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EXTRACTION AND CHARACTERISTICS OF PECTINS FROM MELON PEEL: EXPERIMENTAL REVIEW

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Abstract

The study is devoted to the process of extracting pectin from melon peels by the acid method. The chemical composition of the peel of melon varieties Myrzachulskaya, Gulyabi, Inzhirnaya, Gurbek and Ameri and the content of pectin in the samples were studied. Hydrochloric acid was used as an extractant of pectin substances.

In order to reduce the number of experiments and optimize the study, regression analysis of experimental data was used. To study the influence of some technological factors on the extraction of pectin from samples, experiments were carried out according to the FFE 2^3 plan. Each experiment was repeated three times. Factors affecting the yield of pectin have been established. It was found out that the highest content of pectin was in the samples of the «Myrzachulskaya» variety – 10.9 %. The high accuracy of the mathematical model describing the process under study was noted (determination coefficient – 0.98). The dynamics of the degree of pectin extraction was proved with an increase in acid concentration in the range of 0.5...1.25 %, temperature (60 ... 90 ˚C) and a decrease in the size of raw material particles subjected to hydrolysis. The duration of the extraction process has been established, at which the maximum degree of pectin extraction (95–98 %) is achieved, it is 40 ... 60 min. At the same time, the following extraction parameters are recommended: acid concentration – 1.25 %, temperature – 90 ˚C. A regression equation was obtained that describes the effect of these parameters on the degree of pectin extraction from samples. Based on the analysis of the regression equation, other optimal parameters of the extraction process were also determined: hydromodulus 1 : 5; sample particle size ≤ 5 mm. The results of the conducted research can be recommended for the introduction of a complex technology for processing melons at fruit canning enterprises.

Keywords: pectin; extraction; melon; acid hydrolysis; processing of food raw materials.

ЕКСТРАКЦІЯ ТА ХАРАКТЕРИСТИКА ПЕКТИНІВ З КІРОК ДИНІ: ЕКСПЕРИМЕНТАЛЬНИЙ ОГЛЯД

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Анотація

Дослідження присвячене процесу вилучення пектину з кірок динь кислотним методом. Вивчено хімічний склад кірки динь сортів «Мирзачульська», «Гулябі», «Інжирна», «Гурбек» та «Амері», безпосередньо вміст пектину у зразках. В якості екстрагенту пектинових речовин була використана хлоридна кислота. З метою зниження кількості поставлених експериментів та оптимізації дослідження було використано регресійний аналіз експериментальних даних. Для дослідження впливу деяких технологічних факторів на вилучення пектину із зразків було поставлено експерименти за планом ПФЕ 2^3. Кожен експеримент було відтворено тричі. Встановлено фактори, що впливають на вихід пектину. Визначено, що найбільший вміст пектину був у зразках сорту «Мирзачульська» – 10.9 %. Відзначено високу точність математичної моделі, що описує процес, що вивчається (коефіцієнт детермінації – 0.98). Доведено динаміку ступеня вилучення пектину зі збільшенням концентрацій кислоти в діапазоні 0.5...1.25 %, температури (60...90 ˚С) та зменшення розмірів частинок сировини, що піддаються гідролізу. Встановлено тривалість процесу екстракції, за якої досягається максимальний ступінь вилучення пектину (95–98 %): вона становить 40...60 хв. Рекомендовано наступні параметри екстракції: концентрація кислоти – 1.25 %, температура – 90 ˚С.

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Отримано рівняння регресії, що описує вплив зазначених параметрів на ступінь вилучення пектину із зразків. На підставі аналізу рівняння регресії визначені інші оптимальні параметри процесу екстракції: гідромодуль 1 : 5; розмір частинок зразків ≤ 5 мм. Результати проведених досліджень можуть бути рекомендовані для впровадження комплексної технології переробки динь на плодоконсервних підприємствах.
Ключові слова: пектин; екстракція; диня; кислотний гідроліз; переробка продовольчої сировини.

ЭКСТРАКЦИЯ И ХАРАКТЕРИСТИКА ПЕКТИНОВ ИЗ КОРОК ДЫНИ: ЭКСПЕРИМЕНТАЛЬНЫЙ ОБЗОР

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Аннотация
Исследование посвящено процессу извлечения пектина из корок дынь кислотным методом. Изучен химический состав корки дынь сортов «Мырзачульская», «Гуляби», «Инжирная», «Гурбек» и «Амери», непосредственно содержание пектина в образцах. В качестве экстрагента пектиновых веществ была использована соляная кислота. В целях снижения количества поставленных экспериментов и оптимизации исследования был использован регрессионный анализ экспериментальных данных. Для исследования влияния некоторых технологических факторов на извлечение пектина из образцов были поставлены эксперименты по плану ПФЭ 2^3. Каждый эксперимент повторялся по три раза. Установлены факторы, влияющие на выход пектина. Определено, что наибольшее содержание пектина было в образцах сорта «Мырзачульская» – 10.9 %. Отмечена высокая точность математической модели, описывающей изучаемый процесс (коэффициент детерминации – 0.98). Доказано динамику степени извлечения пектина при увеличении концентраций кислоты в диапазоне 0.5…1.25 %, температуры (60…90 °С) и уменьшении размеров частиц сырья, подвергаемых гидролизу. Установлена продолжительность процесса экстракции, при которой достигается максимальная степень извлечения пектина (95–98 %), она составляет 40…60 мин. При этом рекомендованы следующие параметры экстракции: концентрация кислоты – 1.25 %, температура – 90 °С. Получено уравнение регрессии, описывающее влияние указанных параметров на степень извлечения пектина из образцов. На основании анализа уравнения регрессии определены и другие оптимальные параметры процесса экстракции: гидромодуль 1 : 5; размер частиц образцов ≤ 5 мм. Результаты проведенных исследований могут быть рекомендованы при внедрении комплексной технологии переработки дынь на плодоконсервных предприятиях.
Ключевые слова: пектин; экстракция; дыня; кислотный гидролиз; переработка продовольственного сырья.

Introduction

The modern agro-industrial sector of the economy of all countries sets itself serious and responsible tasks. The world's population is growing, and the amount of nutrients, unfortunately, is becoming less and less. This forces specialists to develop new and improve existing technologies aimed at the synthesis or maximum extraction of nutritional nutrients from existing food raw materials. Pectin is one of the strategic substances with unique properties of cleansing the body of toxins and radionuclides. In addition, the special technological properties of pectins are still of interest, allowing it to be used in various food production technologies as a thickener, stabilizer, emulsifier and structure former. Pectin substances are contained in all fruit, berry and vegetable products, in the ground part of plants, which makes it possible to single out pectin as one of the most demanded ingredients in the nutrition system and technology. Today's pectin extraction technologies are different, as research is being conducted on different raw materials using different extraction methods.

Modern approaches are those that involve physical processes: ohmic heating (Sharifia, et al., 2022; Tunç, Odabaş, 2021), microwaves (Nguyen, Mai, Than, Nguyen, 2021; Nandhu Lal et al., 2021. Dranca et al., 2021), ultrasound (Muñoz-Almagro, Ruiz-Torralba, et al., 2021; Tran et al., 2021), radio frequencies (Zheng, Li et al., 2021), manosonization (Hu et al., 2021). There are also new "green technologies" – enzymatic hydrolysis (Muñoz-Almagro, Ruiz-Torralba, et al., 2021; Milošević, Antov, 2021) and processing in organic extracts (Muñoz-Almagro, Ruiz-Torralba, et al., 2021; Chen, Lahaye, 2021; Valladares-Diestra et al., 2021; Chen, Falourd, Lahaye, 2021). All methods are compared with the classical technology – acid hydrolysis in inorganic acids. It should be noted that although the new methods allow obtaining a higher yield of galacturonic acid, the main structural component of pectin (with various methods, the yield is higher by 8…12 %), nevertheless, there are some problems. Firstly, the studies that were conducted using the so-called "improved technologies" were not carried out on large batches of raw materials, which today casts doubt on the introduction of such methods into industrial production. Installations that would allow processing a large amount of raw materials in single cycle will obviously be expensive and at the moment are only future technologies using powerful specialized equipment, with special measures for labor protection and life safety of specially trained personnel and the population.

Secondly, the introduction of "green technologies" is more likely in the near future, since the reagents involved in the extraction or enzymatic process are available, but are more expensive than inorganic acids. The construction of such enterprises also requires investments in the purchase of equipment and training of personnel, but probably not much financial investment will be required for the disposal of production waste.

Thirdly, it is well known that when using unconventional approaches to pectin extraction, pectin does not have the necessary rheological properties for the production of jams and thermostable fillings, for example, it has a low gelling ability and is practically incapable of structure formation in the presence of calcium, magnesium, and iron cations. This is due to the fact that pectins that have not undergone heat treatment in acidic media have a high degree of methoxylation. Unfortunately, in many of the proposed non-traditional methods for extracting pectin, studies of its rheological properties have not been carried out and recommendations have not been made for its further use in industry, in particular in the confectionery sector. On the other hand, it is reliably known that such pectins gel well, forming a weak gel, and quickly bind with heavy metals and radionuclides, which means they can be used as part of food concentrates, dry drinks, sports and fitness nutrition, diet therapy and nutritional supplements.

Fourthly, the raw material base - fruits, berries, vegetables, melons - that did not pass the primary quality control and were rejected from sale to the population or exporters, is quite large. Much larger than products that were recommended for further processing (production of juices, jams, concentrates, purees, pastes, canned food, etc.) and the processing of which also produces a considerable amount of secondary raw materials containing pectin (pomace, peels, stem and leaf parts of plants).

As an example, the technology of melon processing can be given, particularly melons grown in Kazakhstan. The amount of waste after melon processing is colossal and requires the immediate intervention of technologists of production facilities that process food production waste into physiologically and technologically useful components.

Understanding this problem, it would be worth explaining the nature of pectin. Pectin is structurally a complex polysaccharide that forms and fills almost 30 % of the plant cell wall (Buggenhout, Sila, Duvetter, Loey, & Hendrickx, 2009). Multiple interactions occur between pectin, cellulose and hemicellulose in the plant matrix (Dranca & Oroian, 2018; Ngou´emazong, Christiaens, Shpigelman, Van Loey, & Hendrickx, 2015). Pectin chains also interact with each other through covalent bonds and intermolecular interactions, which leads to the formation of a complex network of polysaccharide chains (Christiaens et al., 2016).

Pectin plays an important role in plant tissue structure and promotes intercellular adhesion, cell wall integrity and rigidity (Lara-Espinosa, Carvajal-Millan, Balandran-Quintana, López-Franco, & Rascon-Chu, 2018). Citrus peels (85.5 %) and apple pomace (14.0 %) are the main sources of commercial pectin, although additional sources have been explored due to growing demand and great interest in exploiting the diverse functional properties of pectin (Müller-Maatsch et al., 2016; Pico-Allen, Ramasawmi and Emmambuk 2020).

Structurally, pectin is a complex heterogeneous polysaccharide consisting mainly of homogalacturonan (HG), rhamnogalacturonan I (RGI), and rhamnogalacturonan II (RG-II). HG is a linear chain of 1.4-linked α-D-galacturonic acid (α-D-GalA) residues that are partially methyl esterified at the C-6 carboxyl group (Mao et al., 2019; Sengkhamparn et al., 2010). Depending on the plant origin of GalA, HG residues can be O-acetylated at C-3 and/or C-2. RG-I is a highly branched polysaccharide and has a backbone of alternating α-L-rhamnose (Rha) and α-D-GalA residues. RG-II includes an HG backbone of approximately nine 1.4-linked α-D-GalA residues, which can be replaced by clusters of various heterooligomeric side chains (Khedmat, Izadi, Mofid, & Mojtahedi, 2020). Although the chemical compositions and structures of HG, RG-I, and RG-II have been elucidated, it remains unclear how the various structural regions of these materials are arranged when combined into one macromolecular structure (Christiaens et al., 2016; Mellinas, Ramos, Jim'enez, & Garrigos, 2020). For example, pectins are covalently bonded to each other (Caffall & Mohnen, 2009; Maxwell, Belshaw, Waldron, & Morris, 2012). Notably, the molecular structure of pectin can be greatly affected by the method used to extract it from the source material. (Dranca & Oroian, 2018).

Different extraction mechanisms produce different pectin structures. Therefore, a comprehensive understanding of the relationship between the extraction method and the chemical structure of the isolated pectin is very important.

Pectin is used as a gelling agent not only in jams and jellies, but also as a stabilizer and thickener in fruit juices and acidified milk drinks (Jiang, Xu, Li, Li, & Huang, 2020; Naqash, Masoodi, Reason, Wani, & Gani, 2017). Pectin is also used in biomedical applications, including target organ delivery of biologically active compounds, wound healing, and tissue engineering (Dranca & Oroian, 2018; Rehman et al., 2019). Pectin is resistant to endogenous digestive enzymes when passing through the stomach and small intestine, but can be fermented by the intestinal microbiota in the colon (Singh et al., 2019), thus acting as a prebiotic. Pectin has been shown to modulate the composition and diversity of the gut microbiota (Licht et al., 2010), attenuate gut inflammation (Singh et al., 2019), prevent atherosclerosis (Chen et al., 2018), and suppress weight gain and fat accumulation in obese rats induced by a special diet (Jiang et al., 2016). However, the physicochemical properties and health functions of pectin are largely determined by its structural characteristics, which can be quite complex (Cui et al., 2019; Dranca & Oroian, 2018). In particular, several variable characteristics of pectin chains, including molecular weight (MW), monosaccharide composition (MC), degree of esterification (DE), number of glycosidic bonds, RG-I/HG ratio, and steric conformation, can greatly influence their structure, functional properties (Ai et al., 2018; Larsen et al., 2019). The study of both the primary structure and the spatial conformation of various pectins will allow a better understanding of their functional properties.

In the Republic of Kazakhstan, there is a tendency to increase the area under cultivation of gourds, in particular watermelons and melons, due to their high taste, rich nutrient composition and increasing technologies for their processing. Melons contain substances indispensable for the human body, such as vitamins (C, A, B vitamins), as well as mineral compounds such as sodium, potassium, iron, chlorine, zinc, copper, manganese, etc. Despite the fact that melon production in Kazakhstan is increasing, melon processing is underdeveloped [1–3].

Since the product spoils rather quickly, technologies for the production of products of increased and long-term storage with the manifestation of all the useful properties of melon have become necessary. Thus, technologies for the production of juices, sorbets, jams, marmalades were proposed, and the extraction of pectin from fruit pulp was also considered [4–10].

The main waste during the processing of melons are seeds and rind. From the seeds, oil is obtained and sold for the food, cosmetic and medical industries [11; 12].

Until today, in Kazakhstan there is no industrial technology for processing a large amount of melon peel as a secondary raw material component. That is why it has become important and interesting to study the chemical composition of the peel of the most widely grown melon varieties, in particular, the content of pectin substances in them with a given and/or controlled level of functional properties [13; 14].

It should be noted that the largest pectin producers are HerculesInc (USA) and HerbstreithundFox KG (Germany). The source of raw materials for the production of pectin abroad is the extraction of citrus fruits and apples, in Ukraine there is a raw material source - beets. It should be noted that the world's leading manufacturers mainly use exclusive or modified equipment [15–27].

The actual obstacle today is not only the technology of pectin extraction without the use of technologically aggressive agents, but also the range of expansion and the type of pectin biologics with well-defined functional properties. Kazakhstan has a diverse raw material base - traditional for the production of pectin secondary raw materials (beet pulp and pressing apples) and non-traditional raw materials for the production of pectin – gourds (table and fodder watermelon, pumpkin, melon).

According to a number of scientists (A.A. Arasimovich, S.V. Baltaga, N.P. Ponomareva, L.V. Donchenko), there is little data on the production and quality of pectin from melon, therefore, the purpose of the work is to choose a technological management for the extraction pectin from melon peels, which are actually grown and sold in Kazakhstan, is extremely important for the development of the country's economy.

The largest number of polished and utilized varieties of melons in the region belongs to Kolkhoznitsa, Myrzachulskaya, Amerika, Gulabi, Inzhirnaya, Gurbek and Zhuldyz with a pulp content of 53.13–71.5%, pulp 24.57 – 34.97 %. peels and 1.18–3.22 % of seeds. The content of pectin in the crust is 5.13–10.9 % (a.d.m.), the share of the protectorate is 75.37–95.25 %, which makes it advisable to industrially extract pectin. The average content of pectin in various melon varieties is presented in Table 1. Further, it became necessary to develop and describe a method for extracting pectin from the peel of widely grown melon varieties.

Materials and Methods

The subject of the study is the peel of melon varieties: Myrzachulskaya, Gulyabi, Ingirnaya, Gurbek, Ameri. The chemical composition is shown in table 1.

Table 1

The content of pectin substances in melons of the studied varieties

Indicator	Variety				
	Myrzachulskaya	Gulyabi	Ingirnaya	Gurbeck	Ameri
Moisture content, %	88.60	87.70	82.40	89.10	87.40
Mass fraction of pectin substances, %	1.18	1.21	1.67	1.41	0.78
Hydratopectin, %	0.26	0.21	0.37	0.20	0.029
Protopectin, %	0.98	1.0	1.30	1.21	0.75
Mass fraction of pectin substances in terms of a.d.m., %	10.90	9.80	9.50	7.43	5.13
Hydratopectin, (a.d.m.), %	2.30	1.70	2.10	1.83	0.23
Protopectin, (a.d.m.), %	8.60	8.10	7.40	5.60	5.90
The share of protopectin in the total content of pectin substances, %	78.90	82.65	77.89	75.37	95.25

Hydrolysis extraction of pectin from melon peels was carried out on a PE-8110 extractor using a liquid thermostat with the function of maintaining the set temperature.

The preparation of raw materials consisted in separating the peel from the pulp of melon fruits, previously cut into slices up to 50 mm wide, using a special device that allows removing a peel 5 mm thick [28; 29]. Then the melon peel was passed through a cylindrical grater.

To study the influence of the degree of grinding in the process and the completeness of pectin extraction, the following sizes were chosen: less than 1. 3. 5. 7. 10 mm. The particle size was controlled by the size of the grater cells.

Based on preliminary experiments, it was found that, taking into account the duration, completeness of extraction and the rate of sediment separation from the solution, the optimal size of the grater cells is 5 mm.

Hydrochloric acid was used as an extractant. The acid extraction method is preferable to the alkaline one, since the disposal of alkaline synthesis products is the most laborious. The acid method is more environmentally friendly. Organic acids that are offered for use are more expensive, unlike hydrochloric acid, which is also the least dangerous to use in production among other inorganic acids possible for pectin extraction.

Sample preparation technology was as follows. The melon peel was crushed to a size of 5 mm and treated with 0.5 % aqueous hydrochloric acid at 80°C for 90 min, with a water modulus of 5, and stirring at a speed of 120 rpm in a thermostated extractor flask.

After extraction, the resulting pectin was separated by vacuum filtration on a paper filter, and then washed with hot distilled water. Precipitation of pectin substances was carried out with calcium chloride, and their purification was carried out with ethyl alcohol.

The precipitate separated on a vacuum filter was dried in an ShS-80-01 SPU oven and weighed on an analytical balance. The degree of extraction of pectin was calculated as a percentage of the weight of the extracted pectin in relation to the weight of the pectin contained in the raw material. According to preliminary experimental data, the highest productivity was achieved using a hydrochloric acid solution as an extractant.

Further, the content of pectin substances was determined titrimetrically in the obtained fraction. The method is based on alkaline titration.

The result of the titration is presented as a proportion of the amount of free to esterified carboxyl groups and multiplied by the corresponding equivalents, which allows you to set the content of polyuronides in pectin substances.

In order to reduce the number of experiments and optimize the study, a regression analysis of the pectin yield study was used. At present, difficulties in making optimal decisions are associated with many other factors [30].

After that, in order to study the influence of some technological factors on the extraction of pectin from melon peels, a full factorial experiment FFE 23 was carried out. Factors were chosen as components that change the pectin yield (η, %) (Table 2):

Table 2

The interval of variation and levels of factors

Factors	Levels of factors	
	-1	+1
The amount of time to processing melon crust with acid (t), min – X_1	30	120
Acid concentration (Ck), % – X_2	0.25	1.25
Temperature (T), ºC – X_3	60	90

Planning matrix with all the interactions shown in Table 3.

Table 3

Planning matrix for the experiment (FFE) 2^3

N	Factors			Interactions		
	X_1	X_2	X_3	X_1X_2	X_1X_3	X_2X_3
1	+	+	+	+	+	+
2	-	+	+	-	-	+
3	+	-	+	-	+	-
4	-	-	+	+	-	-
5	+	+	-	+	-	-
6	-	+	-	-	+	-
7	+	-	-	-	-	+
8	-	-	-	+	+	+

Results and discussions

The data in Table 1 indicate that the content of pectin in the melon peel is in the range from 0.78 to 1.67 % of the total mass of the peel and 6.13... 10.9 % of the mass of dry matter.

The highest content of pectin is distinguished by the Myrzachulskaya variety – 10.9 % of dry matter. The average fruit weight of this variety is usually in the range of 2 to 6 kg or more. The high organoleptic characteristics of this variety, especially the taste and color, should also be noted, which makes it possible to identify the Myrzachulskaya variety as a leader in the production of sweet canned food and juices.

The linear regression equation looks like this:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{22}x_2x_2 \quad (1)$$

The equation describes the effect of three factors on the pectin yield: extraction time (t), acid concentration (Ck) and temperature in the extractor (T). The results of the study of response functions, taking into account all interactions, and the average response values are presented in Table 4.

Table 4

Experiment outcomes

N	Yield of pectin, η (%)			Average result
	η_1	η_2	η_3	η_j
1	98.75	97.55	98.45	98.25
2	91.76	93.22	93.96	92.98
3	85.27	82.34	84.02	84.21
4	63.79	67.56	69.26	65.87
5	97.35	98.80	98.6	98.25
6	75.89	73.84	75.59	75.44
7	75.68	79.25	75.64	77.19
8	54.33	57.12	55.97	55.14
				649.33

The regression coefficients and statistical analysis of the results are shown in Table 5. The presented mathematical model describes the process we are studying in some detail with a determination coefficient of 0.98. Table 5 shows that 5 effects are statistically different from zero (P<0.05) with a 95% confidence interval.

Table 5

Regression coefficients and statistical analysis of options

	Regression coefficients	Sum of squares	F- value	P-value
Constant	4.61229			
A:t	0.5227	1655.85	229.28	0.0000*
B:Ck	24.6858	2430.7	335.36	0.0000*
C:T	0.5918	467.019	64.63	0.0000*
AB	–0.0573	39.861	5.52	0.033*
AC	–0.0039	169.336	23.43	0.0002*
BC	–0.0035	0.016538	0	0.9625

* Significant regression coefficients at P <0.05

After processing the results and ignoring minor effects, the following regression model was obtained (equation 2) [31-34]:

$$\eta = 4.612 + 0.523t + 24.686Ck + 0.592T - 0.057tCk - 0.004tT, \% \quad (2)$$

Summing up the branching of the main effects, the evaluation results are presented in a standardized Pareto chart (Fig. 1).

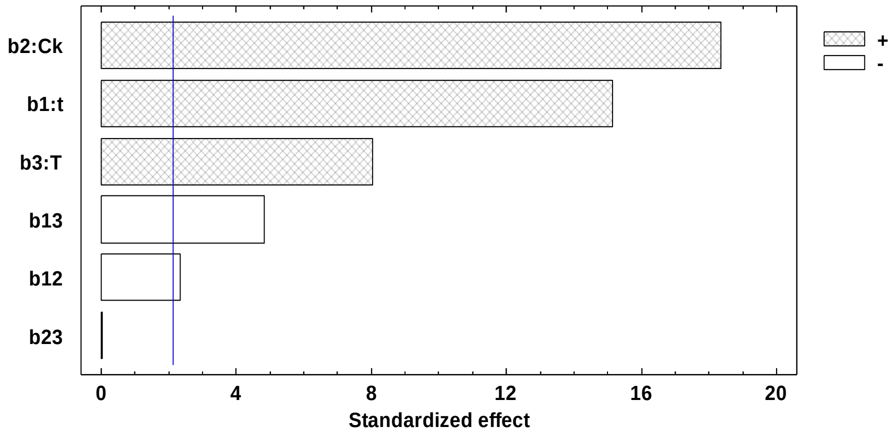

Fig. 1. Pareto diagram with coefficients of the pectin extraction regression model

The duration of pectin treatment with acid has the strongest influence on the extraction of pectin in a given range of parameters. The selected temperature and acid concentration in the solution have the least effect on the response function (pectin yield).

As can be seen from Fig. 2. the change in the yield of pectin η (%) at a constant concentration of hydrochloric acid of 0.75 % largely depends on the temperature and duration of the extraction process.

For example, at a temperature of 90 °C and an extraction time of 30 min, the yield of pectin is about 80 %, and at a temperature of 30 °C and a duration of 120 min, it is only about 76 %. In this case, the process of extracting pectin from melon peels is accelerated due to a higher temperature in the extractor.

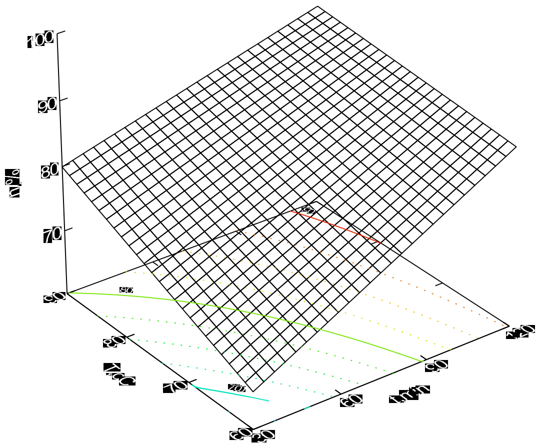

Fig. 2 Effect of t (min) and T (ºC) at Ck =0.75% on η (%)

Fig. 3 shows the influence of Ck in the range of 0.25…1.25 % and T from 60…90 °C on η at t_{const} = 75 min.

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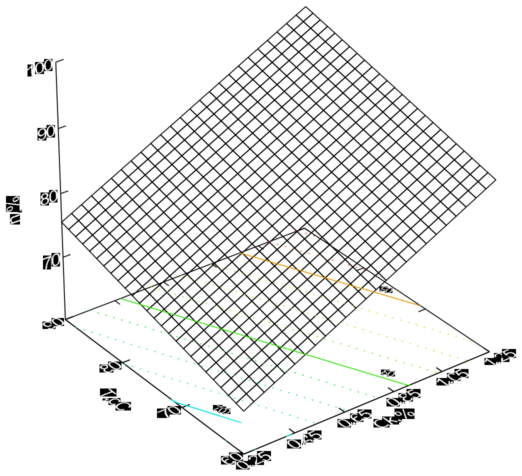

Fig. 3. Effect of T (˚C) and Ck (%) at t = 75 min on η (%)

From Fig. 3 it can be seen that the pectin yield is almost equally affected by Ck and T. For example, at Ck = 1.25 % and T = 60 °C, the pectin yield will be about 74 %, and at Ck = 0.25 % and T = 90 °C, η ~ 76 %. From fig. 3 clearly shows that at T = 60 °C and Ck = 1.25 %, the pectin yield η is the highest.

Fig. 4 shows the influence of Ck in the range of 0.25…1.25 % and t from 30…120 min on η at Tconst = 75 °C.

From Fig. 4 it follows that under these conditions, the pectin yield mainly depends on the concentration of hydrochloric acid, for example, at t = 30 min and Ck = 1.25 %, the pectin yield was about 84 %, at t = 120 min and Ck = 0.25 %, the yield barely reached 68 %. Thus, with an increase in Ck, the yield of pectin also increases.

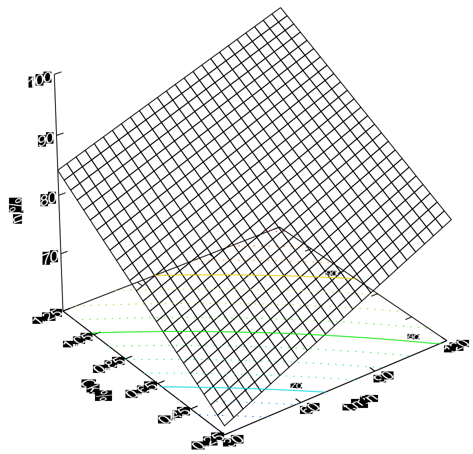

Fig. 4. Effect of t (min) and Ck (%) at T=75 °C on η (%)

For practical verification of the obtained regression equation (2), two experiments were carried out on the extraction of pectin from the same melon peel sample. The first sample was extracted under the following conditions: T = 90 °C; Ck = 1.25 %. The second sample is T = 60 °C; Ck = 0.25 %. Sampling was carried out every 15 min with tmax = 120 min in both cases. The results of the experiments are shown in Fig. 5 and 6.

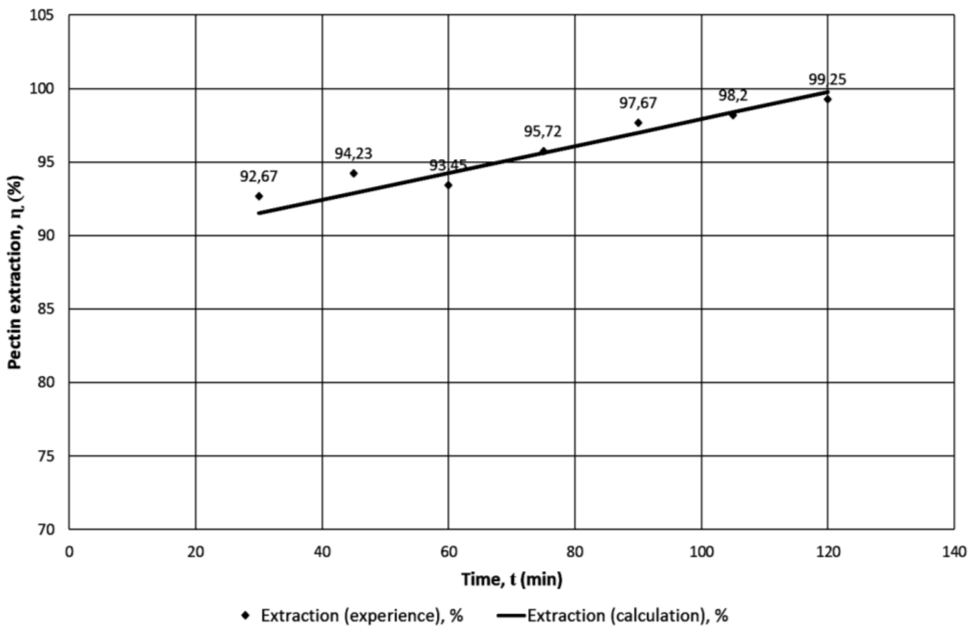

Fig. 5. Pectin yield dynamics η (%) at T = 90 °C, Ck = 1.25 %

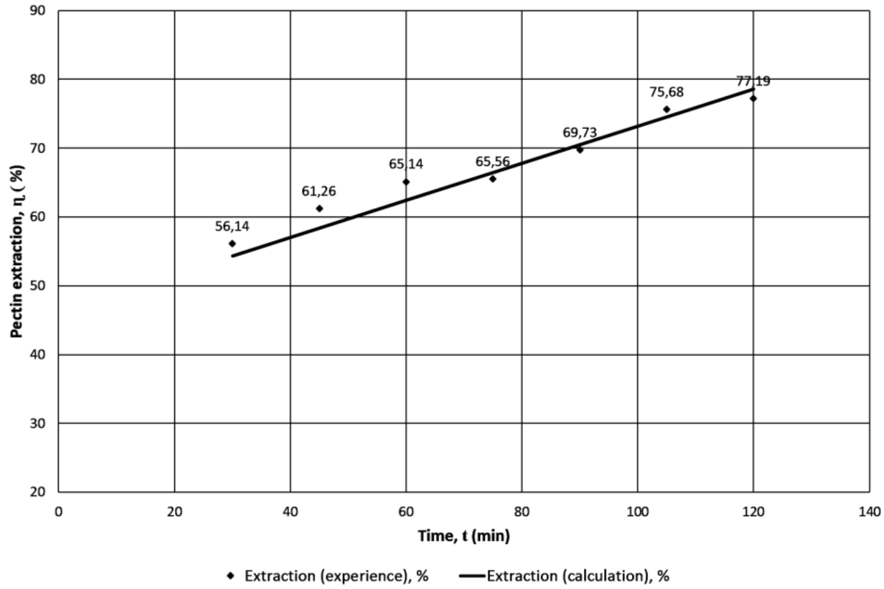

Fig. 6. Pectin yield dynamics η (%) at T = 60 °C, Ck = 0.25 %

Fig. 5 and 6 show the dependences of the pectin yield on time under certain extraction conditions in the form of straight lines. At the same time, the calculations of regression equations were used as the basis for the construction of straight lines. The dots on the graphs indicate the results of pectin yield under the same conditions, but obtained during testing of samples in laboratory conditions. As can be seen from the graphs, the calculated data obtained from the regression equations correlate with the experimental results in the variation interval.

Conclusion

According to the results of the study, it was found out that the pectin yield (η, %) when treated with hydrochloric acid in the range Ck = 0.5…1.25 % increased with an increase in the acid content in the extractor. An even greater yield can be obtained by increasing the temperature from 60 to 90 °C, processing time, hydromodulus, and reducing the size of the particles that undergo hydrolysis. The highest yield of pectin – 95 ... 98 % – is most likely at Ck = 1.25 %, T = 90 ^{0}C and hydrolysis time from 40 to 60 min. At the lowest values of Ck and T, the extraction of pectin does not exceed 90% even during the maximum processing time (t = 150 min). As a result of the research on the planning of the experiment, a regression equation was obtained that described the dependence of the pectin yield on the given parameters. Based on the analysis of the equations, the optimal parameters of the extraction process were determined: Ck = 1.25 %; T = 90 ^{o}C; t = 40…60 min. As additional parameters for acid hydrolysis, it was proposed to use a hydromodulus of 1 : 5 and a melon peel particle size of ≤5 mm.

The results obtained can be used in the implementation of a complex technology for processing melons at canning enterprises.

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