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SECONDARY PLANT RESOURCES AS PROSPECTIVE UNCONVENTIONAL SOURCES OF PECTIC SUBSTANCES

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Abstract. The secondary raw materials have been studied as sources of pectic substances necessary for the endo-ecological protection of the organism in the globally deteriorating living conditions of modern humans. The article reveals the significance and long-term benefits of such sources of pectic substances as fruit and seed coats, which are obtained in considerable quantities as a secondary raw material during the implementation of the technological process, and often do not find rational use. Research has been carried out on new prospective sources of pectin substances – secondary resources of processing soybean Glycine max (L.) Merrill, sainfoin Onobrýchis arenária, rapeseed Brassica napus L. oleifera, Sarepta mustard Brassica juncea (L.) Czern, and black mustard Brassica nigra (L.) W.D.J. Koch, castor bean Ricinus communis L., sunflower Helianthus annuus L. Fruit and seed coats of these plant species have been studied. The prospects of their secondary resources for pectin production have been shown. The assessment of the quantitative and qualitative characteristics of the pectic substances of the objects under study, as well as their fractional composition and analytical indicators, make it possible to characterize the potential functional, technological and therapeutic properties of pectin preparations. It has been indicated that in the polyuronid component (fraction of galacturonic acid), all the studied samples of surface tissues of soybean, mustard, sainfoin, sunflower, one rape variety meet international requirements for food pectin (52.87–73.22%), and one of them, the pectin from seed coat of the Valenta variety, meets the requirements for pectins for medical purposes (75.83%). Pectic substances of soybean, mustard, castor bean varieties are characterized by a high degree of esterification (62.37–76.88%) in contrast to the varieties of sainfoin and sunflower (45.29–55.15%). According to the degree of esterification, rape varieties are close to low-esterified pectic substances – 59.34–61.48%. The prospects of using seed and fruit membranes as an unconventional secondary plant raw material to improve the environmental performance of production and to obtain a valuable therapeutic-and-prophylactic food ingredient have been substantiated.

Key words: pectin substances, fruit membranes, seed membranes, soy beans, mustard, esparset, rape, sunflower.

ВТОРИННІ РОСЛИННІ РЕСУРСИ – ПЕРСПЕКТИВНІ НЕТРАДИЦІЙНІ ДЖЕРЕЛА ПЕКТИНОВИХ РЕЧОВИН

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Анотація. Досліджено вторинні сировинні ресурси як джерела пектинових речовин, необхідних для ендоекологічного захисту організму у глобально погіршених умовах життя сучасної людини. Показано значимість і перспективність таких джерел пектинових речовин, як плодові і насіннєві оболонки, які в значних кількостях отримують в якості вторинної сировини при реалізації технологічного процесу і часто не знаходять раціонального застосування. Проведено дослідження нових перспективних джерел пектинових речовин – вторинних ресурсів переробки сої Glycine max (L.) Merrill, еспарцету Onobrýchis arenária, ріпаку Brassica napus L. oleifera, гірчиці сарептської Brassica juncea (L.) Czern і гірчиці чорної Brassica nigra (L.) W.D.J. Koch, рицини звичайної Ricinus communis L., соняшнику Helianthus annuus L. Досліджено плодові і насіннєві оболонки наведених видів рослин. Показана перспективність їх вторинних ресурсів для отримання пектину. Оцінка кількісних і якісних характеристик пектинових речовин досліджуваних об'єктів, а також їх фракційний склад і аналітичні показники дозволяють характеризувати потенційні функціонально-технологічні та лікувально-профілактичні властивості пектинових препаратів. Показано, що за поліуронідною складовою (частці галактуронової кислоти) всі досліджені зразки покривних тканин сої, гірчиці, еспарцету, соняшника, один сорт ріпаку відповідають міжнародним вимогам до харчового пектину (52,87–73,22%), а один з них – пектин з насіннєвих оболонок сорту Валента – вимогам до пектину для медичних цілей (75,83%). Пектинові речовини сортів сої, гірчиці, рицини характеризуються високим ступенем етерифікації (62,37–76,88%) на відміну від сортів еспарцету і соняшнику (45,29–55,15%). Сорти ріпаку за ступенем етерифікації близькі до низькоетерифікованих пектинових речовин – 59,34–61,48%. Обгрунтовано перспективність застосування насіннєвих і плодових оболонок в якості нетрадиційної вторинної рослинної сировини для підвищення екологічності виробництв і отримання цінного лікувально-профілактичного харчового інгредієнта.

Ключові слова: пектинові речовини, плодові оболонки, насіннєві оболонки, соя, гірчиця, еспарцет, ріпак, соняшник.

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Introduction. Formulation of the problem

The work is aimed at studying secondary raw plant resources as potential sources of pectic substances with different functional and technological properties.

A strategic course in the field of healthy nutrition is the development of food production, providing of protective, health-improving, therapeutic-and-prophylactic products. The leading position among effective natural biological sorbents of toxic compounds of food products is occupied by a plant-based high-molecular polysaccharide – pectin, which has a wide range of complexing, gel-forming and radioprotective properties [1-3].

All over the world, there is currently a stable need for an increase in the volume of production of pectin as a natural food additive with a pronounced functional and physiological orientation, which is registered in the international classifier with the number E 440. The pectin industry that exists abroad allows obtaining its various modifications from traditional raw materials – apples, citruses, sugar beets, sunflowers and waste from their processing, but the volume of production of these products is insufficient [3]. This fact makes it essential to search for new raw sources for the pectic substances production, to increase the environmental friendliness of food production due to both more advanced processing and rational use of secondary resources [4,5]. Integumentary tissues of fruits and seeds of various agricultural crops processed for food needs are potential secondary raw materials for pectin production [6,7]. The expansion of the raw material base for the production of pectin is an active area of research in the direction of searching for unconventional sources of its production, which is especially important in the processing of secondary raw materials.

Thus, research aimed at studying the quantitative and qualitative characteristics of pectic substances contained in fruit and seed coats, which do not find rational use in the food industry, is relevant and promising and has scientific and practical value.

Analysis of recent research and publications

The covering tissues of fruits and seeds in most cases become waste of food and technical industries. Only a few of them have acquired value as secondary raw materials. Most often, this material is not efficiently utilized − it is ploughed into the soil as a source of organic matter or burned as fuel, much less often they are used in the hydrolysis industry or for the production of activated carbon. Meanwhile, the covering and protective functions performed by these tissues cause a high content of pectin substances in the composition of the structural components of the cell walls, which forms their strength characteristics. Due to the high volumes of world production and processing of various citrus fruits, sunflower and cotton, the pectin-containing raw material base is widely represented by the rind of citrus fruits, the sunflower anthodia, and shells of cotton bolls. Technological schemes for producing pectin from these raw materials are repeatedly described in domestic and foreign publications [3,6,8,9].

Up to 60% of the global volume of pectin production is represented by citrus, which is widely used in food technology as a gelling agent. This raw material is typical mainly of the countries of the Mediterranean and the American continent. The content of pectic substances in the peel of citrus fruits is in the albedo (white loose internal layer) and the flavedo (coloured dense outer layer), respectively: orange – 20.5% and 11.5%; lemon – 29.9% and 24.6%; mandarin – 9.3% and 6.8%. Moreover, in the peel of mature fruits, more than 50% of the total amount of pectic substances is in the form of protopectin, which characterizes this raw material as technologically valuable [6].

A large number of fruit coats of cotton received annually in cotton-growing countries during its processing are not used rationally. The mass of this type of cotton waste in the Central Asian region alone is about 2.5 million tons. The proportion of cotton fruit coats in the total waste of the industry reaches 45–50%, the content of pectin substances in them is 8.0–15.2%. Studies conducted in different years allow us to consider cotton boll shells as fully functional and promising pectin-containing raw materials for organizing the production of pectin on an industrial basis. The yield of pectin at the same time can reach 8.3–8.5%, according to its physico-chemical parameters, it can be assigned to the group of gel-forming substances [10].

As a potential source of pectin, some authors suggest the use of coffee fruit shells, the proportion of which is 10–15% of the coffee bean weight. The amount of pectin contained in the absolutely dry mass of this raw material varies from 2.4–10.1% to 29.74%. At the same time, there is a rather high ratio of protopectin to the sum of pectic substances (67.4–80.9%) with a high total amount, which indicates the availability of raw materials for industrial processing. A comparative analysis of the methoxyl component became the basis for conclusions about the high gelatinous ability of pectin obtained from the shells of coffee beans [11].

Pomegranate on the territory of Azerbaijan is the second largest fruit crop. Azerbaijani researchers have studied the characteristics of pectin contained in the pomegranate peel, which are obtained in large quantities during processing of fruits. The share of the pomegranate peel of most cultivars varies between 27.9–51.8%. The yield of pectin during extraction averages 4.5–5.0% of the total dry mass of the peel. Analysis of its physicochemical characteristics showed its high gelling ability [3,12].

Affordable and cheap raw materials for industrial production of pectin on the territory of Eastern European countries are sunflower anthodia, which are harvested during the season of harvesting seeds. Although botanically they are not fruit coats, they are very close to them in function and morphological characteristics. The concentration of pectic substances in this type of raw material ranges 22.0–35.7% of the air-dry weight. It has been established that, according to the content of pectic substances, they are most valuable for the industrial production of the sunflower variety with large anthodia. The weight of dry sunflower anthodia is 50–60% of the seed yield. The share of protopectin is up to 75% of the amount of pectic substances of this raw material. Sunflower pectin has the potential of high gel-forming ability, but it is not without a number of shortcomings, such as the phenomenon of self-coagulation, which complicates the process of isolating it from the extract, the characteristic resinous smell and taste that goes over to the products produced on its basis [13,14].

The integumentary tissues of other fruits and seeds are obtained in smaller volumes, which is the reason for the rare interest of researchers working in this field. However, one of the most important areas of increasing the production of marketable pectin is the expansion of the raw material base of pectin-containing raw materials through exploration in the direction of non-traditional raw materials and the development of new ways to produce pectin products from them. In this regard, in different years, fruit casings of such raw materials as castor bean, tung and black walnut, which proved to be a very valuable promising source of pectic substances for technical and technological purposes, were investigated [11,12].

Secondary raw materials for obtaining oil from tung fruits are fruit coats, which account for 37–44% for Ford tung and 31–46% for Cordata tung. The mass fraction of pectic substances in this secondary raw material reaches 28.5% based on dry weight. The physico-chemical characteristics of pectin from the fruit shell of the tung indicate its ability to become gelatinous.

In the secondary raw material from the black nut, the sum of the fractions of pectic substances in the pericarp is 4.2 %. The ratio of the share of protopectin to the total amount of pectic substances for the black walnut pericarp averages 75.24% [11,12]. Although the surface tissues of the fruits of these cultures studied are characterized as potential sources of pectic substances, they are not of production interest due to low volumes of fruit harvesting.

The leaders in global gross production among the listed plants are soybean (250 million tons per year), castor bean (60 million tons per year), sunflower seeds (53 million tons per year), mustard (23 million tons per year) and the rate of increase in their production convinces that in the coming years it will only grow [15,16].

In this regard, the fruit and seed coats of a wide range of cultivated and processed crops must be investigated for the quantitative and qualitative composition of the pectic substances contained in them, and the research should result in recommendations on appropriate technologies for processing secondary raw materials of these crops.

The purpose of the work is to study the secondary resources of the processing of plant raw materials to assess the prospects of their use as a source of pectic substances.

To achieve this goal, it is necessary to perform the following **objectives**:

1) to monitor the sources of secondary raw materials in the processing of plant crops to obtain pectin substances;

2) to select and characterize the objects of study from the number of modern varieties of food and industrial crops;

3) to investigate the quantitative and qualitative characteristics of the pectin complex of fruit and seed coats of the selected types of secondary raw materials;

4) to make preliminary predictions and recommendations on the direction of using pectic substances extracted from the objects studied.

Research materials and methods

Objects of study. To select the objects of the study, monitoring was carried out for various types of secondary plant materials, which were studied but little as a potential source of pectic substances in the raw material. The assessment of the main quantitative and qualitative characteristics of the pectin complex of secondary resources for processing the studied raw materials was carried out for the selected promising varieties of food soybean Glycine max (L.) Merrill bred by the FGBNU VNIIMK: Vilana, Fora, Vesta, Valens [17] and the Institute of Plant Physiology and Genetics of the National Academy of Sciences of Ukraine: Adamos, EU Mentor, Khortitsa (IFRG NAS of Ukraine (Kiev)), Sarepta mustard (Dyzhonka 329 and winter Novynka) Brassica juncea (L.) Czern, mustard black Brassica nigra (L.) W.D.J. Koch (Sofiia), rapeseed Brassica napus L. oleifera: Felter CL, Buchatsky, sainfoin Onobrychis Mill breeding FSBI "NCP named after P. P. Lukjanenko": Krasnodar 84, Krasnodar 90, Chelbas, Alex [18] and Sandy sainfoin 1251, sunflower Helianthus annuus L: Milonga, LG 5635, castor bean Ricinus communis L: Khortychanka, Khortytska 1 [19]. All objects of research have successfully passed the state crop variety trials and entered into the State registers of plant breeding achievements.

Experimental procedure. When evaluating the values of the parameter of the mass fraction of the shell in the composition of fruits and seeds, the weight method was used. A micrometer was used to determine the thickness of the soybean seed coat of the studied varieties [12].

The following research methods were used for the analytical characteristics of pectin substances of fruit and seed coats of the studied secondary raw materials: mass fraction of pectin substances – by the titrimetric method, in accordance with DSTU 8069: 2015 and the calcium-pectate method of analysis commonly used in pectin production, based on weight accounting for calcium salts of pectic acid, followed by polygalacturonic acid. For this purpose, two proprietary methods were also used – the weight method and reverse conductometry [14]. The polyuronide composition of the pectin under study was determined by the titrimetric method, in accordance with DSTU 6088:2009, the total degree of esterification, the total content of carboxyl, free carboxyl and carboxyl groups esterified with methanol, and the acetyl and methoxyl components of pectin – by the conductometric method [20,21].

Extracts for the isolation of the analysed samples of pectin were prepared according to the methods developed by us. To obtain an extract from the soybean fruit coat, the material was washed with cold drinking water, then dried and crushed to 1–4 mm, purified from impurities, and then hydrolysis-extraction was performed with a 0.3 % solution of succinic acid at a temperature of 80–85ºC and a water ratio of 1:10 for 120 min; at the end of the process, the liquid phase was separated [3,22].

To obtain pectin extracts from the studied samples, the seed coat of soybean and rapeseed underwent a similar procedure, carrying out the hydrolysis-extraction of raw materials with a 0.3% solution of a mixture of succinic and citric acids at a water ratio of 1:15.

To obtain pectin extract from crushed and dried shell-husk of sunflower, the technology traditional for this type of raw material was used [3].

To obtain extracts from sainfoin shells and mustard varieties, the samples were dried, crushed to particle sizes of 1–4 mm, impurities were removed, and then pectin substances were extracted and hydrolysed with a 0.3% citric acid solution at a water ratio of 1:12 and a temperature of 85–90ºC; the duration of the process was 120 min [3,23].

From the obtained samples of the extract, the entire pectin was precipitated by coagulation with ethyl alcohol or acetone, followed by centrifugation [3].

The functional properties of the pectin substances of the samples of raw materials were evaluated by examining their analytical characteristics and by indirect conductometry [20].

Results of the research and their discussion

At the first stage of the described studies, the yield of integumentary tissues during the processing of fruits and seeds of selected crops was evaluated. For the seed coats of soybean, their thickness was additionally determined, since the potential of the studied raw materials entering the pectin production enterprises can be estimated if there is a relationship between the values of the mass fraction of the seed coat of soybean, its thickness and the content of pectic substances in it (Tables 1, 2).

Table 1 – Some quantitative characteristics of the seed coat and soybean seeds

Cultivar	Characteristics of the seed coat		Mass of 1000 seed, grams
	Mass fraction, %:	Thickness, 10^{-6} м	
Vilana	11.51	0.108	163
Fora	5.75	0.099	270
Vesta	9.25	0.116	230
Valenta	8.66	0.117	216
Adamos	7.45	0.105	174
EU Mentor	10.31	0.112	130
Khortytsya	6.54	0.095	191

The leader in the number of detachable seed coat is the Vilana variety. The maximum thickness of seed cover among the studied varieties was found in the Valenta variety. Knowing the natural indicators of the mass of 1000 seeds, according to the regression equation $y=0.0117x+0.0021$, the coefficient of reliability $R^2=0.9951$, it is possible to calculate the predicted amounts of pectic substances in the material under study.

During the processing of raw materials, the fruit coats of soy are formed in much smaller quantities, since the bulk of them remains in the field during the main hulling in the course of harvesting with a combine. The accuracy of the settings of the systems of the combine determines the quality and completeness of separation of the seeds from bean shells and the removal of their fragments from the heap. When seeds received by the enterprise are being cleaned from organic weed impurities and their hulling is being completed, no more than 3–5% of fruit coats is left. Thus, this material cannot become a strategic type of raw material for pectin production; however, its use as an additional source of pectic substances with valuable functional properties is quite acceptable.

Considering the different degrees of heterogeneity of the structure of the fruit coats of other crops studied, and the pronounced relief of their inner and outer surfaces, it is not possible to give a reliable estimate of the thickness of their shells. The mass fraction of seed casings was: for the Sarepta mustard varieties (hot and winter) Brassica juncea (L.) Czern – 8.4% to 10.3%, black mustard Brassica nigra (L.) W.D.J. Koch – 6.8 to 9.5%, rape Brassica napus L. oleifera – 12.4% to 16.3%, sunflower Helianthus annuus L. – 21.7 to 29.5%. The mass fraction of the seed coat of sainfoin has not been evaluated, because at present the raw material of this crop is new and promising, it does not have widespread use in the food industry, and therefore the technological scheme for processing seeds with shell separation has not been developed and the raw material is processed after hulling the surface tissue of the fruit [24].

Signs of raw materials technologically significant for pectin production, causing differences in the technological parameters of extracting pectin, are the parameters of the fractional composition and the amount of the estimated fractions of pectic substances, as well as the ratio of fractions. That is why at the next stage we evaluated these parameters for fruit and seed coats of the studied varieties of secondary raw materials (Table 2).

Table 2 – Mass fraction of pectin fractions and their ratio in soybean and sainfoin varieties

Sample	Fractional composition of pectic substances (absolutely dry mass), %:			The share of individual fractions in the composition of pectic substances	
	soluble pectin	protopectin	Fractions in total	protopectin / soluble pectin	protopectin / fractions in total
Soybean fruit shell					
Sortosmes (Vilana, Fora, Vesta, Valenta)	5.11	14.30	19.41	2.80	0.74
Soybean seed coat					
Vilana	0.51	1.34	1.85	2.60	0.72
Fora	0.51	1.68	2.20	3.30	0.76
Vesta	0.34	1.74	2.10	5.10	0.83
Valenta	0.35	1.55	1.90	4.49	0.81
Adamos	0.42	1.79	2.21	4.26	0.81
EU Mentor	0.38	1.29	1.67	3.39	0.77
Khortytsya	0.54	1.63	2.17	3.02	0.75
Sainfoin fruit shell					
Krasnodar 84	6.20	10.10	16.30	1.63	0.61
Krasnodar 90	7.80	11.50	19.30	1.47	0.59
Chelbas	5.92	13.22	19.14	2.23	0.69
Alex	5.47	12.90	18.37	2.36	0.70
Sandy 1251	5.21	12.05	17.26	2.48	0.70

The data in the table indicate that the seed coats of the raw material of the soybean varieties Fora and Adamos are characterized by the highest value of total pectin fractions in comparison with other studied varieties. With a slightly lower value of this parameter, according to other characteristics (the proportion of protopectin in the composition of the sum of pectic substances and in relation to the soluble fraction), the raw material of the soybean variety Vesta differs favourably. In general, a high proportion of the protopectin fraction in the sum indicator is characteristic of all surface tissues of the raw materials of the cultures studied in the work (the values of this parameter from 70% and higher are significant for the pectin technology).

From the whole amount of data in Table 2, the maximum value of all the studied parameters is that of the fruit shell of soybean. Somewhat lower are their values of the fruit coat of sainfoin. The Alex and Sandy 1251varieties of sainfoin have the most favourable combination of the characteristics under evaluation.

From the results, it follows that the seed coat of soybean is not high in pectin compared to other objects studied. However, taking into account the global volume of production and processing of soybean grain, which determines the quantity and uninterrupted supply of material, the importance of seed coats for pectin production is obvious.

The results of the study of the mass fraction of pectic substances in other types of secondary raw materials make it possible to arrange them in descending order as follows: sunflower, castor bean, rape, mustard, with a significant proportion of protopectin in them – 58 to 73%.

Note that the studied parameters relate to the quantitative characteristics of the studied raw materials, forming the technological and economic components of pectin production. Other equally important information will be obtained if we determine the analytical characteristics of the pectin substances studied, with which you can make a prediction of a number of properties that are potentially characteristic of the samples under investigation from an extremely small amount of pectin powder. Among others, information can be obtained on the degree of solubility, the ability to form jellies or complexes with other substances, the conditions for the manifestation of their characteristic properties, and the directions of applicability of the pectin studied in accordance with the functional properties of the samples. Therefore, at the final stage of the work, these indicators were evaluated and interpreted.

For pectic substances isolated from the fruit and seed coats of soybeans of the studied varieties, the values of their analytical characteristics are given in Table 3.

As follows from the data given in Table 3, the values of the indicators of the total degree of esterification and the acetyl component are at a fairly high level for all samples of surface tissues of soybean fruits and seeds. The degree of esterification determines the linear charge density of the macromolecule, and, consequently, the strength and method of communication of cations. Since the carboxyl groups of galacturonic acid residues in the composition of the pectin molecule, in quantities exceeding 50% of the total number of these functional groups esterified with methanol, determine its gelatinous ability, we should note the gelation potential of pectic substances of the studied samples. In addition, these values of the degree of esterification indicate a good solubility in water of pectins in all the samples studied.

However, a sufficiently high amount of free carboxyl groups in the pectin molecule of the seed coats of soy indicates a possible ability to form complex compounds with metal ions. The jellies will be formed in the presence of calcium ions in the solution. Pectin from soybean fruit coats is highly esterified, with a low content of free carboxyl groups, and such pectins are characterized by acid-sugar type of jelly.

For pectic substances isolated from the shells of sainfoin of the studied varieties, the following parameters of their analytical characteristics are given in Table 4.

Table 3 – Varietal characteristics of the composition of the pectin substances in fruit and seed coats of soybean

Parameters	Parameter values by sample, %:							
	Fruit coat, mixed varieties	Seed coat by varieties						
		Vilana	Fora	Vesta	Valenta	Adamos	EU Mentor	Khortytsya
Total content of carboxyl groups	9.95	10.26	8.98	8.54	9.07	10.45	8.24	9.67
Content of free carboxyl groups	2.3	3.43	2.50	2.48	2.75	3.90	2.13	3.02
Carboxyl group content neutralized by ammonia	–	1.42	1.10	0.95	0.91	0.93	0.90	0.92
Carboxyl group content esterified with methanol	7.65	5.41	5.38	5.11	5.41	5.62	5.21	5.73
General degree of esterification	76.88	66.57	72.16	70.96	69.68	72.41	71.51	68.23
Degree of esterification with methanol	76.88	52.73	59.91	59.17	59.65	58.37	58.43	59.12
Degree of neutralization with ammonia	–	13.84	12.25	11.12	10.03	14.04	13.08	9.11
Polyuronid component	67.52	65.30	73.22	71.04	75.83	64.27	70.52	68.75
Acetyl component:								
of the weight of pectin powder	–	1.36	1.05	0.91	0.87	0.95	0.79	0.97
of the weight of pure pectin	–	0.94	0.65	0.58	0.52	0.61	0.56	0.67
Methoxy component:								
of the weight of pectin powder	5.27	3.73	3.71	3.52	3.73	3.57	3.38	3.56
of the weight of pure pectin	3.51	2.57	2.28	2.23	2.21	2.30	2.39	2.45

Table 4 – Analytical characteristics of pectin substances in sainfoin shells of various varieties

Parameters	Values of the parameters for the samples, %, variety:				
	Krasnodar 84	Krasnodar 90	Alex	Chelbas	Sandy 1251
Total content of carboxyl groups	18.90	20.20	19.40	17.79	18.21
Content of free carboxyl groups	10.10	11.05	8.70	8.80	8.91
Carboxyl group content neutralized by ammonia	0.77	0.51	1.11	0.60	0.54
Carboxyl group content esterified with methanol	8.03	8.64	9.59	8.39	8.76
General degree of esterification	46.56	45.29	55.15	50.53	53.21
Degree of esterification with methanol	42.49	42.77	49.43	47.16	48.15
Degree of neutralization with ammonia	4.07	2.52	5.72	3.37	5.06
Polyuronid component	69.80	70.00	65.13	71.98	68.24
Acetyl component: of the weight of pectin powder	0.74	0.49	1.06	0.57	0.60
of the weight of pure pectin	0.47	0.31	0.73	0.36	0.41
Methoxy component: of the weight of pectin powder	5.53	5.95	6.61	5.78	5.05
of the weight of pure pectin	3.57	3.83	3.14	3.61	3.45

Characteristics of pectin substances of other types of shells and varieties of secondary plant raw materials are given in Tables 5 and 6. From Table 4, it is obvious that the pectin molecule from the fruit shells of sainfoin contains a high amount of free carboxyl groups, mainly responsible for its complex properties, which suggests the presence of these properties in all its varieties studied. Comparing the results obtained for this indicator for pectin substances of mustard, castor bean, sunflower and rapeseed coats, we can note increased values for sunflower and lower values for mustard species, but soybean is significantly inferior to all types of secondary raw materials. Due to the complexing property with respect to metal ions, such pectin is an indispensable component of functional food product formulations for therapeutic and prophylactic purposes. The optimum prophylactic pectin dose is no more than 2–4 g per day for people dealing directly with heavy metals, and in conditions of radioactive contamination – no less than 15–16 g [3,14].

The high amount of acetyl groups contained in the pectin samples indicates their low gelling ability, since acetyl groups associated with the hydroxyl groups of pectin substances significantly impair their gelling properties. The results given in Tables 4–6 allow us to conclude that according to this parameter, the studied objects can be arranged by the degree of reduction in gelation in the following way: mustard, castor bean, sunflower, sainfoin, rapeseed and the smallest gelatinous ability is characteristic of soybean pectin substances (Table 3). Varietal characteristics of sainfoin significantly influence this parameter, which is practically not typical for mustard species and soybean varieties except Vilana.

Table 5 – Characterization of pectin substances of mustard shells of various varieties

Parameters	Values of the parameters for the samples, %, variety		
	Sarepta yaraya (Dyzhonka 329)	Sarepta winter (Novynka)	Black (Sofiia)
Total content of carboxyl groups	13.17	12.23	14.41
Content of free carboxyl groups	7.74	7.03	8.28
Carboxyl group content neutralized by ammonia	0.27	0.31	0.19
Carboxyl group content esterified with methanol	5.16	4.89	5.94
General degree of esterification	66.91	65.37	65.29
Degree of esterification with methanol	65.82	64.09	64.17
Degree of neutralization with ammonia	1.09	1.28	1.12
Polyuronid component	60.80	62.00	61.13
Acetyl component: of the weight of pectin powder	0.44	0.24	0.34
of the weight of pure pectin	0.27	0.15	0.21
Methoxy component: of the weight of pectin powder	7.86	7.19	6.82
of the weight of pure pectin	4.78	4.46	4.17

Table 6 – Analytical characteristics of pectin substances of shells of rapeseeds, castor beans, and sunflowers

Parameters	Values of the parameters for the samples, %, variety					
	Castor bean		Sunflower		Rape	
	Khortychanka	Khortytska 1	Milonga	LG 5635	Felter CL	Buchatsky
Total content of carboxyl groups	15.17	17.23	21.73	22.62	14.17	16.23
Content of free carboxyl groups	7.34	10.24	11.61	11.95	7.67	9.17
Carboxyl group content neutralized by ammonia	0.58	0.52	0.84	0.96	0.61	0.69
Carboxyl group content esterified with methanol	7.25	6.47	9.28	9.71	5.89	6.37
General degree of esterification	64.91	62.37	49.27	47.64	59.34	61.48
Degree of esterification with methanol	62.77	60.00	45.40	42.82	56.65	59.21
Degree of neutralization with ammonia	2.14	2.37	3.87	4.82	2.69	2.27
Polyuronid component	57.84	58.92	62.72	60.25	52.87	61.32
Acetyl component: of the weight of pectin powder	0.50	0.60	0.59	0.68	0.91	0.83
of the weight of pure pectin	0.29	0.35	0.37	0.41	0.48	0.51
Methoxy component: of the weight of pectin powder	6.73	6.42	6.57	7.83	9.68	8.11
of the weight of pure pectin	3.89	3.78	4.12	4.72	5.12	4.97

A number of properties of the pectin substances of the studied samples revealed by the obtained analytical characteristics indicate that the fruit and seed coats of the studied types of secondary raw materials are close to the previously studied plant raw materials of the group of surface tissues of the fruit – sunflower anthodia and cotton leaves, but unlike them, the material studied does not contain ballast substances in such quantities.

Conclusion

The research has shown the relevance and prospects of using secondary raw materials of processing plant crops – various fruit and seed coats – for obtaining pectin substances from them, as these objects are rich in them due to the structural functions of these substances.

Monitoring of modern types and varieties of plant materials recommended by the state registers of breeding achievements and characterized by high agrobiological qualities has shown the prospects of using secondary resources of mustard, castor, sunflower, sainfoin, rapeseed and soybeans to get pectic substances.

The quantitative and qualitative characteristics of pectin substances from the coats of selected nontraditional types of secondary raw materials have been studied according to a number of parameters, which allowed establishing the compliance of the studied raw materials with the requirements for pectin production and the potential value of the obtained pectin products for the food industry, in particular, for therapeutic and prophylactic nutrition.

Analytical characteristics of pectic substances show the feasibility of further research of the studied objects, the selection and testing of rational technological schemes for the extraction of pectins from the material under study in order to obtain the target product of consistently high quality.

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