc.). Acid and enzymatic hydrolysis can be applied to them. Mono- or oligosaccharides formed after hydrolysis contain 2-4 monosaccharide moieties. Hot or cold water is used to extract PSHs from natural raw materials (for mucilages, some bacteria polysaccharides, sulfonated galactans, fructans). Solutions of acids or alkalis are also used. Dialysis, fractional precipitation with alcohol or quaternary ammonium bases, ultrafiltration, fermentolysis, and other methods are used to clean the extract from proteins, mineral salts, water-soluble dyes. Denaturation or selective sorption on calcium phosphate, bentonite can be used to purify PSHs from proteins [2, 3, 4-6].

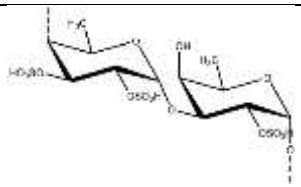
Qualitative and quantitative methods of analysis are based on the physicochemical properties of PSHs. The content of PSHs in plant materials is usually determined by the gravimetric method. The first step is acid hydrolysis; then, the absorption of the colored solutions is measured. Coloring is formed by the interaction of reducing monosaccharides with picric acid (in an alkaline medium) or reactions of phenol or anthron nucleophilic addition to dehydration products, containing an aldehyde group (in a concentrated sulfuric acid medium) [2, 3, 8-10]. PSHs are extremely important in the metabolism of plants and animals. PSHs and their derivatives modified in various ways can be used in medicine as fillers, blood substitutes. They can prolong the action of drugs, have immunomodulatory activity, and increase the resistance of the gastric mucosa. PSHs exhibit anti-inflammatory, antacid, and wound healing effects. Plant PSHs (phytopolysaccharides) include cellulose, hemicelluloses, inulin, starch, mucilages, gums, pectin substances. Crude herbal drugs containing PSHs are harvested during the period of the maximum accumulation of biologically active substances. The aerial parts of plants are harvested in dry weather. Underground parts of plants containing mucilages are usually not washed. Sometimes a cork is removed from them (marshmallow roots). Artificial drying is preferred at a temperature of +50-60 °C. The raw materials are stored according to the general list in a dry, cool (+10-15 °C) room, protecting from barn pests [2, 3, 11-16].

Cellulose (fiber) – a PSH that makes up the bulk of the cell walls of plants (especially the secondary membrane). The molecular weight of cellulose is not known in detail. Presumably, the fiber molecule contains from 1400 to 10000 glucose residues, interconnected by β-1,4-glycosidic bonds in linear chains in different plants (Figure 1). No branching or coiling occurs in cellulose molecule and it adopts an extended and stiff rod-like conformation, aided by the equatorial conformation of the residues of glucose. The numerous hydroxyl groups of the glucose from 1 chain form H-bonds with O atoms on a chain, holding chains tightly together and forming microfibrils. This gives tensile strength in cell walls where cellulose microfibrils are included in a polysaccharide matrix. Cellulose is decomposed into glucose after acid hydrolysis by boiling with concentrated sulfuric acid. The cellobiose oligosaccharide is formed by milder hydrolysis. Cottonwool (*Gossypium*) is the seed trichomes of the species of the *Gossypium* L. genus (*Malvaceae*), which consists of more than 95% fiber. Cottonwool is used in medicine. Cottonwool is a source of collodion and various cellulose derivatives (methyl cellulose, etc.), which are widely used as auxiliary substances in the manufacture of various dosage forms. Paper, cellophane, sorbents, explosives are made from cellulose in engineering [3, 17].





Laminarin



Fucoidan

Figure 1: Formulas of some polysaccharides

Hemicellulose – the name of this group of PSHs was proposed in 1891 by Schulze to describe substances that are quite easily extracted from various plant tissues. He believed that they are cellulose precursors. From this assumption came to the name "hemicellulose" (from the Greek. *hemi* – "semi"). Now, this assumption is refuted. Hemicellulose is the main component of the primary membrane of the walls of a plant cell. They are one of the components of the cell-matrix. Hemicelluloses give the cell wall extra strength without limiting its growth. Hemicelluloses can also be reserve substances, since they are easily hydrolyzed. Hemicellulose macromolecules are branched and built from pentoses (xylose, arabinose) or hexoses (mannose, galactose, fructose). The degree of polymerization is 50-300. There are three subgroups of hemicelluloses (xylans, mannans, and galactans) according to the prevailing monosaccharide [18].

Inulin is a high molecular weight carbohydrate soluble in water (Figure 1). Inulin is precipitated with proton organic solvents miscible with water (e.g. alcohol) or acetone with coagulant from aqueous solutions. The number of fructose residues bound in the inulin molecule by glycosidic bonds between the 1st and 2nd carbon atoms is approximately 34. The macromolecules are linear and end with the α-D-glucopyranose residue. Fructofuranose and a small amount of glucopyranose are formed during the acid hydrolysis of inulin. Inulin is found in large quantities in the underground organs of plants of the *Asteraceae* and *Campanulaseae* families. It replaces the starch in them. The Molisch's test is used to identify inulin in medicinal plant materials. The pink-violet color appears after applying 1 drop of a 20% α-naphthol alcohol solution and 1 drop of concentrated sulfuric acid. Plants containing inulin are used to produce D-fructose. Currently, plant materials rich in inulin (chicory roots, Jerusalem artichoke tubers) are widely used in various nutritional supplements for patients with diabetes. Inulin is fructosan. There are also fructosans of the levan type, except for inulin-like fructosans, in which fructofuranose residues are connected by glycosidic (β1 → 2) bonds. Fructofuranoses of levans are connected by glycosidic (β2 → 6) bonds [10, 19-22]. Levans are linear or weakly branched molecules with a shorter chain than inulin. Fructosans of the levan-type fructans were found in the leaves, stems, and roots of some monocotyledonous plants. For example, levan-type fructans act as reserve PSHs in plants of the cereal family (*Poaceae*) [3, 23].

Starch (amylum) is not a chemically individual substance. It consists of polysaccharides (96-97%), which form α-D-glucose during acid hydrolysis. Mineral content ranges from 0.2 to 0.7%. They are mainly represented by phosphoric acid. High molecular fatty acids (palmitic, stearic, etc.) are also found in starch. Their content is about 0.6%. The carbohydrate part of starch consists of two PSHs: amylose and amylopectin (Figure 1). Amylose is a linear glucan. It includes 60-300 (up to 1500) glucose residues linked by α-glucosidic bonds between the 1st and 4th carbon atoms. Amylose has a molecular weight of 32,000-160,000. It is readily soluble in water and forms solutions with a fairly low viscosity. Amylopectin is a branched glucan. It includes 3000-6000 (up to 20,000) glucose residues connected by α-glucosidic bonds both between the 1st and 4th carbon atoms, and between the 1st and 6th. Amylopectin dissolves in water when heated, forming stable viscous solutions. Its molecular weight reaches hundreds of millions of daltons. The content of amylose and amylopectin in plants varies depending on the type and organ of plant. This ratio changes during the ripening period. Starch can be hydrolyzed by enzymatic and acid hydrolysis. "Soluble" starch is formed by weak exposure to acids. It is often used in the laboratory for iodometry. PSHs of different molecular weights (dextrins) are formed during the hydrolysis of starch as intermediates. Aldehyde groups occur gradually during the formation of dextrins. Thus, reduction ability appears, in contrast to starch. Starch is found as starch grains of various shapes: oval, spherical, etc. in plants. The grain sizes range from 0.002-0.15 mm. The largest grains are formed in potatoes, the smallest – in rice. Starch grains are forming by superimposing new layers on old ones, so they often have a layered structure. The form of starch grains, the size, the position of the center of growth, and the location of the layers can be used to identify some plants and types of starch. A unique property of starch is the ability to turn blue after adding a Lugol's iodine solution (a solution of iodine in an aqueous solution of potassium iodide). The appearance of blue staining can be explained by the formation of complex and adsorption compounds between iodine and starch. Starch only swells in cold water. However, it forms viscous colloidal solutions (starch paste) after heating. The temperature of gelatinization is the temperature of the formation of starch paste. Starch paste is prone to retrograde. They do not withstand high temperatures, freeze-thaw cycles, acids, etc. Native starches are modified using physical and chemical methods to avoid these disadvantages. They are widely used as thickeners, stabilizers, and emulsifiers in the food industry. Plants of the *Poaceae* family (fruits of wheat, rice, corn (about 70% of starch)) are used as plant raw materials for the production of the main types of starch. But starch is difficult to isolate due to the presence of protein and other water-insoluble substances. Potato starch is most easily obtained. Potato tubers (containing up to 25% starch) are sorted, washed thoroughly, and ground in special machines. Then the starch is washed out of the resulting porridge on a sieve. The

starch is cleaned and isolated by sedimentation in sedimentation tanks or centrifuges. Starch is used as filler and to prepare fixed dressings in surgery; it is widely used in powders, ointments, pastes along with zinc oxide, talc. It is taken orally as an enveloping agent for diseases of the digestive system [2, 3, 8-12].

Mucilages and gums are a mixture of homo- and heteropolysaccharides and polyuronides. Gums are mixtures of heteropolysaccharides with the obligatory inclusion of uronic acids. The carboxyl groups of uronic acids are bound to Ca^{2+}, K+ Mg^{2+} ions. Gums are formed as a result of the degeneration of cell walls and the contents of core cells, core rays, etc. Gums accumulate and protrude from natural cracks or from artificial incisions of the trunks after the destruction of the cell. They solidify in the form of a lumpy, ribbon, or other forms. The chemical composition of gums is very complex. For example, apricot gum contains glucuronic acid – up to 16%, galactose – up to 44%, 3 types of gums are distinguished by solubility in water: arabic – well soluble in water (apricot and gum arabic); bassorin – poorly soluble in water, but highly swelling in it (tragacanth gum); cerasine – poorly soluble and slightly swellable in water (cherry gum) [3, 24, 25].

Gums are usually formed in plants growing in arid climates. Gums are found in plants from the families *Fabaceae*, *Rosaceae*, *Combretaceae*, *Burseraceae*, *Rutaceae*. Gum is believed to protect plants from infection by pathogenic microorganisms. They fill in the formed cracks and other damage to the trunks. Gums are used in the preparation of emulsions, tablets, and pills in pharmaceutical practice. Gums also find applications in other industries (food, textile, leather, paint, and varnish). Mucilages are mixtures of hetero- and homopolysaccharides. Mucilages are formed as a result of normal mucosal degeneration of cell walls or cell contents. Individual cells (marshmallow root, violet, and buckwheat species) or entire layers (flaxseed, seeds of *Plantago psyllii*, hysteria) became mucilages. Cells are not destroyed; their integrity is preserved where mucilages occurred [3, 24, 25].

There are 2 groups of mucilages according to the chemical structure: neutral and acidic. Neutral mucilages are the products of the polymerization of monosaccharides – D-galactose, D-mannose, L-arabinose, D-glucose (galactomannans, glucomannans, arabinogalactans). They are found in plants from the *Orchidaceae*, *Liliaceae,* and *Fabaceae* families. Acidic mucilages contain uronic acids with free unsubstituted carboxyl groups. This explains their acidity (mucilages of flax seeds, marshmallow roots, etc.).

Mucilages are solid amorphous substances, water-soluble and insoluble in alcohol and non-polar solvents. Mucilages are precipitated from aqueous solutions by alcohol, salts of Pb^{2+}, Fe^{3+}. The yellow color is formed by the action of solutions of potassium hydroxide, sodium hydroxide, ammonia. When methylene blue is added, a blue color appears. Mascara does not stain mucilages. Methods of isolation, purification, and analysis are based on these physical and chemical properties of mucilages. Qualitative reactions with alkali and ammonia solutions are used to identify mucilages. Yellow staining is the result of these reactions. Micropreparations are prepared in a solution of mascara, methylene blue to detect the localization of mucilages. Cells with mucilages are colorless in mascara and blue in methylene blue. Quantitative determination is performed by the gravimetric method. Mucilages are precipitated from aqueous solutions most often with alcohol or acetone with a coagulant (in plantain leaves, three-part beggarticks herb) [3, 8, 10, 24, 25]. The European Pharmacopoeia recommends determining the swelling index for raw materials containing mucilages. Swelling index – volume in milliliters of medicinal plant material and mucilages after swelling of the material in the aquatic environment [26]. Mucilages play an important role. They serve as reserve substances; protect the plant from drying out. They also contribute to the distribution and fixing of plant seeds in the soil. Mucilages are used as anti-inflammatory and enveloping agents in medicine. In addition, mucilages possess radioprotective and immunomodulating properties.

Pectin compounds (Figure 2) are high molecular weight heteropolysaccharides. The main structural component of pectin compounds is α-D-galacturonic acid (polygalacturonide). Pectin compounds also contain D-galactose, L-arabinose, L-rhamnose, and other neutral monosaccharides, but in much smaller amounts (10-17%). Pectin substances were discovered in 1825; the name comes from the Greek. *pestos* – "curled up, frozen". They are found in large quantities in fruits, tubers, and plant stems. Pectins are part of the intercellular substance serving for cell plasticity. They play an important role in biological processes [27-28]. There are various groups of pectin compounds; classification depends on the structure and degree of polymerization: pectic acids, pectinic acids (pectins), pectates and pectinates, protopectins. The pectic acids are the simplest pectic substances, which are mainly products of the polymerization of residues of α-D-galacturonic acid linked by 1,4-bonds in linear chains. The number of moieties of α-D-galacturonic acid can reach 100. Pectic acids are soluble in water. They are the basis for other groups of pectin substances. Pectinic acids (pectins) are higher molecular weight compounds containing 100-200 units of α-D-galacturonic acid. The carbonyl groups of D-galacturonic acid can be methoxylated to varying degrees. Pectates and pectinates are salts of pectic and pectinic acids. Pectinic acids, pectates, and pectinates dissolve in water in the presence of sugars and organic acids, forming dense gels. Protopectins are high molecular weight polymers of polygalacturonic methoxylated acid with galactan and arabinan cell wall, occasionally interrupted by rhamnose residues; they are insoluble in water. In plants, pectin substances are usually presented in the form of protopectin. Protopectin is found in large quantities in unripe fruits. When the fruits of the plant ripen, the depolymerization of polyuronide chains begins due to the influence of proteolytic enzymes. Thus, protopectin is converted into lower molecular weight groups of pectin substances. The presence of pectin substances must be taken into account during the processing of medicinal plant materials. The methoxyl groups of pectin substances are easily cleaved off under the influence of dilute alkalis or the pectase enzyme, forming methyl alcohol and pectic acid. Pectic acid easily is

precipitated from solution with Ca^{2+}; this property can be used to quantify pectin substances. Pectin compounds are usually extracted by heating from plant materials with a solution of phosphoric or other acids. The extract is concentrated, filtered; then pectin is precipitated with alcohol [27-29]. For the purification of pectin different properties are used. The first one, the property of pectin compounds to form salts with metals $A1^{3+}$, Cu^{2+}, Fe^{2+}, Fe^{3+} – pectates. Pectin compounds from pectates are obtained by the using of acids. The second one, solid materials such as perlite, cellulose, and other sorbent ingredients. These materials help to clarify plant material and filter the pectin extract with the adsorption of fine particles of the extract. The third one, chemical interaction during the processing of pectin-containing raw materials with alkaline earth metal compounds, followed by substitution of the alkaline earth cation for hydrogen by ion exchange. Quantitative determination is carried out by the gravimetric method (precipitation with alcohol). Potentiometric titration is also used and consists of the interaction of pectic acids with calcium hydroxide, etc. The use of pectin substances in medicine is associated with their ability to reduce the gastrotoxicity of salicylates. Pectinic acids can be used as a carrier of drug substances. Pectins have antiulcer and mild laxative effects. They form complex compounds with various metals (chelates), easily excreted from the body. For this reason, products containing pectins are especially necessary for people who live in areas with radioactive contamination. Pectin compounds are widely used in the confectionery industry, bakery, cheese making, textile industry. Pectins are obtained from apple pomace, peel of citrus fruits, beet pulp, ground baskets of sunflower, coniferous bark, quince fruits and fodder watermelon in industry. The food industry needs pectin. Therefore, the development of technologies for obtaining this drug is carried out everywhere from local raw materials. Waste (pulp) after receiving the juice of fruits and vegetables is the dominant raw material in the world practice of pectin production. Noteworthy, *Nicandra physalodes* (L.) Gaertn. seeds, *Angelica acutiloba* (Siebold & Zucc.) Kitag. roots, sickle-leaved hare's-ear (*Bupleurum falcatum* L.) roots, the ginseng (*Panax ginseng* C. A. Mey.) leaves, and others are among the studied unconventional sources of pectin. Many of them are traditionally widely used in East folk medicine [27-29].

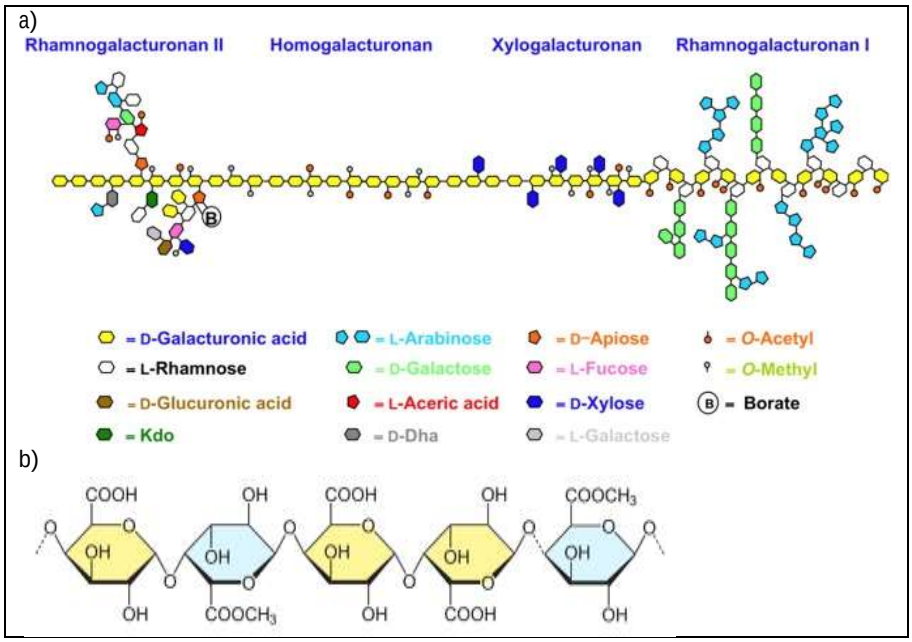


Figure 2: Pectins (a) and protopectins (b) strucrures

Sea herbs of the *Zosteraceae* family are considered as a promising source of pectin. Zosterin isolated from these plants has a low degree of esterification in contrast to the pectin of terrestrial plants. Less than 10% of the carboxyl groups of galacturonan in this pectin are esterified with methyl alcohol. In addition, a structural feature of the zosterin carbohydrate chain is the presence of a large amount of D-apiosis. Fragments of apiogalacturonan are highly resistant to pectolytic enzymes. Most likely, they play a protective role, protecting marine herbs from phytopathogenic microorganisms, rot and decay. Seed experiments with laboratory animals lead acetate showed some properties of zosterin isolated from *Zostera marina* L. First, it delays the entry of lead from the intestines into the internal organs and bones. Secondly, zosterin is involved in removing lead from bones [30].

Seaweed PSHs *Laminaria*, *Ahnfeltia*, *Fucus* are used in medical practice. Red algae of *Ahnfeltia* is a source of agar-agar, which is used in bacteriology and biotechnological industries for the preparation of solid nutrient media. Agar-agar is used in the confectionery industry for the manufacture of jelly, candy, marmalade, jams, etc. Agar-agar is a high molecular weight PSH; it is a mixture of two PSHs – agarose and agaropectin. Agarose is the main fraction (about 70%), consists of residues of D-galactose and 3,6-anhydro-L-galactose, interconnected by α-1,3- and β-

1,4-glycosidic bonds. Few 3,6-anhydro-L-galactose residues have been replaced by 6-sulfate-L-galactose residues in agaropectin molecules. Alginic acid (an analogue of pectic acid) is found in kelp; it consists of residues of β-D-mannuronic and α-L-guluronic acids linked by β-glycosidic bonds (Figure 1). These bonds are located between the 1st carbon atom of the moieties of mannuronic or guluronic acid and the 4th carbon atom of the second residue. Alginic acid is contained in the form of salts of calcium, magnesium, sodium, etc. in algae. It makes up to 30% of the dry mass of algae. Alginic acid is a natural ion exchanger; it can adsorb selectively cations of heavy metals and radioisotopes. The use of alginic acid prevents the deposition of radioactive strontium in humans and animals. The ion-exchange properties of alginic acid depend on the ratio of uronic acids. Higher content of L-guluronic acid provides greater sorption ability.

Therefore, kelp is of great importance in medicine. Primary thallus waste from algae (rhizoids and trunks) is a promising raw material for the production of sodium alginate; alginic acid, enriched with L-guluronic acid, is accumulated in it. Sodium alginate-based drugs are designed to treat wounds and burns. Alginate hemostatic drugs are also designed for gastroenterology. They form a protective and healing coating on the damaged area. In addition, alginates can be used to obtain dressings with a prolonged therapeutic effect [31-33].

Laminarin (laminaran) is a reserve PSH of brown seaweed (Figure 1); it is part of the kelp PSH complex. Laminarin macromolecules are linear or slightly branched, consist of β-D-glucopyranose residues with bonds between the 1st and 3rd (less often the 1st and 6th) carbon atoms in linear chains and with bonds between the 1st and 6th carbon atoms in branched chains. Some macromolecules may be attached to the moiety of the D-mannitol. The content of laminarin in algae can reach 35% dry weight [34]. Complex sulfated PSHs (fucoidans) are found in the cell walls and intercellular space of brown algae. L-fucose is the main monosaccharide residue of fucoidans. Fucoidans (Figure 1) exhibit important biological effects due to their ability to modify cell surface properties. It is believed that they can be used in the development of new drugs with antiviral, anti-inflammatory, antitumor, immunomodulating, contraceptive, and anticoagulant effects. The biological activity of fucoidans is primarily due to the high degree of sulfation of their molecules. *Saundersella simplex* (De A. Saunders) Kylin, *Chordaria flagelliformis* (O.F.Müller) C. Agardh, *Chordaria gracilis* Setchell & N.L.Gardner, *Dictyosiphon foeniculaceus* (Hudson) Greville, *Fucus evanescens* C.Agardh are richest in fucoidans [35].

CONCLUSION

Polysaccharides are one of the important groups of biologically active compounds that pharmacognosy is studying. Polysaccharides (polyoses) are natural polymeric high-molecular carbohydrates, which include various monosaccharides (monoses): glucose, fructose, galactose, etc. Polysaccharides are more often found in the form of fiber, pectin, starch, mucilages, and gums. Polysaccharides are characterized by a wide range of biological activity: enveloping, emollient, anti-inflammatory, wound healing effects. Drugs based on raw materials containing polysaccharides are used for nasopharynx diseases, bronchitis, and intestinal diseases. It has been established that some polysaccharides increase immunity and possess a blood-restoring property; more often they are prescribed in combination with other drugs. Gums in medicine are usually used as emulsifiers. Increased interest in high molecular weight carbohydrates. New biologically active polysaccharide-protein complexes with a high molecular weight antitumor, antiulcer, and antiviral effects have been discovered. Further studies are promising in studying their structure, physicochemical properties, pharmacological activity, ways of standardizing crude herbal drugs, and preparations based on it, development of modern regulatory documentation [36].

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CONFLICTS OF INTEREST

None.

AUTHOR'S CONTRIBUTIONS

Bokov D.O., Sharipova R.I. contributed equally to this work.

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