FRM
Foods and Raw Materials, 2019, vol. 7, no. 1
E-ISSN 2310-9599
ISSN 2308-4057

Research Article
Open Access
DOI: http://doi.org/10.21603/2308-4057-2019-1-26-34
Available online at http:jfrm.ru

Comprehensive assessment of fruit jelly with an improved carbohydrate profile based on unconventional plant raw materials

Igor A. Nikitin[1,*], Marina A. Nikitina[2], Nadezhda M. Allilueva[1], and Andrey Yu. Krivosheev[1]

[1] K.G. Razumovsky Moscow State University of Technology and Management (the First Cossack University), Moscow, Russia

[2] V.M. Gorbatov Federal Research Centre for Food Systems of Russian Academy of Sciences, Moscow, Russia

* e-mail: nikitinia@mgutm.ru

Received July 28, 2017; Accepted in revised form October 18, 2017; Published June 08, 2019

Abstract: One of the negative trends in current nutrition is an increased consumption of refined foods with a low content of useful nutrients and antioxidants and an abundance of oxidation accelerators. Fruit paste and jelly have a relatively low energy value, compared to other confectionery products. Along with this fact, they also have gelling agents and fruit raw materials in their composition, which can classify them as diet food. This paper presents a comprehensive approach to developing a technology for producing fruit jelly with an improved carbohydrate profile. For that, we used viburnum and orange puree, a valuable natural plant material, as a source of carbohydrates, and fructose, as a sugar substitute. The qualimetric model created from the tasting data was used to select the optimal proportions of the main ingredients, viburnum and orange puree, as 25:75 and 75:25. The comparative assessment of antioxidant capacity (AOC) showed that the sample with the 75:25 ratio of viburnum to orange puree had an AOC of 22.33 μmol TEq/g. It was twice as high as AOC of the 25:75 ratio sample. With a glycaemic index of 29.2, this fruit jelly can be recommended as a diet food with preventative properties.

Keywords: Fruit paste, fruit jelly, diet foods, qualimetric modelling, coefficient of concordance, chi-squared test, antioxidant capacity

Please cite this article in press as: Nikitin I.A., Nikitina M.A., Allilueva N.M., and Krivosheev A.Yu. Comprehensive assessment of fruit jelly with an improved carbohydrate profile based on unconventional plant raw materials. *Foods and Raw Materials*, 2019, vol. 7, no. 1, pp. 26–34. DOI: http://doi.org/10.21603/2308-4057-2019-1-26-34.

INTRODUCTION

Today, most countries witness a profound shift in the structure of major causes of death and a growth in chronic disease, stress, and fatigue, with non-communicable diseases increasingly becoming most common in the 2st century.

One of them is metabolic syndrome (MS), also known as Reaven's syndrome, insulin resistance syndrome, or atherothrombogenic syndrome. It is a complex metabolic disorder often found in patients with arterial hypertension and abdominal obesity. MS is linked to tissue insulin resistance that contributes to the development of hyperinsulinemia, activation of the sympathoadrenal system, increased vascular tone and pathological changes in the lipid spectrum of blood [1].

The main risk factors for MS are hypodynamia, hypercaloric nutrition, easily available pseudo-nutrition with a low content of beneficial nutrients or antioxidants and an abundance of oxidation accelerators, increased activity of the sympathetic nervous system, and frequent stress. It explains why, with the last two factors excluded, A. Regenauer (1998) called MS a 'good life' syndrome, referring to a low-active lifestyle. Indeed, several studies show that a decrease in physical activity and a high carbohydrate diet are the main reasons why the incidence of MS is reaching epidemic proportions. About 25% of the population in Western countries suffer from this disorder [2].

According to the Institute of Nutrition of the Russian Academy of Medical Sciences (www.ion.ru), more than a third of the Russian population are overweight or obese. At the same time, the consumption of confectionery foods is growing due to their variety and affordability, as well as people's stable taste preferences.

Yet, their physiological value is quite low: they are rich in fat (up to 40%) and carbohydrates (up to 70%) but lacking in vitamins and minerals [3].

The RF Government's Order No. 1364-p of June 29, 2016 'The Strategy for Improving the Quality of Foods in the Russian Federation until 2030' (www.government.ru) indicates a need to create conditions for the production of new generation foods with specified quality characteristics. They include specialised, functional, enriched, and organic foods. To do this, we need research aiming to provide a biomedical rationale and develop new formulas and technologies.

Prevention of nutritional diseases is a social task that cannot be fulfilled by doctors alone. Great responsibility in addressing this issue rests with the food industry. It must ensure not only food safety but also optimal quality – nutritional value, sensory properties, and health benefits – and its motto should be 'The 21st century foods are health and taste!' [4–8].

Thus, of scientific and practical interest is the development of technologies that can create confectionery products using non-conventional raw materials rich in essential substances [9, 10].

This study aims to develop a formula and a technology for producing fruit jelly with an improved carbohydrate profile using non-conventional bio-raw material (red viburnum berries). We also intend to measure its antioxidant capacity and physicochemical and organoleptic characteristics.

The improvement of the carbohydrate profile implies a partial or complete replacement of mono- and disaccharides with ingredients having a low glycaemic index [11].

STUDY OBJECTS AND METHODS

The study was conducted by the Department of Grain Processing, Baking, Pasta and Confectionery Technologies at K.G. Razumovsky Moscow State University of Technology and Management (the First Cossack University) in collaboration with the Information Technology Section at V.M. Gorbatov All-Russian Research Institute of Meat Industry and the Core Facility 'Industrial Biotechnology' at the Federal Research Centre 'Fundamentals of Biotechnology' of the Russian Academy of Sciences.

We used red viburnum puree and citrus puree (grapefruit, orange, and lemon) were used as the main raw materials to produce test samples and develop the technology. The objects of the study were fruit jelly samples with a different proportion of the main raw materials, namely 25:75, 75:25, 60:40, 40:60, and 50:50.

The control sample was made from apple puree according to the traditional recipe (Table 2) [12].

To prepare the test samples, red viburnum berries and citrus fruits were sieved to make a puree. Then, they were sieved again to separate the puree from any particles of peel or seeds that might be there after the first rough sieve, as well as free it from any foreign matter. For this purpose, it was passed through an MPR-350M-01 (Belarus) pulping machine with a sieve hole diameter of 0.5–1 mm.

Air-dry edible gelatin was soaked in a fourfold volume of water at 20–25°C to swell for 40–60 min. The hydration of macromolecules and the destruction of bonds between them, which occurred during the swelling process, speeded up the dissolution of the gelling agents in water. The swollen gelatin was heated until it was completely dissolved, without bringing it to a boil, and then introduced, in a thin stream and with constant stirring, into a fruit and berry syrup. The syrup was obtained by boiling-out red viburnum puree, citrus puree, and fructose syrup until a dry matter content of 67–69% was reached. The resulting mass was poured into silicone moulds and cooled for 1–2 hours to a temperature of 23–25°C. To form a structure, the jelly mass was cured for 2–3 hours at 23–25°C. Then the samples were removed from the moulds, sprinkled with starch, and dried for 10–12 hours until a crust formed. The crust protects the fruit jelly from getting wet and gives it an attractive appearance.

We tested such sensory characteristics as: taste; colour; aroma; consistency; grittiness; stickiness; and surface condition.

We also examined physicochemical characteristics of the samples, such as acidity, mass fraction of total moisture, glycaemic index, and antioxidant capacity (AOC). For that the following methods were used:

1. Acidity was determined by titration with phenolphthalein.

2. Mass fraction of total moisture was measured by drying on a VChM-A device (Ukraine) at 160–165°C for 3 min.

3. Mass fraction of reducing substances was determined by a method based on the recovery of an alkaline copper solution (hot titration method).

4. The glycaemic index was determined as an amount of glucose accumulated during the product's breakdown *in vitro* [13]. The sample was soaked in 0.1 N hydrochloric acid solution and put into a bath at 37°C. After a 10–15 minute incubation, a preparation of proteolytic enzymes (for example, Panzinorm) was added. Then the reaction mixture was neutralised with sodium bicarbonate to reach a pH of 8.2–8.5. A preparation of the duodenum of laboratory animals (e.g. rats) was added at the same time. Then the sample was incubated for another 1.5 hours at 37°C and filtered or centrifuged. The protein content was determined spectrophotometrically and the glucose content, by an enzymatic method.

5. AOC was measured using an atomic spectrophotometer (Carry 100 Bio, USA). Its operation is based on determining the ratio of two light fluxes that pass through the reference channel and the sample channel in the cuvette compartment. The spectrophotometer also uses the Stop-And-Go scanning principle (stopping the diffraction grating for the chopper rotation cycle). Unlike the traditional non-stop chopper rotation principle, it allows for adequate results without recalibrating the spectrophotometer at any scanning speed, up to 3,000 nm/min in the UV-visible part and up to 8,000 nm/min in the near-IR part of the spectrum. Correct conditions for analysing the spectrum ensure valid analytical results. The

spectrophotometer measured the AOE of the lipophilic and hydrophilic fractions of the samples in relation to the radical cation of the 2-azinobis-3-ethyl benziazolite-6 sulfonic acid diammonium salt (ABTS). Trolox was used as a standard in the AOC analysis and the results were expressed in Trolox equivalents (TEq).

The tasting data were processed by mathematical statistics methods in Microsoft Excel. The experiments were repeated three times. A confidence level of 0.95 was used to test the hypotheses. The consistency of expert opinions was determined by a coefficient of concordance, whose significance was checked with the chi-square test.

RESULTS AND DISCUSSION

The paper describes the main stages of improving the carbohydrate profile of candied fruit jelly, in particular:
– justifying the selection of food ingredients with hypoglycaemic effect;
– developing formulas of fruit jelly samples with an improved carbohydrate profile and testing technological parameters of their production;
– optimising physicochemical and organoleptic characteristics of fruit jelly samples;
– determining the glycaemic index (GI) of fruit jelly samples; and
– studying the antioxidant capacity (AOC) of fruit jelly samples.

The control sample was apple jelly based on the classic recipe and traditional technology.

1. Justifying the use of red viburnum and orange as fruit jelly ingredients. The selection of fruit jelly ingredients (see 'Study Objects and Methods') was based on the comprehensive approach to the development of enriched and specialised foods [14, 15]. This approach contains three groups of criteria, namely:
– biomedical;
– technological; and
– economic.

Medical and biological criteria cover the choice of enriched or specialised products and functional ingredients, setting the amount and restricting the content of specific substances and components, as well as their bioavailability and safety.

Technological criteria are concerned with the simplicity and ease of use of a specific ingredient, its effect on the properties of semi-finished products and the quality of finished ones, its compatibility with the main components, and the method of introducing the ingredient into the formula.

Economic criteria are used to estimate the economic efficiency of an ingredient and its effect on the production cost.

Taking the above criteria into consideration when producing functional and specialised foods will enable us to find an optimal solution based on the technology of effective food functionality.

The plant raw materials used in the study is permitted in the production of sugary confectionery [16], including foods for children aged three and above, and meets the safety requirements specified in the regulatory documents*.

Red viburnum (*Vibúrnum ópulus* L.) is richer in vitamins than many fruits, which makes this beneficial ingredient quite promising in fruit jelly production [17–20].

Due to its pectic substances, viburnum juice can turn into jelly [21], which is essential in fruit jelly production. The percentage of P-active compounds (bioflavonoids) in viburnum berries and juice can reach 300–500 mg/100 g. Viburnum contains vitamins A, D, and E. Interestingly, it has a higher content of vitamin C than citrus fruits. Viburnum is also rich in minerals, such as phosphorus, magnesium, potassium, iron, calcium, copper, manganese, and iodine (Table 1). These berries have plenty of invert sugar (about 30%), tannins, as well as isovaleric and acetic acids [22, 23]. Viburnum seeds contain up to 21% of fatty oil. Isovalerianic acid esters and viburnin glycoside, a natural substance of the cardiovascular and antispasmodic group, give viburnum berries their characteristic smell and bitterness. Despite its beneficial properties, viburnin had a strong negative impact on the sensory indicators of fruit jelly quality. Jelly had an off-odour, so a need arose to eliminate or disguise it in the finished product. The main solutions to this problem were heating, which partially destroys this glycoside, and using strong flavours of natural origin, such as citrus, to neutralise the smell [24].

Citrus fruits have a high biological value due to a variety of biologically active substances. Thus, flavonoids help the body to absorb vitamins, pectic substances protect the cardiovascular system, glycosides (such as naringin) lower blood pressure and cholesterol level, preventing heart attack and acting as a tonic [25].

After testing lemon, orange and grapefruit puree as possible components of viburnum jelly formula that could neutralise the smell of viburnin, orange was selected as the cheapest alternative. Then, we analysed the sensory characteristics (taste, aroma, texture, stickiness, and surface condition) of the test samples made from the above citrus fruits and viburnum puree in a ratio of 75:25 to 25:75. The analysis showed that the fruits only changed the colour and the taste of the finished product and had almost no effect on the other indicators that are essential in the fruit jelly technology.

Orange puree is rich in B vitamins, ascorbic acid, macro- and microelements (Table 1), and fibre. It is a valuable source of amino acids and contains over 170 phytonutrients and 60 flavonoids.

Pectin contained in viburnum puree is not enough to form a strong jelly, therefore gelatin was used as an additional gelling agent.

Gelatin is widely used in the food industry due to its unique structure-forming properties. It gives confectionery a stretchy, jelly-like or foamy texture and has an ability to bind water and stabilise dispersed systems. Proteins make over 85% of gelatin composition, with collagen being the main component. This product contains two essential amino acids, hydroxyproline and proline.

* SanPiN [Sanitary Rules and Norms] 2.3.2.1940-05, Technical Regulations of the Customs Union 029.

Table 1. Chemical composition of red viburnum and orange [26, 27]

Substance	Content per 100 g of finished product	
	Red viburnum	Orange
Chemical composition		
Proteins, g	0.40	0.90
Fats, g	1.50	0.20
Carbohydrates, g	7.00	8.10
Energy value, kcal	26.30	43.00
Vitamins		
Vitamin A, mcg	25.00	8.00
Vitamin C, mg	82.00	60.00
Carotene, mg	1.40	–
Vitamin PP, mg	1.35	0.20
Vitamin B9, mg	0.30	5.00
Vitamin E, mg	2.00	0.20
Minerals		
Potassium, mg	179.50	197.00
Calcium, mg	40.50	34.00
Magnesium, mg	17.50	13.00
Iron, mg	6.10	0.30
Phosphorus, mg	100.00	23.00
Sodium, mg	21.50	13.00
Sulphur, mg	12.00	9.00

Fructose was used as a sweetener. Fructose is slowly absorbed in the intestine and has a glycaemic index of 20. Thus, this contributes to a smooth increase in blood glucose levels, which is especially important for diabetic people. Fructose is 1.75 times as sweet as sucrose and thus can be added to products in smaller quantities to reduce the amount of sucrose by 30–50%. Currently, fructose is used in the production of functional and diet foods, including those for children [28].

2. Developing a formula for diet fruit jelly. A number of experimental studies were conducted to develop products with different ratios of the main raw materials (see 'Study Objects and Methods').

To make fruit jelly dietetic, sugar was replaced with a smaller amount of fructose: it is sweeter than sucrose. This made it possible to significantly increase the amount of puree in the formula. In addition, fructose enhanced the flavour of the fruit jelly.

Table 2 shows the fruit jelly formula developed.

Studies were conducted to measure how the plastic strength of the viburnum-and-orange-based samples made with different amounts of gelatin changed according to the duration of curing, compared to the control sample and the gelatin-free sample.

The gelatin-free jelly had a poor plastic strength of 5.3 kPa (Fig. 1, curve 2), because the amount of pectin contained in viburnum puree is not enough for strong jelly to form.

The percentage of gelatin powder in the test samples was 3%, 5%, and 7% of the formula mass (Fig. 1, curves 3, 4, and 5). Fig. 1 shows how increased amounts of gelatin affected the plastic strength of the jelly mass. With a gelatin amount of 5%, the plastic strength almost reached the value of the control sample (17 kPa), and with a higher amount, it even exceeded it. Thus, we chose a 5% duantity of gelatin powder.

The glycaemic index (GI) of the samples was calculated by measuring the amount of glucose accumulated during the product breakdown *in vitro*.

The analysis (Fig. 2) showed that replacing sugar with fructose reduced the jelly GI almost by half (29.2–32.8 for test samples 1–5 vs. 58.4 for the control sample). This can be explained by a low GI of fructose compared to sucrose (19 vs.75). Some variation of the GI in the test samples seems to be associated with different proportions of viburnum and orange puree in their formulas. The predominance of viburnum puree leads to a slight decrease in the GI.

Table 3 demonstrates the comparison of the nutritional value of five jelly samples with that of the control. As can be seen, all the test samples had a higher content of protein, fats, vitamins, macro- and microelements, compared to the control sample, and almost half of its carbohydrate content and energy value.

The analysis of sensory and physicochemical characteristics of the samples was carried out with expert qualimetry methods by the Department of Grain Processing, Baking, Pasta and Confectionery Technologies at K.G. Razumovsky Moscow State University of Technology and Management.

Table 2. Diet fruit jelly formula based on viburnum and orange puree

Raw material	Dry matter mass fraction, %	Total raw material per 1 ton of finished product, kg					
		Control*	Test 1	Test 2	Test 3	Test 4	Test 5
Granulated sugar	99.85	689.6	–	–	–	–	–
Syrup	78.00	31.0	–	–	–	–	–
Apple puree	10.00	860.0	–	–	–	–	–
Viburnum puree	18.00	–	862.5	690.0	575.0	460.0	287.5
Orange puree	16.00	–	287.5	460.0	575.0	690.0	862.5
Fructose syrup	78.00	–	527.0	527.0	527.0	527.0	527.0
Gelatin powder	84.00	–	92.0	92.0	92.0	92.0	92.0
Lactic acid	40.00	5.3	–	–	–	–	–
Sodium lactate	40.00	9.0	–	–	–	–	–
Total:		1,589.0	1,769.0	1,769.0	1,769.0	1,769.0	1,769.0
Product weight:	69.80	1,000.0	1,000.0	1,000.0	1,000.0	1,000.0	1,000.0

**Note:* the control sample was based on the moulded apple jelly formula. Tests 1–5 refer to the samples with a different proportion of viburnum and orange puree, namely: 75:2; 60:40; 50:50; 40:60; and 25:75.

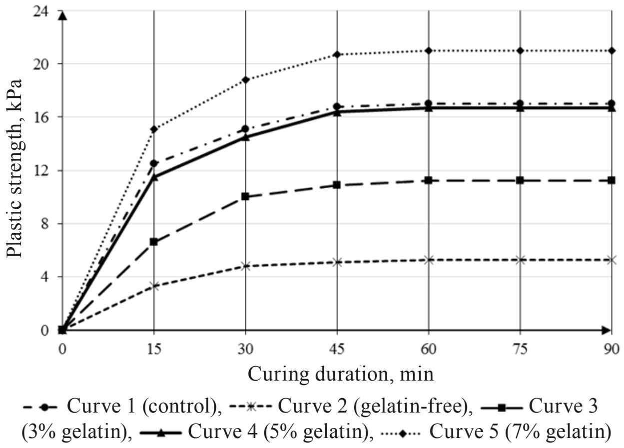

Fig. 1. Changes in the plastic strength of the samples with different amounts of gelatin depending on the curing duration

Twenty respondents aged 20 to 50 took part in the tasting to identify the product relevance among consumers of different age groups.

Of different survey methods used (such as interviewing or questionnaire), interviewing proved most productive: the respondents took the initiative and expressed well-argued opinions.

2.1. Qualimetric modelling as a method of evaluating consumer properties. The key stage of customer satisfaction assessment was data processing based on qualimetric modelling. The method allowed us to combine versatile indicators in one assessment, while taking into account the importance of each of them for the consumer [29]. The qualimetric model was as follows:

$$K = \frac{\sum_{i=1}^{n}\sum_{k=1}^{m}\frac{Y_{ik}}{B_{ik}}}{nm},$$

where m is the number of respondents; n is the number of criteria (indicators); Y_{ik} is the satisfaction of the k-th consumer with the i-th criterion, points; B_{ik} is the importance of the i-th criterion for the k-th consumer, points.

To systematise the data and visualise the results in a compact form, we developed a customer satisfaction matrix that showed individual customer ratings according to selected criteria (taste, colour, aroma, texture, and surface), as well as data processing results.

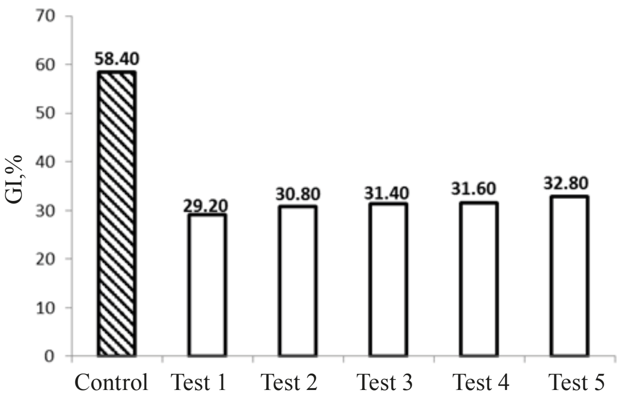

Fig. 2. Effects of the jelly formula on the glycaemic index

The validity of the results was evaluated by analysing the consistency of expert (consumer) opinions using the coefficient of concordance:

$$W = \frac{12\sum_{j=1}^{n} d_j^2}{m^2\left(n^3 - n\right)},$$

where d_j is the deviation of the rank sum for the j-th parameter from the average rank sum.

If there are equal ranks among those given by one expert (consumer), the coefficient of concordance is calculated as follows:

$$W = \frac{12\sum_{j=1}^{n} d_j^2}{m^2\left(n^3 - n\right) - m\sum^{m} T_k},$$

$$T_k = \sum_{k=1}^{m}\left(t_k^3 - t_k\right),$$

where t_k is the number of equal ranks in the k-th group.

The coefficient of concordance W ranges from 0 to 1. $W = 1$ means complete consistency of expert opinions, $W > 0{,}5$ means satisfactory consistency, and $W < 0{,}5$ means poor consistency.

Table 3. Nutritional value of the control and test samples

	Control	Test 1	Test 2	Test 3	Test 4	Test 5
Dry matter	50.44	38.98	38.79	38.66	38.53	38.33
Protein, g	0.32	4.88	4.93	4.96	4.99	5.04
Fat, g	0.11	0.78	0.66	0.57	0.49	0.36
Carbohydrates, g	54.92	27.41	27.51	27.59	27.66	27.76
Moisture, g	49.54	61.02	61.21	61.34	61.47	61.67
Energy value, kcal	222.00	136.19	135.68	135.33	134.99	134.47
Vitamins, mg						
Beta-carotene	–	0.68	0.55	0.46	0.36	0.23
B9	–	0.96	1.42	1.72	2.03	2.49
C	0.86	49.73	47.59	46.16	44.73	42.58
E	0.11	1.01	0.83	0.72	0.60	0.42
PP	0.27	1.44	1.33	1.26	1.18	1.07
Macro- and microelements, mg						
Potassium (K)	68.16	119.59	121.29	122.43	123.57	125.27
Calcium (Ca)	7.77	61.68	61.04	60.62	60.20	59.56
Magnesium (Mg)	3.77	14.81	14.37	14.07	13.78	13.34
Sodium (Na)	0.97	13.17	12.34	11.79	11.23	10.40
Phosphorus (Ph)	9.17	68.10	60.59	55.58	50.58	43.07
Iron (Fe)	0.83	3.13	2.56	2.18	1.81	1.24
Manganese (Mn)	–	0.01	0.01	0.01	0.01	0.01
Copper (Cu)	–	0.08	0.08	0.08	0.08	0.08

Table 4. Qualimetric models of test jelly samples

No. sample	Proportion of ingredients	Qualimetric model
1	Viburnum 75 / Orange 25	$P = 0.20x_1 + 0.18x_2 + 0.16x_3 + 0.17x_4 + 0.15x_5 + 0.13x_6$
2	Viburnum 25 / Orange 75	$P = 0.19x_1 + 0.19x_2 + 0.17x_3 + 0.15x_4 + 0.15x_5 + 0.15x_6$
3	Viburnum 40 / Orange 60	$P = 0.11x_1 + 0.11x_2 + 0.20x_3 + 0.17x_4 + 0.21x_5 + 0.20x_6$
4	Viburnum 60 / Orange 40	$P = 0.14x_1 + 0.16x_2 + 0.17x_3 + 0.16x_4 + 0.18x_5 + 0.18x_6$
5	Viburnum 50 / Orange 50	$P = 0.14x_1 + 0.15x_2 + 0.17x_3 + 0.14x_4 + 0.20x_5 + 0.19x_6$

Table 5. Sensory and physicochemical characteristics of test samples

Indicator	Test sample 1	Test sample 2	Test sample 3	Test sample 4	Test sample 5
			Sensory characteristics		
Colour	Saturated, vivid burgundy	Saturated orange	Unsaturated, pale maroon	Unsaturated, pale orange	Unsaturated, pink
Taste	Sweet, with a pronounced taste of viburnum and a hint of orange	Sweet, with a dominant taste of orange and a hint of viburnum	Sweet taste of orange and viburnum (dominated by orange)	Sweet taste of orange and viburnum (dominated by viburnum)	Sweet, unpronounced taste of fruit and berries
Aroma	Pronounced aroma of viburnum with a hint of orange	Pronounced aroma of orange with a hint of viburnum	Aroma of viburnum with a light hint of orange	Aroma of viburnum with a fruity hint	Aroma of viburnum and orange
Texture	Elastic, gelatinous, tender	Elastic, gelatinous, tender	Elastic, gelatinous, tender	Elastic, gelatinous, tender	Elastic, gelatinous, tender
Shape	Consistent with this type of fruit jelly	Consistent with this type of fruit jelly	Consistent with this type of fruit jelly	Consistent with this type of fruit jelly	Consistent with this type of fruit jelly
Surface	Smooth and shiny	Smooth and shiny	Smooth and shiny	Smooth and shiny	Smooth and shiny
			Physicochemical characteristics		
Acidity, °N	11.1	7.9	6.4	5.9	6.7
Moisture content, %	69.8	67.8	64.3	68.5	66.3
Mass fraction of reducing substances, %	1.5	1.6	1.2	1.3	1.4

Since expert opinions are considered random variables, the criterion χ^2 was used to check the relevance.

Thus, the product quality was assessed at multiple levels, with every consumer opinion taken into account. This once again proves the need for classifying respondents at the first stage of analysis.

A composite quality index is defined as an average weighted index, with individual indicators contributing different weight fractions to its formation.

Thus, the composite quality index for the fruit jelly was determined by six single indicators: x_1 – taste (sweet/bitter), x_2 – taste (like/dislike), x_3 – colour, x_4 – aroma, x_5 – surface condition, and x_6 – texture. Table 4 shows the qualimetric models of the test samples.

Having analysed the above models, we concluded that the least significant indicator for sample 1 was texture; for sample 2 – texture, surface, and aroma; for sample 3 – taste (sweet/bitter) and taste (like/dislike); for sample 4 – taste (sweet/bitter); and for sample 5 – taste (sweet/bitter) and aroma.

We also found that taste was the leading assessment factor for samples 1 and 2, whereas surface condition had the highest value in the rest of the samples.

2.2. Fruit jelly quality indicators. The analysis of the sensory and physicochemical quality indicators enabled us to select the best of the test samples (Table 5).

As can be seen in Table 5, the samples were consistent with the basic requirements for sensory and physicochemical quality indicators, including those stipulated in State Standard**.

The comprehensive organoleptic evaluation and physicochemical studies revealed that samples 1 and 2 manifested the best quality indicators. This could be due to the fact that consumers preferred the samples with pronounced mono taste, aroma, and colour of orange or viburnum, rather than those where they were mixed.

The next stage of research aimed to study the comparative effect that the new formulas of the best jelly samples had on their antioxidant capacity (AOC). This parameter is essential for enhancing the nutritional value and functional significance of the product for the human body.

3. Studying the antioxidant capacity of the jelly samples. It is common knowledge that antioxidants interrupt radical-chain oxidation processes in the human body. These processes are caused by free radicals due to exogenous factors (such as chemical environmental pollutants, ionizing radionuclide emissions) and as a result of biochemical metabolic reactions in body cells [30].

It is also known that using biologically active substances of plant origin can enhance nonspecific immunity

** State Standard 6442-2014

Table 6. Antioxidant capacity of test jelly samples

No. sample	AOC, μmol TEq/g weight *(lipophilic fraction)*	AOC, μmol TEq/g weight *(hydrophilic fraction)*
1	0.04	22.33
2	0.02	9.68

and antioxidant protection of the human body [31]. The latter factor is directly related to the peroxidation of lipids involved in the formation of cell membranes and to the protective functions of the body.

In collaboration with the Bach Institute of Biochemistry, the Russian Academy of Sciences, we measured the antioxidant capacity of the lipophilic and hydrophilic fractions of the test samples. For that, we used a Carry 100 Bio spectrophotometer in relation to the radical cation of the 2-azinobis-3-ethyl benziazolite-6 sulfonic acid diammonium salt (ABTS). Trolox was used as a standard in the AOC analysis and the results were expressed in Trolox equivalents (TEq). The results are presented in Table 6.

As can be seen from Table 4, the main contribution to the jelly antioxidant capacity is made by the hydrophilic fraction. However, the antioxidant capacity of sample 1 is more than twice as high as that of sample 2. Apparently, this is due to a different proportion of orange and viburnum puree in the samples (Table 2). An increased content of viburnum puree in the jelly formula can enhance the antioxidant capacity of the finished product. In addition, sample 1 can be classified as a functional product due to its formula and content of vitamins, as well as macro- and micronutrients.

CONCLUSIONS

The comprehensive analysis of the technology for producing fruit jelly with dietetic and preventative properties and an improved carbohydrate profile was carried out. Here, consumer preferences were taken into account. The analysis opened a prospect for using red viburnum as an unconventional bio raw material with multiple beneficial components.

The study resulted in a fruit jelly formula based on a combination of natural ingredients, viburnum and citrus fruit puree, and fructose used as a sugar substitute. We expect that the new technology will contribute towards the production of specialised preventative confectionery for healthy nutrition.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

The authors are grateful to the Core Facility 'Industrial Biotechnology' at the Federal Research Centre 'Fundamentals of Biotechnology' of the Russian Academy of Sciences (former Bach Institute of Biochemistry of the Russian Academy of Sciences) for their assistance with measuring the antioxidant capacity of the test jelly samples.

CRITERIA OF AUTHORSHIP

The authors share the responsibility for their work and the information provided in this paper.

The authors were equally involved in conducting the study and writing the manuscript and are equally responsible for plagiarism.

REFERENCES

1. James P.T., Rigby N., and Leach R. The obesity epidemic, metabolic syndrome and future prevention strategies. *European Journal of Preventive Cardiology*, 2004, vol. 11, no. 1, pp. 3–8. DOI: https://doi.org/10.1097/01.hjr.0000114707.27531.48.
2. Chumakova G.A., Veselovskaya N.G., Gritsenko O.V., and Ott A.V. Metabolic syndrome: challenging and unresolved issues. *Russian Journal of Cardiology*, 2014, vol. 19, no. 3, pp. 63–71. (In Russ.). DOI: http://doi.org/10.15829/1560-4071-2014-3-63-71.
3. Savenkova T.V., Soldatova E.A., Kiseleva T.L., Glazkova I.V., and Zhilinskaya N.V. The role of the food industry in dietetic therapy of the population. Specialized confectionery diabetic food. *Problems of Nutrition*, 2015, vol. 84, no. 6, pp. 107–115. (In Russ.).
4. Tutel′yan V.A. and Smirnova E.A. Rol′ pishchevykh mikroingredientov v sozdanii sovremennykh produktov pitaniya [The role of food microingredients in the creation of modern food products]. In: Tutel′yan V.A. and Nechaev A.P. (eds) Pishchevye ingredienty v sozdanii sovremennykh produktov pitaniya [Food ingredients in the creation of modern food products]. Moscow: DeLi plyus Publ., 2014, pp. 10–24. (In Russ.).
5. Casala E., Matthys C., Péter S., et al. Monitoring and addressing trends in dietary exposure to micronutrients through voluntarily fortified foods in the European Union. *Trends in Food Science and Technology*, 2014, vol. 37, no. 2, pp. 152–161. DOI: https://doi.org/10.1016/j.tifs.2014.03.001.
6. Mozaffarian D. Dietary and policy priorities for cardiovascular disease, diabetes, and obesity: A comprehensive review. *Circulation*, 2016, vol. 133, no. 2, pp. 187–225. DOI: https://doi.org/10.1161/CIRCULATIONAHA.115.018585.
7. Oliviero T.A., Verkerk R. and Dekker M. Research approach for quality based design of healthy foods: Dried broccoli as a case study. *Trends in Food Science & Technology*, 2013, vol. 30, no. 2, pp. 178–184. DOI: https://doi.org/10.1016/j.tifs.2013.01.005.
8. Ronteltap A., Sijtsema S.J., Dagevos H., and de Winter M.A. Construal levels of healthy eating. Exploring consumers' interpretation of health in the food context. *Appetite*, 2012, vol. 59, no. 2, pp. 333–340. DOI: https://doi.org/10.1016/j.appet.2012.05.023.

9. Tabatorovich A.N. Problems of developing and maintaining a quality marmelade of jelly. *Sibirskiy torgovo-ehkonomicheskiy zhurnal* [Siberian Trade and Economic Journal], 2012, no. 15, pp. 116–120. (In Russ.).
10. Baturina N. and Petrova L. New Types of Non-Traditional Cupcake with Additives of Vegetable Raw Materials. *Problemy ehkonomiki i upravleniya v torgovle i promyshlennosti* [Problems of economics and management in commerce and industry], 2014, vol. 8, no. 4, pp. 61–68. (In Russ.).
11. Kochetkova A.A., Vorobyova V.M., Vorobyova I.S., et al. Theoretical and practical aspects of development of biscuits with a modified carbohydrate profile for patients with type 2 diabetes. *Problems of Nutrition*, 2015, vol. 84, no. 6, pp. 122–131. (In Russ.).
12. Vorob′eva V.M., Kochetkova A.A., Savenkova T.V., et al. Nekotorye aspekty tekhnologii polucheniya marmelada s modifitsirovannym uglevodnym profilem [Some aspects of the technology for producing fruit jelly with an improved carbohydrate profile]. *Problems of Nutrition*, 2016, vol. 85, no. S2, pp. 135. (In Russ.).
13. Bednyh B.S., Gapparov M.M.-G., Nikolskaya G.V., et al. Carbohydrate ingredients in the baby foods. *Dairy industry*, 2014, no. 12, pp. 65–67. (In Russ.).
14. Tsyganova T.B. Kompleksnyy podkhod k razrabotke funktsional′nykh khlebobulochnykh i konditerskikh izdeliy [An integrated approach to the development of functional bakery and confectionery products]. *Materialy IV Mezhdunarodnoy nauchno-prakticheskoy konferentsii "Khlebobulochnye, konditerskie i makaronnye izdeliya XXI veka"* [Proceedings of the IV International Scientific and Practical Conference "Bakery, Confectionery, and Pasta in the 21st Century"]. Krasnodar, 2009, pp. 27–30. (In Russ.).
15. Krasulya O.N., Nikolaeva S.V., Tokarev A.V., Krasnov A.E., and Panin I.G. *Modelirovanie retseptur pishchevykh produktov i tekhnologiy ikh proizvodstva: teoriya i praktika: Uchebnoe posobie* [Modeling recipes of food products and their production technologies: theory and practice: Tutorial]. St. Petersburg: GIORD Publ., 2015. 320 p. (In Russ.).
16. Savenkova T.V. Questions of Ensure Safety and Quality in the Implementation of Innovative Solutions. *Confectionary manufacture*, 2013, no. 6, pp. 6–8. (In Russ.).
17. Rop O., Reznicek V., Valsikova M., et al. Antioxidant Properties of European Cranberrybush Fruit (*Viburnum opulus* var. *edule*). *Molecules*, 2010, vol. 15, no. 6, pp. 4467–4477.
18. DOI: https://doi.org/10.3390/molecules15064467.
19. Popova E.I., Khromov N.V., and Vinnitskaya V.F. Biokhimicheskaya otsenka sortoobraztsov kaliny i perspektivy ee ispol′zovaniya v proizvodstve produktov funktsional′nogo pitaniya [Biochemical assessment of viburnum varietal samples and prospects for its use in the production of functional foods]. *Scientific bulletins of the Belgorod State University. Series: Natural Sciences*, 2012, vol. 140, no. 21–1, pp. 127–131. (In Russ.).
20. Özbek K., Gündoğdu M., Keskin N., and Kaya T. Some Physical and Chemical Characteristics of Gilaburu (*Viburnum opulus* L.). *Fruits in Erzincan Region. Iğdir University Journal of the Institute Science and Technology*, 2011, vol. 4, no. 1, pp. 9–14.
21. *Gilaboru – Gilaburu Meyvesini Tanıyalım.* Available at: http://gilaboru.com/. (accessed June, 22 2017).
22. Mykots L.P., Romantseva N.A., and Gushchina A.V. Izuchenie fiziko-khimicheskikh svoystv pektina, vydelennogo iz plodov kaliny obyknovennoy (*Viburnum opulus* L.) [Studying the physicochemical properties of pectin from viburnum fruits (*Viburnum opulus* L.)]. *Scientific bulletins of Belgorod State University. Series: Medicine. Pharmacia*, 2013, vol. 147, no. 4, pp. 233–235. (In Russ.).
23. Altun M.L., Ozbek H., Gitoglu G.S., et al. Hepatoprotective and hypoglycemic activities of *Viburnum opulus* L. *Turkich Journal of Pharmaceutical Sciences*, 2010, vol. 1, no. 7, pp. 35–48.
24. Cesoniene L., Daubaras R., Vencloviene J., and Viskelis P. Biochemical and agro-biological diversity of Viburnum opulus genotypes. *Central European Journal of Biology*, 2010, vol. 5, no. 6, pp. 864–871. DOI: https://doi.org/10.2478/s11535-010-0088-z.
25. Tefikova S.N., Nikitin I.A., and Allilueva N.M. Produkty pererabotki kaliny obyknovennoy v tekhnologiyakh pishchevykh produktov funktsional′nogo naznacheniya [Viburnum-derived products in functional food technologies]. *Materialy IX Mezhdunarodnoy nauchno-prakticheskoy konferentsii, posvyashchennoy 20-letiyu spetsial'nosti "Tekhnologiya produktsii i organizatsiya obshchestvennogo pitaniya"* [Proceedings of the IX International Scientific and Practical Conference dedicated to the 20th anniversary of the programme "Technology and Organisation of Public Catering"]. Saratov, 2015, pp. 406–409. (In Russ.).
26. Mirzoev G.S., Osmanov T.R., and Samedov Eh.A. Ehkspertiza pokazateley kachestva tsitrusovykh plodov (limonov i mandarinov), realizuemykh v torgovoy seti [Examining quality indicators of citrus fruits (lemons and tangerines) sold in retail chains]. *Herald of Science and Education*, 2016, vol. 19, no. 7, pp. 30–32. (In Russ.).
27. Tutel′yan V.A. *Khimicheskiy sostav i kaloriynost′ rossiyskikh produktov pitaniya* [Chemical composition and energy value of Russian food]. Moscow: DeLi plus, 2012, 283 p. (In Russ.).
28. Andreeva V.Yu., Isaykina N.V., Tsybukova T.N., and Petrova E.V. The study of the elemental composition of fruits of *Viburnum Opulus* L. and *Sorbus Aucu-Paria* L. various modern methods. *Chemistry of plant raw material*, 2016, no. 1, pp. 177–180. (In Russ.). DOI: https://doi.org/10.14258/jcprm.201601893.

29. Plekhanova E.A., Bannikova A.V., and Ptichkina N.M. Development of technology and compositions of milk desserts with dietary purposes. *Food Processing: Techniques and Technology*, 2013, vol. 30, no. 3, pp. 53–57. (In Russ.).

30. Borisova L.V., Dimitrov V.P., and Zubrilina E.M. *Metody statisticheskogo analiza v upravlenii kachestvom* [Methods of statistical analysis in quality management]. Rostov-on-Don: Don State Technical University Publ., 2014. 113 p. (In Russ.).

31. Yashin Ya.I., Ryzhnyov V.Yu., Yashin A.Ya., and Chernousova N.I. *Prirodnye antioksidanty – nadezhnaya zashchita cheloveka ot opasnykh bolezney i stareniya* [Natural antioxidants as reliable protection from dangerous diseases and ageing]. Moscow: TransLit Publ., 2009. 122 p. (In Russ.).

32. Savvin P.N. and Bolotov V.M. Jelly marmalade antioxidatic properties research. *Chemistry of plant raw material*, 2008, no. 4, pp. 177–180. (In Russ.).

ORCID IDs
Igor A. Nikitin http://orcid.org/0000-0002-8988-5911
Marina A. Nikitina http://orcid.org/0000-0002-8313-4105