UDC 663.813
DOI: 10.15587/1729-4061.2023.281929

IMPROVING THE JELLY PLUM JUICE TECHNOLOGY BY USING SECONDARY PRODUCTS OF OIL PRODUCTION

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The object of research is the technology of jelly plum juice.

A significant issue related to using pectin-containing raw materials in the production of juices is the reduced yield of the finished product and the formation of a significant amount of waste. It is proposed to consider the possibility of using wheat germ meal and rosehip fruit meal to increase the yield of jelly plum juice by treating with pomace additives. The rich chemical composition of the proposed additives will enrich the juice with essential substances.

It has been experimentally established that in order to increase the yield of jelly plum juice fortified with meal, it is advisable to ferment the pomace for 60 and 90 minutes, followed by pressing. This technological method will make it possible to increase the output of the finished product by adding wheat germ meal, by 11.4–36.1 % and 29.2–45.2 %, respectively; when fortified with rosehip fruit meal, by 15.3–35.0 and 28.8–46.9 %, respectively. In both cases, this occurs due to the hydrolysis of substances in fruit cells: for a first meal – due to its significant enzymatic activity, for a second meal – due to its high acidity.

It has been proven that the high content of nutrients in the meal contributes to the enrichment of jelly plum juice with proteins, non-starch polysaccharides, and vitamin C.

It was established that in order to achieve high product quality, it is advisable to use wheat germ meal in the amount of 5 %, and rosehip fruit meal – 5–7 % in addition to the total weight of plums.

The data reported in this work could be of practical importance at canning industry enterprises. Owing to the proposed technological solutions, manufacturers will be able to increase the profitability of production, reduce the amount of waste that pollutes the environment, and obtain jelly plum juice of enhanced nutritional value with competitive quality indicators

Keywords: juice yield, juice quality, wheat germ meal, rosehip meal

Received date 11.04.2023
Accepted date 16.06.2023
Published date 30.06.2023

***How to Cite**: Lapytska, N., Syza, O., Gorodyska, O., Savchenko, O., Rebenok, E. (2023). Improving the jelly plum juice technology by using secondary products of oil production. Eastern-European Journal of Enterprise Technologies, 3 (11 (123)), 68–77. doi: https://doi.org/10.15587/1729-4061.2023.281929*

1. Introduction

The problem in the development of modern society is the rapid spread of diseases of an alimentary nature. This, first of all, is connected with the insufficient consumption of necessary nutrients and biologically active substances by humans. Therefore, an important task of the food industry is to devise technologies for food products with an increased content of physiologically functional ingredients [1, 2].

Fruit purees and juices, which are a source of a wide range of vitamins necessary for the human body [3], are promising candidates for enrichment. However, the chemical composition of these products contains a small amount of proteins and minerals, regardless of the origin of the fruit and berry raw materials [3].

Among the wide assortment of fruit and berry raw materials, plums of the "Ugorka" variety are of scientific interest due to their high yield [4]. It should be noted that the use of plums in the canning industry in the production of juices is complicated by the high elasticity and viscosity of the cytoplasmic membranes of the fruit [3], therefore it is advisable to consider the technology of making jelly juice. The significant content of pectin substances in plums (4.39 %) also negatively affects the extraction of juice from them, while it has a positive functional effect for the human body [5]. That is why special attention should be paid to the study of the possibility of using in the production of additional raw materials aimed at increasing the yield of the finished product. In addition, it should be taken into account its effect on the enrichment of the jelly juice with essential substances, especially proteins and vitamin C. It is suggested to use secondary products of oil production as such raw materials. High acidity and enzymatic activity of meal from non-traditional oil raw materials will have a positive effect on the technological process of production of jelly juice from plums. In addition, the significant content of useful nutrients in additives will make it possible to enrich the finished product with a wide range of essential substances [6, 7].

The production of jelly plum juice with an increased content of proteins and vitamin C is important and promising today. Given this, an urgent task is to study the impact of non-traditional raw materials on the technological process of the production of fruit jelly juice, its quality and nutritional value indicators.

2. Literature review and problem statement

The market of natural products, which certainly includes fruit juices, is developing rapidly. The average Ukrainian consumes approximately 8 liters of juice per year, a European – 30 liters, an American – 60 liters. It should be noted that the consumption of juices of various concentrations is growing every year both in Ukraine and throughout the world. The majority of Ukrainian producers work to export products, which is due to the greater interest of foreign citizens in juice products. The world market's need for juices is greater, which makes research on expanding the range of these products relevant [8].

It should be noted that juices contain a significant amount of vitamins, the spectrum of which depends on the raw materials used for their production. These are mainly vitamins A, of B, C, K, P, U groups [9, 10], while this food segment does not contain proteins that play an important role for the human body as they are involved in the restoration of cells, the formation of enzymes, production of antibodies and hormones. The expansion of the range and enrichment of fruit juices mainly occurs due to the use in their technological process of wild berries and fruits containing a larger amount of vitamins [11].

Thus, work [12] proved that the use of viburnum juice in the production of pear juice makes it possible to increase the antioxidant activity of the finished drink. This contributes to the extension of the shelf life of such drinks without the introduction of preservatives and to the improvement of their organoleptic indicators.

However, the enrichment of juice through the use of peppermint, medicinal sage, lemon grass [11], viburnum juice [12] does not allow solving the important issue of enriching the finished product with substances of probiotic action and proteins. In order to solve this issue, paper [13] considers the possibility of making fruit juice from melon fruits and enriching it with four types of lactic acid bacteria: *Lactiplantibacillus plantarum subsp. plantarum MTCC 9511, Lactobacillus acidophilus MTCC 10307, Lactobacillus delbrueckii subsp.* The resulting probiotic fruit juices do not differ from analogs according to sensory evaluation. However, it has been proven that such drinks have a higher titrated acidity, a significant content of polyphenols, and many viable cells of lactobacilli. Paper [13] claims that melon juice fortified with lactobacilli is useful for people who are lactose intolerant and allergic to dairy products. In addition, their use lowers blood sugar.

In work [14] it is proposed to enrich the juice from tropical fruits with probiotics *Lactobacillus rhamnosus LPAA 01, Lactobacillus casei LPAA 02* and strains of *Lactobacillus plantarum LPAA 03*. After that, they dry the obtained fortified product by spraying with an inlet air temperature of 140 °C and a feed flow rate of 0.6 l/h. The work proved that the juice of tropical fruits fortified in this way after recovery has viable cells of lactobacilli and is useful for the human body.

It should be noted that despite the probiotic effect of the fruit juices obtained by researchers in [13, 14], the problem of enriching this product segment with proteins and vitamin C remains. In addition, the rate of juice yield is of great importance for this industry, especially from raw materials rich in pectin substances, which reduce juice yield because pectin substances cause turbidity and high viscosity of fruit juices.

It is known that the loss of fruits and vegetables with waste is about 22 %. This significantly worsens both the economic and ecological situation of the countries of the world: additional emissions of greenhouse gases occur; fresh water is polluted as a result of an increase in the amount of wastewater [15]. This problem requires research aimed at reducing the amount of secondary products and food industry waste. In this regard, the attention of researchers is also directed to the search for technological solutions for improving the juice yield of fruits and berries.

In work [16], it is proposed to pre-treat the fruits with the pectinase enzyme to increase the yield of guava juice. In addition to increasing the yield of juice, such processing allows obtaining a product with an increased content of flavonoids and phenolic compounds. At the same time, the antioxidant capacity and titrated acidity of the juice increase. However, it is noted that the obtained juice has lower organoleptic indicators compared to juice from raw fruits. This may be caused by the interaction of pectinase with the main aromatic components of the fruit and their loss during pressing. Also, the disadvantage of this method of processing is the instability of the pectinase enzyme and the complexity of its production. Therefore, in work [17] it is proposed to use bacterial pectinase. For this purpose, the researchers isolated two bacterial isolates from avocado skin. These are *Serratia marcescens* and *Lysinibacillus*. The analysis of work [17] showed that the bacterial pectinase of *Serratia marcescens* is the best for cleaning fruit juices from turbidity. It is recommended for use in juice production.

After analyzing the literature data on the enrichment and increase of the yield of fruit juices, we can come to the conclusion: the raw materials used for the enrichment of juices do not lead to an increase in its yield, and vice versa. Thus, the search for raw materials that will increase the yield of juice and simultaneously enrich it is an open question.

In this direction, promising raw materials may be secondary products of oil production – meal and cakes. These products are used to enrich bread [7] and flour confectionery [18]. The use of such additives makes it possible to enrich bakery and flour confectionery products with proteins, dietary fibers, a wide range of vitamins and minerals. Enrichment of products occurs even after their heat treatment, which is necessarily provided by the technological process. This is evidence of the expediency of using non-traditional types of raw materials, which, due to their chemical composition, perform the function of enriching components in the finished product. In this regard, our work proposes to use wheat germ meal (WGM) and rosehip fruit meal (RFM) in order to enrich and increase the yield of jelly juice. The proposed meal has the following physicochemical parameters: acidity, 6.0 degrees in WGM and 53.0 degrees in RFM; mass fraction of moisture 12.4 and 7.1 %, respectively; amylolytic activity, 315.0 and 2.0 mg of starch/hour, respectively [7].

Additives also have high nutritional value. So, wheat germ meal contains 37.0 % proteins, 44.8 % carbohydrates, and at the same time only traces of starch, 22.8 % non-starch polysaccharides, including: hemicelluloses – 15.3 %, cellulose – 6.2 %, pectin substances – 1.3 %, lignin – 1.0 %. This meal is a source of potassium, magnesium, iron, phosphorus, vitamins E, PP, and β–carotene [7].

Rosehip fruit meal has a slightly different nutritional value. It contains only 5.7 % of proteins, 59.7 % of carbohydrates, represented mainly by mono- and disaccharides. The content of non-starch polysaccharides is 43.4 %, the vast majority of which (31.4 %) is cellulose, this meal contains 3.0 % hemicellulose, 9.0 % pectin substances, and 17.0 % lignin. This meal is a source of potassium, calcium, magnesium, phosphorus, vitamins E, PP, C, and polyphenols [7].

The addition of an additional amount of pectin substances with meal to jelly plum juice will not significantly change the course of the technological process. This assumption is based on the significant enzymatic activity of WGM and the high acidity of RFM. It is these characteristics of additives that will neutralize the negative impact of additionally introduced pectin substances. At the same time, a significant concentration of other non-starch polysaccharides will have an immunostimulating and antitumor effect, affect the regulation of cholesterol and lipid levels in the blood [5].

Thus, our review of literary sources regarding the possible ways of increasing the yield of juice from pectin-containing raw materials and the features of enrichment of the finished product indicates the feasibility of searching for additives that will positively affect the technological process and nutritional profile of gelatinous plum juice. According to the data of the literature review, wheat germ and rosehip fruit meal can be such additives. In this regard, it is relevant to carry out research to study the influence of the proposed additives on the technological process and nutritional profile of jelly juice from plums.

3. The aim and objectives of the study

The aim of this study is to increase the nutritional value of jelly plum juice and the efficiency of its production process due to the use of wheat germ meal and rosehip fruit meal. This will make it possible to reduce production losses and increase its efficiency.

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

– to investigate the effect of the proposed meal on the yield of jelly plum juice;

– to determine the effect of additives on changes in the content of proteins, non-starch polysaccharides, and vitamin C in the finished product;

– to determine the influence of wheat germ meal (WGM) and rosehip fruit meal (RFM) on the physicochemical and organoleptic quality indicators of jelly plum juice.

4. Research materials and methods

4. 1. Characteristics of the raw materials used in the research and the method of obtaining jelly juice

The use of wheat germ meal and rosehip fruit meal in the production of jelly juice from plums will enrich it with essential substances and increase the output of the finished product with high quality indicators.

Wheat germ meal (TU U 20608169.002–99) and rosehip fruit meal (TU 15.8–32062796–003:2008) were used in the research, which are secondary products in the production of the corresponding oils at the Zhytomyrbioproduct NV TOV enterprise (Ukraine). The technological process during which the specified meal is obtained is carried out in accordance with the international standards DSTU ISO 9001, DSTU ISO 22000 (HASSP), DSTU ISO 14001.

Test samples from plums were obtained by the method of direct pressing. The obtained pomace was re-pressed and added to the main mass. This sample served as a control.

To implement the set tasks, experimental samples of jelly plum juice were prepared according to the principal-technological scheme shown in Fig. 1.

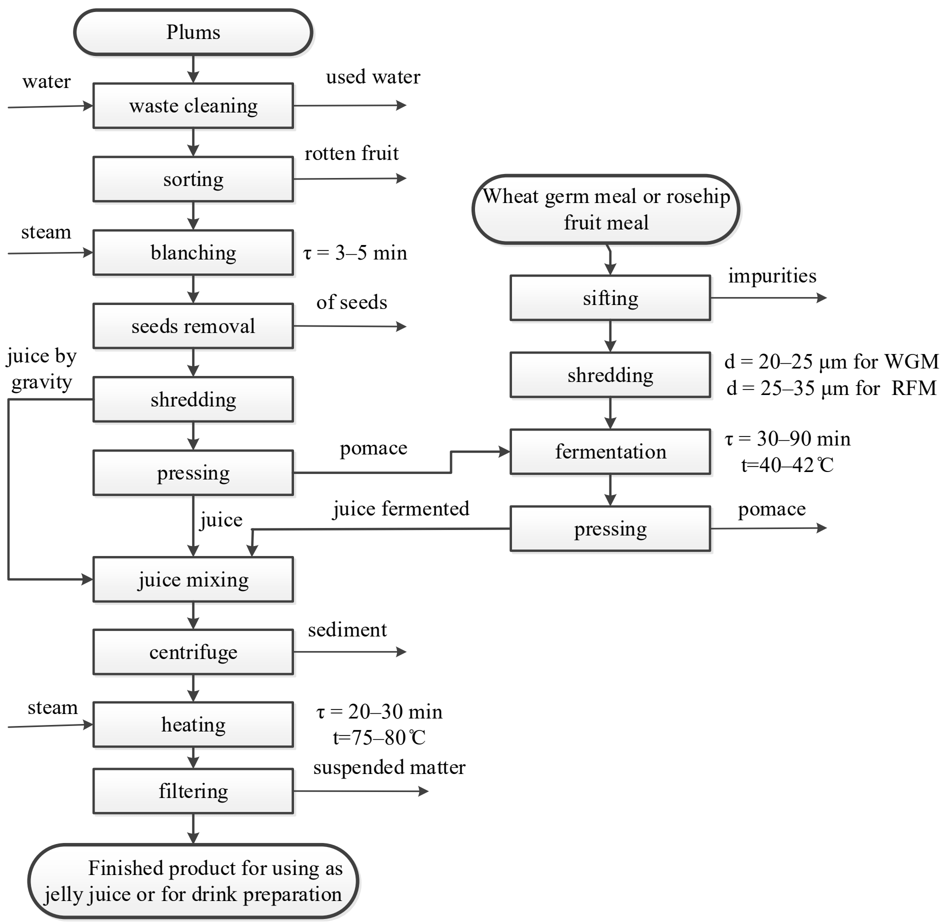

Fig. 1. Principal-technological scheme of production of jelly plum juice using secondary products of oil production

4. 2. Methods for studying the effect of meal on the yield of jelly juice, indicators of quality and nutritional value

The yield of jelly juice from plums was determined at a temperature of 20 °C, by pressing on a household juicer "Moulinex" (France). Seeds were removed from plums before determination. The mass of the resulting jelly juice was recorded on laboratory scales with an accuracy of 0.1 digits.

The protein content in the experimental supplements was determined by the modified Kjeldahl method [19].

The total content of dietary fibers was studied by the enzymatic method [20], pectin substances – by the calcium pectate method [21].

The content of vitamin C in the control and test samples of the jelly juice was determined by the indophenol method, for which a portion of the test material was poured with 20 cm^3 of a 1 % hydrochloric acid solution and ground to form a homogeneous mass. The resulting mass was poured into a 100 cm^3 volumetric flask. The container in which the test product was ground was rinsed several times with a 1 % oxalic acid solution and poured into the same volumetric flask. Its content was brought up to the mark with a 1 % solution of oxalic acid, closed, shaken vigorously and left to stand for 5 minutes. Then the extract was filtered, and the content of ascorbic acid was determined as follows: 10–20 cm^3 of the obtained filtered extract was titrated with a 0.001 mol-equiv/dm^3 solution of sodium 2,6–dichlorophenolindophelate until a pink color appeared, which did not disappear within 0.5–1.0 min. At the same time, a control titration was carried out, where instead of the extract, the same amount of a mixture of 1 % hydrochloric and 1 % oxalic acids was used in a ratio of 1:5. Then the calculation was carried out according to formula (1):

$$\mathrm{AK} = \frac{(A-B)\times 0.088\times V\times 100}{V1\times m}, \qquad (1)$$

where A is the amount of indophelate solution used for the titration of the extract, cm^3;

B is the amount of indophelate solution used for the titration of the mixture of acids, cm^3;

0.088 – the amount of ascorbic acid corresponding to 1 cm^3 of 0.001 mol-equiv/dm^3 solution of sodium 2,6–dichlorophenolindophelate;

V is the volume of the measuring flask, which contained the sample (100 cm^3);

$V1$ – amount of extract used for titration, cm^3;

m is the mass of the product taken for the extraction of ascorbic acid, g.

The granulometric size of the experimental additives was determined microscopically using a USB Digital Microscope (×120), and their linear dimensions were determined using the PhotoM 1.21 digital photo processing program [22].

To determine the water absorption capacity, 3 g of meal and 15 ml of water were mixed in a laboratory mixer for 1 min at a rotation frequency of the working bodies of 50 rpm, then the suspension was left in a thermostat at temperatures of 30 and 60 °C for 20 min. After that, it was centrifuged at 4000 rpm for 5 minutes. The underflow was drained, its mass F, the content of dry substances in it was determined. The water absorption capacity was calculated according to formula (2):

$$\mathrm{WAC} = \frac{B-(F-m)}{\frac{M\cdot(100-W)}{100}-m}\cdot 100, \qquad (2)$$

where B is the amount of water poured into the centrifuge tube, ml;

M is the batch of the product introduced into the centrifuge tube, g;

F – weight of underflow, g;

W – mass fraction of moisture in the product, **%**;

m is the mass fraction of dry substances in underflow: g $\left(m = F\cdot\frac{CP^F}{100}\right)$;

CP^F is the dry matter in the measurement taken for determination, g.

In order to determine the moisture-retaining capacity (MRC) of wheat germ and rosehip fruit meal, a batch of 5 g was taken, placed in a weighed centrifuge tube, and 30 ml of distilled water was added. The mixture was stirred in a laboratory mixer at a speed of 50 rpm. After that, the solution was allowed to stand for 30 minutes, after which it was centrifuged for 15 minutes at a speed of 4000 rpm. The non-adsorbed water was drained, and the test tube was left in an inclined state for 10 min to remove residual water. After that, the test tubes were weighed, and the coefficient of moisture absorption was calculated according to formula (3):

$$\mathrm{MRC} = \frac{m1-m2}{\mathrm{m3}}\times 100,\ \%, \qquad (3)$$

where $m1$ is the mass of the test tube with the batch and bound water, g;

$m2$ – mass of test tube with batch, g;

$m3$ is the weight of the batch, g.

The titrated acidity of jelly plum juice was determined by titration with 0.1 N sodium hydroxide; thymolphthalein was used as an indicator (since the test samples have an intense color) until a persistent blue color appeared according to the method described in [21].

The content of dry substances in the control and test samples of jelly juice was determined by the refractometric method. The research was carried out at a temperature of 20 °C. After checking the device with distilled water, 1–3 drops of the sample of jelly juice under study were applied to the dry surface of the measuring prism with a glass stick. After closing the lid of the chamber, the result was determined on a scale indicating the percentage of dry substances according to the position of the dividing line.

The viscosity of control and experimental samples of jelly plum juice was determined by the Stokes method (falling ball method) on a Hepler viscometer [23].

Organoleptic parameters of jelly juice (appearance and consistency, color, taste, aroma, secondary taste) were determined according to generally accepted methods by conducting a tasting.

4. 3. Statistical processing of research results

The margin of error for all studies was σ=3–5 %, the number of parallel experiments was n=5, and the probability was $P\geq 0.95$. Experimental data were processed statistically by the Fisher-Student method at a reliability level of 0.95. The results were calculated as the arithmetic mean of at least five experiments. The MS Office 2016 software package, including MS Excel, was used to process the experimental data.

5. Results of research on the effect of meal on the yield and nutritional value of jelly plum juice

5. 1. Studying the effect of meal on the yield of jelly plum juice

The key role in the production of juices and juice products is played by their yield because the profitability of production, the amount of secondary products formed, and production losses depend on it. The yield of juice from plums is 58.0–70.5 dal from 1 ton of raw material [3], while about 20–23 % juice remains in the pomace. The use of any additional raw materials can significantly affect this indicator, due to the effect on the structure of pectin substances and the cytological structure of the cellular tissues of the fruit, which leads to a more intensive release of juice. At the same time, the granulometric composition of the additional raw material, its water–absorbing and moisture-retaining capacity are of great importance. Therefore, it was considered expedient to investigate the listed indicators.

The results of determining the dispersity of experimental meal by the microscopic method are given in Table 1.

In the course of research, it was established that the meals proposed for use have a powdery structure. Table 1 shows that 65 % of wheat germ meal particles have a size of 40–60 μm, and 70 % of rosehip fruit meal particles have a size of 60–90 μm. Such particles are too large and can be felt in the product. In this regard, it was proposed to grind the meal before use to be followed by centrifugation of the resulting juice (Fig. 1). Pre–grinding of WGM to a particle diameter of 20–25 microns, and RFM to 25–35 microns, will allow the additive to more effectively penetrate into the pores of plum fruits and interact with non-starch polysaccharides, disrupting their structure, which positively affects the yield of the finished product.

When using additional raw materials in the production of juices, one should take into account its water-absorbing (WAC) and moisture-retaining capacity (MRC). It is these indicators that can significantly influence the passage of the technological process. In connection with this, the determination of WAC (Fig. 2) of wheat germ meal and rosehip fruit meal was carried out.

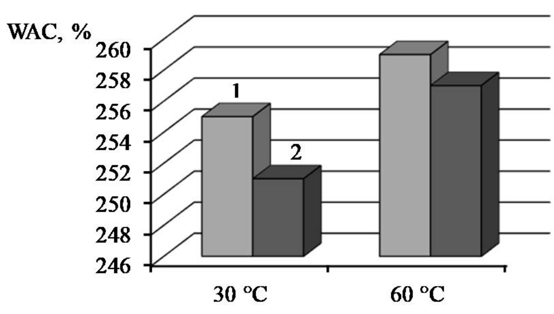

Fig. 2. Water absorption capacity of experimental meal depending on the temperature of the system: 1 – wheat germ meal; 2 – rosehip fruit meal

According to the data shown in Fig. 2, experimental meals have a significant water absorption capacity, which is due to their high content of hydrocolloids. A slightly lower WAC of rose hip fruit meal is probably related to its larger particle size (Table 1). In addition, the polysaccharide composition of this meal is dominated by cellulose, which has a lower water absorption capacity compared to hemicelluloses.

According to the presented data (Fig. 2), with an increase in temperature to 60 °C, the water absorption capacity does not increase significantly relative to the data obtained at 30 °C. Thus, the production of germ meal increases by 1.6 %, and rosehip meal – by 2.4 %. Such data may indicate that an increase in temperature in the technological process will not have a significant effect on the absorption of moisture by additives.

It is also important how long the meal can retain the absorbed moisture. Therefore, at the next stage of research of additional raw materials, the higher quality of the proposed meal was determined (Fig. 3).

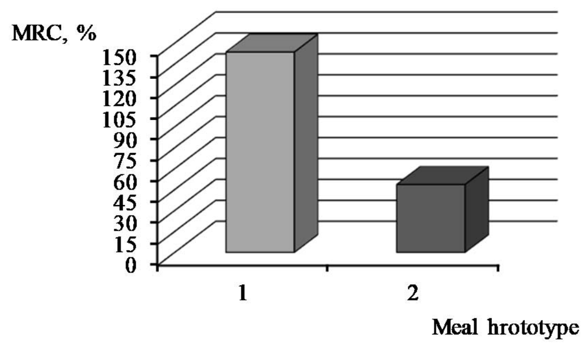

Fig. 3. Moisture retention capacity of experimental meal: 1 – wheat germ meal; 2 – rosehip fruit meal

According to the data shown in Fig. 3, the MRC of germ meal is 2.9 times higher compared to rosehip meal. This may indicate that the yield of juice from WGM-treated plum pomace will be lower compared to the juice yield of plum pomace treated with RFM.

In this regard, it was considered expedient to study the effect of wheat germ meal and rosehip fruit meal on the juice yield of plums during their pressing, depending on the fermentation time.

The results of the research are shown in Fig. 4, 5.

Analysis of the data shown in Fig. 4, 5 reveals that the processing of plum pomace with experimental meal after the first pressing and squeezing it immediately after processing are not appropriate. In this case, the samples fortified with WGM do not give more juice at all, and in those fortified with RFM, the additional yield decreases by 2.1–2.7 times compared to the control sample. It should be noted that with an increase in the dosage of the additive, the additional yield decreases.

Table 1

Fractional composition of experimental meals (n=4, p≤0.05, σ=3...5 %)

Meal name	Fraction content, %									
	10...30 μm	30...50 μm	50...70 μm	70...90 μm	90...110 μm	110...130 μm	130...150 μm	150...170 μm	170...190 μm	190...210 μm
Wheat germ meal	2.0	28.6	34.9	10.6	8.3	9.0	2.0	2.2	1.5	0.9
Rosehip fruit meal	0.0	0.0	20.8	49.7	7.4	3.5	6.2	6.5	3.0	2.9

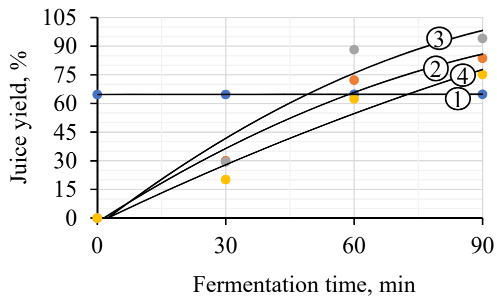

Fig. 4. The effect of wheat germ meal on the yield of jelly plum juice: 1 – jelly juice without additives (control); samples with the addition of: 2–3 % wheat germ meal; 3–5 % wheat germ meal; 4–7 % wheat germ meal

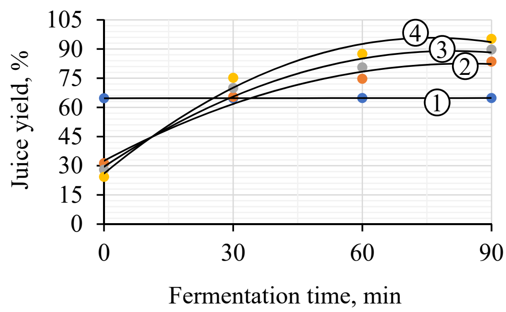

Fig. 5. The influence of rosehip fruit meal on the yield of jelly plum juice: 1 – jelly juice without additives (control); samples with the addition of: 2 – 3 % rosehip fruit meal; 3 – 5 % rosehip fruit meal; 4 – 7 % rosehip fruit meal

However, it was established that the juice output is affected by the contact time of the meal with the raw material. According to research data, the optimal time for processing the pomace to increase the yield of jelly juice also differs. It was established that after 30 minutes of fermentation wheat germ meal begins to affect the additional yield of juice, but this indicator is lower compared to the control sample by 2.1–3.2 times. Such an effect cannot be called positive but it is evidence that the enzymes of the germ meal begin to destroy the structure of the fruit tissues. After 60 minutes of fermentation, we observe a slightly different trend. With the introduction of 3 and 5 % of WGM, the yield of jelly juice increases compared to the control by 11.4 and 36.1 %, respectively. At the same time, adding the additive in the maximum amount (7 %) leads to a decrease in yield by 3.7 %. Increasing the fermentation time with this meal in the amount of 3–5 % to 90 min makes it possible to increase the yield of jelly juice by 29.2–45.2 %. At the same time, adding 7 % of the additive increases the yield of the finished product by only 16.0 % compared to the control sample.

The introduction of RFM to the pomace before re-pressing and their fermentation for 30 min have the opposite effect compared to the use of RFM for enrichment. Thus, with the addition of 3 % additive after 30 min of fermentation, the product yield is within the margin of error with the sample without additives. Adding 5 and 7 % increases the yield by 8.2 and 16.2 %, respectively. After 60 and 90 min, there is an increase in the yield of jelly juice in the entire dosage range by 15.3–35.0 and 28.8–46.9 %, respectively.

5. 2. Determination of the content of proteins, non–starch polysaccharides, and vitamin C in jelly plum juice fortified with meal

The content of proteins, non–starch polysaccharides, and vitamin C was determined in the experimental and control samples of jelly juice because these nutrients are important for the normal functioning of the human body. The results of the research are given in Table 2.

Table 2

Nutrient and vitamin C content in jelly juice fortified with wheat germ meal and rosehip fruit meal (n=5, P≥0.95, σ=3–5 %)

Dosage of enriching additive	Nutrient and vitamin C content		
	Protein, g/100 g	Non-starch polysaccharides, g/100 g	Vitamin C, mg/100 g
No additives (control)	0.80	1.50	0.43
Jelly juice with additional application of WGM			
3 %	1.91	2.18	0.43
5 %	2.65	2.64	0.43
7 %	3.39	3.10	0.43
Jelly juice with additional application of RFM			
3 %	0.97	2.80	1.84
5 %	1.10	3.67	2.78
7 %	1.20	4.54	3.72

The data listed in Table 2 show that the addition of both WGM and RFM enriches jelly plum juice with protein and non-starch polysaccharides. Thus, the protein content in samples with germ meal increases by 2.3–4.2 times, and with the addition of rosehip meal – by 21.2–50.0 % compared to the control. The content of non-starch polysaccharides increases by 45.3–106.7 % and 86.7–202.6 %, respectively.

At the same time, additives affect the content of vitamin C in different ways. With the introduction of WGM, the content of this biologically active substance does not change relative to the value in the sample without additives. While the addition of RFM helps increase the content of ascorbic acid in the finished product by 4.3–8.6 times.

5. 3. Determination of the influence of meals on the quality indicators of jelly juice from plums

Determination of acidity and dry matter content are the main physical-chemical indicators that must be measured during juice production. Indicators of titrated acidity and dry matter content are interrelated. These indicators have a significant impact not only on the organoleptic properties of the finished product but also on the formation of juice yield and its enrichment. In addition, viscosity is an important indicator that forms indicators of the quality of the finished product. It is this indicator that affects the fluidity of the juice and shapes the perception of the finished product by human receptors.

Determination of the titrated acidity, the content of dry substances in the test samples of the jelly juice, and its viscosity was carried out after 60 minutes of fermentation of the extracts and their repeated pressing. The results of the research are given in Table 3.

Table 3

Physical-chemical indicators of the quality of jelly plum juice fortified with wheat germ meal and rose hip meal (n=5, $P \geq 0.95$, σ=3–5 %)

Measured indicator	Control (without additives)	Additive and its dosage					
		WGM			RFM		
		3 %	5 %	7 %	3 %	5 %	7 %
Titrated acidity, degrees	4.2	4.8	5.4	6.0	5.1	6.0	6.8
Solids content, %	17.0	22.0	26.0	32.0	24.0	33.0	41.0
Viscosity, Pa×s	10.2	9.5	7.4	11.3	8.2	6.0	3.8

The results of the research given in Table 3 show that the amount of dry matter in juices with the introduction of experimental meal increases with an increase in the dosage of the additive. This serves as an impetus for the course of biochemical processes that affect the increase in titrated acidity indicators. Such data were confirmed experimentally (Table 3).

According to the data given in Table 3, with the addition of WGM, the content of dry substances in the finished product increases by 29.4–46.9 %, and with the addition of RFM – by 41.2–141.2 % compared to juice without additives. Such data are commensurate with data on the titrated acidity of plum juice. This indicator increases with the addition of germ and rosehip meal by 14.3–42.8 and 24.4–61.9 %, respectively.

Our data on the viscosity of the jelly juices (Table 3) indicate that the fermentation of the extracts from RFM in the entire range of dosages contributes to the reduction of this indicator. When processing pomace with rosehip meal in the amount of 3–7 %, the viscosity decreases by 19.6–62.7 %

However, analyzing the data on the impact of WGM on this indicator, we observe a slightly different trend. Thus, fermentation of pomace with this meal in the amount of 3 and 5 % helps reduce the viscosity of the juice by 6.9 and 27.4 %. At the same time, adding 7 % of the additive causes an increase in the viscosity of the finished product by 10.8 %.

It should be noted that the research data on the physical-chemical parameters of the resulting juices correlate with the data on the effect of additives on the yield of the finished product (Fig. 4, 5) and its enrichment (Table 2). In addition, the content of dry substances and the titrated acidity of juices significantly affect the organoleptic indicators of the finished product (Table 4).

The data given in the table indicate that the introduction of WGM and RFM in the smallest dosages (3 %) does not affect the organoleptic quality indicators. However, the proposed meal in the amount of 5–7 % has different effects on the organoleptic properties of the finished product. The appearance and consistency of the jelly juice does not change with the addition of RFM compared to the control sample. However, analyzing the data on the introduction of WGM, we see that with the addition of an additive in the amount of 5 %, the juice becomes less fluid, slightly heterogeneous. While the maximum amount of meal (7 %) causes the formation of a thick, heterogeneous suspension, which is more like puree, and it is not appropriate to classify it as juice. This indicates that it is not expedient to use WGM in such a quantity.

Table 4

Organoleptic indicators of jelly plum juice fortified with wheat germ meal and rosehip fruit meal

<table>
<tr><th rowspan="4">Indicators</th><th colspan="7">Characteristics of indicators</th></tr>
<tr><th rowspan="3">Control (without additives)</th><th colspan="6">Additive and its dosage, %</th></tr>
<tr><th colspan="3">Rosehip fruit meal</th><th colspan="3">Wheat germ meal</th></tr>
<tr><th>3 %</th><th>5 %</th><th>7 %</th><th>3 %</th><th>5 %</th><th>7 %</th></tr>
<tr><td>Appearance</td><td colspan="5">Fluid with pulp</td><td>Less fluid with pulp</td><td>Thick suspension</td></tr>
<tr><td>Consistence</td><td colspan="5">Homogeneous</td><td>Slightly heterogeneous</td><td>Heterogeneous</td></tr>
<tr><td>Color</td><td colspan="2">Corresponding to plum varieties, homogeneous, bright</td><td>Corresponding to plum varieties with a red tint bright, uniform</td><td colspan="4">Corresponding to the plum variety with a grayish tint, homogeneous</td></tr>
<tr><td>Taste</td><td colspan="2">Saturated, harmonious, characteristic of plums</td><td>Rich, harmonious, sweet and sour, with a slight taste of wild rose</td><td colspan="4">Rich, harmonious, with a sweetish-nutty flavor</td></tr>
<tr><td>Aroma</td><td colspan="2">Well-defined, harmonious, plum</td><td>Well-defined, harmonious, plum, with a slight rosehip aroma</td><td colspan="4">Well expressed, harmonious, plum, with notes of nut</td></tr>
<tr><td>Secondary taste</td><td colspan="2">Identical to taste, quickly disappears</td><td>Identical to taste, does not disappear for a few minutes</td><td colspan="4">Identical to taste, does not disappear for a few minutes</td></tr>
</table>

When adding all the meals in the suggested dosages, we get a finished product with a specific taste and aroma, which is present even in the secondary taste.

6. Discussion of results of the influence of experimental meal on the quality and nutritional value of jelly plum juice

As a result of determining the effect of wheat germ meal and rosehip fruit meal on the yield of jelly plum juice, it was established that their application in the entire range of dosages without additional fermentation leads to a decrease in the yield of juice (Fig. 4, 5). This is caused by the high water–absorbing capacity of additives (Fig. 2) and their granulometric composition (Table 1), which affect the juice yield immediately after processing the pomace.

It was established that the yield of plum juice is positively influenced by the time of fermentation of pomace with meal. Thus, after only 30 minutes, you can get juice from pomace fortified with WGM, and the yield of the product from pomace fortified with RFM is close to the control sample.

The increase in juice yield during fermentation over 60 and 90 min can be explained by the high enzymatic activity of a first meal and the significant content of ascorbic acid and, as a result, the high acidity of the latter. The effect of enzymes and organic acids makes it possible to micro injure the cytoplasmic membrane of plant cells, which allows substances to be released from them (Table 3). When the time of fermentation of pomace with meal increases, glycosidic bonds between poly-galacturonic acid and non-starch polysaccharides also occur. Thus, the use of meal makes it possible to eliminate the negative effect of water-soluble hemicelluloses by their disintegration under the action of the enzymatic-acid complex of additives. This is a prerequisite for increasing the yield of juice, due to the destruction of pectin substances, and its additional enrichment. The last statement was proved experimentally (Table 2). However, it should be noted that with the use of wheat germ meal in the maximum amount (7 %), the juice yield after 90 minutes begins to decrease compared to that with the addition of 5 %. This can be explained by the greater number of non-starch polysaccharides introduced with WGM, its significant water-absorbing (Fig. 2) and moisture-retaining (Fig. 3) capacities.

It has been established that the introduction of the proposed meal in the entire range of dosages contributes to the enrichment of the finished product with proteins and non-starch polysaccharides, and with the addition of rose hip meal – also vitamin C. It should be noted that the use of pectinase enzyme [16] only contributes to increasing the yield of the finished product. This means that the use of wheat germ meal and rosehip fruit meal has an advantage over the studies reported in [16].

The advantage of the proposed technique is that the use of meal makes it possible to enrich juices from raw materials rich in pectin substances. Unlike [12, 13], where the objects of enrichment were pear and melon juices, the proposed technique of processing pomace with meal allows enriching plum juice with useful components. This is important because the extraction of juice from plums is complicated by the structure of the cytoplasmic membrane of the fruits and the significant content of pectin substances in them.

According to research data, the greatest enrichment of proteins and non–starch polysaccharides occurs when germ meal is added in the amount of 5–7 %. However, the optimal dosage of this additive for juice enrichment should be considered 5 %. This can be confirmed owing to our data on the effect of germ meal on the output of the finished product (Fig. 4) and its organoleptic evaluation (Table 4). Addition of WGM in the amount of 7 % not only reduces the yield of juice but also causes the formation of a thick suspension. This is most likely due to the high viscosity of the systems that form this meal (Table 3). This is confirmed by a significant increase in the content of dry substances in the juice after its introduction (Table 3).

Characterizing the influence of rosehip fruit meal on the content of essential substances, it can be said that this meal has almost no effect on the protein content of the finished product, while it makes it possible to significantly enrich it with non-starch polysaccharides and vitamin C. When choosing the optimal dosage of rosehip meal, it is advisable to take into account its effect on the content useful nutrients. It is suggested to use rosehip fruit meal to enrich jelly plum juice in the amount of 5–7 %.

In this way, by using WGM and RFM to increase the output of plum juice and its fortification, a comprehensive use of raw materials is achieved. The advantages of such a technological solution are that secondary products, namely meal, are also used for fermentation and increased juice yield. They are formed during the production of the corresponding oils by means of CO_2 extraction and are accumulated in large quantities at oil and fat enterprises. That is, for their production, it is not necessary to set up a separate technological line and devise a process as is done when obtaining bacterial pectinase from avocado skin [17].

However, when carrying out the technological process of obtaining jelly juice from plums using wheat germ meal and rosehip fruit meal, the fermentation time of pomace and the percentage of additives proposed in the work should be carefully followed. You should not process plum fruits before pressing – this will cause a malfunction of the equipment and will not allow you to get the expected effect. This is primarily due to the high water-absorbing capacity of the meal (Fig. 2).

The shortcomings of this study include the fact that the high water-absorption capacity of the meal was not taken into account. This made the work much more difficult. It is this indicator of additives when the dosage is increased above the established norm that causes the formation of thick suspensions. However, the shortcomings discovered during the research were technologically eliminated and scientifically described. It is recommended not to use wheat germ meal in the amount of more than 5 % of the mass of plum pomace. It is suggested to ferment the extracts for 60–90 minutes. After mixing gravity-obtained juice, pressed juice and fermented juice, centrifugation is recommended (Fig. 1). This technological operation will make it possible to balance the system, separate possible solid particles from it, and provide homogeneity. Heating will allow, firstly, to separate colloidal suspended particles, and secondly, it will contribute to longer storage of the product.

In further studies, it is planned to determine the possibility of using extracts from meal to increase the yield of juice from plums and increase its nutritional value. This will remove the negative effect of significant amounts of powdered meal on the consistency of the finished product and enhance the positive effect. It is also planned to investigate the influence of meal and extracts from them on changes in the quality of jelly plum juice during storage and to establish the optimal storage time. In addition, an important direction of further research is the study of the influence of powdered meal and extracts from them on the quantity and quality of pectin substances in the finished jelly juice. It is also advisable to study the effect of pectin substances remaining in the jelly juice after the fermentation of the pomace on the human body.

7. Conclusions

1. It was established that adding wheat germ meal in the amount of 3–5 % and rose hip meal in the amount of 3–7 % in addition to the mass of plums has a positive effect on the yield of jelly juice during the fermentation of pomace before pressing for 60 and 90 minutes. Thus, the introduction of the former increases the yield of juice by 11.4–36.1 and 29.2–45.2 %, respectively. Adding the latter – by 15.3–35.0 and 28.8–46.9 %, respectively. It should be noted that the use of wheat germ meal in the maximum amount (7 %) causes a decrease in the yield of the finished product compared to the control after 60 minutes of fermentation by 3.7 %. At the same time, when fermentation is carried out for 90 minutes, the yield of fortified juice increases by 16.0 % compared to the sample without additives, but this is 20.1 % less than the yield that can be obtained when using germ meal in the amount of 5 %. This may be one of the reasons for excluding such a supplement from further studies.

2. As a result of the study of the effect of additives on the content of protein, non-starch polysaccharides, and vitamin

C in the finished product, it was established that they have somewhat different effects. Thus, with the addition of wheat germ meal in the entire range of dosages, jelly plum juice is fortified with protein and non-starch polysaccharides. The protein content in the experimental samples is 2.3–4.2 times higher compared to the control. The amount of non-starch polysaccharides is 45.3–106.7 % higher than in the sample without the additive. The addition of WGM does not change the content of vitamin C at all. The introduction of rosehip fruit meal has a somewhat different effect. Also, as in samples with germ meal, the product is fortified with non-starch polysaccharides, the amount of which increases by 86.7–202.6 % compared to the control sample. However, protein fortification occurs to a lesser extent, only by 21.2–50.0 %. It should also be noted that the addition of rosehip meal makes it possible to obtain a product in which the content of vitamin C exceeds that of the control sample by 4.3–8.6 times. Such an effect on the content of nutrients and vitamin C is predictable, taking into account the chemical composition of the proposed meal.

3. To ensure the high quality of the product, it is advisable to use wheat germ meal in the amount of 5 % and rosehip fruit meal in the amount of 5–7 %. This can be asserted based on the data of studies into the physical-chemical and organoleptic indicators of the quality of jelly plum juice. Thus, with the addition of wheat germ meal in the amount of 5 % of the total mass of plum pomace, the amount of dry matter in the jelly juice increases to 26.0 %, which is 52.9 % more compared to the control. The addition of rosehip fruit meal in the amount of 5–7 % helps increase the dry matter content to 33.0–41 %, which is 94.1–141.2 % more than in the control sample. An increase in the content of dry substances contributes to an increase in the acidity of the jelly juice with WGM to 5.4 degrees, with the introduction of RFM – to 6.0–6.8 degrees. The viscosity of the finished product with germ and rosehip meal in the specified dosages is reduced compared to the sample without additives by 6.9 % and by 41.2–62.7 %, respectively. The above results have a direct impact on the formation of organoleptic indicators of jelly plum juice. In appearance, the finished product is a flowing liquid with pulp. However, the introduction of WGM causes the formation of a slightly heterogeneous consistency, which does not impair the taste properties of the product. Nut notes appear in the taste and aroma of jelly juice with germ juice, and with rosehip – sweet and sour rosehip-plum taste and aroma. In both cases, the aftertaste does not disappear for several minutes. In general, the resulting products meet the requirements of DSTU 4283.1:2007, 4882.2:2007, and CODEX STAN 247. However, it should be noted that the use of wheat germ meal in the amount of 7 % of the mass of the pomace has a negative effect on the viscosity of the finished product, increasing it by 10,8 % compared to the control sample. This, in turn, negatively affects the appearance and consistency of the product. Therefore, the use of germ meal in the amount of 7 % of the mass of pomace is not recommended.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

Funding

The study was conducted without financial support.

Data availability

All data are available in the main text of the manuscript.

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