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PREPARATION AND EXPERT EVALUATION OF JELLY-FRUIT MARMALADE FORTIFIED WITH QUERCETIN

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Abstract The technique of obtaining a water-soluble pectin-quercetin complex has been developed. The spectral properties of the resulting complex have been studied. The absorption spectrum of ethanol solution of quercetin with a volumetric particle of ethanol is 96% is characterized by the presence of absorption bands π-π* transitions in the UV region at λ = 251 nm and n→π* transitions at λ = 369 nm. The absorption band of quercetin at λ = 369 nm is broaden **i**n an aqueous solution in the presence of pectin due to interactions with pectin**.** The luminescence of quercetin at 541 and 655 nm is quenched in the water-soluble pectin-quercetin complex. The FTIR spectra of the pectin-quercetin complex lack absorption bands that relate to the functional groups of quercetin, which indicates that quercetin contacted the polysaccharide, forming a complex compound. The obtained jelly-fruit marmalade fortified with quercetin in the form of pectin-quercetin complex as a functional component. The morphological characteristics of raw materials and product are established by optical microscopy. Micromorphological signs of apple pectin powder are polydispercial of the particles of irregular shape, size from 10 to 350 μm. The surface of large particles (250-350 μm) is covered with crystals in size 10-30 μm. The crystalline particles of quercetin have a straight shape, in size polydispersy up to 50 μm in length and up to 5 μm wide. There are no crystalline particles of quercetin on the microphoto of marmalade samples and polydispersed pectin particles, homogeneous, amorphous, and student consistency. Expert evaluation of marmalade, which is fortified with quercetin, found that the samples correspond to regulatory documents on such indicators as: humidity - decreases from 17.5% to 16.1%; acidity - increases from 8.5% to 9.4%. The mass fractions of reducing substances and ash increase slightly with the increase in quercetin concentration in marmalade samples, but also do not exceed the normative data. The antioxidant activity of the samples increases with increasing quercetin content from 0.35 mg/g to 0.69 mg/g.

Keywords: pectin-quercetin complex, marmalade, expertise, healthy foodstuffs, phenolic compounds

Introduction. Formulation of the problem

In today's world, there's a lot of focus on making functional foods that not only taste good but also have a positive impact on people's health. One promising trend is the enrichment of food products with biologically active substances, in particular natural antioxidants. The introduction of innovative approaches to recipes and technology allows for the expansion of product range, improvement of product quality, and increased competitiveness in national and foreign markets. Fruit jelly marmalade is a promising type of confectionery product that combines high nutritional value, excellent consumer properties, a wide range of varieties, and technological flexibility in production. Its popularity among consumers is due to its pleasant taste, delicate texture, variety of shapes, colors, and flavors, as well as the possibility of including beneficial substances such as natural pectins, vitamins, bioflavonoids, etc. Recently, quercetin has been attracting a lot of attention. It is a powerful flavonoid with anti-inflammatory, antioxidant, and antiviral properties, which have been confirmed by numerous scientific studies. In addition, thanks to the use of pectin as a structuring agent, fruit jelly marmalade can be recommended for dietary and preventive nutrition. Pectin helps normalize the functioning of the gastrointestinal tract, remove toxic substances from the body, and lower blood cholesterol levels, making marmalade not only an attractive treat but also a healthy product. Given the popularity of marmalade among consumers of all ages and the possibility of including natural additives in its composition, it is important to scientifically substantiate the possibility of producing fruit jelly marmalade fortified with quercetin while preserving its functional properties and organoleptic characteristics.

Analysis of recent research and publications

It is known that phenolic and polyphenolic compounds exhibit antioxidant properties, are found in the tissues of many plants, and are used in the production of various dietary supplements [1-6]. Phenols containing several hydroxyl groups located in the ortho, para or meta positions have the highest biological activity. Polyphenolic compounds have anti-inflammatory, antihistamine, antioxidant, and immunomodulatory effects, relieve edema, reduce the risk of cardiovascular disease, stabilize cell membranes, inhibit aging processes, and are therefore part of many biologically active supplements and treatments [7-9].

Quercetin is a naturally occurring flavonoid considered to be one of the most powerful antioxidants in nature, but its activity is limited by variable absorption rates, low bioavailability, poor water solubility, and insufficient chemical stability. The latter is the main problem faced by scientists in developing effective nutraceuticals and functional foods. By increasing the bioavailability of quercetin, it is undoubtedly possible to develop increasingly effective nutraceuticals and health products [9, 10].

Studies [11] demonstrate that apple pectin enhances the absorption of quercetin in the human gastrointestinal tract. This enhancing effect depends on the dose and degree of pectin methoxylation. It has been shown that simultaneous consumption of quercetin and low-methoxylated pectin increases the absorption of the former in 2 times.

Pectin is a heteropolysaccharide found in the cell walls of plant tissues, such as apples, apricots, pears, and other fruits. Natural pectin is usually formed from protopectin and consists mainly of monomeric chains of D-galacturonic acid linked by glycosidic bonds, to which other sugars can be attached. It is safe to use, passes unchanged through the gastrointestinal tract, and is partially digested by the bacterial microbiota of the colon [12, 13].

Pectin, as well as combinations of pectin with other biopolymers, are widely used as a matrix for stabilizing quercetin. Examples of such use of pectin are given below.

In [14], the results of obtaining nanoparticles based on pectin and chitosan for the encapsulation of quercetin are presented. For this purpose, the ion gelation method was used. The encapsulation efficiency reached a maximum of 56.2%. The release of quercetin *in vitro* was prolonged, indicating that the obtained nanoparticles may be a promising matrix for stabilizing phenolic compounds. In addition, the antioxidant activity of quercetin after encapsulation increased by 71%.

Scientists [15] have developed a method for obtaining hydrogel beads based on pectin and oligochitosan for targeted delivery of quercetin to the large intestine. Pectin was extracted from the peel of yuzu (*Citrus junos*) and deesterified by enzymatic treatment. Under conditions simulating the stomach and small intestine environments, quercetin release was less than 1%. However, when the obtained beads were exposed to simulated colon fluid for 12 hours, quercetin release increased to 65.37-99.54%. These results showed that hydrogel beads based on deesterified pectin and oligochitosan can be effective delivery systems for quercetin to the colon.

In study [16], a core-shell quercetin delivery system was developed using natural food materials—whey protein isolate and pectin. The beads were made by mixing a protein component emulsion with pectin using ionotropic gelation. *In vitro* studies showed that the quercetin-containing beads were stable in the stomach and small intestine. This indicates that the delivery system obtained is promising for the release of quercetin in the colon and can be an ingredient for the creation of health products.

The soluble complexes of pea protein isolate and highly methoxylated pectin for quercetin encapsulation were created in studies [17]. The photo- and thermal stability, as well as the antioxidant properties of quercetin, were significantly improved in the complex compared to free quercetin. Thus, after 15 minutes of irradiation, free quercetin was almost completely destroyed, and the same effect was observed after its treatment at 85°C. In the complex, about 50% of quercetin remained after 2 hours under the same conditions. It should be noted that *in vitro*, about 4% of quercetin was released in simulated gastric fluid, and 80% in fluid simulating the colon. This indicates the possibility of using the obtained complex as a delivery system to the intestine and effective protection of encapsulated quercetin in the stomach.

The above confirms the effectiveness of using pectin to stabilize quercetin, as well as the prospects for creating health products using such systems.

Purpose and objectives of the study

The purpose of the study was to obtain and characterize the water-soluble complex of quercetin with pectin and to develop a jelly-fruit marmalade with its contents.

Objectives:

- to obtain a water-soluble form of quercetin in the form of the pectin-quercetin complex (PQC);
- to study the spectral properties of the resulting complex;
- to obtain the samples of marmalade fortified with quercetin;
- to carry out an expert assessment of the quality indicators of marmalade fortified with quercetin.

Materials and methods.

The jelly-fruit marmalade was obtain**ed** on the basis of apple puree with the addition of sugar, citric acid, and apple pectin [18].

Quercetin were purchased from Sigma-Aldrich, with a purity of ≥ 95%, in powder form. Highly esterified apple pectin produced by TBF Group was

used, which is capable of forming strong gels in the presence of sugar and at the appropriate acidity level.

The pH of the solutions was measured using a Seven Easy pH meter from Mettler Toledo (China) with a glass electrode. Buffer solutions are used as references points for calibration and adjustment of pH measurements.

The absorption spectra were recorded on a UV-2401 PC spectrophotometer (Shimadzu, Japan).

FTIR spectra were recorded using a Spectrum One FTIR spectrometer (Perkin-Elmer). The spectral range was 4000-450 cm^{-1}, with a resolution of 4 cm^{-1}, 16 scans.

The luminescence spectra were recorded using a Cary Eclipse spectrofluorometer (Varian, Australia) with a 150W xenon lamp.

The morphological characteristics of the raw materials and products were determined by optical microscopy using a LEICA DM 2500 M microscope and an MBS 10 stereomicroscope.

An expert assessment of the quality of marmalade samples fortified with quercetin was carried out in accordance with DSTU 4333:2018.

Antioxidant activity was determined by spectrophotometric analysis [19].

Statistical processing of the test results was carried out in accordance with the requirements of the relevant DSTU standards based on the criteria of convergence of two parallel measurements.

Results of the research and their discussion

The PQC was obtained as follows: apple pectin was dissolved in 0.1 mol/L NaOH solution (Fig. 1), after complete dissolution, quercetin was added (Fig. 2), then the pH of the resulting solution was changed to 7 with HCl solution (Fig. 3). The precipitate was separated by centrifugation; it was free quercetin, which is insoluble at neutral pH values in water solutions [20]. The amount of quercetin that entered the PQC (Table 1) was calculated as the difference between the initial amount of quercetin and its content in the precipitate, which was determined photometrically after dissolution in 96% ethanol.

As can be seen from Table 1, maximum binding of quercetin to pectin can be achieved at a component ratio (quercetin : pectin) of 1 : 10 and a quercetin concentration of 0.5 mg/cm^3. Thus, more than 45% was immobilized on the pectin matrix. The resulting complex was highly soluble in water and insoluble in ethanol, unlike native quercetin.

The PQC and its components were studied using spectral analysis methods: UV-Vis spectroscopy, luminescence spectroscopy, FTIR spectroscopy, and optical microscopy.

Figure 4 and Table 2 show the FTIR spectrum of the apple pectin powder sample, the maxima of its absorption bands, literature data, and the assignment of absorption bands.

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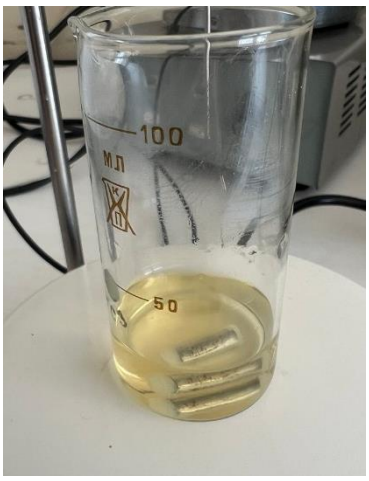


Fig. 1. Alkaline solution of pectin

Fig. 2. Alkaline solution of pectin with quercetin

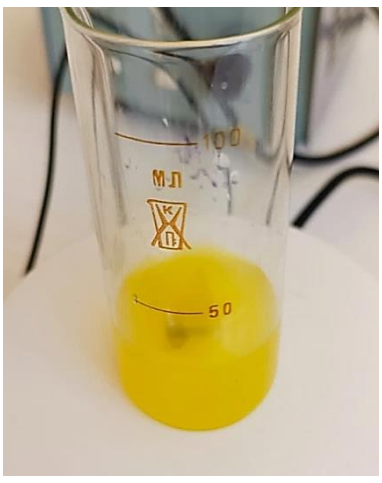


Fig. 3. Mixture of PQC and free quercetin (pH 7)

Table 1 – The amount of quercetin in the composition of PQC depending on the conditions of complex formation

Mass ratio of quercetin : pectin	Concentration of quercetin, mg/cm^3	Concentration of pectin, mg/cm^3	Amount of quercetin in PQC from the initial amount, %
1 : 2	0,5	1,0	36,08
	1,0	2,0	31,66
1 : 5	0,5	2,5	41,23
	1,0	5,0	28,91
1 : 10	0,5	5,0	46,20
	1,0	10,0	24,53
1 : 20	0,5	10,0	44,24
	1,0	20,0	24,25

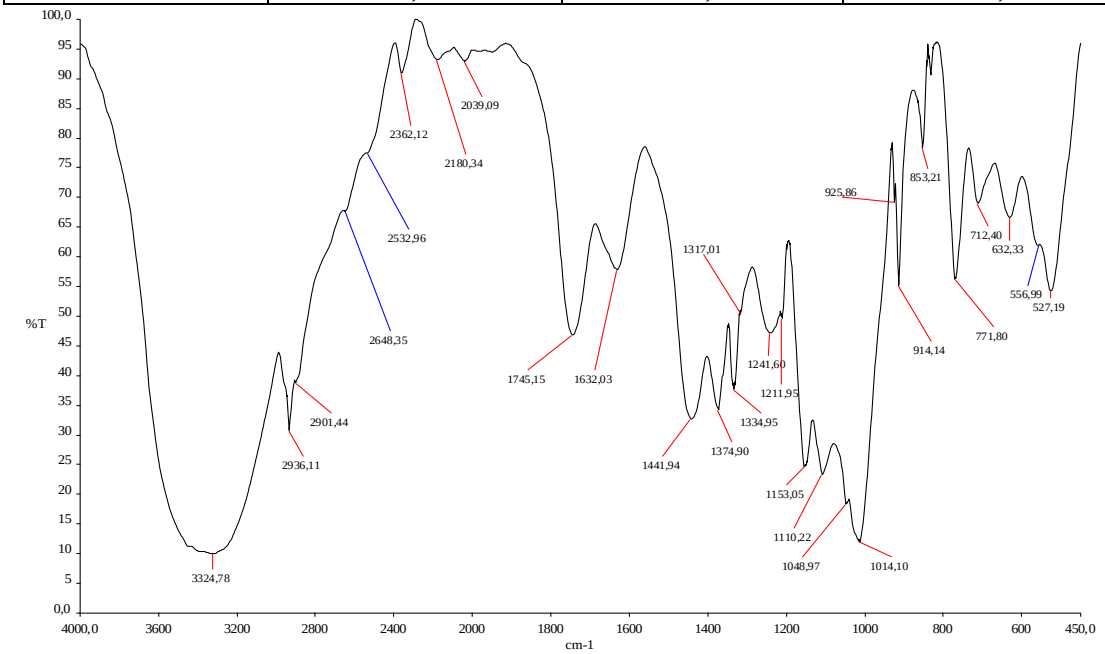


Fig. 4. FTIR spectrum of apple pectin powder in KBr

Table 2 – Absorption bands of the apple pectin sample studied in comparison with literature data and band assignment

Sample, cm^{-1}	Data from literature, cm^{-1}	Assignment of absorption bands
3327	3296–3363	stretching vibrations of OH groups
2936	2937	stretching vibrations of CH groups
1745	1745-1730	stretching vibrations of C=O groups of alkyl esters
1632	1630-1600	antisymmetric vibrations of free carboxyl groups COO- of polygalacturonic acid
1442	1440	antisymmetric stretching vibrations of methyl esters
1375	1370, 1362	vibrations of CH groups
1335	1331-1320	bending vibrations of OH groups of the pyranose ring
1242	1240, 1230	stretching vibrations of C–O groups
1153	1150-1143	vibrations of O–C–O groups of glycosides
1110	1100-1090	stretching vibrations of C–O and C–C groups of pectin rings
1048		stretching vibrations of C–O and C–C groups
1014	1020, 1015, 1014	stretching vibrations of C–O and C–C groups (C2–C3, C2–O2, C1–O1) of skeletal vibrations
972	972	
952	952	bending vibrations of CO groups
914	914	ring vibrations
834	833-830	ring vibrations

As can be seen from Table 2, the absorption bands of the used pectin correspond to the literature data for apple pectin [21-23].

Figure 5 and Table 3 show the FTIR spectrum of quercetin, the maxima of its absorption bands, literature data, and the assignment of absorption bands. As can be seen from Table 3, the absorption bands of used quercetin correspond to the literature data for quercetin [24-26].

Figure 6 shows the FTIR spectrum of dried PQC.

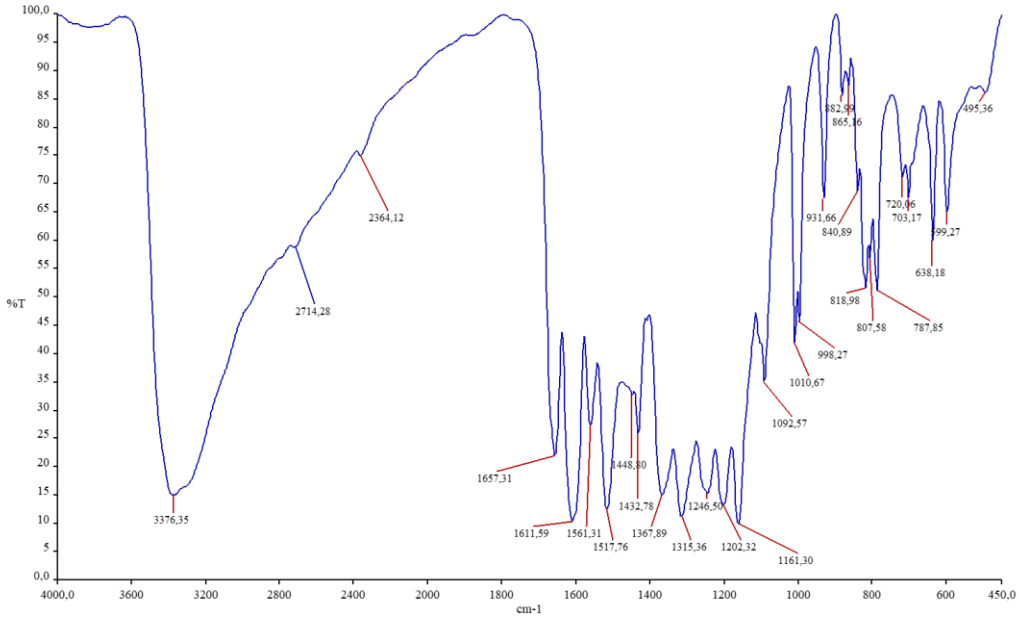


Fig. 5. FTIR-spectrum of quercetin powder in KBr

Table 3 – Absorption bands of the quercetin sample studied in comparison with data from the literature and band assignment

Sample, cm^{-1}	Data from literature, cm^{-1}	Assignment of absorption bands
3376	3392	stretching vibrations of phenolic OH groups
1657	1659	stretching vibrations of aryl ketone group C=O
1612	1612	stretching vibration bands of C=C groups of aromatic rings
1567	1564	stretching vibration bands of C=C groups of aromatic rings
1518	1524	stretching vibration bands of C=C groups of aromatic rings
1449	1446	stretching vibration bands of C-C groups
1432	1429	
1368	1368	bending vibrations of phenolic hydroxyl groups
1315	1317	in-plane bending vibrations in aromatic hydrocarbons
1247	1245	stretching vibrations of C-O groups of aryl ether rings
1202	1200	stretching vibrations of C-O groups of phenols
1161	1165	stretching bending vibrations of C–CO–C groups of ketones
1093	1096	bending vibrations of CO–H groups
1011	1012	bending vibrations of HCC groups
998	1000	
932	933	out-of-plane bending vibrations in aromatic hydrocarbons
883	880	
865		
841		
819	820	out-of-plane bending vibrations in aromatic hydrocarbons
808	797	bending vibrations of CCC groups
788	788	
720	720	bending vibrations of CCO groups
703	698	
638	637	bending vibrations of CCO groups
599	600	out-of-plane bending vibrations in aromatic hydrocarbons
495	496	stretching vibrations of phenolic OH groups

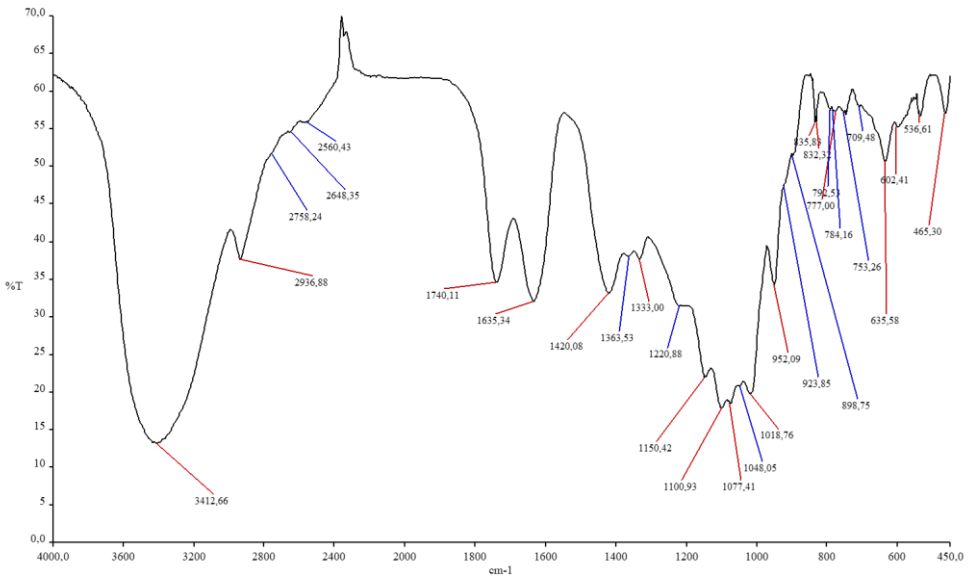


Fig. 6. FTIR-spectrum of the PQC in KBr

As can be seen in Figure 3, there are no absorption bands in the spectrum that correspond to the functional groups of quercetin, which indicates that quercetin has bound to the polysaccharide, forming a complex compound.

The absorption spectrum of quercetin in ethanol with a volume fraction of ethanol of 96% is characterized by the presence of π-π* transition absorption bands in the UV region at λ = 251 nm and n → π* transitions at λ = 369 nm (see Fig. 7).

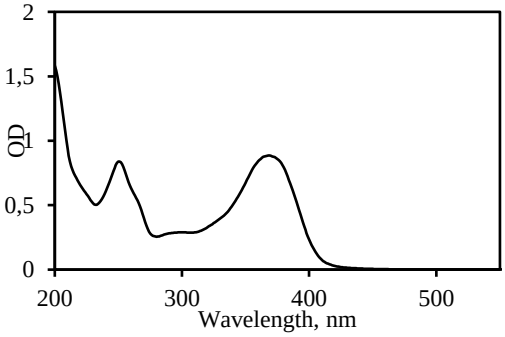


Fig. 7. Absorption spectrum of quercetin in ethanol

The absorption band of querchetin at λ = 369 nm is broaden in an aqueous solution of the PQC due to interactions with pectin (Fig. 8).

An ethanol solution of quercetin is capable of emitting light when irradiated with a xenon lamp. Figure 9 shows the luminescence spectrum of an ethanol solution of quercetin (1), which is characterized by the presence of bands with maxima at 541 and 655 nm.

When the water-soluble pectin-quercetin complex is formed (photo in Figures 2 and 3), the luminescence of quercetin at 541 and 655 nm is quenched (Figure 9). At the same time, very weak luminescence appears at 610 nm, which is associated with the solid state of quercetin, and at 485 nm, which coincides with the calculated value for intramolecular proton transfer in the excited state (ESIPT) of the –OH3 group [27].

The morphological characteristics of the components and the product were determined using optical microscopy. Figure 10 shows micrographs of apple pectin and quercetin powders

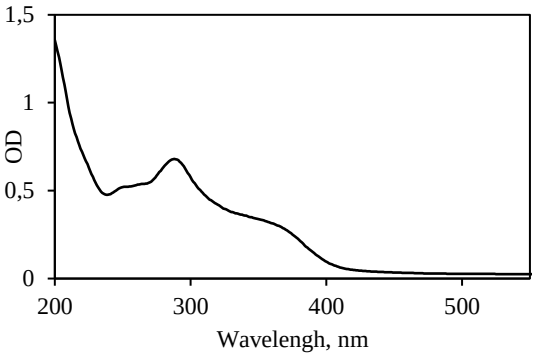


Fig. 8. Absorption spectrum of an aqueous solution of the PQC

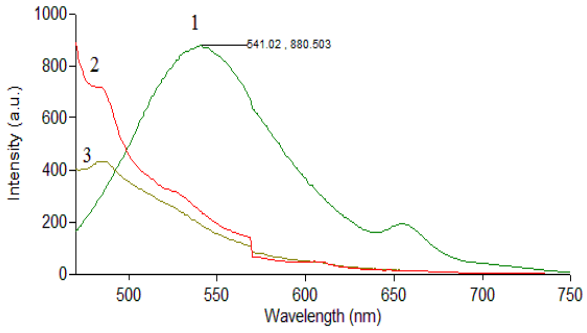


Fig. 9. Luminescence spectrum of quercetin in ethanol (ρ =0.25 mg/cm^3) (1), of the PQC in water (ρ =0.25 mg/ cm^3) (2), of the PQC in water (ρ =0.5 mg/ cm^3) (3), λ_{ex} = 446 nm

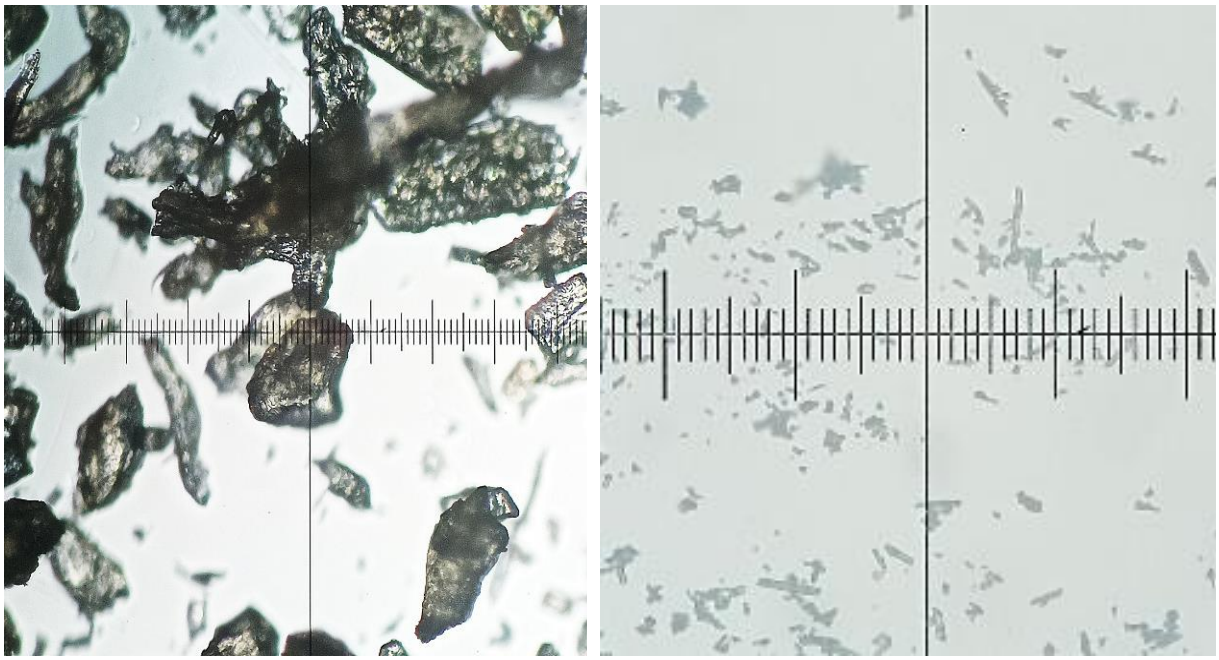


Fig. 10. Microphotographs of apple pectin powders (1): magnification 100^x, image width 1 mm, and quercetin (2): magnification 200^x, image width 0.25 mm.

As can be seen in Figure 10, the micromorphological characteristics of apple pectin powder are polydispersity of irregularly shaped particles ranging in size from 10 to 350 μm. The surface of large particles (250-350 μm) is covered with crystals measuring 10-30 μm. The crystalline particles of quercetin are straight in shape and polydisperse in size: up to 50 μm in length and up to 5 μm in width.

A method has been developed for obtaining jelly-fruit marmalade, which includes adding a filtered aqueous solution of the pectin-quercetin complex to the cooled marmalade mass and thoroughly mixing the mass with the complex.

Figure 11 shows photos of the obtained samples of marmalade fortified with of quercetin in the form of the PQC.

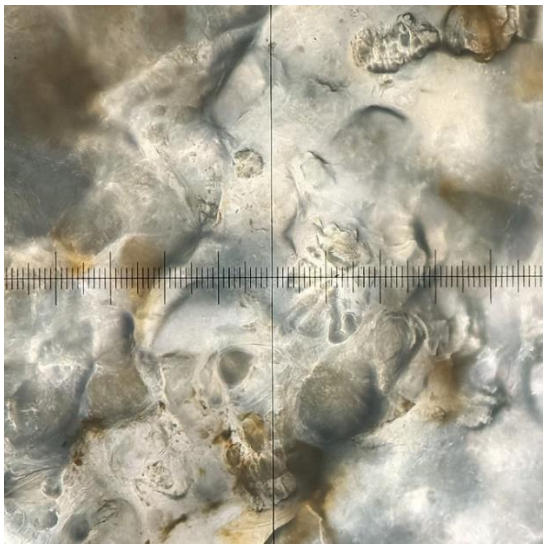
Fig. 11. Samples of jelly-fruit marmalade with different mass concentrations of the PQC: 1 (ρ = 0.25 mg/cm^3), 2 (ρ = 0.50 mg/cm^3), 3 (ρ = 0.75 mg/cm^3), 4 (without PQC)

Figure 12 shows the micrographs of manufactured marmalade fortified with the PQC.

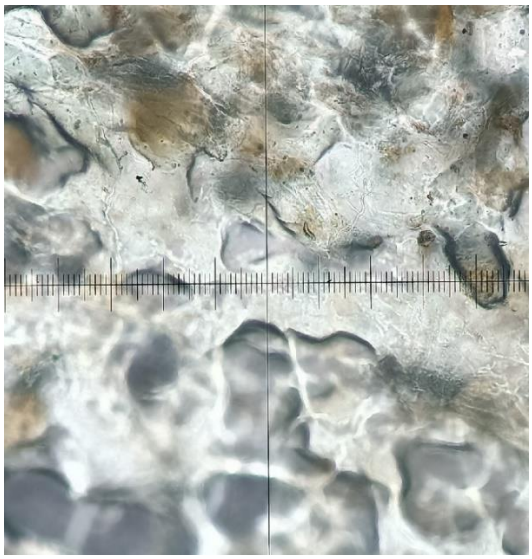
As can be seen from the microphotographs, all samples, regardless of the amount of quercetin, do not contain crystalline quercetin particles and polydisperse pectin particles, the mass is homogeneous, amorphous, jelly-like in consistency, and the samples with quercetin are practically indistinguishable from sample 4, without quercetin, i.e., the particles of the complex have completely dissolved and distributed throughout the product.

An expert assessment of the quality indicators of samples of jelly-fruit marmalade fortified with quercetin in the form of PQC with a quercetin content of 0.5 mg/cm^3 was carried out (Tables 4 and 5).

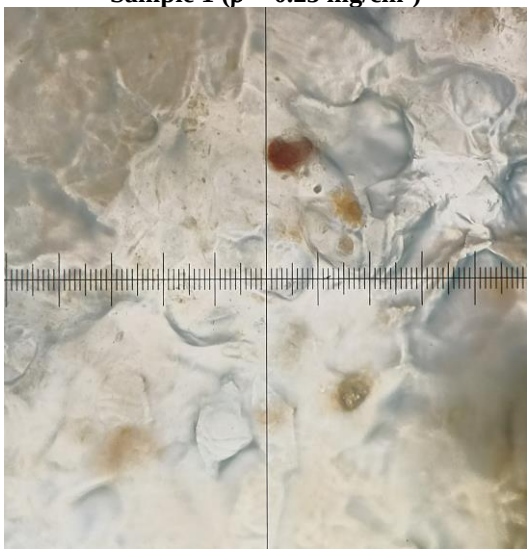
As can be seen from Table 5, marmalade samples fortifed with quercetin in the form of PQC meet the requirements of DSTU 4333:2018 in terms of the following indicators: moisture content – decreases from 17.5 % (without quercetin) to 16.1 % in the second sample; acidity – varies from 8.5 % to 9.4 %. The mass fractions of reducing substances and ash increase slightly with increasing quercetin concentration in marmalade samples, but also do not exceed regulatory requirements. The antioxidant activity of the samples increases with the increase in quercetin content; this indicator is not standardized and varies from 0.35 mg/g (without quercetin) to 0.69 mg/g, i.e., the resulting water-soluble pectin-quercetin complex does not lose the antioxidant properties of quercetin, but increases them in almost 2 times.



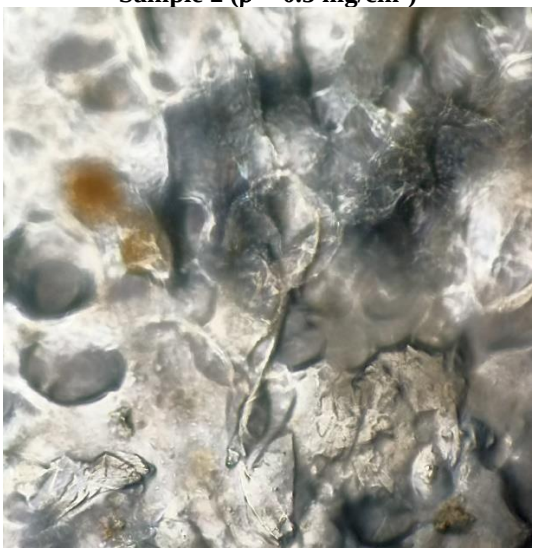
Sample 1 (ρ = 0.25 mg/cm^3)



Sample 2 (ρ = 0.5 mg/cm^3)



Sample 3 (ρ = 0.75 mg/cm^3)



Sample 4 (without PQC)

Fig. 12. Microphotographs of marmalade samples, magnification 100^x, image width 1 mm

Table 4 – Results of determining the organoleptic properties of marmalade samples fortified with the PQC

Indicator	DSTU 4333:2018 Marmalade. General technical conditions	Marmalade fortified with the PQC
Appearance	Homogeneous products of clear shape, without foreign inclusions	Homogeneous products with a clear shape, without foreign inclusions; no cloudiness; the addition of quercetin does not affect the appearance
Taste	Characteristic of a specific type of marmalade, without foreign odor	Pronounced apple, sweet, sweet and sour; no bitterness, harmonious taste properties
Smell	Characteristic of a specific type of marmalade, without foreign odors	Distinct apple aroma, no foreign or extraneous odors; quercetin enrichment does not change the smell
Color	Characteristic of a specific type of marmalade	Uniform, darker than the base product; characteristic of the presence of quercetin, no negative visual impact
Consistency	Jelly-like. Acceptable: jelly-like, sticky consistency	Gelatinous. Dense, elastic, retains its shape; enrichment does not alter the structure
Shape	Clear outline	Homogeneous products with a clear shape, no foreign inclusions; no cloudiness; the addition of quercetin does not affect the appearance

Table 5 – Results of determining the physical and chemical indicators of marmalade samples fortified with the PQC (ρ=0.5 mg/ml)

	Regulatory document	Sample 1	Sample 2	Sample 3	Sample 4 (without PQC)
Moisture content, % 15-24 %	DSTU 4910:2008	16.8±0.1	16.1±0.1	16.2±0.1	17.5±0.1
Total acidity, 7.5-22.5 degrees	DSTU 5024:2008	8.5±0.15	8.9±0.2	9.4±0.2	8.5±0.15
Mass fraction of reducing substances, no more than 28%	DSTU 5059:2008	19.5±0.4	22.1±0.3	23.1±0.5	21.7±0.4
Mass fraction of ash, insoluble in a solution with a mass fraction of hydrochloric acid of 10%, no more than 0.1%	DSTU 4672:2006	0.032±0.001	0.038±0.001	0.045±0.002	0.030±0.001
Antioxidant activity, mg/g	not regulated	0.42±0.01	0.54±0.01	0.69±0.01	0.35±0.01

Conclusion

In order to increase the bioavailability of quercetin, a method was developed for obtaining the water-soluble pectin-quercetin complex, the properties of which were studied using spectral analysis methods: UV-Vis spectroscopy, luminescence spectroscopy, FTIR-spectroscopy, and optical microscopy. The conclusion about the formation of the complex was made by analyzing the absorption spectra: when pectin is added to quercetin. The absorption band of querchetin at λ = 369 nm is broaden in an aqueous solution of the PQC due to interactions with pectin**.** Also, when obtaining the water-soluble pectin-quercetin complex, the luminescence of quercetin at 541 and 655 nm is quenched. The FTIR spectra of the pectin-quercetin complex lack absorption bands associated with the functional groups of quercetin, indicating that quercetin has bound to the polysaccharide to form the complex compound.

A method has been developed for obtaining fruit jelly marmalade fortified with quercetin in the form of the PQC as a functional component. The morphological characteristics of the raw materials and the product were established by optical microscopy. The microphotographs of the marmalade samples show no crystalline particles of quercetin or polydisperse particles of pectin; the mass is homogeneous, amorphous, and gelatinous in consistency.

An expert assessment of the quality of marmalade samples fortified with quercetin in the form of a pectin-quercetin complex was conducted. It was established that the samples comply with regulatory documents in terms of the following indicators: moisture content – decreases from 17.5% to 16.1%; acidity – increases from 8.5 % to 9.4 %. The mass fractions of reducing substances and ash slightly increase with the increase in quercetin concentration in marmalade samples, but also do not exceed regulatory data. The antioxidant activity of the samples increases with an increase in quercetin content from 0.35 mg/g to 0.69 mg/g, which confirms the production of a functional product.

In the future, it is advisable to continue scientific research on optimizing the composition of marmalade, searching for new natural ingredients, increasing the biological value of the product, and studying the influence of various factors on its stability and preservation of useful properties during storage.

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ОТРИМАННЯ ТА ЕКСПЕРТНА ОЦІНКА ЖЕЛЕЙНО-ФРУКТОВОГО МАРМЕЛАДУ, ЗБАГАЧЕНОГО КВЕРЦЕТИНОМ

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Анотація. У роботі наведено дослідження щодо отримання мармеладу желейно-фруктового з вмістом водорозчинного комплексу кверцетину з пектином. Вивчені спектральні властивості отриманого комплексу. Спектр поглинання етанольного розчину кверцетину з об'ємною часткою етанолу 96% характеризується наявністю смуг поглинання π-π* переходів в УФ-області при λ = 251 нм і n → π* переходів при λ = 369 нм. Смуга поглинання кверцетину при λ = 369 нм у водному розчині у присутності пектину розширюється через взаємодію з пектином. При отриманні водорозчинного пектино-кверцетинового комплексу відбувається гасіння люмінесценції кверцетину при 541 та 655 нм. У FTIR спектрах пектино-кверцетинового комплексу відсутні смуги поглинання, які відносяться до функціональних груп кверцетину, що свідчить про те, що кверцетин зв'язався з полісахаридом, утворюючи комплексну сполуку. Отримано желейно-фруктовий мармелад, збагачений кверцетином у вигляді пектино-кверцетинового комплексу як функціонального компонента. Встановлено морфологічні характеристики сировини і продукту методом оптичної мікроскопії. Мікроморфологічними ознаками порошку яблучного пектину є полідисперсність часток неправильної форми, розмірами від 10 до 350 мкм. Поверхня великих часток (250-350 мкм) вкрита кристалами розміром 10-30 мкм.

Кристалічні частки кверцетину мають пряму форму, за розмірами полідисперсні до 50 мкм у довжину та до 5 мкм у ширину. На мікрофото зразків мармеладу відсутні кристалічні частки кверцетину і полідисперсні частки пектину, маса однорідна, аморфна, драглеподібної консистенції, що свідчить про те, що частинки комплексу повністю розчинилися і розподілилися по продукту. Проведено експертну оцінку якості зразків мармеладу, збагаченого кверцетином у вигляді пектино-кверцетинового комплексу. Встановлено, що зразки відповідають нормативним документам за такими показниками як: вологість – зменшується від 17,5 % до 16,1 %; кислотність – зростає від 8,5% до 9,4%. Масові частки редукувальних речовин і золи незначно збільшуються зі зростанням концентрації кверцетину у зразках мармеладу, але також не перевіщують нормативні дані. Антиоксидантна активність зразків зростає зі збільшенням вмісту кверцетину від 0,35 мг/г до 0,69 мг/г.

Ключові слова: пектино-кверцетиновий комплекс, мармелад, експертиза, оздоровчі продукти, фенольні сполуки