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STUDY OF THE NEW METHOD TO INTENSIFY THE PROCESS OF EXTRACTION OF BEET PULP

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Висвітлено експериментальні дослідження процесу кислотного екстрагування пектинвмісної сировини (бурякового жому) із застосуванням нової моделі перемішувального елементу порівняно зі звичайною решітчастою мішалкою. Розроблено експериментальну установку і методику обробки результатів дослідження процесу екстрагування пектинових речовин із пектинвмісної сировини (бурякового жому) із застосуванням нового комбінованого перемішувального елементу. Побудовані математичні моделі у вигляді нелінійних регресійних рівнянь за методом планування багатофакторного експерименту з вхідними параметрами температури, тривалості та гідромодуля. При цьому встановлено, що основний вплив на зміну вихідних параметрів становлять вхідні змінні температури та тривалості процесу.

Приведені графічні залежності кількісних та якісних характеристик пектинових екстрактів (концентрація пектинових речовин, молекулярна маса, комплексо- та драглеутворювальна здатність) в залежності від вхідних параметрів температури та тривалості процесу екстрагування пектинових речовин. Аналіз цих характеристик дозволив встановити раціональні вхідні параметри процесу екстрагування пектинових речовин. Раціональними робочими параметрами процесу кислотного екстрагування пектинових речовин з бурякового жому із застосуванням нового методу інтенсифікації процесу є температура 60…70 °C, тривалість – 1…1,1 години та гідромодуль 8…10.

Дане дослідження проведене з метою інтенсифікації вилучення пектинових речовин з пектинвмісної сировини, підвищення технічного рівня процесу екстрагування та реалізації розробленого методу в промислових умовах. За результатами досліджень було встановлено доцільність застосування нового методу інтенсифікації. Подальше впровадження цих результатів у харчову та переробну промисловість дає змогу налагодження виробництва широкого асортименту пектинопродуктів (екстракти, рідкі та сухі пектинові концентрати)

Ключові слова: пектінвмісна сировина, процес кислотного екстрагування, пектинові речовини, перемішувальний елемент

1. Introduction

Lack of dietary fiber in human nutrition has a negative impact on human health, reducing the resistance of his organism under unfavorable environmental impact. Dietary fibers are a complex of polysaccharides, cellulose, lignin and associated proteins that make up the cell walls of plants [1].

The use of secondary material resources has become at present one of the most important technical, resource-saving and environmental problems around the world. In this case, large-ton waste generated during processing of various raw materials must be utilized first of all. A considerable amount of waste forms in the processing of agricultural raw materials of plant and animal origin, which require further disposal [2].

At the same time, food industry currently produces a wide variety of confectionery, bakery, meat, dairy and fish products, beverages, canned goods, in line with the trend aimed at enriching the diet of domestic population with biologically active additives (BAA). Using pectin extracts (PE) as BAA, pectic concentrates (PC) and powdered pectin makes it possible to obtain food products with the predetermined technological properties. This will contribute to the pectin prophylaxis of people [3, 4].

The food industry exploits the main properties of pectin substances – complex-and gel forming capabilities, which makes it possible to enrich foods with pectin products that have therapeutic and preventative value [5, 6].

At present, there exist a sufficient number of food production technologies that imply the addition of pectin products [7]. However, there are not enough data on the use of PC with high nutritional value in food production. Because these data are fragmented, that necessitated the purpose and relevance of present research whose results would help expand the range of therapeutic and preventive food products.

2. Literature review and problem statement

To obtain good quantitative and qualitative indicators of PE, we selected three types of raw materials for this study: beet pulp, apple pomace, and sunflower baskets. This is primarily due to the high levels of pectin content in these kinds of plant raw materials and to their high degree of esterification (indicator of pectin application in food industry) [8]. In addition, this relates to the presence of sugar plants, production lines for making juices, and sunflower processing plants. However, the focus of this research is beet pulp. In this case, we undertake a limited study into extraction process from a given raw material using organic acids [9].

Currently, there are many techniques for obtaining PE from any plant raw material [10, 11]. However, all these techniques have both advantages and disadvantages: the complexity of subsequent processing of raw materials, considerable consumption of reagent, complicated and expensive equipment design and its maintenance, low quantitative or qualitative indicators of pectin extracts, etc. The criterion of effectiveness of any technology should be its universality, sustainability, and low waste [12]. Therefore, the best solution is the development and implementation of combined techniques for different stages of the general production technology of pectin. Specifically, this applies to the analyzed process of beet pulp extraction.

At present, the efficient technique to extract pectin substances (PS) is the use of inorganic and organic acids (hydrochloric, nitric, acetic, lactic, citric acid, etc.) [13, 14]. Such a technique is one of the most promising for its further industrial implementation. However, that implies that the employed equipment should be resistant to corrosion (especially if the process occurs at a high temperature) [15].

The course of the process for extracting pectin-containing raw materials is a complicated one [16]. In this case, the choice of the technique for extraction might both simplify and complicate the further stages of pectin production (processes of concentration, purification, drying, etc.) [17]. These circumstances should be taken into consideration in the development of the new technologies for pectin extraction.

Currently, modern technologies for the extraction of PS from beet pulp face a number of issues relating both to increasing the amount of extracted PS and improving quality indicators of PE [18, 19]. This hampers the implementation of existing extraction methods into industrial production. Therefore, there is a need to introduce new methods for the intensification of extraction process. In this case, it is important to study and determine the rational parameters and modes of this process: temperature, hydromodule, duration and so on.

3 The aim and objectives of the study

The aim of this work is to study the process of acidic extraction of pectin-containing raw materials using the new model of a stirring element to improve the qualitative and quantitative characteristics of pectin extracts.

To accomplish the aim, the following tasks have been set:

– to identify benefits of the extraction process of pectin-containing raw materials using methods of intensification;

– to define factors that affect the process of acidic extraction of pectin-containing raw materials using the new model of a stirring element;

– to determine, based on the research results, the rational parameters for acidic extraction of pectin-containing raw materials (beet pulp).

4. Materials and methods to study the acidic extraction of pectin-containing raw materials using the new stirrer

4. 1. Scheme of the experimental extraction installation and its working principle

We conducted our study on the choice of optimal parameters for carrying out the acidic extraction of pectin-containing raw materials at the research laboratory «Nanotechnologies of food products» at Kharkiv State University of Food and Trade (Ukraine). In order to improve the process of acidic extraction of pectin-containing raw materials, we selected the process intensification method that allows the participation of hydromechanical processes.

One of the factors for the intensification of extraction of plant raw materials is the uniform distribution of the raw material's particles in terms of size. This determines the efficiency of process of the extraction of biologically active substances. And in a combination with the active circulation of an extractant, it quantitatively provides for the removal of one or another component [19].

The principle of operation of the experimental extraction installation, as well as modeling of extraction process of pectin substances, are described in detail in paper [20].

5. Results of studying the application of an agitation method in the process of acidic extraction of pectin substances

The dynamics of change in the concentration of PS in the process of extraction of beet pulp using a grid and combined stirring elements are shown in Fig. 1, 2. Dependences of qualitative characteristics of PE, obtained using the combined stirring element for fresh and dried raw materials, are shown in Fig. 3, 4.

The data in Fig. 1, 2 show that the dependences of change in the concentration of PS, molecular weight, complex-forming capability, on various technological factors in the process of extracting PS from different raw materials are non-linear in character.

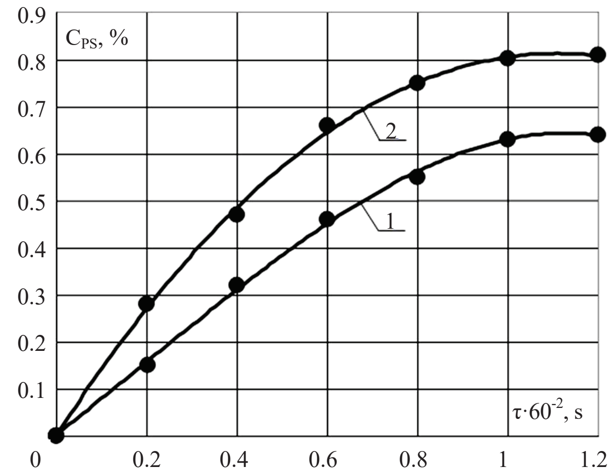

Fig. 1. Dependence of change in the PS concentration on duration of extracting the fresh beet pulp at $t = 65$ °C, $q = 10$, using the following stirring elements: 1 – grid; 2 – combined

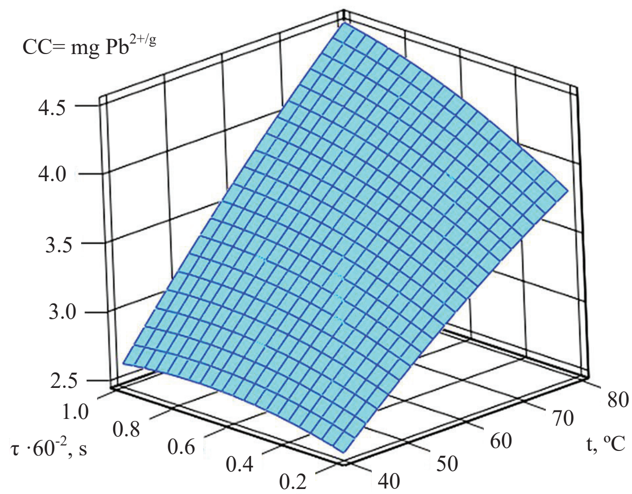

Fig. 4. Dependence of change in the PE complex-forming capability on temperature (t) and duration of the fresh raw materials extraction (τ)

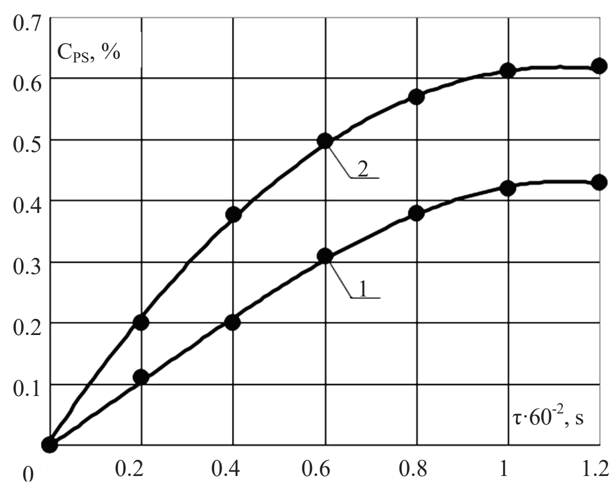

Fig. 2. Dependence of change in the PS concentration on duration of extracting the dried beet pulp at $t = 65$ °C, $q = 10$, using the following stirring elements: 1 – grid; 2 – combined

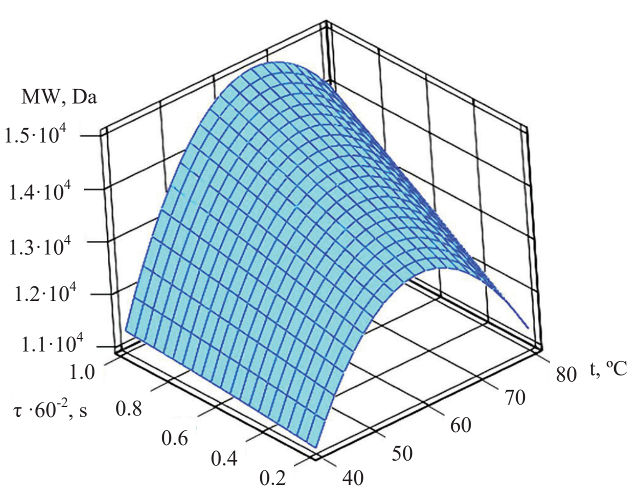

Fig. 3. Dependence of change in the PE molecular weight on temperature (t) and duration of the fresh raw materials extraction process (τ)

Curves of change in the amount of PS in the extract, depending on parameters of duration of the process for PS extraction are similar in character both in the case of using a grid and combined stirring elements. Graphical dependence of influence of duration of the process of extraction of beet pulp on the concentration of PS shows that over $(1.0...1.1)\cdot 60^2$ s one observes the intense at first, and then the slow, growth of PS concentration in the extract. During further extraction, the concentration of PS in pectin extracts acquires the set value.

The application of the combined stirring element significantly increases the magnitude of PS concentration in the extract – by 21...33 % compared to that when using a grid stirring element.

The surface of molecular weight dependence on temperature and duration of the PS extraction process (Fig. 3) in the direction of an increase in temperature of the process for both types of beet raw materials is non-linear in character. Increasing the temperatures to 60...70 °C leads to an increase in the PS molecular weight up to a maximum of MW = 1.86·104 Da for fresh raw materials and MW = 1.86·104 Da for dry raw materials. At the subsequent rise in temperature to 80 °C one observes a sharp decrease in the PS molecular weight, which is probably a consequence of the reduced physical-mechanical properties of PS in the extract under high temperature values.

The value of the complex-forming capability of PS (Fig. 4) grows in proportion to an increase in temperature and duration of the PS extraction process. Thus, the maximum values for the complex-forming capability (CC_{max} = = 4.0...4.5 mg $Pb^{2+/g}$ for fresh raw materials and CC_{max} = = 2.5...2.6 mg $Pb^{2+/g}$ – for dry raw materials) are observed at a temperature of 70...75 °C and a process duration of $(1.0...1.1)\ 60^2$ s.

6. Discussion of results of studying the new method to combat a polarizing layer

The above data show that the extraction of PS from beet pulp in acidic environment is fairly complex in character. Such a character is revealed using a mathematical model that represents the regression equations whose coefficients have been determined based on the realization of the full factorial experiment. Such an approach could be considered justified in this case by the ultimate goal of research: determining a change in the extraction process output characteristics depending on input parameters applying the new method of intensification [21–25].

The derived dependences of change in the PS concentration, molecular weight, complex- and gel-forming capabilities on various technological factors in the process of PS extraction from different raw materials are non-linear in character. In this case, an analysis of the derived dependences shows that the change in the PS concentration and in the PE qualitative indicators (molecular weight, complex- and gel-forming capabilities) in the extract is mainly influenced by the parameters of temperature and duration of the process, which is confirmed by studies conducted by other scientists in this field [26, 27].

The obtained high values for the PS concentration in the extract is substantiated by using the combined stirring element. Compared to using the grid stirring element, the PS concentration in the extract increases by 1.3...1.4 times for both dry and fresh beet pulp.

Comparative analysis of the estimated output qualitative and quantitative characteristics of the obtained PE demonstrated a rather high convergence between the calculated and experimental input parameters of the process for both types of raw materials.

Benefits of this research are in the fact that, by using the constructed mathematical model, we identified conditions for obtaining PE from the fresh and dry pectin-containing raw material (beet pulp). This made it possible to ensure high values of PS concentration in the extract, molecular weight, complex- and gel-forming capabilities, as well as the possible maximum value for the specified characteristics under optimal parameters.

Optimization results obtained using the mathematical model are given in Table 1.

The data provided show that those PE that were obtained from fresh raw materials have a larger molecular weight and high values of complex- and gel-forming capability than those PE that were extracted from dry raw materials.

Table 1

Estimated values of the optimal parameters for obtaining PE based on physicochemical indicators

Characteristic Y to be defined	Optimization parameters			
	t, °C	$\tau \cdot 60^{-2}$, s	q	Y_{max}
Dry beet pulp				
PS concentration, C_{PS}^{L} (%)	60	1	10	0.62
PS concentration, C_{PS}^{C} (%)	40	1	10	0.91
Molecular weight, MW (Da)	70	0.9	4	$1.185 \cdot 10^4$
Complex-forming capability, CC (mg Pb^{2+}/g)	60	1	5	2.591
Fresh beet pulp				
PS concentration, C_{PS}^{L} (%)	60	1	10	0.87
PS concentration, C_{PS}^{C} (%)	50	1	10	1.165
Molecular weight, MW (Da)	65	1	6	$1.519 \cdot 10^4$
Complex-forming capability, CC (mg Pb^{2+}/g)	70	1	9	4.179
Gel-forming capability, GC (G)	70	0,6	9	101

It should be noted, however, that extracting PS from fresh raw materials under the above-specified conditions did not make it possible to obtain high values for the gel-forming capability (GC). Indicator $GC_{max}=106$ G, even though the concentration of PS in the extract using the combined stirring element was fairly high compared to using the grid element.

Based on the results of derived dependences (Fig. 4) and defined rational parameters of the beet pulp extraction process using the combined stirring element (regression equations (2) to (7)), it was found that the most acceptable technological modes for the process are:

– temperature of the process $t=60...70$ °C;
– duration of the process $\tau=1.0...1.1 \cdot 60^2$ s;
– hydromodule $q=8...10$.

A shortcoming of this study may be the complexity in varying the experiment parameters, as well as the use of a different type or variety of original raw material, at which resulting indicators can differ greatly from the estimated ones.

The results obtained could be used when studying other technological parameters during extraction of other types of pectin-containing raw materials, as well as to improve the hardware for production lines that process pectin-containing raw materials. The difficulty in the industrial application of research results is the need to use specialized equipment and special preparation of raw materials, specifically, dried raw material.

This study is continuation of research into improving the process of extracting pectin-containing raw materials, using the new methods for process intensification through the development of new types of stirring elements.

7. Conclusions

1. We have conducted a study into improvement of the extraction process of pectin-containing raw materials using the new method of intensification. Technical solution to this method is to use a combined stirring element. The advantage of the latter implies improving the quantitative and qualitative characteristics of the extraction process of pectin-containing raw materials. This conclusion is based on the results of the full factorial experiment for the extraction process using the combined stirring element compared to the grid stirrer.

2. The derived graphical dependences on the influence of parameters of temperature, duration and hydromodule of the extraction process on the degree of concentration of pectin substances in pectin extract are non-linear in character. At the same time, the calculated coefficients of regression equations show that a substantial impact on molecular weight, complex- and gel-forming properties is exerted by the input parameters of temperature and duration of the process. The result of the latter's growth is a substantial increase in the above-specified output quantitative and qualitative parameters of the process. In this case, the estimated and experimental data showed that increasing the process temperature above 65 °C is not

feasible because there is degradation of PS in a raw material. Increasing the values of the extraction process duration to exceed $1.1 \cdot 60^2$ s does not lead to a significant improvement in the PE qualitative characteristics since the yield of PS acquires a constant value.

3. We have obtained results that made it possible to determine the rational parameters for the extraction process from pectin-containing raw material (beet pulp) using the combined stirring element. These parameters are:

– temperature of the extraction process is 60...70 °C;

– duration of extraction of pectin substances is about $(1.0...1.1) \cdot 60^2$ s;

– hydromodule for the ratio of pectin-containing raw material to extractant is 8...10.

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RESEARCH INTO PRESERVATION OF BROCCOLI DEPENDING ON THE TREATMENT WITH ANTIMICROBIC PREPARATIONS BEFORE STORAGE

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Досліджено дію препаратів антимікробної дії – Байкал ЕМ-1, 0,5 %-ний розчин лимонної, 0,2 %-ний бензойної, 0,05 %-ний сорбінової кислот, 0,5:0,5 % розчин вітамінів С та Р (аскорутин) – на збереженість та якість капусти броколі. Встановлено, що препарати антимікробної дії сприяють подовженню строку зберігання капусти броколі на 5–20 діб залежно від гібриду. Обробка препаратами зменшує втрати за добу у 1,2–3,0 рази, забезпечує вихід товарної продукції 76,8–86,2 %.

Обробка капусти броколі препаратами антимікробної дії, особливо аскорутином, забезпечують вміст сухої речовини в 1,1–2,6 рази більше, ніж у контролі, сприяє зниженню інтенсивності витрачання сухих розчинних речовин та вітаміну С. У кінці зберігання вміст загального цукру та дисахаридів на рівні з контрольним варіантом, або перевищує його вміст відповідно в 1,2 та 1,5–2,0 рази. Більше у варіантах з кислотами та аскорутином. Вміст моносахаридів зберігається на початковому рівні. Втрати маси за рахунок випаровування води більше в 1,3–1,8 рази.

Байкал ЕМ-1 та аскорутин краще, ніж інші препарати стримують інтенсивність розвитку хвороботворних мікроорганізмів на 10–15 діб. Аскорутин забезпечує за тривалого зберігання менші на 0,8–2,2 % втрати маси від хвороб та фізіологічних розладів і на 4,1–7,6 % більший вихід товарної продукції. Більш активно пригнічує розвиток хвороботворних мікроорганізмів на капусті броколі аскорутин, лимонна, сорбінова та бензойна кислоти. Проте, від фізіологічних розладів під час зберігання препарати не захищають плоди. Спосіб оброблення капусти броколі препаратами антимікробної дії перед зберіганням дозволяє використання антисептиків – Байкал ЕМ-1, 0,5 %-ний розчин лимонної, 0,2 %-ний бензойної, 0,05 %-ний сорбінової кислот, 0,5:0,5 % розчин вітамінів С та Р (аскорутин) – для післязбиральної обробки овочевої сировини. У розробці нових, низьковитратних, екологічно чистих і доступних технологій це є важливим прийомом

Ключові слова: якість капусти броколі, антисептики, строк зберігання, компоненти хімічного складу, збереженість

1. Introduction

Fresh vegetables have a limited storage period even under conditions of optimum temperature and humidity. The reasons are a large natural loss of weight and the loss due to diseases and physiological disorders. In addition, vegetables lose freshness and consistency. They also lose content of components of their chemical composition. Fresh fruits