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Analysis of the raw material base for pectin production

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Abstract. The addition of pectin to food products is important because this natural polysaccharide plays a key role in improving the quality and stability of the product, it allows for high-quality preservation of products that have a long shelf life, which is important for the health and well-being of consumers. The purpose of the study is to investigate the main raw materials of plant origin for the synthesis of pectin, which can be used as a promising raw material for food industry enterprises in Ukraine. The study was carried out using various methods of analysis, a thorough comparative analysis of papers by Ukrainian and foreign researchers, which are published in the scientometric databases Scopus, Web of Science, Journal Citation Reports, Scimago Journal & Country Rank, and Google Scholar. Based on the results of analytical studies, the main raw materials used for the production of pectin and pectin-containing pastes were analysed, and the main problems of the production process were identified. It has been found that adding pectin to food products can have a significant number of benefits: increasing the viscosity of the product, which is useful for creating a thick texture of the product; increasing the resistance of the product to heat treatment, reducing the risk of product separation or quality degradation; increasing functionality; introducing it into products can help improve the consistency and appearance of the product, add taste and color properties, and reduce the amount of sugar that must be

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added to the product to ensure viscosity and taste. It is established that the main raw material for the production of pectin in Ukraine is apple fruits. It is proven that pectin can be obtained from other fruits, berries, and vegetables, such as gooseberries, currants, cherries, pumpkins, etc. The intensification of the pectin production process should provide the population with a high-quality product that will prevent various types of intoxication by removing radionuclides from the body and contribute to the recovery of people in the post-war period. The practical significance of this study lies in the ability to help manufacturers find optimal sources of raw materials with a high pectin content to ensure the quality of the final product. In addition, this study will also facilitate the development of appropriate technological solutions for the optimal process of producing pectin from the selected raw materials

Keywords: food; shelf life; pectin pastes; vegetable raw materials; production process

Introduction

Pectin production is quite common in the world, especially in countries with developed food industries. Major pectin producers include the United States, the European Union (France, Italy, Germany, the Netherlands), India, China, and Brazil (Cho *et al.,* 2019).

Each of these countries has its pectin production methods, which are mainly based on traditional technologies. Each manufacturer can have its characteristics in the production process and the use of different types of raw materials. For example, in the United States, pectin is produced mainly from apples, citrus fruits, and sugar beets, as well as from juice and wine production waste (Cho *et al.,* 2019). In the European Union, the dominant sources of pectin are apples and citrus fruits, although other raw materials are also used. In China, pectin is produced mainly from citrus fruits and apples, while in Brazil it is produced from Brazilian guarana (Çilingir *et al*., 2021).

Pectin production abroad usually takes place in large enterprises that have the appropriate technical and human resources to carry out all stages of the production process. Major pectin producers generally ensure the quality of the product and ensure that it meets the requirements of international food safety standards (Güzel & Akpınar, 2019).

In Ukraine, pectin production is carried out on an industrial basis in several regions of the country, the most famous pectin plants are located in the Zakarpattia, Volyn, Khmelnytskyi, and Lviv oblasts. The most common source of pectin in Ukraine is apples, citrus processing products, and molasses formed during sugar production. However, in addition to traditional sources, Ukraine is exploring the possibility of obtaining pectin from other plants, such as sunflowers, peas, and corn, and from various food industry waste (Sukhenko *et al.,* 2019).

Nowadays, Ukrainian pectin plants produce pectin of various quality and applications – from food to medical and pharmaceutical industries. The plants export pectin to Europe and Asia and meet the domestic needs of the Ukrainian market (Guo *et al*., 2020).

Pectins are polysaccharides that are commonly found in plant cell walls. They can be isolated from fruits, vegetables, berries, citrus fruits, and from some types of cereals.

Pectins are used in the food industry as a stabilizer, thickener, and binder. They provide structure and texture in foods such as jams,

jams, jellies, and other desserts. In addition, pectins also have health benefits, such as lowering blood cholesterol and supporting gastrointestinal health (Kazemi *et al.*, 2019).

Classical pectin production technologies usually include the following steps (Palamarchuk *et al.*, 2022):

➤ Collection and preparation of raw materials: the plant material is cleaned of impurities, cut, and mixed with water.

➤ Extraction: the prepared raw materials are exposed to acids or enzymes that help dissolve pectin and other components of the plant cell wall. Next, the resulting solution is filtered.

➤ Cleaning: the pectin solution goes through a series of cleaning processes that help remove impurities and other unwanted substances.

➤ Concentration: the resulting pectin solution is concentrated to reduce the volume and increase the pectin concentration.

➤ Drying: the concentrated pectin solution is dried, usually in hot air or the sun.

➤ Fractionation: pectin is divided into fractions with varying degrees of esterification and properties.

➤ Packaging: the finished product is packed in the appropriate container and prepared for transportation.

Depending on the type of raw material and production technology, the process may differ in detail, but the general principle remains the same.

The purpose of the study was to conduct a thorough analysis of the raw material base and various components of plant origin for the production of pectin and pectin-containing pastes.

AAnalysis of the main plant components for the production of pectins and pectin-containing pastes

The plant components used for pectin production may vary in composition and properties. The main sources of pectin are apples, citrus fruits, sugar beets, and other crops (Acosta *et al.*, 2020). The study considers the composition and properties of these plant components.

Malic pectin has a high degree of methoxylation and the galacturonic acid content is about 70-75%. Apple pectin has a good gelling ability, which ensures its use as a stabilizer and thickener (Zheplinska *et al.*, 2021). Citrus pectin contains less galacturonic acid (40-60%) compared to apple pectin but has a high content of methoxyl groups, which makes it more soluble in water. Citrus pectin is used to increase viscosity and stabilize fruit juices (Mzoughi & Majdoub, 2021). Beetroot pectin contains the highest content of galacturonic acid (80-85%) compared to other sources of pectin. Beetroot pectin has a high gelling capacity, but less stability than apple or citrus pectin. It is used to thicken and stabilize liquid foods such as soups, sauces, and canned food (Zheplinska *et al.*, 2022).

Ukraine is a producer of sugar beet, which can be used as a source of raw materials for the production of pectin. Studies show that sugar beet contains approximately 10-15% pectin, which makes it a fairly effective source of raw materials for the production of pectin (Picot-Allain *et al.*, 2022). Raw materials for industrial production of pectin from the standpoint of economic feasibility of its use are mainly apple and citrus pomace, sugar beet pulp, citron melon, sunflower heart, and pumpkin (i.e., food processing waste). The content of pectin substances in plant materials varies widely: from 0.1-0.5% to 50%. The highest pectin content is found in lemon pomace (30-35%), orange and tangerine pomace (25-30%), sunflower pericarp (about 25%), beet pulp (20-25%), apple pomace (5-15%). Pectins are unevenly localized in different parts of plants. For example, in citrus fruits, the main amount of pectins is concentrated in the albedo, in apples – in the epidermis and adjacent tissues, in sugar beet – in the pulp (Picot-Allain *et al.*, 2022). Classification of pectin-containing raw materials by the content of pectin substances is given in Table 1.

Table 1. *Characteristics of pectin substances by type of raw material*

Type of pectin-containing raw materials		Pectin content, %
Subgroup	**Raw material**	
Group 1 "Vegetables"		
Tubers, root vegetables	Potatoes; beets, carrots	5.4...2.0 30.0...6.4
Leaf, stem	Cabbage, onions, celery	7.5...4.8 10.1...9.2
Fruited vegetables	Eggplant, pepper, tomatoes	11.0...9.2
Gourd	Pumpkins, melons, watermelons	23.6...1.7
Legumes, cereals	Green peas, corn, wheat, barley, oats, rice	2.5...1.5 3.0...4.0
Group 2 "Fruits and berries"		
Pome	Apples, pears, quinces, rowan	9.0...1.9
Stone fruits	Cherry, sweet cherry, plum, apricot	
True, accessory, compound	Grapes, currants, strawberries, raspberries, lingonberries, blueberries, cranberries	12.0...4.2 7.9...3.3 6.7...3.2
Subtropical citrus fruits	Figs, feijoas, persimmons, kiwis, grapefruits	14.0...4.9
Tropical citrus fruits	Pomegranates, bananas, lemons, oranges, tangerines	5.8...5.5
Group 3 "Other types"		
Leaves		14.0...4.9
Sunflower stalks		35.7...20.0
Sunflower hearts		24.0...12.0
Shells of cotton bolls		5.4...10.0
Tree bark	Pine, spruce, larch	9.0...8.0

Source: compiled by the author based on (Selvendran, 1985; Li *et al.*, 2022)

After analysing the data in Table 1, it can be concluded that the most promising raw materials for the synthesis of pectin and pectin-containing pastes in Ukraine may be different types of root vegetables, new melon varieties, seeds of different varieties, and sunflower (Bédouet *et al.*, 2003; Fishman *et al.*, 2019).

In scientific papers, researchers have proposed their classification of pectin-containing raw materials by the content of pectin substances, it has the following form:

➤ High-pectin raw materials (more than 35% pectin): Chinese yellow pea gum, concentrated lemon or lime juice, and apricot seeds.

➤ Medium-pectin raw materials (from 10% to 35% pectin): apple skins, orange zest, lemon zest, and pumpkin pulp.

➤ Low-pectin raw materials (less than 10% pectin): currant leaves, cherry stalks, black pepper, and hops.

Based on the results of the literature review, the level of development of the technological process and the analysis of the applicability of progressive solutions are established. There is a known method (Colodel *et al.*, 2020) for the production of purified pectin from fruit pomace by extracting ammonium oxalate with an aqueous solution of ammonium oxalate, simultaneously grinding the raw material, followed by filtration and vacuum concentration of the extract. Pectins are precipitated from the extract with ethanol and dried. Then they are treated with an aqueous solution of ammonia. Hydrochloric acid is added to the reaction mixture and kept at 18°C for 1 hour, pectin is isolated. The complexing ability of pectin is 922.77 mg Pb2+/g.

The following method (Demir *et al.*, 2021) refers to the production of drugs that have a detoxification ability and can increase the purity and binding capacity of the resulting product. This method is used to extract pectin samples, such as beetroot, *citrus, and apple pectin, with a 0.5% ammonium citrate solution.* After filtration, an electrolyte is added to the pectin extract in the form of a 0.1 mol solution of potassium chloride and dialysis is performed through a cellophane membrane at a temperature of 38°C for 24 hours. The resulting dialysate is evaporated under a vacuum and treated with 96% ethanol. Pectins are separated and treated with a 5% ammonia solution in a ratio of 1:10 at pH 10.5 for 2 hours.

The method described in H. Chen *et al.* (2019) involve a mixture of beet pulp and apple pomace. This mixture swells in an acidic aqueous solution, then washed with water and subjected to hydrolysis with a mixture containing aqueous solutions of hydrochloric and acetic acids. The final stages of the process are the separation of hydrolysate, its cooling, and neutralization, precipitation of pectin with ethyl alcohol, its purification, and drying.

There are several ways to obtain food pectin from vegetable raw materials (Brito *et al.*, 2019; Bashta *et al.*, 2021). The essence of these methods is as follows: beet pulp and apple pomace are mixed in a ratio of 1:(1-9), cellulose phosphate is added in an amount of 2-4% (by wt.), the raw material is soaked in a mixture of ultrafiltrate and water in a ratio of 1:(1-2) for 2 hours. Next, whey with an acidity of 290-300°T is heated to a temperature of 90-95°C, kept for 15-25 minutes, followed by cooling and filtration.

A special feature of the method of obtaining pectin, described by A. Bashta *et al.* (2021), is the hydrolysis of protopectin from fresh extracts of quince, apples, and pears with enzyme preparations of the cellulosic complex in the amount of 0.1-0.3% by weight of raw materials. To increase the yield of pectin, raw materials are frozen for 25-30 minutes at a temperature of 30-40°C, followed by defrosting with hot water. Hydrolysis is carried out at 45-50°C for 2-3 hours.

Preparation of pectin from apple pomace by the method (Naqash *et al.*, 2021) contains the following steps: washing of crushed apple pomace, acid thermal hydrolysis of washed raw materials, water extraction of pulp obtained after hydrolysis for more complete extraction of pectin, separation of the resulting hydrolysate and extract, precipitation and purification of pectin with ethyl alcohol, and drying. Before washing, the raw material is pre-evaporated for 15 minutes to intensify the separation of ballast substances, next the raw material itself is washed with water at a hydraulic module of 1:6 and a temperature of 50-60°C. Next, acid thermal hydrolysis of the washed raw materials with a solution of citric acid is performed at a temperature of 60-70°C. Pulp extraction is carried out with water at a temperature of 70-75°C, carried out by vacuum evaporation to the content of pectin substances of 10-12% to a completely dry mass.

The essence of the method of obtaining pectin from fruit pomace is that the raw material is washed with the addition of mineral acid in an amount that provides a pH of the solution of 2.5-3.0 for washing apple pomace, and 2.5-3.5 for citrus pomace (Hosseini *et al.*, 2020).

A well-known method for obtaining pectin from apple waste (Vásquez *et al.*, 2022), developed by Japanese scientists, involves processing raw materials with a solution of phosphoric acid, followed by filtration and purification on anion-exchange and cation-exchange resins.

The following method of pectin extraction uses the microwave radiation method (Dao *et al.*, 2021). Raw materials (oranges, tangerines, apples, and carrots) are pretreated with alcohol, and extraction takes place with an irradiation of 2.45 Mhz for several minutes and with repeated exposure. Solutions of hydrochloric, sulphuric acids, or solutions of ammonium oxalates are used as an extractant.

Japanese researchers (Ma *et al.*, 2020) developed a method for producing pectin under pressure for the food industry, for example, for making jam from pectin-containing plants, such as lemon, lime, and apple.

According to the method (Ázar *et al.*, 2020), pectins can be isolated from secondary products (mainly apple and citrus pomace) obtained by pressing juice from mature fruits and vegetables as a result of selective adsorption, and polyphenols – as a result of subsequent desorption of the adsorbent. The disadvantage of this method is the additional use of ethanol for the pretreatment of raw materials and the production of pectin with a low molecular weight

Depending on the application, different types of pectin-containing raw materials can be used for different purposes. For example, high-quality raw materials can be used to make jellies and marmalade, medium-quality raw materials can be used to make sauces and beverages, and low-quality raw materials can be used to make food additives and flavorings.

According to the results of analytical studies, it is established that the use of the above-mentioned plant raw materials is due to the high content of pectin and the latest trends in its use in the food industry for the production of new products for health and preventive purposes, as well as large volumes of raw materials that are considered waste after the production of basic products at fruit and vegetable enterprises from the above-mentioned raw materials. Therefore, Ukrainian producers of pectin products and their derivatives can use traditional raw materials and apple pomace, melons, and sunflower.

Application of pectin substances in the food industry

In the context of the global environmental situation, which is associated with the growth of industrial production, the use of chemical technologies in the industry, agriculture, and everyday life, the development of nuclear energy, rational nutrition is of particular importance, which produces new opportunities for the use of pectins and their derivatives: in the production of canned food and confectionery, bakery products, soft drinks, and in the field of winemaking (Gamonpilas *et al.*, 2021; Gavahian *et al.*, 2021).

In the food industry, the main property of pectin is used – gelling ability. Pectin is widely used in the production of confectionery products of the pastille and marmalade group (marshmallows, jelly marmalade, etc.) and sweets (jelly and fruit jelly), which are in demand among the population. Unlike other gelling agents, pectin substances form jelly in aqueous solutions only in the presence of sugar and acid. The amount of sugar that is needed to form jelly varies depending on the amount and physicochemical properties of pectin. For thickening, not only the amount of acid added is important, but also its properties, which are conditioned by different concentrations of hydrogen ions. Solid jelly is produced in the presence of weak acids, such as tartaric, at a pH in the range of 3.0-3.2. The dry matter content has a significant effect on the gelatinous properties. The higher the dry matter content, the higher the gelatinisation temperature and the strength of the final product. The content and composition should also be optimal.

C. Buathongja *et al*. (2020) found that an important technological aspect of the gelatinisation process is the dosage of buffer salt and acid. With the help of a buffer system, the pH value is regulated and thus affects the inversion of sugar during cooking (Freitas *et al*., 2021). In the fruit canning industry, pectin is used in the production of jelly products: jellies, candies, and jams, and for the production of other products based on pectin for therapeutic and health-improving purposes (purees, jelly, juices, beverages, canned vegetables, etc.). To obtain the thickening and structural and mechanical properties of the resulting products, there is the type of pectin, the calcium content in fruits and water, pH, temperature, and filling time.

Traditional apple pectin, in addition to its pronounced sorption properties, has a high molecular weight and degree of esterification, an increased melting point, which enables accurate control of the temperature and time of gelatinisation. Fruit and jelly fillings based on apple pectin are ideal for bakery products and can withstand temperatures of about 220°C for 15-20 minutes, they are heat-resistant, do not boil off, and do not deform during baking. Traditional citrus pectin, unlike apple pectin, is mainly used in the production of dairy products (Biel-Nielsen *et al*., 2022), for example, for the stabilisation of fermented milk drinks, cottage cheese, liquid yogurt, and in the production of fruit juices and beverages with pulp. The relatively low molecular weight and viscosity of citrus pectins, their neutral color, and taste allow them to be used for the industrial production of stabilized dairy products. When citrus pectin is added to fruit juices, the viscosity of the product does not increase significantly, and the nutritional value increases.

The study by Wang *et al*. (2021) substantiates the use of traditional apple and citrus pectins in the production of various products. Various varieties of pectins with a high and medium degree of esterification were investigated: apple pectins with an esterification degree of 71.3% and 60.9%, and citrus pectins with an esterification degree of 70.0% and 60.1%, respectively. All samples were standardized in terms of gelling property according to a specially developed USA-SAG methodology. Apple and citrus pectins with the same standardization index have different properties in the resulting gels.

Wang *et al*. (2021) have shown that apple pectin gels have a higher strength, i.e., obtaining a product with the same fracture strength requires a lower consumption of apple pectin.

The study (Huang *et al*., 2021) considered the influence of the properties of products with pectin on the change in the internal strength of the gel and it was found that at the pH of 2.9-3.1, characteristic of most confectionery products, the ultimate strength of the gel from apple pectin is significantly higher than from citrus pectin.

W.G. Sganzerla *et al.* (2020) investigated the effect of gel pH on gelling properties when standardizing apple and citrus pectins using the USA-SAG method. At pH 2.0-2.3 (according to the standard method), the standard or gelling property of apple pectin is higher.

To improve the quality of bakery products, both in Ukraine and abroad, various fillers are used that affect the components of wheat dough and ensure the production of high-quality products. Surfactants are increasingly used as fillers to intensify the bread production process, improve the quality of bakery products, and preserve their freshness (Marque *et al*., 2020).

Currently, pectin and its derivatives are increasingly used in baking. In baking technology, such properties of pectin substances as swelling, viscosity, gelling property, regulating crystal formation, increasing water absorption, and emulsifying properties are important. The possibility of using various types of pectins in the preparation of bread – apple, citrus, beetroot – was investigated. It was found that the introduction of pectins into the dough affects the biological, colloidal, and microbiological processes of cooking. When pectin is added to the dough, its initial acidity increases and the pH decreases. The fermentation process in the dough is more active. Activation of the fermentation process is associated with the introduction of sugars together with pectin. When pectin is added to the dough, gluten is strengthened. Beetroot pectin, followed by apple and citrus pectin, has the most noticeable effect on strengthening the structural and mechanical properties of the dough. The introduction of pectin in bakery products not only improves the quality of finished products but also gives them medicinal properties. For the production of dietary wheat bread intended for binding and removing heavy metals from the body, it is advisable to use pectin products – fruit and vegetable powders, pectin extracts, and concentrates (Marque *et al.*, 2020).

Thus, the use of pectin and other pectin-containing products in baking can not only improve the quality of finished products but also expand the range of therapeutic and health-improving food products. A steady trend in the production of non-alcoholic beverages is an increase in the production of special-purpose beverages, which include beverages with the addition of biologically active components that have a health-improving effect on the human body. In the range of non-alcoholic products of therapeutic and health-improving action, more and more importance is attached to drinks enriched with pectin substances (Staubmann *et al.*, 2023). The limited range of therapeutic and health-improving pectin-containing beverages currently produced is explained by the acute shortage of pectin in the food industry, which was already mentioned above. Expanding the production of soft drinks enriched with pectin substances can be solved by mastering the production of pectin extract. For example, apple pectin extract produced by industry contains at least 0.5% pectin substances, easily digestible sugars (glucose, fructose), proteins, organic acids, and a complex of macro- and microelements (Staubmann *et al.*, 2023).

Water-retaining, complexing, and emulsifying abilities of pectin substances determine their use in the production of dairy, meat, and fish products of mass assortment and therapeutic and health-improving purposes.

Pectin substances are used as a stabiliser in the production of yogurt, mayonnaise, margarine, and butter. Pectin substances are also used in the production of dairy products to stabilise and increase their biological value. The use of dairy raw materials (whole and skimmed milk, buttermilk, whey) in combination with pectin concentrates facilitates not only the rational use of all milk components but also allows obtaining biologically healthy pectin-containing dairy products with good organoleptic characteristics, which solves the problem of expanding the range of milk-based products (Çilingir *et al.*, 2021).

Effective blocking of the intake of radionuclides in the body has led to the use of pectins in the manufacturing of sausage products. The introduction of pectin into sausage products not only increases their biological value but also improves quality indicators.

No less effective was the use of pectins in the production of fish products, in particular fish souffle. It was found that the introduction of pectin at a concentration of 0.5-0.9% not only improves the quality indicators of fish souffle but also increases its biological value, which allows recommending the developed product for therapeutic and health-improving nutrition (Bagal-Kestwal *et al*., 2019).

Analysis of Ukrainian and foreign literature shows that at present, a versatile and very significant experimental material on pectin polysaccharides has been accumulated. However, despite the huge number of studies devoted to the isolation of pectin substances from various sources (Palamarchuk *et al*., 2020), large-scale pectin production in Ukraine has not yet been implemented. This may be conditioned by many shortcomings of the developed technological schemes – the need for significant energy and capital expenditures, the high cost of acid-resistant equipment, and low profitability.

Thus, the search for new efficient, and cost-effective sources of raw materials for the production of pectin in Ukraine and the development of pectin technology is still an urgent task of the food and chemical industry.

The importance of pectin substances for human health

The human body is not able to use pectins as a source of carbon – they play a different role in it. Once in the human stomach, pectin swells and puts pressure on the walls, which produces a feeling of satiety. Thus, pectin is effective in the fight against excess weight. At the same time, pectin gel envelops the walls of the stomach, preventing acute exposure to many substances and the formation of ulcers (Albuquerque *et al*., 2022). In addition, pectins easily form complexes with hydroxyl-retaining compounds – cholesterol, glucose, bile acids, fatty acids, and substances of phenolic nature, contributing to their elimination from the body, thereby being an important preventive tool in the fight against hypercholesterolemia, hyperlipidemia, and diabetes mellitus. With a daily dose of 15 g of pectin for 2-3 weeks, bile excretion increases by more than 30%; cholesterol levels in the blood decrease by 13-15%. Modern researchers are also investigating the sorption properties of pectin substances from various sources (Wang *et al.,* 2019).

The paper (Souza *et al.,* 2020) presented the results of a series of experiments involving laboratory animals and discovered that a diet with the addition of amaranth and dietary fiber (pectin and cellulose) reduces cholesterol in the blood serum and liver. It was found that pectin can bind and remove lipids from the body, and in an amount 4 times higher than its weight (Li *et al.,* 2021). The specificity of this interaction is explained by the electrostatic nature of the generation of pectin complexes with low and very low-density lipoproteins (Chiu *et al*., 2022). Due to the formation of gel-like structures, pectin can adsorb on its surface and remove from the body not only excess cholesterol but also other substances formed during vital activity (enzymes, products of bacterial origin, products of bile acid breakdown, etc.). One possible mechanism for lowering cholesterol in the blood when pectin is included in the diet is the binding of bile acids, which are products of cholesterol metabolism. This binding probably occurs due to the appearance of calcium bridges between the carboxyl groups of pectins and bile acid molecules (Bermúdez-Oria *et al*., 2021).

Having a moisture-binding ability (in some cases up to 100 volumes per 1 volume of pectin) and at the same time sharply increasing in volume, pectin, along with other dietary fibers, improves the motor-evacuation function of the digestive canal and has a normalising effect on the intestinal microflora. Thus, pectins facilitate normal intestinal motility. The possibility of using pectin for the treatment of hypertension was also investigated. It was found that with oral administration of pectin 0.5-1.0 g 3 times a day in patients with stage 1 and 2 of the hypertension disease, a persistent (for 4-10 months) decrease in blood pressure and improvement in general condition were observed. Pectin is particularly effective in combination with ascorbic acid (Kruger *et al.*, 2020). The affinity of pectin for phenols makes it an excellent dosage form when taking vitamins P: quercetin, rutin, robinin, and other flavonoids that are poorly soluble in water. Another phenolic compound, aspirin, in combination with pectin penetrates faster into the blood and irritates the stomach wall less (Mercado-Mercado *et al.*, 2020).

Skin ointments containing sulfur, salicylic and boric acids are prepared based on pectins (Hosseini *et al.*, 2020). Pectin acid in the intestine forms salts not only with metals but also with highly toxic nitrogenous bases generated during the decomposition of amino acids by the intestinal microflora (ammonia, putrescine, cadaverine, neuron, indole, skatole). Pectins from alkaloid plants (tobacco, rauvolfia) are produced in the form of salts with alkaloids. Tobacco nicotinate can be used to produce alternative smoking pills (Hosseini *et al.*, 2020)

Japanese researchers reported the formation of natural pectin salt with alkaloids (dimeric morphine) in the fruits of sleeping poppies *(Papaver somniferum)* (Wang *et al.*, 2022). Unlike the original pectin, such a salt, in which alkaloid molecules act as bridges that cross macromolecules of pectin, is resistant to the action of pectinolytic enzymes released by phytopathogenic fungi. This cross-linked pectin is a barrier to fungal infections entering the plant. Pectin acid also has a pronounced bactericidal activity, being an important regulator of the level of bacterial contamination of the intestine. Carbohydrate residues in pectin macromolecules are homologous to bacterial cell ligands for intestinal epithelial receptors. The interaction of pectin and bacterial cells thus blocks the ability of the latter to adhere to the intestinal wall.

Pectin acid is the least toxic antibiotic for the human body, does not cause allergies, does not have the maximum permissible concentration, and does not cause dysbiosis – the normal intestinal microflora is insensitive to it. Moreover, good results were obtained in the study of kiwi pectins as probiotics (Shen *et al.*, 2019).

The hemostatic activity of pectins is known: being coagulants, they exhibit a hemostatic effect. In the presence of pectin, blood clots one and a half to two times faster (Wang *et al.*, 2021). The combination of hemostatic and bactericidal properties makes pectin an excellent wound-healing agent (Wang *et al.*, 2021). Pectins do not cause erythrocyte sedimentation, so a 0.75% aqueous solution of highly purified pectin is used as a substitute for blood plasma, which is more effective than saline.

Based on the results of the study (Brito *et al.*, 2019) it was found that pectin preparations have a pronounced hemostatic effect, which is characterised by a certain chemical composition: the degree of esterification, molecular weight, the content of acetyl groups, the pH of a 1% aqueous solution (Kazemi *et al.*, 2019).

An even more promising substitute for plasma is a preparation based on pectin acid ester (Cho *et al.*, 2019; Brito *et al.*, 2019). Pectin sulfate, on the other hand, inhibits blood clotting like natural poly heparin saccharide sulfate. Pectin sulfates also inhibit the activity of hyaluronidase enzymes in some diseases that destroy connective tissue in the body (Kazemi *et al.*, 2019; Kruger *et al.*, 2020). Pectin sulfate esters are also applicable as anti-inflammatory agents.

American oncologists have proven that pectin forms a strong complex with cancer cells

(Chauhan *et al*., 2020). It is assumed that galactose sequences on pectin macromolecules are specific to protein complexes on the surface of cancer cells responsible for adhesion to healthy tissues. Rhamnogalacturonan I has the greatest antimetastatic effect (Chauhan *et al*., 2020). The ability to inhibit the proliferation of malignant cells was found in citrus pectin (Prado *et al*., 2019).

Pectins dramatically activate the immune response (Su *et al*., 2023). Pectins from angelica, Eleutherococcus, hollyhock, astragalus, marigold, mullein, plantain, stinging nettle, and many other plants stimulate supplements and promote the production of interleukin-2. The antiviral effect of tragacanth gum from Astragalus can be explained by this. This gum at a dose of 3.2-100 mcg/kg of body weight completely protects mice from infection with cytomegalovirus (Frediansyah, 2021). More recently, pectin has been isolated from the leaves of *Aspalathus linearis*, which inhibits the reproduction of HIV, again affecting the human immune system (Webster *et al*., 2019).

At the Nutrition Research Institute (Washington), studies were conducted on screening pectin drugs for the relief of toxic pulmonary oedema with nitrogen dioxide. The most effective product purified by diafiltration is obtained from beet pectin (Teaford *et al*., 2020).

The Centre for Preventive and curative nutrition (Prague) developed a method for treating obesity using diet therapy in combination with a protein-pectin complex (Yang *et al*., 2021). Pectin derived from hollyhock is a fairly strong antitussive agent (Ciriminna *et al*., 2020).

The most important factors for obtaining high-quality pectin are the purity of raw materials and their chemical composition. To ensure the quality of pectin, it is necessary to use high-quality raw materials and control production processes, this area of research will be presented in the following publications.

The papers of many Ukrainian and foreign researchers are devoted to the investigation of methods for obtaining pectin from a variety of pectin-containing plant raw materials. The papers mainly cover studies on the extraction of pectin from various plant raw materials using reagents of various origins (Sukhenko *et al.,* 2019), but too little attention is paid to the analysis of the raw material base for its production.

Some Ukrainian and foreign enterprises receive juice from pumpkin pulp, which is used in the food industry. This leads to a significant amount of waste in the form of pumpkin pomace, which contains a variety of biologically active substances such as vitamins, carbohydrates, polysaccharides, and fatty acids, which can be a promising source for their production. However, today enterprises dispose of pumpkin waste (pomace from the pulp is thrown away, and meal from seeds is sometimes used for feeding livestock) (Palamarchuk *et al.,* 2022). It is known from literature sources that the mass fraction of pectin substances in pumpkins range from 10% to 20%. Therefore, the technology of obtaining pumpkin pectin, as well as grape pectin, needs further study and improvement.

Extracting pectin in its pure form from plant raw materials is impractical and very difficult, especially in certain cases. In the process of such extraction, all multivitamins that are inherent in this raw material are lost (Su *et al*., 2023). Therefore, to completely and efficiently remove pectins from plant raw materials, it is necessary to solve many problems. One of the important tasks is to maintain the optimal temperature during the process since pectin belongs to macromolecular compounds and does not melt. However, when the temperature reaches more than 90°C, it begins to decompose, its molecular weight decreases, and its ability to bind toxic substances and heavy metals is lost (Shen *et al*., 2019). Therefore, it should be highlighted that pectin can not be boiled. This is especially important when choosing equipment for the hydrolysis of plant raw materials.

Another important task in the production of pectin pastes is the mechanical purification of pectin extract from solid microparticles since the presence of foreign impurities can affect the quality of the finished product – its color and taste. For this purpose, filtration or centrifugal cleaning is most often used.

In addition, pectin-containing raw materials should not contain sugars that can be reduced, as this can lead to the formation of dark compounds, such as melanoidin, which complicate the process of lightening pectin extract. Therefore, the residual sugar content during the production of pectin pastes should be minimal, as this is an important requirement for obtaining light products. The main properties of pectin-containing substances that must be considered in the production of pectin-containing pastes are as follows: solubility, viscosity, gelling power, and complexing ability. Equally important factors are the establishment of optimal operating modes of production processes: the ratio of dry substances to the liquid phase, pH of the medium, temperature, and time. These conditions may be different for different raw materials and their physical and chemical state.

Based on the realities of today, pectins have gained special importance in the last three decades, when information appeared about the ability of pectin to form complexes and remove lead, copper, mercury, zinc, cobalt, molybdenum, radionuclides cesium-137, strontium-90, radium, etc. from the human body. Pectin substances also can absorb and remove biogenic toxins, analytics, xenobiotics, pesticides, metabolic products, and biologically harmful substances that can accumulate in the human body. Pectin substances can also have a positive effect on the content of cholesterol, bile acids, urea, mast cell products, and toxin-forming fungi. Researchers around the world are studying the properties of pectin, discovering more and more of its healing qualities.

Because pectin is based on galacturonic acid molecules, it is a unique biologically active product with health-improving and radioprotective properties (Albuquerque *et al*., 2022). Pectin substances are used to treat diabetes mellitus, atherosclerosis, and hemophilia, in the healing of wounds and burns, and in the treatment of bacterial infectious diseases of the gastrointestinal tract. As a component of plants, pectin substances have always been components of food since the origin of man. According to the World Health Organisation, pectin substances are recognised as absolutely toxicologically safe food products. There are no restrictions on their use and they are recognised in most countries of the world as valuable food products (Sukhenko *et al.,* 2019).

Pectins are currently one of the most demanded and widely used food ingredients due to their multifunctionality in the world of pectin, also known by the code name E-440 (Chiu *et al*., 2022). On the one hand, dietary fibers are used as technological additives that can change the structure and chemical properties of food, and on the other hand, dietary fibers are excellent functional ingredients that can favorably affect individual systems and the entire human body.

Conclusions

In the current environmental situation, especially in Ukraine, there is an urgent need for healthcare products, among which pectins occupy a special place. Evaluating modern achievements in the study of pectin production, it can be stated that pectins are a unique product that has gained a strong place in modern food technologies. At the same time, it has a wide range of biological activities.

Pectins are used for therapeutic and preventive purposes – in the treatment of diabetes, atherosclerosis, heart ischemia, and diseases of the gastrointestinal tract, they increase the body's resistance to allergies, normalise the amount of cholesterol, and are used as regulators of metabolic processes in the human body. In the literature, there are data on the effectiveness of pectins in the treatment of cancer tumors. Thus, modern research allows expanding the scope of application of pectin substances, which leads to an increase in market demand for pectin.

Based on the results of the study, the main physicochemical, structural, and biological properties of raw materials of plant origin for the synthesis of pectins isolated from various types of traditional and unconventional raw materials are analysed. The possibilities of using pectins in the food industry for lightening whey, improving the quality of bread, and making functional products that have a therapeutic and health-improving effect are revealed.

It is established that at the present stage of development of industrial production, manufacturers are faced with the task of developing and applying new technologies for the production of pectin and pectin pastes with high biological value, which will provide for minimal impact on their natural properties and will not disrupt the balance of the main components. The use of pectin will increase immunity and avoid many diseases in the human body, and the development and introduction of new varieties of pectins in industrial production will expand the range of useful and inexpensive food products with unique properties.

The combination of different types of pectins from raw materials of plant origin can contribute to the creation of completely new products or dosage forms with improved properties, open up new markets for export, and create new jobs in the post-war period. Possible areas for further research in the context of this problem may be the following: the investigation of the influence of plant growth factors and processing on the content and quality of pectin, the use of new methods of analysis and quality control of pectin, the study of the use of industrial waste for obtaining additional products, the improvement of purification and refining of pectin, the study of the possibilities of using genetically modified organisms for the production of pectin, or the use of enzymatic processes to increase the yield of pectin.

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Conflict of Interest

None.

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Аналіз сировинної бази для виробництва пектину

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Анотація. Додавання пектину в харчові продути має важливе значення оскільки цей природний полісахарид відіграє важливу роль у покращенні якості та стійкості продукту, він дозволяє якісно зберігати продукти, які мають тривалий термін зберігання, що важливо для збереження здоров'я та добробуту споживачів. Метою дослідження є вивчення основних сировинних джерел рослинного походження для синтезу пектину, які можуть бути використані в якості перспективної сировини для підприємств харчової промисловості України. Дослідження проводили з використанням різноманітних методів аналізу, проведено ґрунтовний порівняльний аналіз наукових праць вітчизняних та закордонних вчених, які розміщено в наукометричних базах Scopus, Web of Science, Journal Citation Reports, Scimago Journal & Country Rank та Google Scholar. За результатами аналітичних досліджень, було проведено аналіз основних сировинних джерел, які використовуються для виробництва пектину та пектиновмістних паст, встановлено основні проблеми технологічного процесу виробництва. Встановлено, що додавання пектину в харчові продукти може мати значну кількість, переваг: збільшення в'язкості продукту, що корисно для створення густого текстури продукту; підвищення стійкість продукту до термічної обробки, зменшуючи ризик розділення продукту або зниження якості; збільшення функціональності, введення в продукти може допомогти покращити консистенцію та вигляд продукту, додати смак та кольорові властивості та знизити кількість цукру, який потрібно додавати до продукту для забезпечення в'язкості та смаку. Встановлено, що основною сировиною для виробництва пектину в Україні є плоди яблук. Доведено, що пектин можна отримати з інших фруктів, ягід та овочів, таких аґрус, смородина, вишня, гарбузи та інші. Інтенсифікація процесу виробництва пектину повинна забезпечити населення якісним продуктом, що дозволить запобігати різного типу інтоксикаціям, шляхом виведення з організму радіонуклідів і сприятиме оздоровленню людей у післявоєнний час. Практичне значення цього дослідження полягає в можливості допомогти виробникам знайти оптимальні джерела сировини, які мають високий вміст пектину, з метою забезпечення якості кінцевого продукту. Крім того, це дослідження також дозволить розробити відповідні технологічні рішення для оптимального процесу виробництва пектину з вибраної сировини

Ключові слова: продукти харчування; термін зберігання; пектинові пасти; рослинна сировина; процес виробництва