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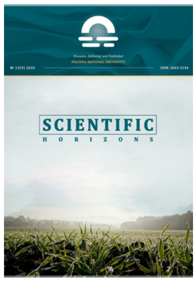

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Modes and methods of treatment of blackcurrant pomace with an enzyme preparation to increase juice yield

Nina Osokina
Doctor of Agricultural Sciences, Professor
Uman National University of Horticulture
20300, 1 Instytutska Str., Uman, Ukraine
https://orcid.org/0000-0002-2822-2989
Olena Herasymchuk*
PhD in Agricultural Sciences, Associate Professor
Uman National University of Horticulture
20300, 1 Instytutska Str., Uman, Ukraine
https://orcid.org/0000-0003-4242-0946
Kateryna Kostetska
PhD in Agricultural Sciences, Associate Professor
Uman National University of Horticulture
20300, 1 Instytutska Str., Uman, Ukraine
https://orcid.org/0000-0003-2387-5400
Hryhorii Podpriatov
PhD in Agricultural Sciences, Professor
National University of Life and Environmental Sciences of Ukraine
03041, 13 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-3164-5798
Volodymyr Piddubnyi
Doctor of Engineering, Professor
State University of Trade and Economics
02156, 19 Kioto Str., Kyiv, Ukraine
https://orcid.org/0000-0002-1497-7133

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Abstract. Blackcurrant is a multivitamin crop with high dietary and medicinal properties and is a source of exceptionally valuable raw materials for juice production, but its extraction is complicated by its chemical composition. The endocarp of blackcurrant fruit (the actual pulp) is formed by the slimy arylus surrounding the seeds, which prevents juice extraction. The purpose of this study was to scientifically substantiate the modes and methods of effective extraction of blackcurrant juice with preliminary enzymatic treatment of the pomace while preserving its natural chemical composition

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*Corresponding author

and biologically active substances. The study was conducted with blackcurrant fruits of the varieties Mynai Shmyrev, Belarus sweet, Novyna Prykarpattia in the laboratory of the Department of Technology of Storage and Processing of Plant Production and the Training and Production Department of the Uman National University of Horticulture. Research methods (physical, chemical, physical-chemical) and statistical processing of results (analysis of variance) are generally accepted. Blackcurrant fruit usually yields an unsatisfactory juice yield of 18-24%, which lacks its inherent colour. According to Harrington's desirability assessment, enzymatic treatment with pectofoetidine increases the juice yield from crushed fruit to satisfactory (37-44%) and very good (57-60%) for crushed fruit (pomace), which is 2-3 times higher. During the fermentation of pomace, three stages are distinguished: the first is the destabilisation of the colloidal system of the pomace (up to 1 hour); the second is the degradation of the pomace structure (up to 2 hours); and the third is the stabilisation of the process (after 3 hours). Optimum conditions for pomace fermentation are ensured by using 0.03% by weight of the preparation suspension, a temperature of 42-45 °C, and a process duration of 2 h. This results in up to 60% juice extraction, 96-102% acid conversion and up to 97% ascorbic acid content. The increase in juice yield by 6-15% correlates with the characteristics of the variety. In juices with sugar, the content of ascorbic acid is 1.7 times lower, but its preservation reaches 98-99%. Sugar and hot bottling are the factors that stabilise ascorbic acid in juices. Increasing juice yield and improving its quality is economically and technologically feasible

Keywords: enzymatic treatment; juice yield; juice quality; ascorbic acid preservation

INTRODUCTION

Blackcurrant juice has no equal in terms of nutritional and dietary value. Fruits with 88-94% cellular juice. However, it is not possible to completely separate the liquid and solid phases of the fruit during the extraction process. Natural blackcurrant juice has its own characteristics. O. Cherevko *et al.* (2020) formulated the objective reasons for the differences in juice extraction from blackcurrant fruits. The latter is conditioned by the fact that the value of the juice, namely flavour, aroma and, especially, colouring substances, is mainly localised in the cells of the integumentary tissues, which are difficult to destroy, even with varying degrees of mechanical grinding or crushing of the fruit. The juice yield of fruit depends on the cellular permeability of the fruit pulp, which has a mucilaginous consistency due to the pectin gel. Its splitting can loosen the tissues, reduce the viscosity of the juice, and facilitate its separation. Pectin substances in blackcurrant fruits are in a mobile state and to a certain extent determine the formation of physical and mechanical properties of fruit tissue.

According to O-C. Bujor *et al.* (2018), the hydrophilic biopolymer pectin can increase the water-holding capacity of plant tissue. The destruction of structural polymers that make up the middle plates of plant cells occurs, which leads to the breakdown of connections between cells and is the result of tissue breakdown into individual cells. The intercellular protopectin of the middle lamellae is connected to each other by ionic and covalent bonds. Ionic bonds are destroyed by heating at pH ≤ 4.5. Covalent bonds are broken by a complex of enzyme preparations. The process of enzymatic hydrolysis of protopectin can occur due to the destruction of internal or external bonds of the cellulose-hemicellulose-pectin complex.

Furthermore, the shape, nature, and degree of strength of water bonds with fruit pulp affects juice extraction. Blackcurrant juice, as a biological liquid, belongs to a heterogeneous dispersed system. Adsorption processes occur on the surface of its particles, which help to stabilise the colloidal juice solution. C. Colodel *et al.* (2018) found that the total amount of bound water in blackcurrant fruits is in osmotically bound and colloidally bound forms, with a share of 78%. In currant fruits, osmotically bound water accounts for only about 46%, while in apples, cherries, pears, and other types of fruit, it accounts for 60-70%. It forms a coarse fibrous structure of pectin substances between which there is a spatial grid, the cells of which are filled with water molecules. The proportion of colloidally bound (adsorbed) water in currant fruit is 32%, while in the previously listed fruits it is 15-25%. It is formed due to the concentration of water molecules in the surface layer of colloidal particles of the product, which is part of the micelles of various hydrophilic colloidal solutions – proteins, polysaccharides. Extracting such water is quite difficult. In juice production, some of the colloidally bound water can be extracted by enzymatic treatment of the raw material and, as a result, the hydrate layer is destroyed.

D. Chettri and A. Verma (2023), K. Aaby and M.R. Amundsen (2023) substantiated that various biochemical changes occur during juice production, associated with processes such as hydrolysis, oxidation, reduction, condensation, etc. Some of these processes are necessary to form and improve the taste properties of juices, but the vast majority cause the formation of undesirable or harmful substances and, as a result, deterioration of juice quality. Namely, the presence of oxidising enzymes that cause darkening of the juice, enzymes that reduce the content or change colouring substances, enzymes that oxidise ascorbic acid, and reduce the value of the juice is undesirable in preparations.

Considering the high extractivity and acidity of natural blackcurrant juice, it is considered a semi-finished product for the production of pleasant and harmonious tasting juices with sugar. The purpose of this study was to establish optimum conditions and rational methods of preliminary enzymatic treatment of blackcurrant pulp to increase juice yield and their influence on changes in quality indicators.

LITERATURE REVIEW

One of the most promising methods of pre-treating fruits and berries for juice extraction is the use of enzyme preparations. Generally, pectolytic, cytolytic, and proteolytic enzyme preparations are used in the canning industry. According to B. Flaumenbaum *et al.* (1986), H. Schmidt *et al.* (2022), pectolytic preparations are widely used in juice production, primarily for clarification of natural juices and for depectinisation of juices before concentration. However, as pointed out by K. Fan *et al.* (2019), with the right type of preparation and treatment regimes, it is possible to increase the juice yield from fruits and berries by 5-20-30% (del Rocío Castro-López *et al.*, 2016; Ninga *et al.*, 2018).

The crucial factor affecting the completeness and speed of juice extraction is the presence of pectin substances. Their breakdown helps to loosen the tissues, reduce the viscosity of the juice, and facilitate its separation. However, the amount and fractional composition of pectin substances in fruits and berries is not the same. For each type of raw material, the most effective preparations with a specific enzyme complex should be selected. Pectolytic enzymes are obtained from extracts of Aspergillus avamori and Foetidus fungi. Such preparations, apart from a complex of pectolytic enzymes, contain hemicelluloses, celluloses, proteinases, polyphenol oxidases, etc. The amount of accompanying enzymes in the preparations is not the same. Some of them can negatively affect the quality of the juice, for instance, change its colour, oxidise ascorbic acid.

A. Todaro *et al.* (2016) describe the mechanism of action of enzyme preparations as follows: enzymes destroy protopectin, which cements individual cells together, resulting in cell separation and tissue loosening. Furthermore, the protopectin encrusting the cell membranes is destroyed, which weakens their mechanical strength and, as a result, the protective properties of the protoplasmic membranes underneath. Then enzymes and some non-enzymatic substances enter the cell, causing coagulation of protein-lipid colloids and cell death. This is due to the long-term effect of the temperature factor. These changes increase cellular permeability, protoplasmic membranes rupture, and juice yield increases. Notably, hydrolysis of protein compounds in pomace and juices also occurs with the help of pectolytic enzyme preparations with high proteolytic activity, such as pectofoetidine. The effect of pectolytic enzyme preparations on the juice yield from fruits and berries has been studied in research institutions and laboratories. M. Siddiq *et al.* (2018) found that when apple pomace and some types of berries were processed, depending on the enzyme preparation, the juice yield increased by 4.5-15%.

The most effective use of preparations is for raw materials that are difficult to juice. The treatment of gooseberry pulp with nigrin (0.05% and 0.1% by weight) increased juice yield by 11-19%, and additional heating of pulp to 70°C increased it by 29%. The addition of 0.02% suspension of pectavamorin, pectofoetidin, and phylazim to plum pomace at 80°C increased juice yield by 10%. Comparable data were obtained by I. Olawuyi *et al.* (2021) and A. Marsol-Vall *et al.* (2021), who claim that treated aronia, blueberry, and plum pomace increased juice yields to 61%, 87% vs. 57%, 50%, respectively. Treatment of blackcurrant fruit pomace with pectavamorin P10x (0.075% by weight) for 2 hours provided 67% juice yield (control -20%). The juice's sugar content increased by 78%, polyphenols by 2.5 times, and the amount of pectin decreased from 0.68% to 0.10%.

Analogous studies M. Siddiq *et al.*, (2018) found the feasibility of 4-hour fermentation of the pomace. The juice yield was 64% (control – 16%). A sharp decrease in juice viscosity and pectin content (from 0.98% to 0.10%), an increase in polyphenols (from 0.22% to 0.55%), sugars (from 10.8% to 13.7%), and vitamin C (from 175 to 207 mg/100 g) was observed. Heating blackcurrant pomace to 45°C, adding 0.02% suspension of pectofoetidin P10x and pectavamorin P10x, and keeping for 4 hours at 40°C increased juice yield by 27-28%. The highest juice yield from blackcurrant pulp by centrifugation was obtained after treatment with pectofoetidine G20x – 75% (control – 32%). Under these conditions, A. Marsol-Vall *et al.* (2021) obtained up to 64% juice. The loss of pectin substances in the juice was 83.3%, and its viscosity was reduced by 8.3 times.

However, the use of pectin-degrading pectolytic preparations is only beneficial in weakening the protective properties of the cell membrane, which is deprived of the encrusting element, and facilitating pressing by reducing the viscosity of the flowing juice. The majority of the cell wall of blackcurrant fruit, which has completed its formation, is the secondary membrane, which mainly consists of polysaccharides – cellulose and hemicelluloses. They form a cell membrane matrix that prevents juice from leaking out. Therefore, it is advisable to use cytolytic enzyme preparations, such as cellulases, amylases, and hemicelluloses.

Experimental data showed that the maximum extraction of the liquid phase from apples (up to 85%) is provided by the cytolytic complex cellulase-100 due to the deep hydrolysis of a complex of polymers that determine the structural strength and water retention capacity of tissues. The complex treatment of raw materials with enzyme preparations pectofoetidin and celloretin increased the juice yield of currant berries by 22.5%. Furthermore, pectin substances (27% of the raw material), sugars, and colouring agents were better preserved. The source of cytolytic preparations can be enzymes of malt raw materials – cellulase, hemicellulose. They break down β-glucans and destroy the connection of pectin substances with cellulose and hemicellulose of plant tissue through the neutral polysaccharides arabinoxylans and arabinogalactans.

A complex of barley malt enzymes is used to produce a pectin extract. S. Wang *et al.* (2023) and T. Yu *et al.* (2023) confirmed the feasibility of using barley malt cytolytic enzymes for the pretreatment of blackcurrant berries (ratio of pulp: barley malt – 1:0.4, temperature – 40°C, duration – 2 hours). The juice yield was increased by centrifugation to 70%. The preservation of pectin content is 61-70% compared to 15.5% when treated with pectofoetidine. Considering the specifics of the raw materials and the features of the technological process, optimum conditions were created for the action of enzyme preparations for currant fruits: temperature – 35-40°C, pH – 2.8-3.5.

According to the technological instruction, the calculated amount of the preparation for the treatment of pomace is dissolved with a small amount of warm water (35-40°C), poured with 10 times the amount of juice heated to 45-50°C, and stirred until a homogeneous suspension is obtained. It is prepared immediately before introduction. The suspension is applied to the pomace of pome fruit immediately after grinding. 10-15% of water is added to the pulp of stone fruit, heated to 40-45°C, mixed with a slurry, and temper for 40-60 min before pressing. However, the Technological instruction (1992) does not contain any references to the specifics of processing the pomace of berry fruits and specifically blackcurrant fruits with enzyme preparations. The fermentation temperature is not specified. However, other scientific literature suggests that the pomace of crushed blackcurrant fruit is heated to 40-45°C, 0.03% of the enzyme preparation avamorin is added as a suspension in juice or water, mixed thoroughly, tempered for 4-6 h, and then pressed (Wang *et al.*, 2015).

Therefore, to increase juice extraction from blackcurrant fruits, preparations with a certain complex of enzymes should be selected: pectolytic, in which the presence of cytolytic and proteolytic enzymes is desirable, and by means of a differential approach, optimum conditions for their action should be created.

MATERIALS AND METHODS

Research on juice extraction was conducted during 2003-2006 with blackcurrant fruits of the varieties Minai Shmyrev, Belarus sweet, Novyna Prykarpattia in the laboratory of the Department of technology of storage and processing of crop production and in the Educational and Production Department of the Uman National University of Horticulture. Blackcurrant plantations are located in the central part of the Right-Bank Forest-Steppe of Ukraine. The region's climate is temperate continental with unstable moisture, uneven precipitation, and unstable temperatures.

Blackcurrant fruits of consumer ripeness were harvested at the end of June under favourable weather conditions, berries without tassels were selected in boxes-trays weighing 4-5 kg and transported to the laboratory. The weight of blackcurrant fruits of each variety is 60 kg. Juice was extracted by pressing with a screw press (pressure 0.3-0.4 MPa) after inspection, washing of the fruit, obtaining the pulp, preparation of the pulp by the following methods of pretreatment with the enzyme preparation pectofoetidine G20x (E 1500 units/g), dose 0.03%:

1. Mechanical grinding to the pomace (control).
2. Treatment with pectofoetidine, fermentation for 4 h at 42-45°C:

a) pomace of ground fruit; b) pomace of crushed fruit.

3. Pectofoetidine treatment of the pulp of crushed fruit at 37-40°C, 42-45°C:

a) a suspension of the dry preparation; b) an extract of the preparation after fermentation (1–2 h).

The suspension was prepared from the dry powder with a small amount of juice (to dissolve) before adding to the pomace. The extract of the preparation was obtained by pouring 5-10 times the amount of juice and insisting for 1-2 h.

4. Treatment of the pomace of ground fruits with pectofoetidin at 37-40°C, 42-45°C with a fermentation duration of 0.5, 1, 1.5, 2, 3, 4, 5, 6, and 8 h.

The mass of the sample for pressing – 1.5-2 kg. Threefold repetition. The juice yield was estimated using the generalised Harrington desirability function. To harmonise the taste of freshly pressed natural juices by chemical composition, they were used to prepare juices with sugar. According to the content of dry substances and acids that are regulated by (DSTU 4150:2003, 2004), they corresponded to the highest grade. According to the Technological instruction (1992), the recipe was 60% juice + 40% sugar syrup (30%).

The method of making blackcurrant juices with sugar involved mixing boiled syrup with juice, heating to 90-95°C, packaging, sealing (hot bottling). In raw materials, freshly pressed natural juices and juices with sugar (after 15 days of storage), the content of dry soluble substances, total sugar content, acid content, sugar-acid index, and ascorbic acid content were determined. Organoleptic evaluation of juices was performed. Preservation of ascorbic acid in juices was calculated according to the following formula (1):

$$P_{AA} = \frac{AA_1 \times m_1}{AA_2 \times m_2} \times 100\%, \quad (1)$$

where AA_1 is the content of ascorbic acid in the finished product, g; AA_2 is the content of ascorbic acid in the raw product, g; m_1 is the mass of the finished product, g; m_2 is the mass of raw product, g.

Determination methods:

- for the content of dry soluble substances – refractometric (Shirokov, 1974);
- for acid content – titrometric (Pleshkov, 1976);
- for total sugar content, invert sugar content, glucose – ferricyanide (Shirokov, 1974);
- ascorbic acid content - iodometric (Pleshkov, 1976);
- preservation of ascorbic acid (Flaumenbaum *et al.*, 1986).

The repetition of chemical analyses was threefold. The mass of the sample for analysis – 2 kg of fruit or 1.5 kg of product. Statistical processing of research results was performed using variance analysis. Experimental studies of plants (both cultivated and wild), including the collection of plant material, were following the institutional, national, or international guidelines. The study adhered to the standards of the Convention on Biological Diversity (1992) and the Convention on Trade in Endangered Species of Wild Fauna and Flora (1979).

RESULTS AND DISCUSSION

Technochemical evaluation of pectofoetidine in the processing of blackcurrant pulp. The most effective enzyme preparation for juice extraction from blackcurrant fruits – pectofoetidine G20x (E 1500 units/g) – was used. It consists of a complex of enzymes: pectinase, polygalacturonase, pectin methyl esterase, cellulase, and amylase (Todaro *et al.*, 2016). According to the technological instruction, the dosage of the product is 0.01-0.03%. As the amount of pectin in the raw material increases, the dose of the product increases, but the excess of 0.03% is not allowed.

According to Table 1, pomace processing dramatically increased juice yield. This is due to the liquefaction of the pomace, reduction of the juice viscosity, and its easy separation. The influence of the raw material processing method on the juice yield is 98%. Juice extraction from fruit according to the Harrington desirability level (Cherevko *et al.*, 2020): very good – more than 55%, good – 48-55, satisfactory – 40-48, unsatisfactory – 35-40, very unsatisfactory – less than 35%.

Table 1*. Juice yield depending on the method of pretreatment of blackcurrant fruits of different varieties (preparation dose – 0.03%, fermentation – 4-6 h, temperature – 42-45°C), %*

Preprocessing method	Minai Shmyrev			Belarus sweet			Novyna Prykarpattia		
	2003	2004	2005	2003	2004	2005	2003	2004	2005
Mechanical grinding of fruits to pomace (control)	21.8	19.2	20.1	19.0	17.8	18.6	23.4	20.3	22.4
Pectofoetidine treatment of the pomace of ground fruit	59.2	57.3	58.8	58.2	56.7	57.5	60.3	57.2	59.6
Treatment of the pomace of crushed fruit with pectofoetidine	42.9	37.2	42.0	42.3	36.7	40.5	44.3	38.7	43.0
LSD_{05}	2.1								

Source: *developed by the authors of this study*

The physical and mechanical properties and specific anatomical structure of the raw materials adjusted the juice yield. When the preparation was used to treat the pomace of crushed fruit, the juice yield increased 3 times compared to the control and reached a very good score of 57-60%. With analogous treatment of the pomace of crushed fruits, the juice yield was estimated as satisfactory and amounted to 37-44%, which is only 2 times higher than in the control. The enzymatic maceration of crushed fruits increased the effectiveness of the preparation by 1.5 times. The result indicates that the blackcurrant pomace should be ground as much as possible when treated with an enzyme preparation. Currants have a dense, elastic skin. Grinding it increases the contact area and creates optimum conditions for the action of enzymes, as noted by L. del Rocío Castro-López *et al.* (2016). Clogging of the channels during the pressing of macerated pomace is not dangerous, as the juice flows out easily and only needs to be separated from the fruit tissue particles.

The difference in juice yield by variety is not always significant and ranged within 1.0-3.6%, which is due to the chemical composition of the fruit, tissue structure, the degree of cell damage during grinding, etc. No direct evidence of the influence of the chemical composition of the raw materials on the effect of the preparation was found, but in the pomace of different varieties of fruit, enzyme activation or inhibition processes may occur, as evidenced by T. Yu *et al.* (2023). In terms of chemical composition, freshly pressed juices obtained by treating raw materials with an enzyme preparation (Table 2) are close to fresh fruit. They differed in appearance – they lost their inherent viscosity and had a liquid, highly extractable phase. The colour of the juice is intense, the smell is well pronounced, typical of blackcurrant fruit. Whereas the juice from the control variants was devoid of natural colour.

***Table 2**. Indicators of the chemical composition of blackcurrant fruits of different varieties and juices from them (fermentation with pectofoetidine (dose – 0.03%, duration – 4-6 h, temperature – 42-45 °C)*

Preprocessing method	2003				2004				2005			
	Dry soluble substance content, %	Total sugar content, %	Acid content1), %	Sugar-acid index	Dry soluble substance content, %	Total sugar content, %	Acid content1), %	Sugar-acid index	Dry soluble substance content, %	Total sugar content, %	Acid content1), %	Sugar-acid index
Minai Shmyrev												
Fruits	16.0	7.26	3.32	2.19	15.8	7.01	3.05	2.30	16.4	8.91	2.65	3.36
Mechanical grinding of fruits to pomace (control)	15.6 / 21.4	7.06 / 16.24	3.20 / 1.92	2.21 / 8.46	15.4 / 21.2	6.83 / 16.1	2.92 / 1.75	2.34 / 9.20	16.0 / 21.6	8.68 / 17.2	2.50 / 1.52	3.47 / 11.3
Treatment of pomace of shredded fruits with the preparation	16.0 / 21.6	7.29 / 16.37	3.25 / 1.95	2.24 / 8.39	15.8 / 21.6	6.92 / 16.15	3.00 / 1.81	2.31 / 8.92	16.4 / 21.8	8.82 / 17.3	2.60 / 1.56	3.39 / 11.09
Treatment of pomace of crushed fruits with the preparation	15.8 / 21.4	7.20 / 16.32	3.20 / 1.92	2.25 / 8.50	15.6 / 21.4	6.92 / 16.15	2.95 / 1.77	2.35 / 9.12	16.0 / 21.6	8.63 / 17.17	2.50 / 1.50	3.45 / 11.45
Belarus sweet												
Fruits	16.0	8.82	2.55	3.46	14.2	6.56	2.31	2.84	16.8	9.21	1.86	4.95
Mechanical grinding of fruits to pomace (control)	15.6[2)] / 21.4	8.68 / 17.20	2.42 / 1.45	3.59 / 11.8	13.8 / 20.4	6.38 / 15.8	2.12 / 1.27	3.01 / 12.4	16.4 / 21.8	9.12 / 17.4	1.76 / 1.05	5.18 / 16.24
Treatment of pomace of shredded fruits with the preparation	16.0 / 21.6	8.80 / 17.28	2.50 / 1.50	3.52 / 11.52	14.2 / 20.6	6.48 / 15.89	2.24 / 1.34	2.85 / 11.85	17.0 / 22.20	9.28 / 17.57	1.82 / 1.09	5.10 / 16.12
Treatment of pomace of crushed fruits with the preparation	16.0 / 21.6	8.76 / 17.26	2.48 / 1.48	3.53 / 11.66	14.0 / 20.4	6.38 / 15.82	2.18 / 1.30	2.93 / 12.17	17.0 / 22.20	9.30 / 17.57	1.79 / 1.07	5.19 / 16.42
Novyna Prykarpattia												
Fruits	14.6	7.91	2.61	3.03	13.2	6.01	2.18	2.76	13.8	8.40	1.79	4.69
Mechanical grinding of fruits to pomace (control)	14.0 / 20.4	7.56 / 16.61	2.41 / 1.45	3.17 / 11.52	12.8 / 19.6	5.80 / 15.48	2.10 / 1.25	2.76 / 12.38	13.4 / 20.0	8.26 / 16.96	1.65 / 1.00	5.01 / 16.96
Treatment of pomace of shredded fruits with the preparation	14.6 / 20.8	7.80 / 16.68	2.52 / 1.50	3.10 / 11.12	13.0 / 19.8	5.86 / 15.52	2.04 / 1.22	2.87 / 12.72	13.8 / 20.2	8.32 / 17.00	1.83 / 1.10	4.55 / 15.45
Treatment of pomace of crushed fruits with the preparation	14.4 / 20.6	7.78 / 16.67	2.48 / 1.50	3.13 / 11.11	12.8 / 19.6	5.76 / 15.46	2.00 / 1.22	2.88 / 12.67	13.8 / 20.2	8.26 / 16.95	1.80 / 1.08	4.59 / 15.69
LSD_{05}	0.04 / 0.12	0.41 / 0.68	0.09 / 0.11	0.22 / 0.88	0.04 / 0.12	0.41 / 0.68	0.09 / 0.11	0.22 / 0.88	0.04 / 0.12	0.41 / 0.68	0.09 / 0.11	0.22 / 0.88

***Note:** 1) in terms of citric acid; 2) above dash – natural juice, under dash – juice with sugar*
***Source:** developed by the authors of this study*

Juices with sugar met the standard's quality requirements. The positive effect of the treatment of raw materials with the enzyme preparation on the preservation of ascorbic acid was established (Table 3). The juices lost mainly 6-7% of ascorbic acid from the content in the fruit, or its retention was about 94% (control – 83-85%). That is, the ascorbic acid content in the juices of the natural experimental variants is on average 10% higher.

Table 3. Ascorbic acid content (mg/100 g) and its preservation (%) in blackcurrant fruits of different varieties and in juices from them (preparation dose – 0.03%, duration – 4-6 h, fermentation temperature – 42-45°C)

Preprocessing method	2003		2004		2005	
	Content	Preservation	Content	Preservation	Content	Preservation
Minai Shmyrev						
Fruits	182.1	-	176.0	-	172.0	-
Mechanical grinding of fruits to pomace (control)	151.1* 88.7	83.0 97.8	149.7 88.0	85.1 98.0	144.5 85.0	84.0 98.0
Treatment of pomace of shredded fruits with the preparation	171.7 101.5	94.3 98.5	156.2 92.6	88.8 98.8	162.2 96.0	94.3 98.6
Treatment of pomace of crushed fruits with the preparation	170.8 101.1	93.8 98.7	165.1 98.0	93.8 98.9	161.3 95.4	93.8 98.6
Belarus sweet						
Fruits	273.5	-	308.0	-	272.8	-
Mechanical grinding of fruits to pomace (control)	227.0 133.2	83.0 97.8	261.5 152.9	84.9 98.1	289.1 134.8	84.0 98.1
Treatment of pomace of shredded fruits with the preparation	257.1 152.0	94.0 98.5	289.5 171.3	94.0 98.6	256.4 151.7	94.0 98.6
Treatment of pomace of crushed fruits with the preparation	258.2 152.9	94.4 98.7	288.3 170.9	93.6 98.8	255.3 151.5	93.6 98.9
Novyna Prykarpattia						
Fruits	229.3	-	180.4	-	192.4	-
Mechanical grinding of fruits to pomace (control)	191.2 112.4	83.4 98.0	153.3 90.3	85.0 98.2	162.0 95.1	84.2 97.8
Treatment of pomace of shredded fruits with the preparation	216.2 128.3	93.4 98.9	170.0 101.0	94.2 99.0	151.0 89.5	78.5 98.8
Treatment of pomace of crushed fruits with the preparation	215.1 128.0	93.8 99.2	142.1 84.7	78.8 99.3	152.2 90.4	79.1 99.0
LSD_{05}	6.25 5.72	-	6.25 5.72	-	6.75 5.72	-

Note: *above dash – natural juice, under dash – juice with sugar*
Source: *developed by the authors of this study*

The high preservation of ascorbic acid in juices was facilitated by the conditions of the technological process – heat treatment of raw materials, their deaeration, and the lack of oxygen access during fermentation (Marsol-Vall *et al.*, 2021). However, in freshly pressed juices from Novyna Prykarpattia fruit, the amount of ascorbic acid was lost by 26-27% of the amount contained in fresh fruit, and its preservation in juices decreased to 79%. These results are probably not natural. They are attributed to the oxidation of the pomace by air oxygen during prolonged fermentation and a breach of the hermetic state, while other process conditions did not change.

In juices with sugar, a 1.7-1.9-fold decrease in ascorbic acid content was observed (control – 2-fold). Juices with sugar in the experimental variants contained, as a rule, 11-14% more ascorbic acid. The preservation of ascorbic acid in juices with sugar in the control variant is 98%, in the experimental variant it is about 99%. The characteristics of blackcurrant varieties had a significant impact (80%) on the ascorbic acid content in juices. Its high content in the fruits of the Belarus sweet variety had a positive effect on the indicator in juices. The level of the juice index is 1.2-1.4 – 1.5-1.7 times higher than in juices from the Novyna Prykarpattia and Mynai Shmyrev varieties.

Influence of heat treatment of raw materials and methods of application of enzyme preparation on the yield and quality of juices from blackcurrant fruits. According to I.F. Olawuyi *et al.* (2021), the accelerated action of a pectolytic enzyme preparation is provided by heat treatment of raw materials. This process partially destroys protopectin, coagulates and dehydrates colloids, as a result of which the cells lose their ability to retain juice. Such changes promote greater enzyme contact, facilitate the enzymatic hydrolysis of pectin substances, which considerably increases the effectiveness of the enzyme preparation, even though heat treatment apparently partially inactivates the pectolytic enzymes of raw materials. Furthermore, heat treatment of raw materials prevents microbiological and oxidative processes. Therefore, only with the use of complex thermal and enzymatic treatment of the pomace can one count on a high result. As already mentioned, the optimum temperature for the action of enzyme preparations for blackcurrant fruits is 35-40°C.

The effect of temperature on the efficacy of pectofoetidine G20x in the blackcurrant pomace was not found. However, it is known (Wang *et al.*, 2015) that enzyme preparations are thermostable and do not inactivate at 65-70°C for 10-15 min. Complete inactivation is achieved at 70°C in one hour. By raising the temperature to 45-50°C, the enzymatic hydrolysis of pectin substances can be significantly enhanced. However, the optimum temperature for the action of the pectinase enzyme, which is part of pectofoetidine, is 40°C. Exceeding a temperature of 45°C leads to its inactivation. The researchers found a variant that combined the most favourable conditions – heating the pomace to 50-52°C before fermentation. At the same time, the methods of applying the enzyme preparation in the form of a suspension and an extract were studied. The positive result of applying the enzyme preparation does not depend on the amount of juice applied, but on its time sustained in the juice. During this time, it is inactivated by the polyphenolic substances in the juice. With less juice, the enzyme inactivation is less.

The studies have shown (Table 4) that the method of application of the preparation and the temperature of processing the pomace of crushed fruit had a considerable effect on the juice yield. Under the same conditions, the process of applying the enzyme preparation in the form of a suspension is more efficient – the juice yield reached 58-63%, which is 11-15% more than from the pomace treated with the preparation extract. The use of the enzyme preparation for blackcurrant pomace does not require any preliminary preparation of the extract. Before adding the preparation to the pomace, the dry powder should first be dissolved in a small amount of juice.

Table 4*. Juice yield from blackcurrant fruit pulp of different varieties depending on the method of preparation application (fermentation time – 4-6 h, dose – 0.03%), 2006, %*

Method of application of the preparation into the pomace	Minai Shmyrev		Belarus sweet		Novyna Prykarpattia	
	Pomace fermentation temperature, °C					
	37-40*	42-45	37-40*	42-45	37-40*	42-45
Suspension	60.0	60.5	57.0	58.8	62.8	63.4
Extract	51.8	53.6	48.1	50.5	54.3	55.2
LSD_{05}	1.38					

Note: ** the pomace was preheated to 50-52°C*
Source: *developed by the authors of this study*

According to the results of juice yield, depending on the fermentation temperature, the increase in juice yield from the pomace fermented at 42-45°C was not always significant. The reasons for this effect lie in the processing time and the sensitivity of enzymes to temperature. The fermentation of the pomace for 4 h proved to be long-lasting and had an ambiguous effect on juice extraction, which is confirmed by Z. Wang *et al.* (2015). The temperature probably also changed the effect of the preparation. Preheating the pomace to 50-52°C had two effects: it intensified the reactions and did not irreversibly inactivate enzymes (e.g., pectinase). However, further fermentation at 37-40°C inhibited the activity of the enzymes of the added preparation. Fermentation at 37-40°C with the integrated use of preheat treatment of the pomace can be recommended for the extraction of juice from certain varieties of blackcurrant. However, increasing the temperature of fermentation of the pomace to 42-45°C is more effective regardless of the variety.

According to Table 4, the difference in juice yield when treating the fruit of the studied varieties with the enzyme preparation ranged from 3-5% to 12-15%. In terms of chemical composition, freshly pressed juice from raw materials treated with an enzyme preparation is close to fresh fruit (Table 5). It is logical to increase the acidity of juices by 1.4-2.8% due to the accumulation of galacturonic acid due to the breakdown of pectin. Its enzymatic hydrolysis is quite complicated under the influence of a complex of enzymes, and the specific effect of various chemical compounds on their activity. Acid degradation, neutralisation, and complexation with metals as a result of the long enzymatic process are possible. This assumption can be confirmed by the fact that the pH of the juices decreases, which is in line with analogous statements by S. Wang *et al.* (2023). Comparison of freshly pressed juices obtained at different fermentation temperatures showed no difference in physicochemical parameters.

***Table 5**. Indicators of the chemical composition of blackcurrant fruits of various varieties and juices from them, 2006*

Method of application of fermented preparation to the pomace	Fermentation temperature 37–40°C						Fermentation temperature 42–45°C					
	dry soluble substance content, %	total sugar content, %	acid content (in terms of citric acid), %	sugar-acid index	ascorbic acid content, %	preservation of ascorbic acid, %	dry soluble substance content, %	total sugar content, %	acid content (in terms of citric acid), %	sugar-acid index	ascorbic acid content, %	preservation of ascorbic acid, %
Minai Shmyrev												
Fruits	13.2	7.10	2.10	3.38	169.8	-	13.2	7.10	2.10	3.38	169.8	-
Suspension	13.0 19.8	7.01 16.20	2.05 1.23	3.45 13.17	163.6 96.9	96.3 98.7	13.2 20.0	7.02 16.21	2.07 1.24	3.39 13.07	164.6 97.3	96.9 98.5
Extract	12.6 19.6	6.85 16.12	2.06 1.25	3.32 12.90	154.0 91.5	90.7 99.0	12.8 19.8	6.90 16.14	2.05 1.20	3.37 13.45	155.7 92.3	91.7 98.8
Belarus sweet												
Fruits	17.0	8.80	1.44	6.11	252.6	-	17.0	8.80	1.44	6.11	252.6	-
Suspension	16.8 22.0	8.69 17.22	1.47 0.86	5.91 20.02	242.3 143.6	95.9 98.8	16.8 22.0	8.72 17.23	1.40 0.84	6.23 20.51	242.0 144.1	96.2 98.8
Extract	16.4 21.8	8.60 17.16	13.9 0.84	6.19 20.43	224.8 133.5	89.0 99.0	16.4 21.8	8.65 17.19	1.46 0.88	5.92 19.53	226.1 134.0	89.5 98.8
Novyna Prykarpattia												
Fruits	13.2	7.80	1.41	5.53	226.2	-	13.2	7.80	1.41	5.53	226.2	-
Suspension	12.8 19.8	7.60 16.54	1.45 0.84	5.24 19.69	219.4 130.5	97.0 99.1	13.2 20.0	7.72 16.63	1.37 0.81	5.64 20.53	217.6 129.3	96.2 99.0
Extract	12.6 19.6	7.50 16.50	1.40 0.82	5.36 20.12	205.8 122.5	91.0 99.2	12.8 19.8	7.61 16.57	1.39 0.85	5.47 19.49	207.0 122.7	91.5 98.9
LSD_{05}	0.02 0.04	0.28 0.54	0.06 0.07	0.29 1.67	4.76 4.46	-	0.02 0.04	0.28 0.54	0.06 0.07	0.29 1.67	4.76 4.46	-

***Note:** above dash – natural freshly pressed juice, under dash – juice with sugar*
***Source:** developed by the authors of this study*

The characteristics of the variety had a significant impact on the chemical composition of the juices – the influence was 95%. The juices of the Belarus sweet variety have high soluble solids and sugars content, and due to their low acidity, their sugar-acid index is on average 1.8 times higher than that of the Minay Shmyrev variety. The quality of the freshly pressed juices was reflected in the finished product – juices with sugar. In terms of dry soluble solids (19.6-22.0%), the latter met the requirements of the standard. However, in terms of acid content (0.82-0.88%), juices with sugar from Belarus sweet and Novyna Prykarpattia did not meet the standard, which is due to the initial acid content of 1.4% in the fruit. The sugar-acid index of juices from the Minay Shmyrev variety was medium, and the sugar-acid index of the Belarus sweet and Novyna Prykarpattia varieties was high – 20. The organoleptic evaluation of juices with sugar revealed a natural appearance, aroma, and colour typical of blackcurrant. They had a liquid consistency and high extractability. The taste of the juices was pleasant but lacked softness and lightness due to the liquefaction of the fruit mass during fermentation and the transfer of insoluble substances not specific to juice components to the juice.

The preservation of ascorbic acid in freshly pressed juices is high – 90-97% and depended more on the method of application than on the temperature of pomace fermentation. In the juices from the pomace treated with the preparation suspension, the retention of ascorbic acid is 96-97%, and in the preparation extract – 89-92%. The preheating of the pomace to 50-52°C before fermentation at 37-40°C played a crucial role in this. Under these conditions, oxidative enzymes are inactivated, which increases the preservation of ascorbic acid. On the other hand, a higher juice yield results in a better extraction of ascorbic acid, especially from the peel. In juices with sugar, the content of ascorbic acid decreased by 1.7-1.9 times, but its preservation was high – about 99%.

Influence of the duration of enzyme treatment and pomace temperature on the yield and quality of blackcurrant juices. The treatment of pomace with an enzyme preparation, along with the hydrolysis of pectin substances (reducing viscosity), also involves biochemical and microbiological transformations. These processes do not affect the quality of the juices during short-term ageing, but in the case of prolonged fermentation, the quality of the juices deteriorates and in some cases the product may spoil. Oxidation processes often cause undesirable changes in the taste and colour of juices. Furthermore, the pomace contains the microflora of the raw material, which multiplies freely at 20-40°C and can cause undesirable microbiological changes. Heat treatment of raw materials to some extent prevents microbiological and oxidative processes. However, the effects of oxidising enzymes cannot be avoided, even in the case of heat treatment of raw materials.

The advantage of blackcurrant as a raw material for juice production is that its fruit has a low activity of oxidative enzymes. It contains ascorbic acid, which acts as a natural antioxidant. Its content of 1 mg/g already has a positive effect. Ascorbic acid simultaneously increases the activity of enzymes. In the scientific literature, there are quite opposite conclusions regarding the duration of pomace treatment – from 40-60 min to 4-6 h or more. This is due to different raw materials, different enzyme preparations and their activity. The influence of the duration of treatment of pomace with a suspension of the enzyme preparation pectofoetidin G20x at different temperatures on the yield of blackcurrant juice was studied.

A detailed analysis of the data (Table 6) showed that the duration of pomace processing affected the efficiency of juice extraction. Regularities in the increase of juice yield during the process were established. After only 0.5 h of fermentation, the juice yield was 36-42%, which was about 60-65% of the total yield. Each subsequent 0.5 h of pomace fermentation, up to a total duration of 2 h, significantly increased the juice yield: by 7-11% in 1 h, by 10-15% in 1.5 h, and by 14-16% in 2 h. If the juice extraction from the fermented pomace for 1 h was 65-72%, then for 1.5 h it was 74-81%, and for 2 h it was 82-93%.

***Table 6**. Juice yield depending on the temperature and duration of fermentation of blackcurrant pulp of different varieties, 2006, %*

Fermentation duration, h	Minai Shmyrev		Belarus sweet		Novyna Prykarpattia	
	Fermentation temperature, °C					
	37-40*	42-45	37-40*	42-45	37-40*	42-45
0.5	37.4	39.2	35.7	36.2	40.8	42.3
1.0	40.3	43.6	38.2	40.3	43.8	46.3
1.5	45.7	49.5	43.0	46.4	48.3	52.2
2.0	52.5	56.3	47.0	53.7	55.6	60.0
3.0	57.8	60.0	52.6	57.0	59.8	62.3
4.0	60.0	62.1	55.0	58.0	61.8	63.4
5.0	61.0	62.5	56.6	58.5	62.8	63.8
6.0	61.5	62.8	57.0	59.0	63.3	64.0
8.0	61.7	63.4	57.2	59.6	63.5	64.4
LSD_{05}	3.8					

Note: ** preheated to 50-52°C*
Source: *developed by the authors of this study*

Fermentation of the pomace for 2 to 4 hours increased the juice yield, but the intensity of the process was slowed down. If the juice extraction from the pomace fermented for 3 h was 92-97%, and for 4 h – 96-98%, the increase in juice yield was 4–10% and 2-5%, respectively. Juice extraction after 4 h was 98-99%, but the increase was not significant – 0.3-2%. The characteristic changes in the pomace during fermentation depended on temperature and variety characteristics (Table 6). Regardless of the process duration, the juice extraction has always been better from the pomace at a fermentation temperature of 42-45°C: the juice yield is 1-8% higher. The difference is most pronounced in the first hours of fermentation. After 2 h of pomace fermentation, juice extraction at 37-40°C was 82-87%, at 42-45°C – 89-93%, after 3 h – 94% and 95-97%, and after 4 h – 96-97% and 97-98%. Further fermentation of the pomace is not advisable.

The process of fermenting the pomace depended on the characteristics of the variety. Juice extraction from the flesh of the Novyna Prykarpattia variety was the best. Regardless of the duration of the process, the juice yield was 3-9% higher than that of the Minay Shmyrev fruit pulp, and 9-15% higher than that of the Belarus sweet fruit pulp. When fermenting the pomace for up to 8 h, the juice yield may increase.

However, this fermentation time is technologically and economically impractical. Due to the deep hydrolysis of pectin substances, the acidity of the juice increases and ethyl and even methyl alcohols can accumulate (Ninga *et al.*, 2018).

This is confirmed by the acid content of the juices. Within half an hour of fermentation (Table 7), the colloidal system was so destabilised that 94 to 99% of the acids were transferred to the juices. Then a gradual increase (by 2.7-5.0%) in the acid content of the juices was observed by 3 h. The fermentation of the pomace was 97-103%. However, the difference in the acid content of the juice between the second and third hour of fermentation is 1%. After 4 h, the accumulation of acids in the juices decreased (2.9-5.4%), and their transfer to the juice remained at 98-103%. Only after 8 h of fermentation, the acidity of the juices increased again by 3.2-5.7%, and the acid content reached 98-104%.

***Table 7**. Acid content in freshly pressed natural juice from blackcurrant fruits of different varieties (in terms of citric acid), 2006, %*

Fermentation duration, h	Minai Shmyrev		Belarus sweet		Novyna Prykarpattia	
	Fermentation temperature, °C					
	37-40*	42-45	37-40*	42-45	37-40*	42-45
0.5	2.064	2.097	1.360	1.380	1.360	1.380
1.0	2.070	2.104	1.367	1.387	1.374	1.394
1.5	2.084	2.124	1.380	1.401	1.394	1.414
2.0	2.104	2.144	1.387	1.420	1.420	1.441
3.0	2.117	2.157	1.401	1.434	1.427	1.447
4.0	2.124	2.164	1.407	1.441	1.427	1.454
5.0	2.124	2.164	1.407	1.441	1.427	1.454
6.0	2.124	2.164	1.407	1.442	1.434	1.454
8.0	2.131	2.171	1.414	1.447	1.434	1.461
LSD_{05}	0.02					

Note: ** preheated to 50-52°C*
Source: *developed by the authors of this study*

The process of fermentation of blackcurrant pulp can be divided into 3 stages: the first (up to 1 h) – destabilisation of the colloidal system, characterised by a sharp decrease in pomace viscosity, mainly by the transition of raw material components into juice; the second (up to 3 h) – degradation of the pomace structure, characterised by liquefaction, a significant decrease in its viscosity and increased transition of raw material components into the juice due to the destruction of polysaccharides; third (after 3 h) – stabilisation of processes due to the completion of structural changes.

It can be assumed that after destabilisation of the colloidal system, the breakdown of polygalacturonic acids begins. Due to the formation of galacturated acids, the amount of reduced substances increases, but there is no further reduction in pomace viscosity. The acidity of freshly pressed juices increased by 0.5-3.6%. With an increase in the temperature of pomace fermentation to 42-45°C, the accumulation of acids in the juices increased by 1-2%. Furthermore, while 100% of the acid content in pomace juices at 37-40°C was recorded after 2 h of fermentation, at 42-45°C it was recorded after 1.5 h. The characteristics of the variety affected the juice yield of raw materials. The pomace from the fruits of the Novyna Prykarpattia and Minai Shmyrev varieties had the best technological properties. The extraction of acids from it into the juice was more intensive and reached 102-103%. Structural changes in the pomace from the Belarus sweet variety were slower. This affected the juice yield.

The issue of preserving vitamin C in juices during pomace fermentation is of scientific and practical importance (Table 8). After fermentation of the pomace for 0.5 h, the content of ascorbic acid in the juices decreased by 6-11%. Its safety was high – 90-94%. Its loss during pomace production was obviously to some extent overlapped with its extraction from the pomace, as already established above (Table 7). After 1-1.5 h of pomace fermentation, the content of ascorbic acid in the juices continued to increase by 2-4%, and its preservation was up to 93-97%. Fermentation of the pomace for up to 3 h caused its loss in juices, but its preservation stayed at 95-96%. With further fermentation of the pomace, the content of ascorbic acid in the juices decreased and the level of its preservation decreased sharply – from 93-94% in 4 h to 80-86% in 8 h.

***Table 8**. Ascorbic acid content (mg/100 g) and its preservation in freshly pressed natural juice from blackcurrant fruits of different varieties, 2006*

Fermentation duration, h	Minai Shmyrev		Belarus sweet		Novyna Prykarpattia	
	Fermentation temperature, °C					
	37-40*	42-45	37-40*	42-45	37-40*	42-45
0.5	154.6 91.1	156.0 91.8	227.0 89.9	230.2 91.1	208.4 92.1	213.0 94.2
1.0	159.6 94.0	163.0 96.0	234.8 93.0	240.3 95.1	214.0 94.6	219.4 97.0
1.5	163.1 96.0	164.8 97.1	240.0 95.0	244.8 96.9	219.4 97.0	218.9 96.8
2.0	163.3 96.2	164.9 97.1	245.0 97.0	245.0 97.0	219.4 97.0	219.0 96.8
3.0	162.6 95.8	163.0 96.0	239.5 94.8	240.3 95.1	217.4 96.1	214.9 95.0
4.0	159.0 93.6	159.3 93.8	234.4 92.8	234.0 92.9	212.5 93.9	212.6 94.0
5.0	157.8 92.9	157.1 92.5	230.0 91.0	231.2 91.5	210.3 93.0	211.5 93.5
6.0	153.7 90.5	151.7 89.3	225.3 89.2	222.3 88.0	206.5 91.3	205.9 91.0
8.0	145.2 85.5	140.8 82.9	210.3 83.3	204.2 80.8	195.2 86.3	190.7 84.3
LSD_{05}	5.0 1.0					

Note: ** preheated to 50-52°C*
Source: *developed by the authors of this study*

Temperature had a significant effect on the ascorbic acid content of the juices only up to 2 h of fermentation. Its preservation in juices from pomace fermented at 42-45°C is 1-2% higher, which is due to an increase in its extraction into the juice. Fermentation of the pomace for up to 6-8 h sharply reduced the content of ascorbic acid in the juices. Moreover, its losses in juices at 42-45°C are higher, and its preservation is lower – 81-84% versus 83-86% at 37-40°C. Apparently, as noted by M. Siddiq *et al.* (2018), at higher temperatures during the long process, the oxidation of ascorbic acid was more intense. The content of ascorbic acid in the juices depended on the variety, with a 92% effect. Juices from the Belarus sweet and Novyna Prykarpattia varieties contained almost 1.3-1.5 times more ascorbic acid than juices from the Minay Shmyrev variety. Its preservation had a comparable trend.

Based on the analysed data, it can be concluded that, unlike other scientists who have conducted analogous studies, it was found that the enzymatic treatment of the pomace with pectofoetidin increases the juice yield from crushed fruit to satisfactory (37-44%) and very good (57-60%) for ground fruit, which is 2-3 times higher than without treatment. Rational conditions for pomace fermentation are ensured by using 0.03% of the preparation by weight, a temperature of 42-45°C, a processing time of 2 h with up to 60% of the juice extracted, with 96-102% of acids transferred to it and up to 97% of ascorbic acid content.

Studies confirm the findings of K.A. Ninga *et al.* (2018), S. Wang *et al.* (2023) that the juice in blackcurrant fruits is firmly retained by living tissue. Mechanical destruction of the cell membrane by grinding is not sufficient. It is necessary to use additional methods of exposure, which is explained by the specific features of the structure and physiological properties of the cellular tissue of blackcurrant fruits. Their ability to juice is less dependent on the resistance of cytoplasmic membranes to mechanical stress, and more on their viscosity and elasticity, the cytological and anatomical structure of the cell tissue, and the content of pectin substances. The presence of the latter, with a high calcium content in the mineral composition of the juice, increases the stability of its cytoplasm and makes it difficult to extract the juice. Juice flow is inhibited by the high content of soluble pectin substances in blackcurrant, which increase the viscosity.

It is not enough to mash blackcurrant fruits; they must be subjected to special processing. Treatment with enzymatic pectolytic preparations, which primarily destroy soluble pectin, is quite effective. This is confirmed by I.F. Olawuyi *et al.* (2021) and A. Marsol-Vall *et al.* (2021). However, on the other hand, pectolytic enzymes also act on cells with toxic non-enzymatic substances that are part of the preparation and cause coagulation of protein-lipid membranes and plant cell death. It is as a result of such transformations that cell permeability increases, protoplasmic membranes break and juice yield increases. The disadvantage of the studies is the lack of safety indicators for blackcurrant juice.

Furthermore, a classic enzyme preparation, pectofoetidine, was used in the studies. However, there are other enzyme preparations with different composition and enzyme activity. Their disadvantages and advantages during the extraction of blackcurrant juice with a high content of ascorbic acid were not established. Blackcurrant juices are healing products for children (del Rocío Castro-López *et al.*, 2016). However, a question arises regarding their study for use in infant and dietary nutrition due to the use of enzyme preparations. No direct evidence of their negative impact on juice quality has been found. In recent years, the environment has been increasingly contaminated by mutagens of physical, chemical, and biological origin. Hormonal imbalance due to chronic stress is a source of mutagenic danger. Mutagenesis can pose a threat to human health. A range of mutagens have carcinogenic effects. It is important to establish the antimutagenic properties of blackcurrant juice. This is a priority for further research.

It should be borne in mind that scientists and breeders are working on developing blackcurrant varieties with specific consumer properties, improving technological methods of growing the crop, protecting it from pests and diseases in different weather conditions, etc. All this requires constant, ongoing research into the impact of both internal and external factors on the quality of blackcurrant as a raw material with high C-vitamin activity. Thus, the use of blackcurrant genetic resources, both today and in the future, is inexhaustible. And the study of the formation of the biochemical value of fruits, ways to increase juice yield is a theoretical and practical prerequisite for the production of high-quality juices that solve the problem of providing the population with biologically valuable products of natural origin all year round.

CONCLUSIONS

Based on the study, the high efficiency of blackcurrant pomace treatment with pectofoetidine G20x for juice extraction was established. In the absence of concrete recommendations for the extraction of blackcurrant juice in the technological instructions for the use of enzyme preparations, it was found that the yield of blackcurrant juice increases when the pomace is treated with the enzyme preparation pectofoetidine G20x. Moreover, depending on the method of mechanical impact on the fruit, from a satisfactory level of 37-44% (crushing) to a very good level of 57-60% (grinding), which is 2-3 times more than without processing. The effectiveness of the preparation is increased by 1.5 times by grinding the fruit before fermentation.

For maceration of blackcurrant pomace from the preparation, it is not advisable to prepare the extractor beforehand. Since the juice yield from pomace treated with a powder suspension (0.03% by weight) is 11-15% higher. Fermentation of blackcurrant pomace is a lengthy process, which includes three stages: the first is destabilisation of the colloidal system of the pomace (up to 1 h); the second is degradation of the pomace structure (up to 2 h); the third is stabilisation of the process (after 3 h). Optimum conditions for pomace maceration: temperature – 42-45°C, duration – 2 h. Under these conditions, the juice yield increases to 56-60%. The juice is characterised by almost complete conversion of acids, including ascorbic acid, from the raw material.

The quality and biological value of freshly pressed blackcurrant juices from fermented raw materials are close to fresh fruit in terms of physicochemical and organoleptic characteristics. The preservation of ascorbic acid in juices with sugar is 90-97% (83-85% without processing). The strength of the variety's influence on the preservation of ascorbic acid in freshly pressed juices is 92%. The production of blackcurrant juices with sugar does not reduce the C-vitamin value of the product. Therewith, the content of ascorbic acid in juices is reduced by 1.7 times due to the preparation technology, but its preservation is high – 99%. The characteristics of the blackcurrant variety substantially affect the juice yield. An increase in juice yield by 6-15% correlates with the chemical composition of the fruit. Considering that scientists are working towards the development of the latest enzyme preparations, possibly even complex ones, further research is promising.

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CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

REFERENCES

[1] Aaby, K., & Amundsen, M.R. (2023). The stability of phenolic compounds and the colour of lingonberry juice with the addition of different sweeteners during thermal treatment and storage. *Heliyon*, 9(5), articl number e15959. doi: 10.1016/j.heliyon.2023.e15959.

[2] Bujor, O-C., Ginies, Ch., Popa, V.I., & Dufour, C. (2018). Phenolic compounds and antioxidant activity of lingonberry (*Vaccinium vitis-idaea* L.) leaf, stem and fruit at different harvest periods. *Food Chemistry*, 252, 356-365. doi: 10.1016/j.foodchem.2018.01.052.

[3] Cherevko, O., Deinychenko, G., Dmytrevskyi, D., Guzenko, V., Heiier, H., & Tsvirkun, L. (2020). Application of membrane technologies in modern conditions of juice production. *Advanced Techniques and Technologies of Food Production, Restaurant Business and Trade,* 2(32), 67-77.

[4] Chettri, D., & Verma, A.K. (2023). Endo-arabinase: Source and application. In *Glycoside hydrolases. Biochemistry, biophysics, and biotechnology* (pp. 243-254). London: Academic Press. doi: 10.1016/B978-0-323-91805-3.00007-1.

[5] Colodel, C., Vriesmann, L.C., & de Oliveira Petkowicz, C.L. (2018). Cell wall polysaccharides from Ponkan mandarin (*Citrus reticulata Blanco* cv. Ponkan) peel. *Carbohydrate Polymers,* 195, 120-127. doi: 10.1016/j.carbpol.2018.04.066.

[6] Convention on Biological Diversity. (1992, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_030#Text.

[7] Convention on International Trade in Endangered Species of Wild Fauna and Flora. (1979, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_129#Text.

[8] del Rocío Castro-López, R., Gómez-Plaza, E., Ortega-Regules, A., Lozada, D., & Bautista-Ortín, A.B. (2016). Role of cell wall deconstructing enzymes in the proanthocyanidin – cell wall adsorption-desorption phenomena. *Food Chemistry,* 196, 526-532. doi: 10.1016/j.foodchem.2015.09.080.

[9] DSTU 4150:2003. (2004). *Juices, juice drinks, fruit, vegetable and melon nectars. General technical conditions*. Retrieved from https://dnaop.com/html/61125/doc-%D0%94%D0%A1%D0%A2%D0%A3_4150_2003.

[10] Fan, K., Zhang, M., & Bhandari, B. (2019). Osmotic-ultrasound dehydration pretreatment-improves moisture adsorption isotherms and water state of microwave-assisted vacuum fried purple-fleshed sweet potato slices. *Food and Bioproducts Processing,* 115, 154-164. doi: 10.1016/j.fbp.2019.03.011.

[11] Flaumenbaum, B.L. Tanchev, S.S., & Grishin, M.A. (1982). *Fundamentals of food preservation*. m.: Agropromizdat.

[12] Marsol-Vall, A., Kelanne, N., Nuutinen, A., Yang, B., & Laaksonen, O. (2021). Influence of enzymatic treatment on the chemical composition of lingonberry (*Vaccinium vitis-idaea*) juice. *Food Chemistry,* 339, article number 128052. doi: 10.1016/j.foodchem.2020.128052.

[13] Ninga, K.A., Sengupta, S., Jain, A., Desobgo, Z.S.C., Nso, E.J., & De, S. (2018). Kinetics of enzymatic hydrolysis of pectinaceous matter in guava juice. *Journal of Food Engineering,* 221, 158-166. doi: 10.1016/j.jfoodeng.2017.10.022.

[14] Olawuyi, I.F., Akbarovich, S.A., Kim, C.K., & Lee, W.Y. (2021). Effect of combined ultrasound-enzyme treatment on recovery of phenolic compounds, antioxidant capacity, and quality of plum (*Prunus salicina L.*) juice. *Journal of Food Processing and Preservation,* 45(1), article number e15074. doi: 10.1111/jfpp.15074.

[15] Pleshkov, B.P. (1976). *Practicum on biochemistry*. m: Kolos.

[16] Schmidt, H. de O., Rockett, F.C., Sartori, G.V., Rezzadori, K., Tischer, B., Rodrigues, E., Rios, A. de O., & Manfroi, V. (2022). Influence of processing conditions on the composition of feijoa (*Acca sellowiana*) juices during storage. *Journal of Food Composition and Analysis,* 114, article number 104769. doi: 10.1016/j.jfca.2022.104769.

[17] Shirokov, E.P. (1974). *Practicum on technology of storage and processing of fruits and berries.* m.: Kolos.

[18] Siddiq, M., Dolan, K.D., Perkins-Veazie, P., & Collins, J.K. (2018). Effect of pectinolytic and cellulytic enzymes on the physical, chemical, and antioxidant properties of blueberry (*Vaccinium corymbosum L.*) juice. *LWT – Food Science and Technology,* 92, 127-132. doi: 10.1016/j.lwt.2018.02.008.

[19] Technological instruction on the use of enzyme preparations in the production of fruit and berry juices. (1992).

[20] Todaro, A., Cavallaro, R., La Malfa, S., Continella, A., Gentile, A., Fischer, U.A., Carle, R., & Spagna, G. (2016). Anthocyanin profile and antioxidant activity of freshly squeezed pomegranate (*Punica Granatum* L.) juices of Sicilian and Spanish provenances. *Italian Journal of Food Science,* 28(3), 464-479. doi: 10.14674/1120-1770/ijfsv332.

[21] Wang, S., Liu, Z., Zhao, S., Zhang, L., Li, C., & Liu, S. (2023). Effect of combined ultrasonic and enzymatic extraction technique on the quality of noni (*Morinda citrifolia L.*) juice. *Ultrasonics Sonochemistry,* 92, article number 106231. doi: 10.1016/j.ultsonch.2022.106231.

[22] Wang, Z., Zhang, M., & Wu, Q. (2015). Effects of temperature, pH, and sunlight exposure on the color stability of strawberry juice during processing and storage. *LWT – Food Science and Technology,* 60(2), 1174-1178. doi: 10.1016/j.lwt.2014.09.015.

[23] Yu, T., Wu, Q., Liang, B., Wang, J., Wu, D., & Shang, X. (2023). The current state and future prospects of *Auricularia auricula's* polysaccharide processing technology portfolio. *Molecules*, 28(2), article number 582. doi: 10.3390/molecules28020582.

Режими та способи обробки м'язги чорної смородини ферментним препаратом для підвищення соковіддачі

Ніна Максимівна Осокіна
Доктор сільськогосподарських наук, професор
Уманський національний університет садівництва
20300, вул. Інститутська, 1, м. Умань, Україна
https://orcid.org/0000-0002-2822-2989
Олена Петрівна Герасимчук
Кандидат сільськогосподарських наук, доцент
Уманський національний університет садівництва
20300, вул. Інститутська, 1, м. Умань, Україна
https://orcid.org/0000-0003-4242-0946
Катерина Василівна Костецька
Кандидат сільськогосподарських наук, доцент
Уманський національний університет садівництва
20300, вул. Інститутська, 1, м. Умань, Україна
https://orcid.org/0000-0003-2387-5400
Григорій Іванович Подпрятов
Кандидат сільськогосподарських наук, професор
Національний університет біоресурсів та природокористування України
03041, вул. Героїв Оборони 13, м. Київ, Україна
https://orcid.org/0000-0002-3164-5798
Володимир Антонович Піддубний
Доктор технічних наук, професор
Державний торговельно-економічний університет
02156, вул. Кіото, 19, м. Київ, Україна
https://orcid.org/0000-0002-1497-7133

Анотація. Чорна смородина – полівітамінна культура з високими дієтичними та лікувальними властивостями є джерелом виключно цінної сировини для виробництва соків, проте витягання його ускладнене хімічним складом. Ендокарпій оплодня чорної смородини (власне м'якоть) формується ослизненими арилусами, які оточують насінини, що перешкоджає добуванню соку. Мета роботи – наукове обґрунтування режимів та способів ефективного витягання соку чорносмородинового з попередньою ферментативною обробкою м'язги за збереження його природного хімічного складу та біологічно активних речовин. Дослідження проведено з плодами чорної смородини сортів Минай Шмирьов, Білоруська солодка, Новина Прикарпаття в умовах лабораторії кафедри технології зберігання і переробки продукції рослинництва та навчально-виробничого відділку Уманського національного університету садівництва. Методи досліджень (фізичні, хімічні, фізико-хімічні) та статистична обробка результатів (дисперсійний аналіз) загальноприйняті. З плодів чорної смородини, зазвичай, одержують незадовільний вихід соку – 18-24 %, що позбавлений властивого забарвлення. За оцінкою бажаності Харрінгтона ферментативна обробка пектофоетидином збільшує вихід соку з роздавлених плодів до задовільного (37-44 %) та дуже доброго (57-60 %) для плодів подрібнених (м'язга), що в 2-3 рази більше. Під час ферментації м'язги виділено три стадії: перша – дестабілізації колоїдної системи м'язги (до 1 год.); друга – деградації структури м'язги (до 2 год.); третя – стабілізації процесу (після 3 год.). Оптимальні умови ферментації м'язги забезпечуються застосуванням 0,03 % від маси суспензії препарату, температури 42-45°C, тривалості процесу 2 год. Це спричинює повноту витягання соку до 60%, переходом у нього 96-102% кислот та збереженістю до 97 % вмісту аскорбінової кислоти. Підвищення виходу соку на 6-15 % корелює з особливостями сорту. У соках із цукром вміст аскорбінової кислоти в 1,7 рази нижчий, проте її збереженість сягає 98-99 %. Факторами стабілізації аскорбінової кислоти у соках є цукор і гарячий розлив. Збільшення виходу соку та покращення його якості економічно та технологічно доцільне

Ключові слова: ферментативна обробка; вихід соку; якість соків; збереженість аскорбінової кислоти