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Juice yield and pectin indicators in apple and carrot pomace

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ABSTRACT:

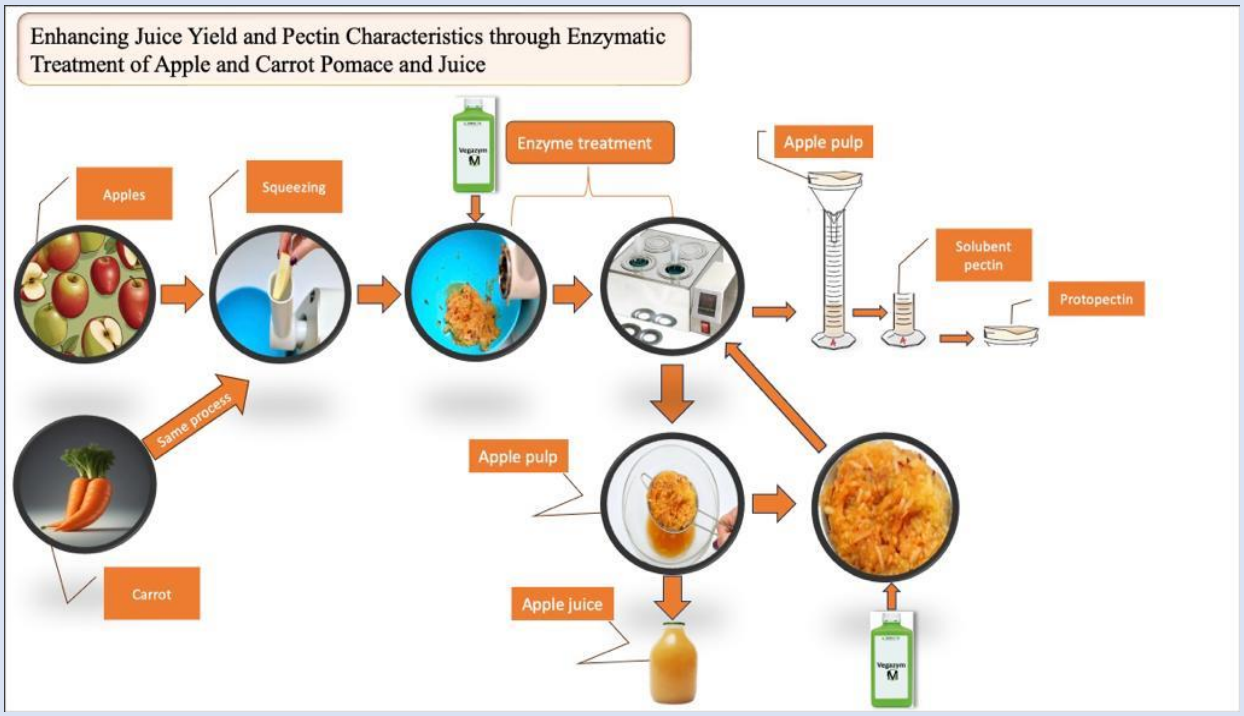
Background: Pectin exhibits different properties based on its degree of esterification, forming gels and serving as a structure-forming agent in food products, or forming complexes with heavy metal ions, finding applications in the development of therapeutic products for the elimination of heavy metal ions from the human body.

Context and purpose of this study: The purpose of this study is to investigate the influence of enzymatic treatment on the yield and quality of apple and carrot juices, as well as the quality parameters of pectin in pomace. Our objectives were to select an enzymatic preparation for processing apple and carrot pomace and to study changes in the properties of pectins present in the pomace depending on the dosage of the enzyme preparation.

Results: The results of our experiments revealed that for apple pomace processing, it is more beneficial to use the enzyme preparation Vegazym M with a dosage of 0.09% of the pomace mass, while for carrot pomace processing, the enzyme preparation Fructozym MA with a dosage of 0.07% of the pomace mass proved to be the most suitable. These enzyme preparations in the specified amounts ensure maximum juice yield. It has been established that changing the dose of enzymes changes the complexing properties of pectin, which allows its use in food products with therapeutic and prophylactic properties.

Conclusions: The enzyme preparations allow for specific modifications, such as pectin modification in this case, enabling the versatile use of pectin as either a structure-forming agent or for the development of therapeutic and preventive food products.

Keywords: Apple and carrot juices, enzyme preparations, apple and carrot pomace, pectin, soluble and insoluble pectin, degree of esterification and pectin complexation, functional products.



Graphical Abstract:

INTRODUCTION

Apple and carrot juices and their blends are widely consumed beverages worldwide, and their use in the food industry is increasing due to their nutritional and physiological value, taste, and aroma [1-3]. To extract the juice contained inside the plant cells of fruits and vegetables, it is necessary to break down the cell wall. Components present in the plant cell include cellulose, hemicellulose, and pectin substances. Pectin substances include protopectin (insoluble pectin), soluble pectin, and pectic acids, which are found both within the plant cell and in the intercellular space. The main obstacle to juice extraction from plant raw materials is soluble pectin, which, upon contact with water, increases the juice viscosity, hindering its efficient extraction. To enhance juice yield, microbial pectolytic enzyme preparations are used, which typically consist of enzymes with various substrate specificities [4-6]. Due to significant differences in the chemical composition and morphological structure of various fruits and vegetables,

it is essential to select a specific enzyme preparation for each type of plant raw material, containing a unique set of enzymes, and sometimes supplement the enzyme action with additional enzymes of required substrate specificity to form a composition of enzyme preparations [7-9].

Microbial pectolytic enzyme preparations are a group of enzymes capable of breaking down and hydrolyzing pectin, the main component of plant cell walls. They exhibit specific activity towards pectin and can act on various types of linkages present in the pectin molecule. The action of pectolytic enzymes on pectin can result in various effects in food products, including texture modification, improved juice extraction, softening of cell structures in fruits and vegetables, as well as enhancing clarification and filtration in the juice and wine industries [10-11].

Scientists confirm that high consumption of natural functional foods, rich in bioactive compounds, is associated with a reduced risk of chronic diseases such as cardiovascular diseases, cancer, metabolic syndrome, type II diabetes, and obesity [12-13]. Pectins found in fruits and vegetables are valuable components. Pectin, a polysaccharide, is an essential nutritional substance with unique properties that can either form dense gels or bind and remove toxic substances from the body, such as heavy metals and radionuclides [14]. Pectin can be sourced from various plant materials, including vegetable oils (e.g., corn oil), apple pomace, beet pulp, nuts, seeds, and meat products such as poultry, pork, and beef. The different properties of pectin in these products are attributed to the distribution of carboxyl groups along the partially esterified polygalacturonic acid molecule, where monomeric units are linked by glycosidic chains at position 1,4 [15-16].

Pectins are classified based on their degree of esterification and can be divided into two main categories. High methoxy pectin has a high degree of esterification. It forms gels when interacting with sugars and acids, such as sucrose and citric acid. The gel formed using high methoxy pectin is irreversible and exhibits heat stability [17]. Low methoxy pectin has a low degree of esterification. It forms gels when interacting with calcium ions. The gels formed using low methoxy pectin can undergo syneresis at elevated temperatures and have a reversible structure [18]. Pectin also holds promising potential for use in the production of functional food products with health benefits [19]. Medicinal and preventive applications of pectin differ from those used in the food industry.

During the process of food digestion, pectin is converted into polygalacturonic acid, which binds with radionuclides and toxic heavy metals to form insoluble salts that are not absorbed through the gastrointestinal mucosa. These salts are subsequently eliminated from the body through feces. Pectin can bind with strontium, cesium, zirconium, ruthenium, yttrium, lead ions, lanthanum, and niobium, and evacuate up to half of these elements from the body within 1-3 hours. Pectin enhances the body's resistance to radiation, making it a vital component of preventive and therapeutic nutrition. The recommended preventive dosage of pectin for healthy individuals is 2 grams per day, while the therapeutic preventive dosage is 4 grams per day, and the therapeutic dosage is 8 grams per day [20].

The raw material source widely used for obtaining pectin as a food additive is fruit and vegetable pomace, which remains after juice extraction. An important indicator of pectin is its degree of esterification, which depends on the degree of pectin degradation and its molecular weight, influenced by the dosage of added enzymatic preparations. Depending on the degree of esterification and complex-forming properties, pectins extracted from pomace can be used either as gelling

agents or as food additives for creating products with therapeutic and preventive effects [21-23].

MATERIALS AND METHODS

Materials: The experimental research utilized fresh carrots of the Nantes variety and fresh apples of the Simirenko variety, harvested in 2022 from the Krasnodar Krai region in Russia. The fruits were randomly selected based on their uniform color, size, and ripeness degree. They underwent several procedures, including cleaning, cutting into small pieces, and homogenization using a food blender (Polaris PHB-1385).

The apple and carrot pulp were divided into seven equal parts, with one part serving as the control group without enzymatic treatment, and the remaining six parts being treated with pectolytic enzyme preparations from the company ERBSLÖH (Germany): Fructozym P6-L, Fructozym MA, Fructozym BE, Fructozym Press, Vegazym M, and Vegazym HC. These preparations contain the following enzymes (Table 1).

Table 1. Content of enzyme preparations.

Enzyme preparation	Main enzymes
Fructozym P6-L	Pectinase, pectinesterase, pectin lyase, endo-polygalacturonase, exo-β-glucanase
Fructozym MA	
Fructozym BE	
Fructozym Press	
Vegazym M	Pectinase
Vegazym HC	Pectinase, hemicellulase, cellulase

The enzymatic treatment was carried out for 60 minutes at a temperature of 50°C, followed by juice extraction using a hydraulic press. After apples and carrots treatment, the pulp and pomace were briefly heated to a temperature of 90°C for 5 minutes to inactivate the enzymes.

Modified "calcium-pectate" method for determination of pectin substances [24]: To determine the amount of soluble pectin in apple pomace, 10 g of dry pomace was finely ground in a porcelain mortar to a homogeneous mass. The resulting mass was quantitatively transferred to a 150 cm3 flask, 100 cm^3 of water at 40°C was added, and it was kept on a water bath at 40°C for 30 minutes. The obtained solution was filtered through a folded paper filter. The operation was repeated. The solid precipitate was poured with 75 cm^3 of water and filtered through the same filter, then again, the solid precipitate was poured with 50-60 cm^3 of water and filtered through the same filter. The obtained extracts were collected in a 250 cm^3 volumetric flask and brought to the mark with distilled water. A solution of hydrated pectins was obtained.

To determine the mass fraction of protopectin and pectic acid in pomace, the residue obtained on the filter after extracting soluble pectin was poured with 50 cm3 of 0.3 N hydrochloric acid solution and transferred to a 50 cm^3 volumetric flask. It was sealed with a stopper equipped with a reflux condenser and kept for 30 minutes on a boiling water bath. Then, the extract was filtered through a folded filter into a 500 cm3 volumetric flask. The residue on the filter was washed four times with 75 cm^3 of distilled water. The washings were filtered through a folded paper filter into the same flask. The

residue on the filter, along with the filter, was placed in the flask, poured with 50-70 cm^3 of a 1% solution of ammonium citrate, and placed on a boiling water bath for

30 minutes. The resulting extract was filtered through a paper filter into the same volumetric flask. The filter was washed with hot distilled water, after which the contents of the flask were cooled and brought to the mark.

To prepare the hydrated pectin and protopectin solutions, a 200 cm^3 sample was taken from 10 g of finely ground dry pomace. For the protopectin sample, 0.1 N NaOH solution was added while incorporating a phenolphthalein indicator until a constant pale-pink color was observed. Then, 2.5 cm^3 of 40% NaOH solution was added to both the hydrated pectin and protopectin solutions, which were then incubated at room temperature for 15 minutes. This incubation period facilitated the saponification of pectin substances, resulting in the solutions acquiring a dark maroon color.

The formed pectic acid was treated with 10 cm^3 of concentrated HCl. The resulting precipitate was filtered through pre-dried folded paper filters until a constant mass was achieved. The filtered precipitate was then thoroughly washed multiple times with cold distilled water to completely remove chloride ions. The efficiency of the washing process in removing chloride ions was evaluated through a qualitative reaction between the wash water and $AgNO_3$.

Afterward, the filter was carefully emptied, and the precipitate was transferred into containers. These containers were then placed in a drying oven and subjected to a temperature of 105°C until a constant mass was achieved through careful drying.

Subsequently, the mass of the precipitate was determined by subtracting the combined mass of the dried filters containing the precipitate, the mass of the dried filters before filtration, and the mass of the hydrated pectin, which was determined using formula (1).

$$\omega_{HP} = \frac{m_2}{m_1 \cdot 0.8} \cdot 100, \quad (1)$$

ω_{HP} – The mass fraction of the hydrated pectin fraction, expressed as a percentage.

m_1 – The mass of the sample of the investigated raw material taken for analysis, expressed in grams (g).

m_2 – The mass of the sediment obtained from the sample, expressed in grams (g).

0.8 – Coefficient for converting the volume of hydrated pectin solution used for analysis to the total volume of pectin extract.

100 – Calculation coefficient of percentage.

The mass of pectin substances in the protopectin solution was determined using formula (2):

$$\omega_{PP} = \frac{m_2}{m_1 \cdot 0.4} \cdot 100, \quad (2)$$

ω_{PP} – The mass fraction of the protopectin fraction, expressed as a percentage.

m_1 – The mass of the sample of the investigated raw material taken for analysis, expressed in grams (g).

m_2 – The mass of the sediment obtained from the sample, expressed in grams (g).

0.4 – Coefficient for converting the volume of protopectin solution used for analysis to the total volume of pectin extract.

100 – Calculation coefficient of percentage.

Method for determining the degree of pectin esterification [25]: The degree of pectin esterification was determined as follows: 0.5 grams of dry apple pomace were transferred to a 250 ml flask, moistened with 2 ml of ethanol, and dissolved in 100 ml of carbon dioxide-free water. After complete dissolution, five drops of phenolphthalein were added, and the sample was titrated with 0.5 M sodium hydroxide solution with the

initial titration result recorded. Then, 10 ml of 0.5 M sodium hydroxide solution was added, and the sample was vigorously shaken and left for 15 minutes. Next, 10 ml of 0.5 M hydrochloric acid solution was added, and the sample was shaken until the pink color disappeared. After adding five drops of phenolphthalein, the solution was titrated with 0.5 M sodium hydroxide solution until a pale pink color appeared, which persisted after vigorous shaking (endpoint). The volume of titration was recorded as the saponification titre (final titre). The degree of pectin esterification was calculated using formula (3).

(3)

$$DE = \frac{ET}{IT + ET} \cdot 100,$$

DE – Degree of pectin esterification.
ET – Endpoint titration.
IT – Initial titration.
100 – Calculation coefficient of percentage.

Method for determining the complex-forming ability of pectin with respect to copper: The determination of the complex-forming ability of pectins with respect to copper is based on the photometric measurement of copper in the form of a copper-ammonium complex. This complex exhibits an intense blue color with a maximum absorbance of 620 nm. The complex is formed by adding ammonia solution to a solution containing copper sulfate, according to the following reaction:

$$CuSO_4 + 4NH_4OH = [Cu(NH_3)_4]SO_4 + 4H_2O$$

To determine the complex-forming ability of pectins with respect to copper, the following reagents were used: a 5% ammonia solution, 1% and 4% copper sulfate solutions, and a 0.5% solution of crushed apple and carrot pomace.

To construct the calibration curve, a 1% copper sulfate solution was prepared, and then solutions with lower concentrations (Table 2).

Table 2. Copper sulfate solutions for constructing the calibration curve.

Solution	Content of solution	The concentration of copper sulfate, mg/cm^3
1	The initial 1% $CuSO_4$ solution	10
2	9 cm^3 of 1% CuSO4 solution mixed with 1 cm^3 of water	9
3	8 cm^3 of 1% CuSO4 solution mixed with 2 cm^3 of water	8
4	7 cm^3 of 1% CuSO4 solution mixed with 3 cm^3 of water	7
5	6 cm^3 of 1% CuSO4 solution mixed with 4 cm^3 of water	6
6	5 cm^3 of 1% CuSO4 solution mixed with 5 cm^3 of water	5
7	4 cm^3 of 1% CuSO4 solution mixed with 6 cm^3 of water	4
8	3 cm^3 of 1% CuSO4 solution mixed with 7 cm^3 of water	3
9	2 cm^3 of 1% CuSO4 solution mixed with 8 cm^3 of water	2
10	1 cm^3 of 1% CuSO4 solution mixed with 9 cm^3 of water	1

The contents of the test tubes were mixed, and the reaction of copper ammonium complex formation was carried out. For this, 2 cm^3 of the test solution was taken, and 1 cm^3 of ammonia solution and 2 cm^3 of water were added. The test tubes were shaken, and the intensity of the resulting coloration was measured using a photoelectric colorimeter. Based on the obtained data, a calibration curve of optical density versus the concentration of the copper sulfate solution was constructed (Figure 1).

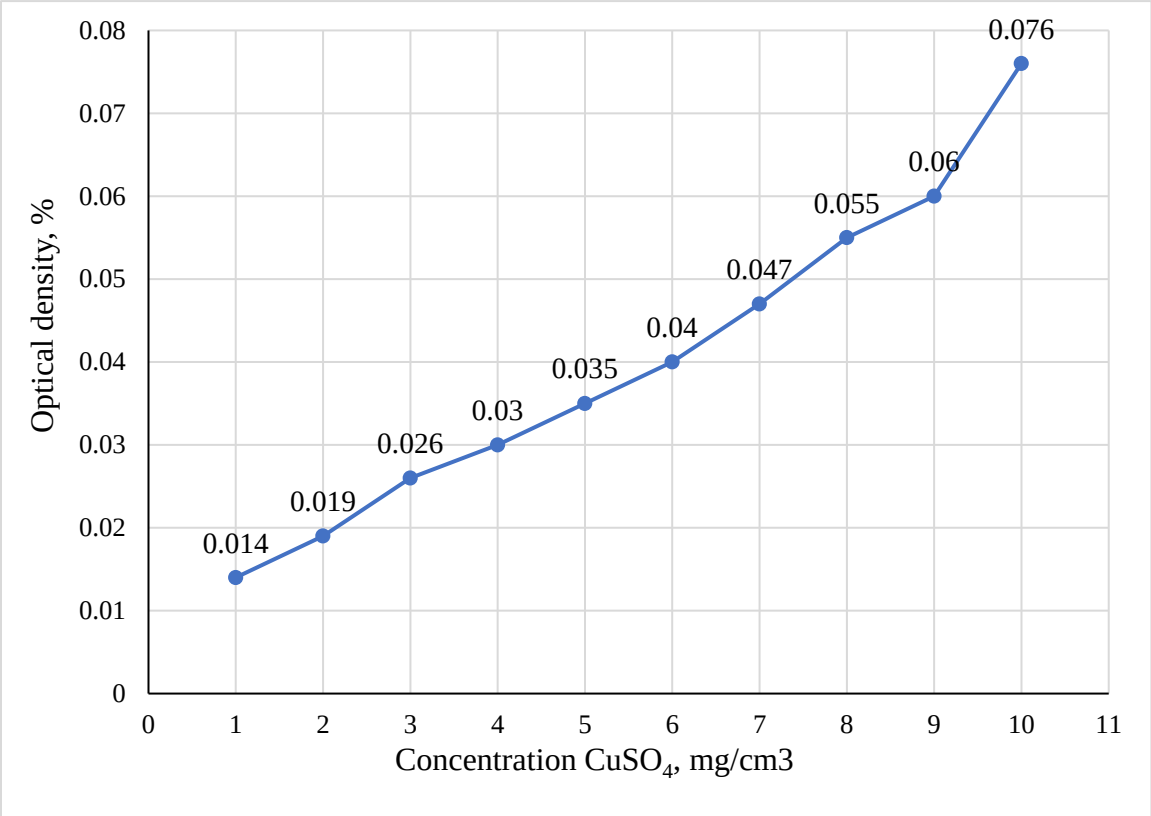


Figure 1. Calibration curve of optical density versus the concentration of the copper sulfate solution.

To determine the complexing ability of pectin present in apple and carrot pomace, test solutions were prepared as follows: 1 ml of a 4% CuSO4 solution was added to 2 ml of a 0.5% solution of apple and carrot pomace, followed by the addition of 2 ml of water. The contents of the test tubes were mixed and filtered, and the optical density of the filtrate was measured. Using the calibration curve, the amount of copper bound by pectin in the pomace was determined.

RESULTS

The enzymatic treatment of apple and carrot pulp revealed the most effective enzyme preparation: In the first stage of the experiments, different substrate-specificity enzymatic preparations were added to the apple and carrot pulp at a concentration of 0.03% of the mass. The enzymatic treatment was carried out at 50°C for 60 minutes, after which the juice was pressed out, its quantity was measured, and the percentage of juice mass yield relative to the mass of the used pomace was calculated. The results are presented in Table 3.

Table 3. The juice yield after treating apple and carrot pulp with different substrate-specificity enzymatic preparations.

Enzyme preparations	Juice yield relative to volume (%)	
	Apple pomace	Carrot pomace
Control	62,0	57,0
Fructozym P6-L	78,0	61,4
Fructozym MA	81,0	66,4
Fructozym BE	83,0	61,4
Fructozym Press	80,0	65,2
Vegazym HC	76,0	63,4
Vegazym M	84,0	64,6

The table shows that during the treatment of apple pulp with enzymatic preparations, the highest juice yield was obtained when adding the Vegazym M enzyme preparation, with a juice yield of 84.0%, which is 35% higher than the juice yield in the control sample.

For carrot pulp treatment, the highest juice yield of 66.4% was achieved when using the Fructozym MA enzyme preparation, which is 9.4% higher than the control sample.

The impact of different doses of enzyme preparations on the yield of juice: In the next stage of the experiments, the dose of enzymatic preparations was varied in the range from 0.01% to 0.15% with an interval of 0.02%. The enzymatic treatment was carried out under the same parameters – at a temperature of 50°C for 60 minutes. After pressing, the amount of obtained juice was measured, and the juice yield was calculated. The results are presented in Table 4 and Figure 4.

Table 4. The indicators of juice yield depending on the dose of the enzyme preparation

Indicator name	Juice yield relative to volume (%)								
	Dose of enzyme preparation (% of juice mass)								
	-	0.01	0.03	0.05	0.07	0.09	0.11	0.13	0.15
Processing of apple pulp with Vegazym M	62,0	76,0	84,0	90,0	91,0	93,0	90,0	85,0	83,0
Processing of carrot pulp with Fructozym MA	57,0	67,6	66,4	66,0	70,8	68,6	64,0	63,8	63,8

The table shows that the highest yield of apple juice was obtained with a dose of Vegazym M at 0.09% of the pulp mass, and the highest yield of carrot juice was obtained with a dose of Fructozym MA at 0.07% of the pulp mass.

Quantitative values of pectin quality indicators: For the rational utilization of plant raw materials, including fruits and vegetable residues, it is essential to maximize the beneficial use of the by-products obtained during their processing. The secondary products after juice extraction

from apple and carrot pulp are apple and carrot pomace, which contain bioactive components, including an important component like pectin. The characteristics of pectin, and therefore its application, will depend on the molecular weight of the pectin, i.e., the degree of its destruction, which will vary depending on the dose of enzyme preparations added. Parameters such as the amount of soluble and insoluble pectin, the degree of its esterification, and its complex-forming abilities will be affected.

In the next stage of the experiments, apple and carrot pomaces were used, which were obtained after extracting juice from these samples.

Since it has been established in previous experiments that Vegazym M is the most suitable for pectin destruction in apple pomace and Fructozym MA for carrot pomace, these enzyme preparations were used for processing apple and carrot pomaces. The results obtained are presented in Table 5 and Figures 2-4.

Table 5. Quantitative values of pectin quality indicators

Indicator Name	Dose of enzyme preparation (% of juice mass)								
	-	0.01	0.03	0.05	0.07	0.09	0.11	0.13	0.15
Apple pomace									
Soluble pectin, %	0.80	1.00	0.87	2.49	2.70	3.89	5.17	2.43	2.69
Protopectin, %	0.28	0.37	0.52	0.75	0.55	0.46	0.50	0.62	0.53
Esterification degree, %	79.69	60.00	55.60	44.40	44.40	40.00	36.80	58.80	68.40
$CuSO_4$ complex formation, mg/cm^3	5.20	5.40	5.77	6.06	6.65	6.20	5.90	5.00	5.35
Carrot pomace									
Soluble pectin, %	0.48	0.54	0.57	0.62	0.65	0.60	0.65	0.42	0.42
Protopectin, %	1.13	1.22	1.51	1.04	1.37	1.37	1.53	1.27	1.55
Esterification degree, %	64.57	54.97	43.42	41.40	41.24	40.08	34.42	34.98	36.25
$CuSO_4$ complex formation, mg/cm^3	8.00	9.30	9.00	9.50	10.00	9.75	9.75	9.30	8.00

During the processing of apple juice with the enzyme preparation Vegazym M, the content of soluble pectin gradually increased until it reached the maximum percentage at an enzyme concentration of 0.11%. Subsequently, there was a decrease in the percentage of soluble pectin. Insoluble pectin (protopectin) showed the highest percentage at an enzyme concentration of 0.05% and then also decreased. The best indicator of complexation for apple pectin with copper ions was observed when adding Vegazym M at a concentration of 0.05-0.09% of the juice mass.

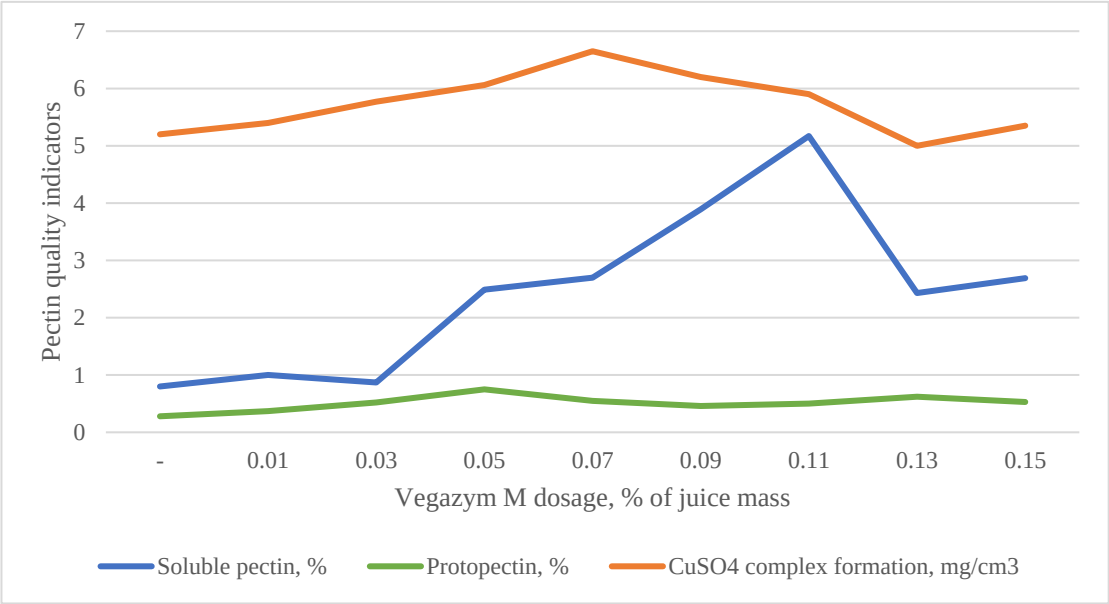


Figure 2. The effect of enzyme preparation Vegazym M on the pectin quality indicators in apples

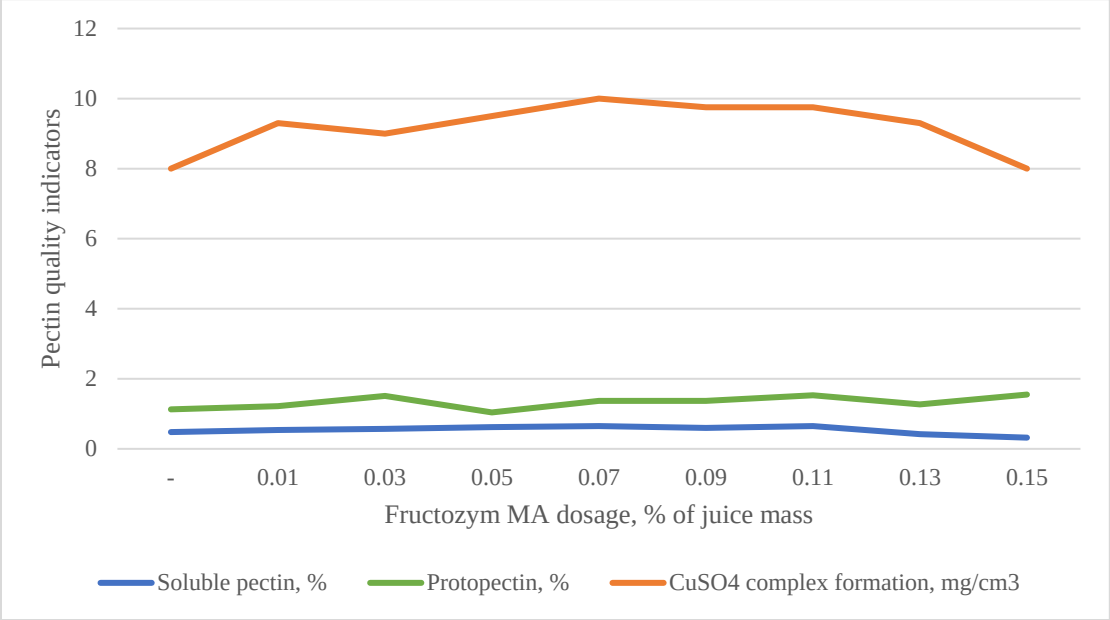


Figure 3. The effect of enzyme preparation Fructozym MA on the pectin quality indicators in carrots

There was no significant increase in the soluble and insoluble pectin of carrot pectin depending on the dose of the enzyme preparation Fructozym MA. However, the use of moderate doses from 0.03 to 0.11% still has a positive effect on these indicators. A good result was achieved in terms of pectin complexation with copper ions thanks to the enzyme preparation. At a dosage of 0.07% Fructozym MA, pectin molecules showed a 25% better binding with copper ions.

It was found that the amount of soluble pectin in apple pomace is 60% higher than in carrot pomace, but the complex-forming properties of pectin in carrot pomace are 53.8% higher than in apple pectin.

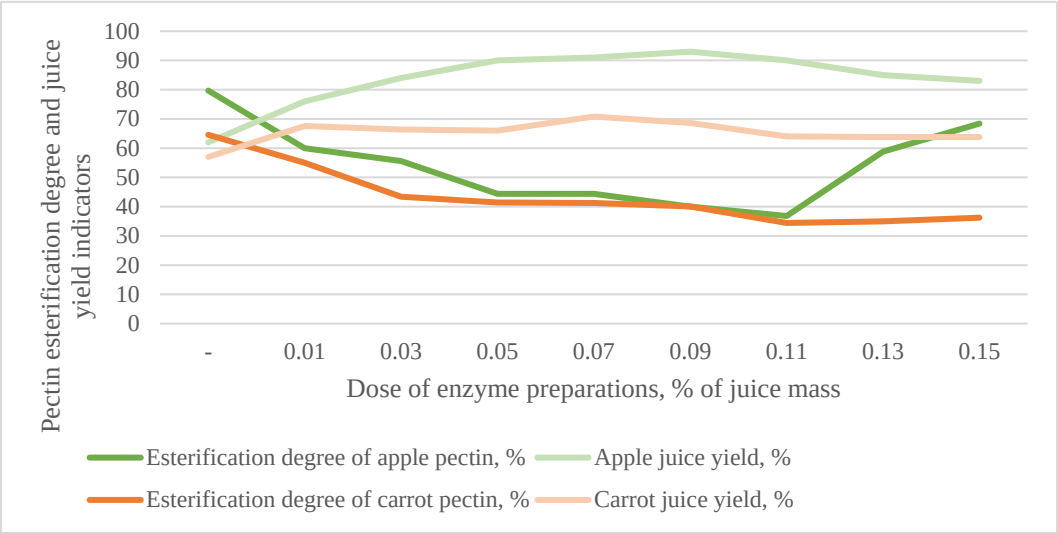


Figure 4. The effect of enzyme preparations Vegazym M and Fructozym MA on the pectin esterification degree and juice yield indicators

On this graph, we can clearly see that in both cases of applying enzyme preparations to apple and carrot juice, there was a significant impact on juice yield and the degree of pectin esterification. When processing the pomace at dosages from 0.01% to 0.11%, the degree of pectin esterification actively decreased. With an increase in the dosage of the enzyme preparation, the degree of pectin esterification began to increase too, indicating that further increasing the dosage of the enzyme preparation loses its effectiveness.

The degree of pectin esterification influences not only the gel-forming but also the complex-forming ability of pectins. The ability to bind polyvalent cations increases with a decrease in their degree of esterification and an increase in the degree of dissociation of free carboxyl groups. Therefore, pectins with a lower degree of esterification (below 50%) exhibit the greatest complex-forming ability, as seen in Figures 2 and 3.

DISCUSSION

In this study, the influence of pectolytic enzyme preparations and their dosages during the processing of apple and carrot pulp was investigated to enhance juice yield. It has been found that to increase juice yield from apple pulp, it is necessary to use the enzyme preparation Vegazym M, while for carrot pulp, the enzyme preparation Fructozym MA is more suitable. It should be noted that in previous studies with carrots of different varieties and from different regions, it was found that the enzyme preparation Fructozym MA was the most effective for carrot processing, as it not only resulted in a higher juice yield but also a higher yield of carotenoids [26-27]. The need to use different enzyme preparations for apple and carrot pulp can be explained by the distinct morphological structures of apples and carrots as fruits.

The objective was to investigate how changing the dosage of enzyme preparations would affect juice yield. It was found that increasing the dosage of Vegazym M to 0.09% resulted in a maximum juice yield of 93%, which is 31% higher than the juice yield in the control sample. Similarly, increasing the dosage of Fructozym MA to 0.07% from the mass of the pulp resulted in a juice yield of 70.8%, which is 13.8% higher than the juice yield in the control sample. It was found that increasing the dosage

of enzyme preparations in the apple pulp to 0.11%, 0.13%, and 0.15% of the pulp mass led to a decrease in juice yield. This effect is attributed to the fact that at high concentrations of the enzyme preparation in the substrate, the enzymatic activity of the enzymes decreases.

To make rational use of plant food sources, it is essential to maximize the benefits of by-products obtained during the processing of vegetables and fruits. Apple and carrot pomaces are secondary products after juice extraction, containing bioactive compounds, including pectin substances. There is a lack of information in the literature about the impact of enzymatic treatment on apple and carrot pomaces concerning crucial pectin indicators like the degree of esterification and complex formation with heavy metal ions.

For the enzymatic treatment of apple and carrot pomace, the same enzymatic preparations were used, which were selected for the treatment of the pulp. It was established that the amount of soluble pectin, protopectin, degree of esterification, and complex formation of pectin in apple and carrot pomaces varies depending on the dose of enzyme preparations. The amount of soluble pectin in apple pomace is 60% higher than in carrot pomace, however, the complex-forming properties of pectin in carrot pomace are 53.8% higher than in apple pectin. This allows including carrot pomace in food product formulations or extracting pectin with desired technological and functional properties from the pomace. At low dosages of the enzyme preparation, apple pomace can be used to extract pectin with gelling properties, while dosages ranging from 0.05% to 0.11% are suitable for obtaining pectin with complex-forming properties.

The literature analysis, including research results on the determination of the main properties of pectin [28-30] for its use in the food industry and medicine, shows that pectin possesses structural-forming properties, which play a role in the development of food products [31-32]. Additionally, it can form complexes with heavy metal ions and remove them from the human body, which is crucial in the development of functional and therapeutic foods [33-36]. Given the worsening environmental conditions worldwide, the development of food products and medicinal phytopreparations based on plant materials with detoxifying properties is highly relevant [34].

Equally important is the search for new innovative methods of extracting pectin from plant materials. Traditional methods of pectin extraction involved the use of organic and inorganic salts [17], but modern research explores ways to intensify pectin extraction using physical methods such as microwaves, ultrasound, as well as the application of enzyme preparations [37]. We did not find similar studies where enzyme treatments of secondary resources from fruit and vegetable processing, such as pulps, were investigated, and the influence of enzyme preparations on the pectin content and its qualitative indicators in them was studied. Our research indicates that enzyme-treated pulps can be used to develop food product formulations with properties capable of exerting physiological effects on the human body. Developing technologies for the use of secondary raw materials from fruit and vegetable waste is undoubtedly a promising direction in scientific research, as such production reduces the amount of waste polluting the environment.

CONCLUSION

The results presented in this article demonstrate the effectiveness of using enzyme preparations. By making the right choice of enzyme preparations and their dosages for each type of plant material, it becomes possible to create resource-saving processing technologies. Enzymatic modification of secondary

resources from fruit and vegetable processing, with subsequent extraction of valuable food ingredients, allows for a comprehensive, waste-free approach to plant material processing. Furthermore, enzyme preparations enable the modification of pectin, in this case, in a way that it can be used either as a structural additive or for creating functional food products with therapeutic properties in the future.

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Conflict of Interest: The authors declare no conflict of interest.

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