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TECHNOLOGY OF CURD CAKE WITH SUCLAROSE AS HIGHLY EFFECTIVE SWEETENER

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The article presents the results of developing technology for the production of curd cake using a low-calorie sweetener sucralose. An analysis of literary sources has shown the relevance of developing food technologies with lower calories and glycemic index as a preventive measure in the fight against an increase in diabetes. The implementation of this direction in the form of a partial replacement in the sugar formulation for effective sweeteners sucralose is proposed.

The obtained integral quality estimates of sugars and sucralose at the levels of 0.82 and 0.60, respectively, using qualimetric analysis on five characteristics allowed us to conclude in favor of the predominant use of sucralose. The optimization of the technology for the production of curd cake using sugar substitute sucralose was carried out. As a prototype, a sugar-based recipe was used, in which a partial replacement (at the level of 30, 50 and 70%) of sugar with sucrose was carried out. The latter was used as a commercial sweetener TM Splenda. All samples, including the control on sugar, were subjected to organoleptic evaluation, which showed the absence of extraneous flavors in all samples and their similarity in terms of sweetness. However, unsatisfactory indicators were found for the sample with a replacement of 70%, we are talking about the color and characteristics of the crumb. This made it possible to opt for technology with sugar substitution in the range of 30–50%. All investigated samples of curd cake in terms of organoleptic and physico-chemical parameters met the requirements of regulatory documentation. Based on the results obtained, a technological scheme for the production of curd cake with sucralose was developed.

Calculation of the energy value of the obtained product in comparison with the control sample on sucrose showed a decrease in the calorie content of the product by 10%.

The results are important for the development of technology foods for people with diabetes.

Keywords: *sucralose, curd cake, sucrose, diabetes, glycemic index.*

ВИКОРИСТАННЯ ВИСОКОЕФЕКТИВНОГО ПІДСОЛОДЖУВАЧА СУКРАЛОЗИ У ВИРОБНИЦТВІ КЕКСУ СИРНОГО

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Наведено результати розробки технології виробництва кексу сирного з використанням низькокалорійного підсолоджувача сукралози. Як прототип було використано технологію кексу сирного. У дослідних зразках

здійснено часткову заміну (30, 50 і 70%) цукру сукралозою. Як джерело сукралози використано комерційний підсолоджувач ТМ Splenda.

Органолептичне оцінювання вироблених зразків дозволило зробити вибір на користь технології з заміною цукру в інтервалі 30–50%. Усі досліджені зразки кексу сирного за органолептичними та фізико-хімічними показниками відповідали вимогам нормативної документації. Розрахунок енергетичної цінності розробленого продукту порівняно з контрольним зразком на сахарозі показав зменшення цього показника на 10%.

Ключові слова: сукралоза, кекс сирний, сахароза, діабет, глікемічний індекс.

ИСПОЛЬЗОВАНИЕ ВЫСОКОЭФФЕКТИВНОГО ПОДСЛАСТИТЕЛЯ СУКРАЛОЗЫ В ПРОИЗВОДСТВЕ КЕКСА ТВОРОЖНОГО

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Приведены результаты разработки технологии производства кекса творожного с использованием низкокалорийного подсластителя сукралозы. В качестве прототипа использована технология кекса творожного, в которой была осуществлена частичная замена (30, 50 и 70%) сахара сукралозой. В качестве источника сукралозы использован коммерческий подсластитель ТМ Splenda.

Органолептическое оценивание произведенных образцов позволило сделать выбор в пользу технологии с заменой сахара в интервале 30–50%. Все исследованные образцы кекса творожного по органолептическим и физико-химическим показателям соответствовали требованиям нормативной документации. Расчет энергетической ценности разработанного продукта по сравнению с контрольным образцом на сахарозе показал уменьшение калорийности продукта на 10%.

Ключевые слова: сукралоза, кекс творожный, сахароза, діабет, глікемічний індекс.

Statement of the problem. The growing incidence of diabetes and the emergence of a high percentage of overweight people are prompting the industry to develop recipes for low-sugar flour confectionery or to replace it completely with highly effective sweeteners. The WHO guidelines [1] provide recommendations to reduce the consumption of free sugars by different age groups to less than 10% of the total caloric content of food, and ensuring a level of less than 5% will significantly improve health.

According to the International Diabetes Federation [2], today 9.3% of the adult population in the world aged 20–79, which is about 463 million people, have diabetes. In addition, about 1.1 million children and adolescents

under the age of 20 live with first type diabetes. According to experts of this organization, the number of diabetics among the population will reach 578 million in 2030, and in 2045 will be more than 700 million (fig. 1).

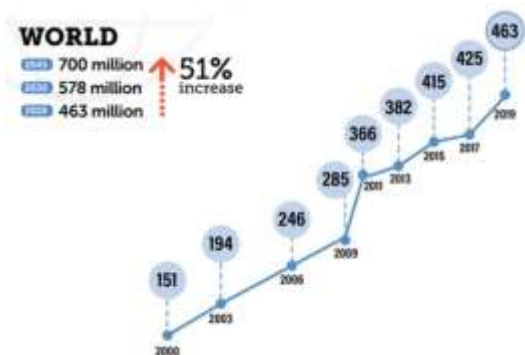


Fig. 1. Dynamics of number of people with diabetes worldwide and projections for 2030 and 2045 years [2]

One of the areas of prevention and prevention of further development of the situation is the development of the food industry sector, associated with the development of technologies for the production of low-calorie and glycemic index foods. It is known that the latter is an indicator of how quickly a certain amount of food will cause an increase in blood sugar. According to the Rating System for Glycemic Index (GI) have a scale: below 55 – low GI, 56 to 69 – medium GI. above 70 – high GI [3].

The implementation of this direction is associated with the use of sweeteners in food recipes with partial replacement of sugars [4–7]. According to a review [7], this practice of using sweeteners provides significant benefits in the daily life of the population, namely:

- choice of food and beverages in the control of calorie, carbohydrate and/or sugar consumption;
- help maintain or lose weight;
- help in the treatment of diabetes;
- help in the fight against dental caries;
- increasing the ease of use of pharmaceuticals and cosmetics;
- providing sweetness during sugar deficiency;
- promotes the economic use of limited resources.

The reason for such use in the first three cases is the fact that sweeteners have both functional and dietary properties for widespread use in

the production of food for diabetics. The first is prebiotic action, the second is due to low glycemic index and low caloric content [8].

Thus, the further development of the direction of the development of food technologies for creating products for the prevention of high blood sugar and for human consumption, already suffering from type 2 diabetes, is an actual task.

Review of the latest research and publications. In the review [7] the necessary properties for an ideal sweetener are given. Among the latter were named the following:

- water solubility and stability in environments of different acidity in a wide range of temperatures;
- stability over time, which provides a significant shelf life of the final product;
- ensuring the taste of the final food product, which is similar to the traditional one;
- be compatible with a wide range of food ingredients, as sweetness is only one component of a complex taste system.

Such requirements are met by sucralose, a sweetener widely used in the food industry in the United States, Canada and Europe.

According data of table 1, sucralose has sufficient solubility in water, low caloric content and zero glycemic index. The melting point allows sucralose to be stable during heat treatment in a wide pH range [9–11]. This sweetener is almost 600 times sweeter than sucrose. But this figure varies depending on the level of sucralose concentration and exposure to other ingredients [12].

Table 1

Physico-chemical properties sucralose

Property	Unit	Symbol	Value	Referance
Sweetness	sugar unit	P ₁	600	[12]
Glycemic index	%	P ₂	0	[3]
Energy	kJ/g	P ₃	0	[11]
Melting point	°C	P ₄	130	[13]
Solubility at 20 °C	%	P ₅	28.20	[12]

From a chemical point of view sucralose (IUPAC name: 1,6-Dichloro-1,6-dideoxy-β-D-fructofuranosyl-4-chloro-4-deoxy-α-D-galactopyranoside, CAS Reg. No. 56038-13-2) is a derivative of chlorinated sucrose, and is an artificially created compound. Sucralose is structurally identical to sucrose except that 3 of the alcohol groups OH are replaced by chlorine molecules (fig. 2).

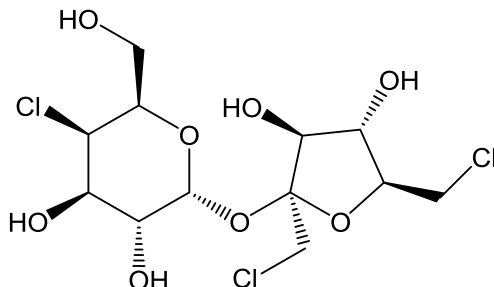


Fig. 2. Structure of sucralose

Sucralose is approved for use in food as a non-nutritive sweetener [14]. Sucralose is sold under the brand name Splenda®, which includes other related components and is available in the form of granular tablets and powder.

Sucralose is widely used in North America and Europe, but is a new product for the Ukrainian sweetener market. For example, the Food and Drug Administration (US Food and Pharmaceutical Regulatory Authority) has approved sucralose for use in 15 food categories, as well as a sweetener for general-purpose foods in a range of low-energy foods and beverages under certain conditions of use [15;16].

In the European legislation of the EU countries, according to the regulation «On food additives» [17], sucralose under the code E955 belongs to the functional class «sweeteners», namely to substances used to give a sweet taste to food or table sweeteners. The same regulation limits the maximum content of sucralose in buttery bakery products at the level of 700 mg/kg of product, and for dietary food products the maximum dose is 320 mg/kg. The analysis of literature sources showed that in Ukraine there are no publications that would cover the technology of flour confectionery with sucralose. Therefore, in the absence of domestic experience, further research to develop the technology was based on European standards regarding the daily dose of sucralose for dietary products.

Another, no less important, is the question of the equivalence of sucrose and sucralose in the formulation. The authors of the study [17; 18] used a just-about-right (JAR) scale. Ideal sucrose concentration to be added to probiotic Petit Suisse curd, obtained with the use this scale.

During the substantiation of the prescription composition, the previously proposed technologies were taken into account, which included the replacement of sugar with sucralose [18–20]. In the study [18] in the recipe of biscuits was replaced by 30% sugar to a combination of sucralose

(0.05%) and maltodextrin (30%). The obtained cookie samples had qualitative characteristics that were identical to the performance of sugar cookies. The replacement of 30% sugar with sucralose, as the most suitable option in flour confectionery, noted in the study [19]. At the same time, cupcakes made on pure sugar substitute, consisting of sucralose, maltitol and polydextrose, had unsatisfactory organoleptic and structural-mechanical properties [20].

The objective of the research is to develop advanced technology of curd cake based on sweeteners of sucralose (with partial replacement of sugar) with dietary-functional properties.

Presentation of the main research material.

Materials. The ingredients used in this study obtained from local stores in city Kharkiv, Ukraine. Sucralose as SPLENDA TM was purchased from Tate&Lyle PLC, UK and used as food grade.

Sampling. As a prototype, a curd cake was chosen according to [21]. The maximum levels of sucralose in buttery bakery products, as well as in dietary foods were mentioned above. However, in the production of curd cake was used sucralose in the form of sweetening TM Splenda. The manufacturer of this brand states that the product contains not only sucralose but also maltodextrins. But the full chemical composition in percentage on the package is not indicated. This situation dictates the need to select the dose of this sweetener instead of complying with the legislation. Based on the literature, in further studies, the prescription amount of sweetener based on sucralose (TM Splenda) was decided based on the replacement of 70%, 50% and 30% of sugar for sucralose. In the recipe, a partial replacement of sugar (70%, 50% and 30%) with sucralose (TM SPLENDA) was carried out, thus in the composition of cupcakes for the tradition of sweetness instead of sugar, a highly effective sweetener based on sucralose was introduced (0.1; 0.05 and 0.03 g of sucralose, respectively).

Patients with diabetes mellitus by 15–20% should cover the daily requirement by eating protein, and at least 50% should be animal protein [17]. Based on this, the main component was chosen sour milk curd, which contains 14–17.5% protein.

Based on the above, the following prescription compositions of four study samples were formed (table 2).

The curd cakes were baked in silicone molds, the weight of each cake before baking was 100 g. The cupcakes were baked at a temperature of 170 °C for 30 minutes.

Calculations of glycemicity indicator. The indicator of glycemicity was calculated according to the method [22]. Complex quality index was calculated using the following equation (1).

$$K_0 = M_1 \frac{P_1}{P_1^b} + M_2 \frac{P_2}{P_2^b} + M_3 \frac{P_3}{P_3^b} + M_4 \frac{P_4}{P_4^b} + M_5 \frac{P_5}{P_5^b}, \quad (1)$$

where M_1, M_2, M_3, M_4, M_5 – the importance of the coefficients of weighting of the indicator; $P_1^b, P_2^b, P_3^b, P_4^b, P_5^b$ – the value of the relevant indicators in the base sample are equal 10 in our case; P_1, P_2, P_3, P_4, P_5 the corresponding values of profilograms.

Table 2

Formulations of samples

Ingredients, g	Samples			
	S1 (control with only sugar)	S2 (sugar replacement 30%)	S3 (sugar replacement 50%)	S4 (sugar replacement 70%)
wheat flour	288.6	288.6	288.6	288.6
butter	154.6	154.6	154.6	154.6
sugar white	329.8	229.3	164.9	98.94
cottage curd (fat 9%)	258.4	309.0	340.8	372.3
melange	165.9	212.9	243.4	269.9
baking powder	10	10	10	10
sucralose	-	3	5	10
Total, g	1207.3	1207.3	1207.3	1207
Yield, g	1000	1000	1000	1000

Qualimetric analysis of the quality of sucrose and sucralose. According to the methodology [22], a comparison of the quality of sucrose and sucralose by a complex indicator was performed taking into account the basic physico-chemical properties for sucralose (table 1) and sucrose [8]. In the calculations, the indicators were transformed into ten-point scale, followed by the construction of a profilograms (fig. 3). Analysis of profilograms shows that the largest area of the figures has sucralose.

In accordance with the basic principles of qualimetry, the impact of individual indicators on quality is determined taking into account weight factors. The latter were determined by the method of quantifying the opinion of experts (method Delphi) [23]. The experts were teachers, graduate students and masters of Kharkiv State University of Food Technology and Trade (Ukraine) in the amount of 10 people. The average value of weights was taken into account when calculating the complex quality indicator: (M_1) for sweetness equal 0.25, (M_2) for glycemic index – 0.15, (M_3) for energy – 0.25, (M_4) for melting point – 0.15, (M_5) for solubility – 0.20.

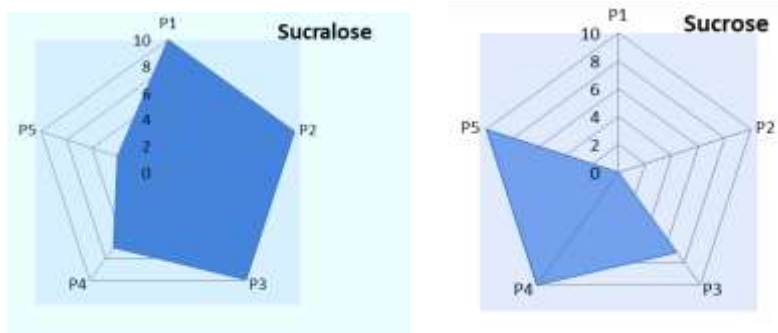


Fig. 3. The profile graphics of indicators of quality

According to formula (1) on the basis of physicochemical data (table 1) and profilogram data, calculations were performed complex indicator of quality K_o (table 3). A value of 0.82 was obtained for sucralose and 0.60 for sucrose. According to the evaluation data of the scale for K_o , for which the score was excellent at value in range 0.9 – 1.0, the score was good in range 0.75 – 0.89, the score was satisfactory at 0.60 – 0.74 and unsatisfactory less than 0.59. From table 3 it was seen sucralose have the highest an assessment than sucrose.

Table 3

The value of the complex indicator of quality

Name of sample	Complex indicator of quality	An assessment
sucrose	0.60	satisfactory
sucralose	0.82	good

Technology of production of curd cake based on sweeteners. According to the conducted researches the basic technological scheme of production of a curdcake with sucralose is developed that provides the

following stages (fig. 4): preparation of raw materials for production; preparation of a mixture of butter, sugar, melange and homogenized cottage curd; sifting flour; preparation of a mixture of flour, baking powder, sucralose and its thorough mixing; mixing and stirring the oil mixture and the mixture of dry substances; decomposition into molds and baking at temperatures of 170 °C for 30 minutes. The appearance of the obtained product is presented in fig. 5.

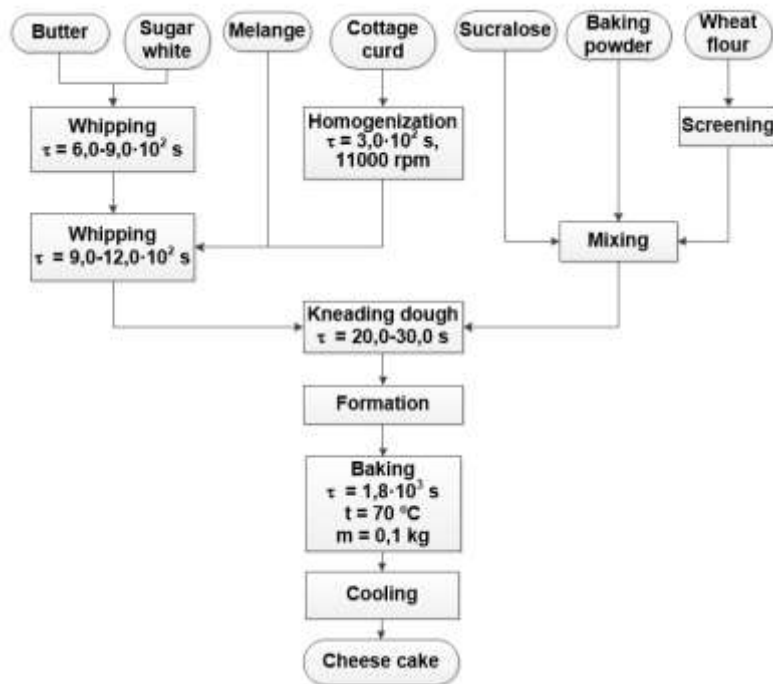


Fig. 4. Technological scheme of manufacture of curd cake with dietetic and functional properties

Research of indicators of quality and safety of curd cake with sucralose. After baking, the organoleptic and physicochemical parameters of the cakes were evaluated. In table 4 shows the organoleptic characteristics of curdcakes with different content of sucralose in the formulation.

Organoleptic evaluations of experimental samples made it possible to note the following indicators:

- sample S4 has a lighter color; it rose worse than other samples; the crumb is more than KOM and dark in comparison with other samples;

- like S3 had a higher density and lack of a pleasant caramel crust;
- all investigated samples were the same in sweetness;
- foreign tastes in one of the samples was not detected.

As a result of the tasting, samples S2 and S3 were recognized as the most suitable.

Thus, it was noted that the replacement of sugar in the product by more than 50% – is unsuitable for this type of flour confectionery.



Fig. 5. Appearance of the curd cake sample with the replacement of 50% sugar with a sweetener

Table 4

Organoleptic properties of curd cakes

Property name	Sample			
	S1	S2	S3	S4
Form	Correct, corresponding to the form established in the recipe without fractures			
Surface	Not burned. The surface of the cupcakes with the presence of cracks and tears, which do not change the product			
Color	Dark brown		Brown	Light brown
Appearance (section) of the curd cake	A well-baked curd cake			
Taste and smell	Intrinsic to this variety of cake without the foreign taste and smell			

In the table 5 the physico-chemical properties of investigated samples S2–S4 are compared with the control S1. The obtained results are within the normative indicators according to the state standard [24].

Thus, all the studied samples of curd cake in organoleptic and physicochemical parameters meet the requirements of regulatory documentation.

Table 5

Physico-chemical properties of samples of curd cake

Property name	Normative indicator [24]	Sample			
		S1	S2	S2	S4
Mass fraction of total sugar (sucrose) in terms of dry matter, %	16.0–60.8	40.95	28.60	20.68	12.70
Mass fraction of fat in terms of dry matter, %	2.2–34.2	19.01	19.67	20.24	20.98
Moisture content, %	10.0–31.0	19.48	19.90	20.71	22.14
Alkalinity in terms of solids (cake with chemical baking powder), degrees, not more than	2.0	0.70	0.49	0.32	0.25

Indicator of energy value. The resulting product contains more protein, has fewer carbohydrates and fewer calories. The latter is evidenced by the data of table 6, which shows the calculations of the energy value of the obtained curdcakes.

Table 6

Indicator of energy value of samples of curd cake

Amount, g/100 g of product	Sample		
	S1	S2	S3
Proteins	9.4	10.8	11.7
Fats	17.4	18.3	18.9
Carbohydrates	54.2	44.4	38.0
Energy value / caloric content, kkal/100 g product	410.2	385.7	369.3

It should be noted that the amount of protein and fat increases slightly due to the introduction of more cottage curd and melange, but this can not be considered a disadvantage of the proposed technology.

Conclusions. The conducted researches allow to formulate the following conclusions:

1) the technology of production of curd cake for dietary-functional purpose was developed on the basis sucralose with particle preplacement of sugar in the formulation;

2) the studied organoleptic parameters of this product showed the inexpediency of replacing more than 50% in the prescription composition of white crystalline sugar with sucralose. It is noted that the content of sucralose in the curd cake does not exceed the requirements of regulations;

3) the calculation of the energy value of the obtained curd cake indicates a 10% reduction in caloric content of the product compared to the control sample of sugar.

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