EFEITO DA SUBSTITUIÇÃO DO AÇÚCAR POR XAROPE DE MILHO ALTA DE FRUTOSE NA GELEIA DE FÍSALIS

EFFECT OF SUBSTITUTION OF SUGAR BY HIGH FRUCTOSE CORN SYRUP OF THE CONFITURE ON THE BASE OF PHYSALIS

ЭФФЕКТ ЗАМЕНЫ САХАРА ВЫСОКОФРУКТОЗНЫМ КУКУРУЗНЫМ СИРОПОМ НА ОСНОВЕ КОНФИТЮРА ИЗ ФИЗАЛИСА

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RESUMO

A *Físalis* contém todos os aminoácidos essenciais e não essenciais, em maior quantidade de aminoácidos essenciais L-valina e L-isoleucina, e os aminoácidos intercambiáveis L-tirosina. Também consiste em polifenóis, ácido ascórbico (vitamina C), carotenos (vitamina A), tiamina (vitamina B1), riboflavina (vitamina B2), niacina (vitamina B3) e macro e microelementos. O xarope de milho com alto teor de frutose (XMAF) é um adoçante que substitui a sacarose, que contém de 42% a 55% de frutose e o restante, glicose, e é comumente usado em muitos alimentos e bebidas. Descobriu-se que a substituição parcial ou total de açúcar por XMAF-55 não tem influências significativas nas propriedades organolépticas e físico-químicas dos confeitos a base de *Físalis*. Ao aumentar uma proporção de volume de XMAF em vez de açúcar, a fração de massa de sólidos solúveis, acidez titulável e teor de cinzas diminui nos valores aceitáveis. A análise comparativa do conteúdo macro e microelementos das amostras de confeitos mostrou a presença de minerais essenciais, como sódio, magnésio, silício, fósforo, potássio, cálcio e outros. O XMAF-55 pode ser substituído por açúcar na produção de confeitos a base de *Físalis* com características de qualidade química dos alimentos e valores nutricionais iguais.

Palavras-chave: *Físalis*, xarope de milho com alto teor de frutose (XMAF), geléia, valor nutricional, química alimentar.

ABSTRACT

Physalis contains all essential and non-essential amino acids, in the largest number of essential L-valine and L-isoleucine, and as the interchangeable amino acids L-tyrosine. It also consists in polyphenols, ascorbic acid (vitamin C), carotenenes (vitamin A), thiamine (vitamin B1), riboflavin (vitamin B2), niacin (vitamin B3) and macro- and microelements. High Fructose Corn Syrup (HFCS) is a sweetener substituting for sucrose that contains 42–55% fructose with the remainder as glucose and is commonly used in many food and beverage products. It was discovered that the partial or full replacement of sugar by HFCS-55 has not significant influences for the organoleptic and physicochemical properties of the confitures on the base of *Physalis*. By increasing a ratio of HFCS volume instead of sugar, the mass fraction of soluble solids, titratable acidity, and ash content decrease in the acceptable values. The comparative analysis of the macro- and

microelements contents of the confiture samples showed the presence of essential minerals, such as sodium, magnesium, silicon, phosphorus, potassium, calcium, and others. The HFCS-55 can be substituted of sugar in the production of confiture on the base of *Physalis* with equal food chemical quality characteristics and nutritional values.

Keywords: *Physalis*, High Fructose Corn Syrup (HFCS), confiture, nutritional value, food chemistry.

ABSTRACT

Физалис содержит все заменимые и незаменимые аминокислоты, в наибольшем количестве незаменимые, такие как L-валин и L-изолейцин, а также заменимую аминокислоту L-тирозин. Он также содержит полифенол, аскорбиновую кислоту (витамин С), каротин (витамин А), тиамин (витамин В1), рибофлавин (витамин В2), ниацин (витамин В3), макро- и микроэлементы. Высокофруктозный кукурузный сироп (ВФКС) является подсластителем, заменяющим сахарозу, которая содержит 42-55% фруктозы с остатком в виде глюкозы, и обычно добавляется во многие пищевые продукты и напитки. Установлено, что частичная или полная замена сахара на ВФКС-55 не оказывает существенного влияния на органолептические и физико-химические свойства конфитюра, приготовленного из физалиса. В результате использования ВФКС вместо сахара, массовая доля растворимых сухих веществ, титруемая кислотность и зольность снижаются до допустимых значений. Сравнительный анализ на содержание макро- и микроэлементов в образцах конфитюра показал наличие незаменимых минералов, таких как: натрий, магний, кремний, фосфор, калий, кальций и др. Высокофруктозным кукурузным сиропом можно заменить сахар при изготовлении конфитюра из физалиса, поскольку он обладает равными пищевыми химическими качественными характеристиками и пищевой ценностью.

Ключевые слова: *физалис, высокофруктозный кукурузный сироп (ВФКС), конфитюр, пищевая ценность, пищевая химия.*

1. INTRODUCTION

Physalis is a member of the Solanaceae family that owns a large number of edible plants: potatoes, tomatoes, eggplants, and others. In recent years, *Physalis* has begun to firmly conquer the world markets due to its high nutritional value and the promise of its application in medicine in the treatment of malaria, hepatitis, rheumatism, arthritis, dermatitis, asthma, cardiovascular and oncological diseases, Alzheimer's disease, dementia, and anti-fatigue. *Physalis* contains all the essential and non-essential amino acids, in the largest number of essential L-*valine* and L-*isoleucine*, and of the interchangeable amino acids L-*tyrosine*. The phytoncide content makes the *Physalis* fruits as good physiological an antiseptic, they also contain polyphenols, ascorbic acid (vitamin C), carotenes (vitamin A), thiamine (vitamin B1), riboflavin (vitamin B2), niacin (vitamin B3), calcium, ferrum, phosphorus and other organic acids, macro- and microelements, tannins. The content of solids is in the range from 6% to 10%. *Physalis* is used in the treatment of diseases of the gastrointestinal tract, chronic cholecystitis, in hypertension, like a multivitamin, and extracts of the *Physalis* have anti-inflammatory, hemostatic and analgesic effects. Due to the presence of water-soluble pectin and gelling properties,

Physalis has been used in the cooking, in the preparation of jelly, marmalade, confiture, jam, yogurt and soft drinks (Alibekov *et al.*, 2018).

Table 1 presents the main indicators of the nutritional value of *Physalis*, including macronutrients: proteins, carbohydrates, and fats; as well as micronutrients: minerals and vitamins.

In recent years, *Physalis* has begun to firmly conquer the markets of the whole world due to its high nutritional value and the promise of medical use in the treatment of malaria, hepatitis, rheumatism, arthritis, dermatitis, asthma, cardiovascular and oncological diseases, Alzheimer's disease and dementia (Zhang *et al.*, 2013). In addition, *Physalis* has an anti-fatigue effect and improve the general physiological state of a living organism (Hjartåker *et al.*, 2015).

Physalis is used for the preparing of the food coloring. Dried fruits resemble for the raisins. It is a dietary product (The Plant List, 2013). It was investigated that an increase in antioxidant capacity, the content of ascorbic acid and polyphenols were observed during the ripening of *Physalis* and with maximum values at the ripe stage (Valdenegro *et al.*, 2012).

Fructose, a monosaccharide, is naturally present in fruits, vegetables, and honey, usually accompanied by other sugars including glucose

and the disaccharide sucrose. It is also found as a component of sweeteners used in many processed food products, usually as sucrose or high-fructose corn syrup (Keim *et al.*, 2015).

High fructose corn syrup (HFCS) was introduced in the 1960s-70s as an added sweetener substituting for sucrose in the U.S. This sweetener contains 42–55% fructose (with the remainder as glucose), and is commonly used in many food and beverage products (Patterson *et al.*, 2018; Gridina and Andreev, 2018).

HFCS refers to sweeteners made from corn-derived fructose and glucose. It is named by the percentage of fructose contained in the final product: The Food Chemicals Codex stipulates that HFCS-55 must contain a minimum of 55% fructose (Institute of Medicine..., 2003).

It is well known that HFCS also contains maltose and glucose oligomers-up to 5% in HFCS-55 (White *et al.*, 2015). Popular beverages made with HFCS have a fructose-to-glucose ratio of approximately 60:40, and thus contain 50% more fructose than glucose. Some pure fruit juices have twice as much fructose as glucose (Walker *et al.*, 2014; Andreev and Gridina, 2016).

In the confectionery industry, the HFCS is compared by functional property with invert sugar. It is used in the production of soft candies, marshmallows, chewing gums. Substitution of 100% sugar by HFCS does not alter for the sweetness, aroma, and structure of the product. The presence of a large number of monosaccharides and especially hygroscopic fructose provides excellent wetting ability. Due to this, pastries remain fresh for a long time, do not dry out. HFCS can replace up to 20-50% sucrose in cakes, up to 20% when making white icing, 25-75% in the icing for marshmallow and completely replace sucrose in jelly fillings. In caramel production, it is not used due to a high hygroscopicity (Petrushevsky *et al.*, 1989).

2. MATERIALS AND METHODS

In the presented work for the preparing of the confiture, the Physalis, HFCS-55, lemon, and apple pectin have been used. Organoleptic and physicochemical properties have analyzed in accordance with the GOST (State standard) 34447-2018 "Confiture" (GOST 34447-2018).

The content of mineral substances in confiture was determined by the method of Mass-spectrometry with inductively coupled plasma (ICP-MS) and using a Scanning Electron

Microscope (SEM). The method of mass-spectrometry with inductively coupled plasma (ICP-MS) allows defining a number of metals and several non-metals at concentrations up to $10^{-10}\%$, i.e., one particle of 10^{12} , with the atomic mass from 7 to 250, i.e., from Li to U elements. It is able to determine the content of nanograms per liter to 10 to 100 milligrams per liter. The method is based on using inductive-connected plasma, as a source of ions and mass spectrometer for their separation and detection in an argon atmosphere. Unlike atomic absorption spectroscopy, defining only one element, ICP-MS can identify all elements simultaneously, which allows to considerably speed up the process of measurement (Thompson and Wolsh, 1988).

Scanning electron microscope (SEM) allows observing the subtle features of using micro-analyzing of chemical composition, and the details of the structure of micro-objects on the atomic and molecular level. It can also to receive the image of object surface with a high (up to 0.4 nm) spatial resolution, also information about the composition, structure, and some other properties of the surface layers. SEM has a great depth of focus that allows observing the three-dimensional image of the structure with the possibility of its qualitative evaluation (Alibekov *et al.*, 2017).

Preparation of ash samples for the analysis of the chemical composition was performed according to the GOST (State standard) 26929-94 (GOST 26929-94). The method of dry mineralization is based on the full decomposition of organic substances by combustion of the sample in an electric stove at a controlled temperature of 450-500 C° (Shingisov and Alibekov, 2017; Andreev and Gridina, 2017).

3. RESULTS AND DISCUSSION:

On the first stage, the selection and experimental determination of the main components of confiture were done. As the base composition, an equal amount of the Physalis and sugar were used. Further quantities of the required additives of lemon and apple pectin were studied.

3.1 Sensory evaluation

In the process of the selection of the ratio of components, options for the adding of lemon juice in the amount of 1%; 3%; 5%; 8% and 10% were considered (Figure 1). As a result, a sample with a 5% content of lemon has the highest

sensory evaluation. In the cases of the increasing of the lemon concentration until 10%, it was observed more acidic taste and deterioration in the quality of confiture.

Then the samples of confiture containing 5% lemon, and with the addition of apple pectin: 1%; 3%; 5%; 8% and 10% were analyzed (Figure 2).

It was found that by adding 3% apple pectin, the organoleptic properties, in particular taste, smell, color, and appearance, are significantly improved. Further increasing of the apple pectin content leads to the sharp thickenings of the confiture samples and degradation of the organoleptic properties.

3.2 Development of the confiture compounds

After that, a study of the replacement of sugar content by High Fructose Corn Syrup (HFCS) was done. By conducting multiple tests of the correlation ratios of the added components, four optimal compounds were selected containing: Physalis, sugar, HFCS, lemon, and apple pectin (Table 2).

3.3 Organoleptic characteristics of the confitures

The organoleptic characteristics of confiture, according to the "GOST 34447-2018 Confiture" (GOST 34447-2018) were investigated (Table 3).

3.4 Physicochemical characteristics of the confitures

The physicochemical characteristics of the confitures, according to the GOST 34447-2018 (GOST 34447-2018) were investigated (Table 4).

The organoleptic and physicochemical characteristics of all confiture samples correspond to the GOST 34447 - 2018 requirements (GOST 34447-2018). The composition No4 that based on the base Physalis and HFCS (without sugar) has the following characteristics:

- smearing consistency with a thick, gelling, slowly spreading mass on a horizontal surface without candying;
- taste is a sweet and a pleasant, smell is without foreign flavor and odor;
- color has a light brownish shade;
- 50% of the mass fraction of soluble solids;

- 16 °T of titratable acidity;

- 5.55% of ash content.

Thus the substitution of sugar by HFCS has not significant influences for the organoleptic and physicochemical properties for the confiture on the base of Physalis. By increasing a ratio of HFCS volume instead of sugar, the mass fraction of soluble solids, titratable acidity, and ash content decrease in the acceptable values.

3.5 Macro- and microelements contents in the confitures

The compositions of macro- and micro elements of the investigated confiture samples by using ICP-MS have the following data (Table 5; Figure 3.1-3.5).

The comparative analysis of the macro- and microelements contents of the samples versus control sample containing the raw Physalis showed the presence of essential macro- and microelements: sodium, magnesium, silicon, phosphorus, potassium, calcium et al. Particularly, the composition No 4 that on the base of Physalis and HFCS contains all the listed elements.

4. CONCLUSIONS:

Thus, partial or full replacement of sugar by High Fructose Corn Syrup (HFCS-55) has not significant influences for the organoleptic and physicochemical properties of the confitures on the base of Physalis. By increasing a ratio of HFCS volume instead of sugar, the mass fraction of soluble solids, titratable acidity, and ash content decrease in the acceptable values. The comparative analysis of the macro- and microelements contents of the samples showed the presence of essential minerals, such as sodium, magnesium, silicon, phosphorus, potassium, calcium, and others. The HFCS-55 can be substituted of sugar in the production of confiture on the base of Physalis with equal food chemical quality characteristics and nutritional values.

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Table 1. Nutritional value of *Physalis* (*Physalis* Nutritional Value)

Name of component	Amount	Daily values, %
Macronutrients		
Protein	2.66 g	5.32%
Carbohydrate	15.68 g	12.06%
Total Fat (lipid)	0.98 g	2.80%
Water	119.56 g	
Energy	74 Kcal	
Micronutrients		
Ferrum, Fe	1.4 mg	17.50%
Phosphorus, P	56 mg	8.00%
Calcium, Ca	13 mg	1.30%
Vitamins		
Vitamin B3 (Niacin)	3.92 mg	24.50%
Vitamin C (Ascorbic acid)	15.4 mg	17.11%
Vitamin B1 (Thiamin)	0.154 mg	12.83%
Vitamin A	50 µg	7.14%
Vitamin B2 (Riboflavin)	0.056 mg	4.31%

*Above mentioned Percent Daily Values (%DVs) are based on 2,000 calorie diet intake. Daily values (DVs) may be different depending upon your daily calorie needs. Mentioned values are recommended by a U.S. Department of Agriculture. They are not healthbenefitstimes.com recommendations. Calculations are based on average age of 19 to 50 years and weighs 194 lbs (*Physalis* Nutritional Value).

Table 2. The ratio of components in the samples

Component	Compound 1, %	Compound 2, %	Compound 3, %	Compound 4, %
Physalis	52	56	56	56
Lemon	5	5	5	5
Sugar	40	18	12	
HFCS		18	24	36
Pectin	3	3	3	3

Table 3. *Organoleptic characteristics of the confitures*

Name of indicator	GOST 34447-2018 Confiture	Compounds			
		No1	No2	No3	No4
Appearance and consistency	The smearing mass has a jelly texture with uniformly distributed fruits and / or vegetables or their parts, flavoring components (spices, nuts, etc.). Slowly spreading mass on a horizontal surface is allowed. Candying is not allowed.	The smearing mass having a gel consistency with evenly distributed parts and slowly candying.	The smearing mass like a jelly texture with a uniform consistency.	The smearing consistency with a slow gelling and spreading texture.	The smearing consistency with a thick, gelling, slowly spreading mass on a horizontal surface without candying.
Taste and smell	The taste is sweet, sour-sweet, pleasant, typical of fruits (vegetables) and / or flavor components, from that confiture is made. Smell - corresponding to the fruit (vegetables) and / or flavor components from that the confiture is made. The slight smell is allowed by the end of the shelf life. Extraneous flavor and odor are not allowed.	Taste is a sweet, typical for Physalis. Smell is without extraneous taste and smell.	Taste is a sweet. Smell is without extraneous flavor and odor.	Taste is a sweet. Smell is without extraneous flavor and odor.	Taste is a sweet and a pleasant. Smell is without extraneous flavor and odor.
Colour	Peculiar to the color of the fruit or vegetables from which confitures are made. Allowed: light brown shades - for confitures from light-colored fruits; brownish shade - for confitures from dark-colored fruits	Color has a light brownish shade	Color has a light brownish shade	Color has a light brownish shade	Color has a light brownish shade

Table 4. *Physicochemical characteristics of the confitures*

Name of indicator	GOST 34447-2018 Confiture	Compounds			
		No1	No2	No 3	No4
Mass fraction of soluble solids in confitures	not less: for sterilized (pasteurized) 50%	52.0%	51.0%	50.5%	50.0%
Titratable acidity	not provided	26 °T	22 °T	18 °T	16 °T
Ash content	not provided	7.95%	7.10%	6.65%	5.55%
Mass fraction of mineral impurities in confitures	not allowed	-	-	-	-
Impurities of plant origin, not provided for by the formulation (sepals, twigs, etc.) Extraneous impurities	not allowed	-	-	-	-

Table 5. Content of chemical elements in confiture ashes

Chemical element	Samples, mass percentage (%)				
	Control, Physalis	No1	No 2	No 3	No4
C (carbon)	13.01	74.47	75.25	71.45	60.85
O (oxygen)	37.07	18.24	19.20	20.92	22.08
Na (sodium)	0.36	0.37	0.28	0.16	0.09
Mg (magnesium)	2.61	0.63	0.25	0.17	0.19
Si (silicon)			0.06	0.14	0.18
P (phosphorus)	3.49	0.54	0.30	0.35	0.45
S (sulfur)	1.79	0.23	0.22	0.34	0.49
Cl (chlorine)	0.78	1.66	0.03	0.07	0.19
K (potassium)	39.91	5.74	4.63	6.37	12.59
Ca (calcium)	0.99	0.23	0.20	0.16	0.74

Figure 1. Sensory evaluation of confiture based on the *Physalis* with lemon, in scores

Figure 2. Sensory evaluation of confiture based on the *Physalis* and 5% lemon with apple pectin, in scores

Figure 3.1. ICP-MS of compound N. 1

Figure 3.2. ICP-MS of compound N. 2

Figure 3.3. ICP-MS of compound N. 3

Figure 3.4. ICP-MS of compound N. 4

Figure 3.5. ICP-MS of compound N. 5 control (*Physalis*)