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Investigation of water-soluble polysaccharides and pectin substances of fruits and meal of red currant (*Ribes rubrum*), sea buckthorn (*Hippophae rhamnoides*), and feijoa (*Acca sellowiana*)

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Abstract: *pectin is a polysaccharide found in fruits, vegetables, and roots. It is a gelling agent, thickener and stabilizer (De-Qiang Li etc, 2021). Pectin substances are natural enterosorbents. At the moment, according to the literature analysis (Olufunke D.Akin-Ajani etc, 2021; Paola Foti etc, 2022; Annie Stuart 2021; Yao J. etc, 2022; Welela Meka Kedir etc, 2022) the following pharmacological effects of pectins can be mentioned: they regulate digestion, improve intestinal microflora, have antibacterial effects, are used as prebiotics, regulate blood glucose, help lower blood cholesterol and eliminate toxic substances.*

For the study of pectins, we chose plant materials: fruits and waste products of red currant (Ribes rubrum), sea buckthorn (Hippophae rhamnoides), and feijoa (Acca sellowiana).

The aim of the study was to investigate the water-soluble polysaccharides and pectin substances of the selected raw materials. The technological parameters of the raw materials were determined, the correlation between fresh and dried fruits and waste products, and losses after juice extraction were established. The yield of the finished product – dried waste products – was obtained: red currant (Ribes rubrum) – 12 ± 0.25%, sea buckthorn (Hippophae rhamnoides) – 15 ± 0.32%, feijoa (Acca sellowiana) – 18 ± 0.38%. It was found that the use of waste products as a secondary raw material can be used as a waste-free, resource-saving production.

The research methods were the method of determining the swelling index and the fractionation method. it was found that grinding reduces the swelling index, during studying plant materials by determining the swelling index. It was found by the method of fractionation that quantitatively PS are most contained in feijoa: 3.55 ± 0.15% in fruits, and 4.05 ± 0.17% in waste products; red currant fruits contain 2.63 ± 0.07% of PS, and 3.73 ± 0.11% in waste products; and sea buckthorn has the lowest number of PS: 1.07 ± 0.04% in fruits, and 2.38 ± 0.09% in waste products.

The results of the research give grounds to conclude that the fruits and waste products of red currant (Ribes rubrum), sea buckthorn (Hippophae rhamnoides), and feijoa (Acca sellowiana) are a powerful source of pectin.

Keywords. fruit, pectins, polysaccharides, research, waste products.

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Introduction

Pectin substances (PS) are a natural sorbents and source of soluble fibers. Pectin is recognized by the WHO as a toxicologically safe substance. Pectin is valuable for its unique beneficial properties for humans.

These substances are used for gastrointestinal disorders and to lower blood cholesterol levels (Yao J. etc, 2022). They reduce the toxicity of antibiotics, have antidiabetic, antioxidant, and antitumor effects, and exhibit antibacterial properties (Welela Meka Kedir etc, 2022). PS is used in the food industry, cosmetics, pharmacology, medicine, and as a substitute for more dangerous additives (Rosaria Ciriminnaa etc, 2022).

Even though all plants contain pectin, most of the pectin is found in fruits, such as citrus peel, which is why it is called fruit pectin.

The diversity of pectin-containing plant raw materials proves the feasibility of using and processing secondary raw materials (waste products), which can become a resource-saving and waste-free production technology.

Plant materials are used to produce pectins, but valuable active ingredients remain in the waste products, a product that is classified as a waste product of fruit and vegetable processing (Petkowicz C.L.O. etc, 2020). Thus, we can offer to use production waste as a valuable source of PS, and this will create conditions for waste-free production. Waste-free technologies will allow us to maximize the extraction of valuable substances from raw materials, in our case, pectin (Maria-Guadalupe Guizar-Amezcua etc. 2022).

Every year, the consumption of pectin in the world is growing, so in the 1990s the average amount was 18,000 tons, and in 2020 it was already 70,000 tons. (Zeeb B. etc, 2021).

The global market uses apple, citrus and beetroot meals to produce pectin (Dawit Mamiru etc, 2023). However, there is a wide variety of pectin-containing plant materials from which to extract the PS.

Due to the increase in demand, special attention should be paid to finding new sources of industrial raw materials. Pectin production and its pricing policy will depend on finding a range of cheap and affordable technological plant raw materials (Vinay Chandel etc, 2022).

Aim

The study of water-soluble polysaccharides (WSPS) and PS of fruits and fruit waste products of red currant (*Ribes rubrum*), sea buckthorn (*Hippophae rhamnoides*) and feijoa (*Acca sellowiana*).

Materials and methods

For the study, we chose dried fruits and waste products of red currant (*Ribes rubrum*), sea buckthorn (*Hippophae rhamnoides*) and feijoa (*Acca sellowiana*). Dried fruits and waste products were ground into powder d = 1.0-2.0 mm. The fruits were harvested during the fruiting period in 2022. The country of origin of sea buckthorn and red currant is Ukraine, Transcarpathian region, feijoa is Azerbaijan, Astara district.

Determination of technological indicators of raw materials. The weight of fresh fruit, dried fruit, juice, fresh waste products, and dried waste products was determined by the weight method. After that, the ratio between fresh and dried fruits, waste products, and losses after juice production were determined.

Determination of the swelling index. The swelling index was determined in accordance with the method of the State Pharmacopoeia of Ukraine (State Pharmacopoeia of Ukraine). It was calculated as the average value of the results of three tests (State Pharmacopoeia of Ukraine).

Fractionation method. The study of WSPS and PS was carried out in accordance with a well-known fractionation method. It is based on the extraction of WSPS with water and subsequent precipitation in a 3-fold volume of 96% ethanol. The PS was obtained from the waste products remaining after the extraction of the WSPS. The extraction was carried out with a mixture of 0.5% solutions of oxalic acid and ammonium oxalate (1:1), followed by precipitation in a 3-fold volume of 96% ethanol. The resulting precipitates were filtered, washed with 96% ethanol, dried and weighed (Savych A. etc, 2021).

Results

As a result of the preparation for the study, we obtained 12 types of plant materials from the selected plants – red currant, sea buckthorn, feijoa: dried whole fruits, dried fruit powder, dried waste products, dried waste products powder (Table 1).

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Table 1. Yield of dried fruit, fruit waste products, red currant juice, sea buckthorn, feijoa

Type of raw material	Red currant	Sea buckthorn	Feijoa
Fresh fruits, (%)			
	100 ± 0,1	100 ± 0,13	100 ± 2,60
Yield of dried fruit from the initial weight of fresh fruits, (%)			
Moisture in fresh fruit, (%)	No less than 74	No less than 72	No less than 68
Fresh waste products yield from the initial weight of fresh fruits, (%)			
	40,0 ± 0,84	41,0 ± 0,86	50,0 ± 1,05
Yield of dried waste products from the initial weight of fresh fruits, (%)			
	12,0 ± 0,25	15,0 ± 0,32	18,0 ± 0,38
Fresh waste products moisture, (%)	No less than 69	No less than 63	No less than 63

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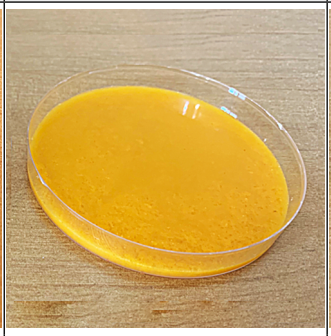
Continuation of Table 1.

Type of raw material	Red currant	Sea buckthorn	Feijoa
Juice yield from the initial weight of fresh fruits, (%)			
	52,0 ± 1,09	59,0 ± 1,24	39,0 ± 0,82
Losses after juice and waste production, (%)	8,03 ± 0,28	0,5 ± 0,02	11,21 ± 0,42

As a result of the studies, it was found that the yield of the finished product in the form of dried waste products per 100 g of fresh raw materials was 18 ± 0.38% for feijoa, 12 ± 0.25% for red currant, and 15 ± 0.32% for sea buckthorn (Table 1). The losses after fruit juice extraction are: for feijoa 11.21 ± 0.42%, red currant 8.03 ± 0.28%, and sea buckthorn 0.5 ± 0.02% (Table 1).

Results of determining the swelling index.

The results of determining the swelling index are shown in Table 2.

Table 2. Indicators of swelling of the tested raw materials

Raw materials	Red currant	Sea buckthorn	Feijoa
Dried whole fruits	9	8	9
Powder from dried fruits	8	7	8
Dried waste products	7	7	7
Dried waste products powder	6	6	5

The swelling index for dried whole currant fruit is 9, for dried fruit powder – 8, for dried waste products and dried waste products powder – 7 and 6, respectively.

This trend is also observed in sea buckthorn and feijoa raw materials. Dried whole sea buckthorn fruits had a swelling index of 8, dried waste products – 7, and after grinding, the swelling index decreased further and was already 6. This is also typical for feijoa fruits: the index of dried whole fruits was 9, and of dried waste products – 7, respectively, their powders 8 and 5.

The index of dried whole fruits and powder from dried whole fruits in red currant and feijoa was the same, and in sea buckthorn these indicators were lower by 1 unit. The dried waste products of red currant, sea buckthorn and feijoa had a swelling index of 7. The powder from the dried waste products of red currant and sea buckthorn had the same value – 6, in feijoa it was equal to – 5, that is, by one unit less.

Results of determination by the fractionation method.

As a result of the studies conducted by the fractionation method (Fig. 1), it was found that the dried fruits of red currant contain 5.01 ± 0.13% of WSPS, and 5.77 ± 0.15% in the waste products. PS in the dried fruits of red currant is 2.63 ± 0.07%, in the waste products 3.73 ± 0.11%.

Sea buckthorn, according to the results of the content of WSPS, has the following indicators: in dried fruits – 1.89 ± 0.07% and in waste products – 3.89 ± 0.14%. The results of the PS studies: in fruits – 1.07 ± 0.04%, and in waste products – 2.38 ± 0.09%. And these are the lowest values of the selected raw materials.

Feijoa is the highest in terms of the content of WSPS: 7.11 ± 0.22% in fruits, 7.33 ± 0.23% in waste products. The PS content in fruits is 3.55 ± 0.15%, and in waste products –

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Figure 1. Isolation of PS by fractionation from red currant (Ribes rubrum) fruit waste products

4.05 ± 0.17%. The results of the fractionation method are shown in Figures 2 and 3.

Accordingly, after the fractionation method of quantitative determination of the content of WSPS and PS, it was found that in the studied types of plant material, PS is most quantitatively contained in feijoa: in fruits – 3.55 ± 0.15%, and in waste products – 4.05 ± 0.17%. Red currant fruits contain 2.63 ± 0.07% of PS, and 3.73 ± 0.11% in the waste products. Sea buckthorn has the lowest indicator of PS: in fruits – 1.07 ± 0.04%, in waste products – 2.38 ± 0.09%. The results of comparing the content of PS in the selected types of raw materials are shown in Fig. 4.

Discussions and conclusions

As a result of the research, in terms of the initial mass (100 g) of fresh raw materials, we obtained the yield of the finished product – dried waste products: red currant (*Ribes rubrum*) – 12 ± 0.25%, sea buckthorn (*Hippophae rhamnoides*) – 15 ± 0.32%, feijoa (Acca sellowiana) – 18 ± 0.38%. As for fresh raw materials, almost half of it is used for waste and losses during juice and waste products production. For example, losses in juice and waste products production in red currant (*Ribes rubrum*) are 8.03 ± 0.28%, sea buckthorn (*Hippophae rhamnoides*) – 0.5 ± 0.02%, and feijoa (*Acca sellowiana*) – 11.21 ± 0.42%. Therefore, it can be said that to

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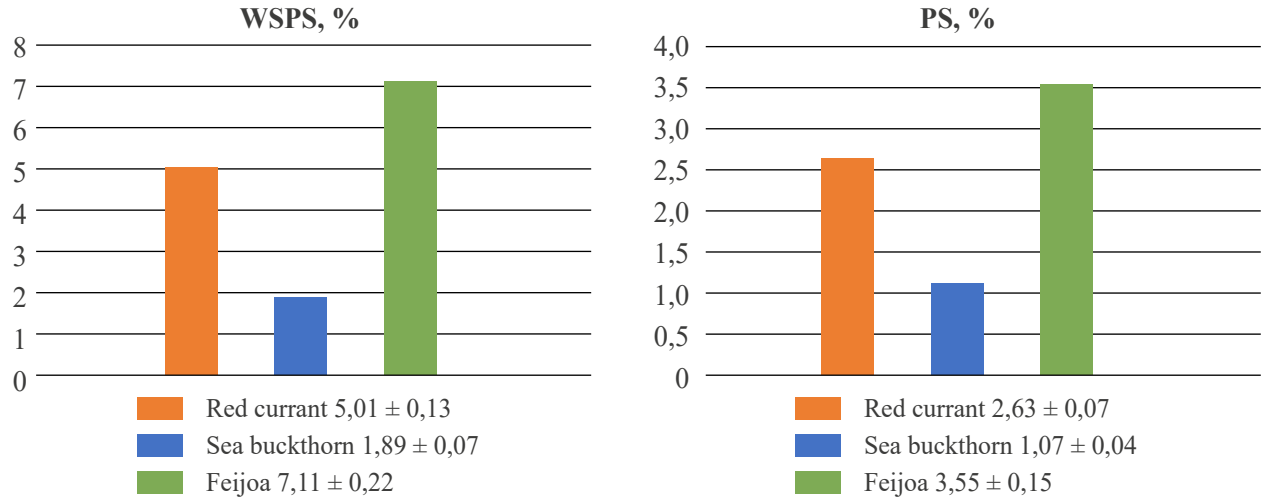

Figure 2. The results of fractionation of the WSPS and PS of dried fruits: red currant (*Ribes rubrum*), sea buckthorn (*Hippophae rhamnoides*), feijoa (*Acca sellowiana*)

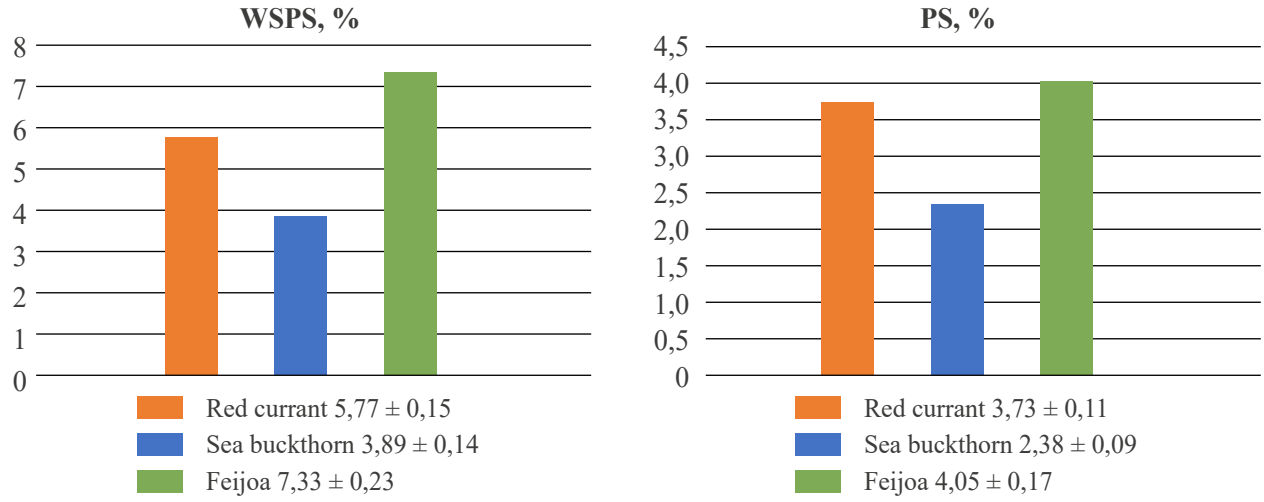

Figure 3. The results of fractionation of dried waste products: red currant (*Ribes rubrum*), sea buckthorn (*Hippophae rhamnoides*), feijoa (*Acca sellowiana*)

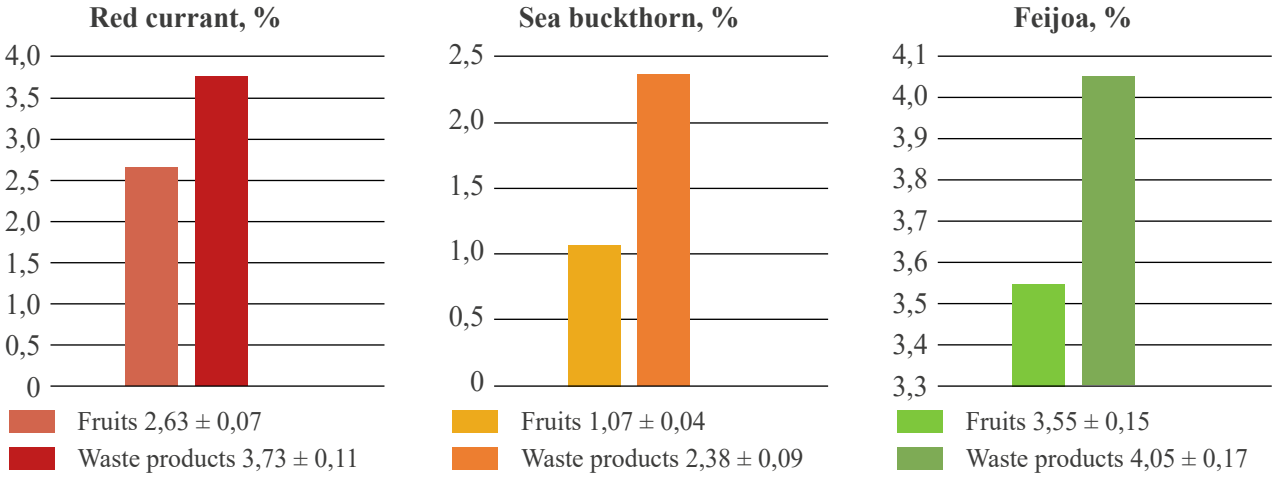

Figure 4. The results of quantitative determination by the method of PS fractionation: red currant (*Ribes rubrum*), sea buckthorn (*Hippophae rhamnoides*), feijoa (*Acca sellowiana*)

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prevent the irrational use of the waste after juice extraction as a secondary raw material, it can be further used to obtain the PS for pharmacy and medicine.

The determination of the swelling index shows us that grinding reduces the swelling index of plant material. We can say, that grinding of long chains of polysaccharides leads to a loss of swelling ability. The comparing the swelling index shows a decrease in this parameter in the waste products by one unit in all raw materials, which indicates the loss of PS during obtaining juice from fruits. The presence of PS in the juice of red currant (*Ribes rubrum*) fruit is indicated by the fact that the swelling index differs by 2 units between the fruit and the red currant (*Ribes rubrum*) meal. The highest swelling index was observed in the raw materials of feijoa and red currant, and the lowest in the raw materials of sea buckthorn.

The study by fractionation method confirmed that the highest content of PS was in feijoa: in fruits – 3.55 ± 0.15% and waste products – 4.05 ± 0.17%. The content of PS in the raw materials of red currant was slightly lower: in fruits – 2.63 ± 0.07% and waste products – 3.73 ± 0.11%. The lowest content of PS was observed in sea buckthorn fruits – 1.07 ± 0.04% and waste products – 2.38 ± 0.09%.

The obtained results of quantitative determination of the PS in the selected raw materials confirm that after juice extraction from red currant, sea buckthorn, and feijoa fruits, a significant content of polysaccharides remains in the waste products. The waste products are secondary raw materials, so they can be used as resource-saving and waste-free production technologies.

Financing

This study did not receive external funding.

Conflict of interest

There is no conflict of interest in this article. No rewards received.

Consent to publication

All authors of the article are acquainted with the final version of the manuscript and have no objections to its publication. The article does not use personal data and information about patients.

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A – Conception and design of the work, B – Data collection and analysis, C – Responsibility for the statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article.

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Дослідження водорозчинних полісахаридів і пектинових речовин плодів та шроту смородини червоної (*Ribes rubrum*), обліпихи крушиновидної (*Hippophae rhamnoides*), фейхоа (*Acca sellowiana*)

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Анотація: *пектин – це полісахарид, який міститься в фруктах, овочах і кореневищах. Він є гелеутворювачем, загусником і стабілізатором (De-Qiang Li .etc, 2021). Пектинові речовини є природними ентеросорбентами. На даний момент, із проведеного аналізу літератури (Olufunke D.Akin-Ajani etc, 2021; Paola Foti etc, 2022; Annie Stuart 2021; Yao J. etc, 2022; Welela Meka Kedir etc, 2022) можна назвати наступні фармакологічні ефекти пектинів: регулюють процеси травлення, поліпшують кишкову мікрофлору, мають антибактеріальну дію, використовують в якості пребіотиків, регулюють вміст глюкози в крові, сприяють зниженню рівня холестерину в крові та виведенню токсичних речовин. Для дослідження пектинів нами було обрано рослинну сировину: плоди та шрот смородини червоної (Ribes rubrum), обліпихи крушиновидної (Hippophae rhamnoides), фейхоа (Acca sellowiana). Метою дослідження було вивчення водорозчинних полісахаридів і пектинових речовин плодів та шроту обраної сировини. Визначили технологічні показники сировини, встановили співвідношення між свіжими і висушеними плодами та шротом, втрати після одержання соку. Отримали вихід готового продукту – шроту висушеного: смородини червоної (Ribes rubrum) – 12 ± 0,25%, обліпихи крушиновидної (Hippophae rhamnoides) – 15 ± 0,32%, фейхоа (Acca sellowiana) – 18 ± 0,38%. Встановили, що використання шроту, як вторинної сировини може бути використане як безвідходне, ресурсозберігаюче виробництво. Методами дослідження були: метод визначення показника набухання і метод фракціонування. Досліджуючи рослинну сировину методом визначення показника набухання встановлено, що подрібнення зменшує показник набухання. Після проведення дослідження методом фракціонування кількісного визначення вмісту ПР, встановлено, що кількісно ПР найбільше міститься в фейхоа: в плодах – 3,55 ± 0,15%, а в шроті – 4,05 ± 0,17%; в плодах смородини червоної ПР міститься 2,63 ± 0,07%, в шроті 3,73 ±0,11%; а найменший показник ПР має обліпиха: в плодах – 1,07 ± 0,04%, в шроті – 2,38 ± 0,09%. Результати досліджень дають підстави зробити висновок: плоди та шрот плодів смородини червоної (Ribes rubrum), обліпихи крушиновидної (Hippophae rhamnoides), фейхоа (Acca sellowiana) є потужним джерелом одержання пектину.*

Ключові слова. Дослідження, пектин, плоди, полісахариди, шрот.