Pectins are complicated heteropolysaccharides belonging to the group of acidic plant polysaccharides, glycanogalacturonans [1]. Pectic substances are components of plant cell walls and are found in the intercellular space of flowering land plants, phanerogams, and some freshwater algae [2]. Pectins create a matrix that binds cellulose microfibrils and are involved in ion transport and water regimen. They also influence germination of seeds, growth, and vegetation of plants and play a defensive role between plants and phytopathogens [3]. Overall, functions of pectin in plants have been extensively investigated.

Pectins were first identified by the French scientists Braconnot and Payen in 1825, and the physiological activity of these plant cell polysaccharides have received much attention since then. Humans consume pectins in the form of food and medicines. The daily consumption of pectins by an individual is 1-7 g, corresponding to 10-100 mg/kg body weight [4]. Because crude plant food has been consumed by humans for millions of years [5], it is hypothesized that the human gastrointestinal tract is evolutionarily adapted to pectins. Epidemiological and clinical investigations demonstrated that a deficiency of pectic polysaccharides causes severe diseases.

Studies of the effects of pectin on immunity are of a great interest because of the importance of the immune system in humans and animals. The regulation of immunological surveillance may lead to prophylactic treatments and possibly cures for various illnesses and diseases. Therefore, substances that increase weakened immunity or decrease undesirable immune reactions have been extensively studied.

Preliminary interest in pectins that influence immunity was due to the observation that dietary pectins decreased the risk of cancer. The frequency of cancer in Seventh Day Adventists is two times lower than for Californians. Members of this religion are vegetarians, and they consume two to three times more pectin [6, 7]. There is extensive clinical and experimental data regarding the antitumor, anti-infectious, and anti-allergic properties of pectins [8-16].

Pectins are resistant to digestive enzymes and maintain macromolecular structural patterns of their sugar chains in the stomach and small intestine [17, 18]. Therefore, special consideration has been focused on the elucidation of the relation between structural features and
immunomodulatory activity of pectic polysaccharides. The structure of pectic substances depends on numerous parameters, and they may substantially change during growth and vegetation of the plant, whereas the dynamic character of pectin structures is ensured by the non-regular structural pattern of the sugar chain containing various macromolecular fragments in the linear and branched regions [19].

In this review, the immunomodulatory activity of pectins with respect to the structure of the macromolecule is analyzed. The activity of pectins isolated from edible plants, plants of the European north of Russia, and pectins used in the food industry are described. Phagocytosis and the antigen-specific cellular and humoral immune responses of mice treated orally with pectin solutions are considered to be targets of pectin action.

**STRUCTURAL PATTERN OF PECTINS**

Pectin macromolecules include various fragments of linear and ramified regions that appear to be covalently connected [20, 21]. The linear region consists of units of 1,4-α-D-galacturonic, which represent the backbone of all pectins. These units are bound to each other with one or two α-L-rhamnopyranose residues by 1,2-linkages. The ramified region is represented by different heteropolysaccharides. The structural constituents of the macromolecule include a heterogeneous mixture of pectic polysaccharides that have been obtained by isolating pectins from plant tissue. Homogalacturonan, rhamnogalacturonan-I (RG-I), xylagalacturonan, and apioagalacturonan are the primary pectic polysaccharides [19, 22]. The structural features of these polysaccharides differ significantly from each other and have various physiological effects.

In addition, the pectin polysaccharides are different for various plants. Galacturonan differs in the degree of methyl esterification and molecular weight, rhamnogalacturonan differs in the fine structure of the branched chains that consist of galactose, arabinose, and other sugars, and xylo- and apioagalacturonans differ in the degree of branching.

A set of polysaccharides with different chemical characteristics has been obtained from more than 50 plants of the European north of Russia and the corresponding cell (callus) cultures [23]. A modified procedure for isolating biologically active polysaccharides from raw plant materials by extraction [24, 25] allowed the isolation of pectins with structures that are closely related to native pectins.

The isolated pectins were shown to have common chemical structural features. The structural patterns of these pectins differed in the content of galacturonic acid residues (from 50 to 90%) and side chain structures of the ramified regions.

The pectin backbones consist of 1,4-linked α-D-galactopyranosyl uronic acid residues. Comaruman, pectin of the marsh cinquefoil *Comarum palustre* L., appears to have a branched core of galacturonic [26, 27].

The majority of pectins contain RG-I; however, they show individual differences in the structure of the ramified regions. In particular, the structure of the tanacetan macromolecule, a pectin from the tansy *Tanacetum vulgare* L., contains blocks of arabinogalactan, arabinan, and galactan. Arabinogalactan consists of branched side chains of 1,5-α-L-arabinofuranan joined by 1,3- and 1,4-linkages to the linear chains of 1,4-β-D-galactopyranan. The arabinofuranose residues in arabinan are linked by α-1,2- and α-1,5-linkages, and the branch points are 2,5-di-O- and 3,5-di-O-substituted α-L-arabinofuranose. The galactose residues in galactan are connected by β-1,6-linkages, and the 4,6-di-O-substituted β-D-galactopyranose residues of long sugar chains with a high degree of branching are present at the branch points [28].

The ramified region of silenan, a pectin from the campion *Silene vulgaris* Moench (Garke (Oberna behen) L.), differs from tanacetan in the occurrence of small RG-I blocks [29, 30]. The side chains of silenan consist of 1,5-linked residues of α-arabinofuranose and 1,3-, 1,4-, and 1,6-linked β-galactopyranose. The β-1,3-galactopyranan appears to be bound to α-1,5-arabinofuranan via branch points of 2,3-di-O-substituted galactopyranose residues. In addition, the presence of branch points with 3,6- and 4,6-di-O-substituted galactopyranose residues and 3,5-di-O-substituted arabinoarabinose residues confirmed a covalent bond between the fragments of arabinan and galactopyranan in the side chains of silenan.

The ramified regions of comaruman contain rhamno-galacturonan with side chains consisting of 1,6- and 1,4-linked residues of β-D-galactopyranose, 3-O-substituted galactopyranose, and 5-O-substituted arabinofuranose. The branch points of the side chains are 3,4- and 4,6-di-O-substituted galactopyranose residues and 3,5-di-O-substituted arabinofuranose residues confirmed a covalent bond between the fragments of arabinan and galactopyranan in the side chains of silenan.

The ramified regions of apioagalacturonan and heteroglycanagalacturonans are present in lemnan, a pectin from the duckweed *Lemma minor* L. [31, 32]. Using NMR spectroscopy, the side chains of the lemnan macromolecule were shown to comprise single and/or 1,5-linked D-apiofuranose residues attached to the 2- and 3-positions of the galacturonic acid residues of the backbone. In addition, the ramified region of lemnan contains a small amount of heteroglycanagalacturonan. The main neutral sugar residues of lemnan are apiose, arabinose, galactose, and xylose. The L-arabinofuranose residues are the primary terminal residues of the side chains of the ramified region of the lemnan macromolecule, and significantly fewer D-galactopyranose and D-xylopyranose (or 2-O-methyl-xylopyranose) residues occupy the terminal positions. Additionally, greater amounts of 1,3-linked D-