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TECHNOLOGY OF CANDY CARAMEL WITH DIETARY-FUNCTIONAL PROPERTIES

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The article presents the results of the development of the technology of candy caramel for dietary-functional purpose using monosaccharide fructose and sweeteners of the new generation – polyols isomaltitol and maltitol. The feature of this technology is the lack of starch molasses in the formulation. The physical-chemical, structural-mechanical and sorption-desorption properties of the obtained caramel samples in comparison with caramel produced on the basis of traditional *sugar technology are investigated. The content of reducing agents in the developed caramel samples is 6.5 and 6.7%, respectively, for samples on isomaltitol and maltitol, which is more than 3 times less than in caramel based on sucrose and starchy molasses. Isotherms of adsorption-desorption of moisture showed that the equilibrium moisture of samples at a_w 0.7−0.75 varies within 2.0−2.5%, which contributes to the absence of violation of the amorphous structure during storage, despite the reduced content of reducing agents. Calculation of glycemic index and energy values indicates that new types of caramel deserve the labeling of "Product with reduced glycemicity" and "Low calorie product". On the basis of the research, new types of candy caramel "Fruity lightness" on the basis of isomaltitol and "Nasoloda" on the basis of maltitol were developed.*

Keywords: *candy caramel, isomaltitol, maltitol, fructose, glycemic index.*

ТЕХНОЛОГІЯ ЛЬОДЯНИКОВОЇ КАРАМЕЛІ З ДІЄТИЧНО-ФУНКЦІОНАЛЬНИМИ ВЛАСТИВОСТЯМИ

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Наведено результати розробки технології льодяникової карамелі дієтично-функціонального призначення з використанням моносахариду фруктози та цукрозамінників нового покоління – поліолів ізомальтитолу і мальтитолу. Проведена кваліметрична оцінка рецептурних компонентів моносахариду фруктози та сахарозамінників ізомальтитолу, мальтитолу. Показано, що ці речовини мають вищий комплексний показник якості за основними фізико-хімічними показниками, ніж сахароза. Розроблена технологічна схема виробництва льодяникової карамелі на основі поліолів. Особливістю цієї технології є відсутність крохмальної патоки у складі розробленого продукту. Досліджено фізико-хімічні, структурно-механічні та сорбційно-десорбційні властивості отриманих зразків карамелі порівняно з карамеллю, виготовленою на основі традиційної технології. Вміст відновлюючих речовин у розроблених карамельних зразках становив 6,5% та 6,7% відповідно для зразків з ізомальтитолу та мальтитолу, що у 3 рази менше, ніж у карамелі на основі сахарози та крохмальної патоки. Отримані методом Мак-Бена ізотерми адсорбції-десорбції вологи показали, що рівноважна вологість зразків при активності води в інтервалі значень 0,7–0,75 змінюється в межах 2,0–2,5%. Одержані результати свідчать про сприятливість умовам, за яких відсутнє порушення аморфної структури під час зберігання продукту, незважаючи на зменшення вмісту редукуючого агента. Розрахунок показників глікемічності та енергетичної цінності зразків карамелі вказує на те, що нові види карамелі заслуговують на маркування «Продукт зі зниженою глікемічностю» та «Продукт зі зниженою калорійністю». На підставі результатів дослідження було розроблено нові види льодяникової карамелі «Фруктова легкість» на основі ізомальтитолу та «Насолода» на основі мальтитолу.

Ключові слова: *льодяникова карамель, ізомальтитол, мальтитол, фруктоза, гликемічний індекс.*

ТЕХНОЛОГИЯ ЛЕДЕНЦОВОЙ КАРАМЕЛИ С ДИЕТИЧЕСКИ-ФУНКЦИОНАЛЬНЫМИ СВОЙСТВАМИ

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Приведены результаты разработки технологии леденцовой карамели диетически-функционального назначения с использованием моносахарида фруктозы и сахарозаменителей нового поколения – полиолов изомальтитола и мальтитола. Исследованы физико-химические, структурно-механические и сорбционно-десорбционные свойства карамели, рассчитаны показатели гликемичности и энергетической ценности.

Ключевые слова: *леденцовая карамель, изомальтитол, мальтитол, фруктоза, гликемический індекс.*

Statement of the problem. Nowadays during the development of confectionery products, great attention is paid to products with functional (health-improving), dietary (taking into account the morbidity – diabetes mellitus, celiac disease, etc.) and dietary-functional properties. The work [1] presents requirements for confectionery products with dietary-functional properties.

One of the confectionery products that has high organoleptic characteristics, low price and long shelf life, is caramel. This product is widely represented in the markets of many countries. The driver of its attractiveness for consumers is its unique taste and texture [2]. The main raw material for the production of candy caramel is white crystalline sugar (sucrose) [3], which has a high glycemic index. Due to this, such caramel can not be consumed by patients with diabetes, due to metabolic disorders and malformations of the pancreas. Statistical data [3] show that the number of such patients increases with each passing year. The trend for this growth is projected to be 85% from 2015 to 2030 in Ukraine, while in Europe – by 20%, and in Africa – by 98%. That is, this problem has global signs. In this sense, prophylactic measures against diabetes mellitus at the level of the nutrition system, which include the inclusion of foods with reduced glycemicity and reduced caloric content, are important. One of the directions of development of technologies for the production of such foods is associated with the use of sweeteners. During the last decades, the amount of confectionery sweeteners has considerably expanded. However, consideration of such substances with the purpose of sweetening, even in the context of functional and dietary properties, is a one-sided approach that ignores the presence of physical-chemical processes associated with the content of sugar in the product [5]. It is known that in confectionery and many other food products, control of sweeteners is critical to achieving the desired characteristics, from appearance to texture [6]. Thus, sweeteners can be dissolved in the water phase of the product, be in solid state as a crystalline phase, or have an amorphous or glassy state. Sometimes, it can be a combination of these states. For example, depending on the type of sugar (crystalline, non-crystalline or partially crystalline), we have several types of caramel with different textures.

Thus, the technology of producing candy caramel as a functional product on the basis of confectionery sweeteners as functional replacements of sugars should combine both medical and physical-chemical components of the development.

Review of the latest researche and publications. Sweetenrs possessing both functional (prebiotic) and dietary (low glycemic index and caloric content) properties have been widely used in the manufacture of food products, in particular confectionery products, for patients with diabetes [7]. Thus, technologies of different groups of confectionery products (biscuits, muffins, marshmallow, chewing caramel and on the basis of plant extracts) were developed with the use of sweeteners of a new generation – polyols [8–15]. Polyols are also known as sugar alcohols or polyhydric alcohols. Among the large number of polyols in Ukraine, isomaltol and maltitol have become sufficiently distributed in the manufacture of confectionery products. According to the literature sources [16–18], isomaltitol (E953) and maltitol (E965) are low-calorie sweeteners, which, in some respects, are similar to sucrose. Both substances have prebiotic properties. Their use does not cause caries and doesn't increase blood glucose levels. Isomaltilol has a high tolerance (66 g/day), which is 2,8 times greater than that of sorbitol (24 g/day). Tolerance of maltitol is 87 g/day, which is more than 30% in comparison with isomaltitol and 3,6 times in comparison with sorbitol. Isomalt has a low solubility in comparison with other sweeteners, which requires an individual approach to its use. Isomaltol is not practically absorbing moisture from the atmosphere, and therefore caramel, based on it will have low hygroscopicity. Isomaltitol and maltitol do not take part in the Maillard reaction and caramelization.

Thus, in spite of the increasing number of publications devoted to the technologies of the production of candy caramel for patients with diabetes on the basis of various polyols (isomaltitol, maltitol, sorbitol), the question of improving these technologies in the direction of creating a high-quality product with dietary-functional properties without the addition of molasses and artificial sweeteners is relevant.

The objective of the research is to develop advanced technology of candy caramel based on sweeteners of maltitol and isomaltitol with dietary-functional properties.

Presentation of the main research material.

Materials. The chemicals used in this study are as follows: sugar white crystalline (Ukrproduct, Ukraine), caramel molasses (DKK, Ukraine), isomaltitol (Isodeco, Italy), maltitol (Intenson,Poland) and fructose (Vitamin, Ukraine).

Sampling. Samples of candy caramel based on maltitol&fructose (CMF) and isomaltitol&fructose (CIF) were used in the study. Caramel, made on the basis of traditional sugar technology, was chosen as the control sample in the study.

ethods. The following methods and techniques for studying caramel samples were used in the study in accordance with [19]: mass fraction of moisture by refractometric method of analysis on refractometer RPL-3 (Kiev Plant of Analytical Instruments, Ukraine); the content of reducing substances by copper-alkaline method; dispersion of caramel mass by the technique at the same temperature of casting drops of caramel; specific volume on the principle of displacement of caramel friable filler (manka). The strength of the caramel mass was determined on the MIP-100 device (ZIP LLC, Russia) by the principle of determining the maximum load for breaking the caramel shapes of the same size. Isotherms of sorption-desorption of samples were examined on a Mac-Ben device [20] at room temperature. The samples were weighed in a laboratory scale balance CBA-300-0.005 (T-Scale, China).

Calculations. The indicator of glycemicity was calculated according to the NUFT method [19]. Energy value was determined taking into account the amount of energy liberated from 1 g of product, taking into account the content of proteins, fats and carbohydrates [21].

Complex quality index was determined using the following equation [22]:

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

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

Qualimetric analysis of the quality of sugars and sweeteners. According to the methodology [22], a comparison of the quality of disaccharide sucrose, monosaccharide fructose, isomaltilol polyols and maltitol by a complex indicator was performed taking into account the basic physical and chemical properties (table 1). In the calculations, the indicators were transformed into ten-point scale, followed by the construction of a profilograms (fig. 1).

Table 1

Physicochemical properties sugar and sweeteners

Name of sample	Solubility at 293 K, %	Glycemic index (GI), %	Energy, kJ/g	Melting point, K	Sweetness, unit
	P_1	P_2	P_3	P_4	P_5
Sucrose	69.00	68.00	16.75	453.00	1.00
Fructose	**78.00**	20.00	16.75	**377.00**	**1.50**
Isomaltitol	24.50	**9.00**	**10.05**	419.00	0.55
Maltitol	65.00	36.00	**10.05**	421.00	0.90

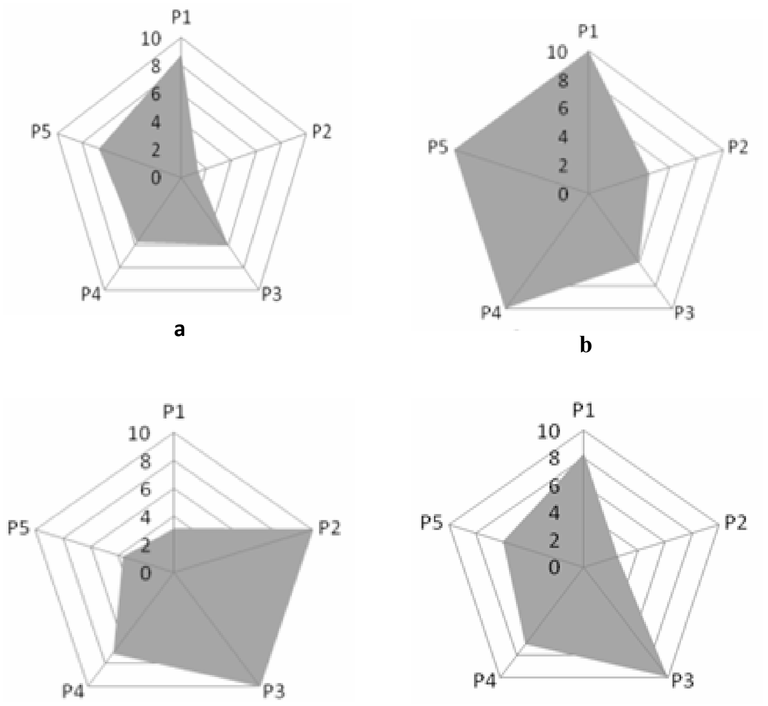

Fig. 1. The profilegraphics of indicators of quality:
a – sucrose; b – fructose; c – isomaltitol; d – maltitol

Analysis of profilograms shows that the largest area of the figures has monosaccharide fructose. However, the calculations did not take into account the importance of the impact of indicators on overall quality.

According to the basic principles of qualimetry, the influence of individual indicators on quality is determined taking into account weighting factors. The latter were determined by the method of an expert survey of teachers, postgraduates, and undergraduates from the National University of Food Technology (Ukraine) using the Delphi method (table 2). The average value of weighting factors was taken into account in the calculations of the integrated quality index.

Depending on the value of the complex indicator (K_0), an assessment of the complex quality index was given. If K_0 = 0.9 – 1.0 – the score was excellent, K_0 = 0.75 – 0.89 – the score was good, K_0 = 0.60 – 0.74 – the score was satisfactory, K_0 = less than 0.59 – unsatisfactory. Using the data of profilograms and table 1, the calculation of the complex index of sugar quality according to formula (1) was performed. From table 3 it was seen that the recipe components (monosaccharide fructose, polyols, isomaltitol, and maltitol) have the highest complex quality index in terms of basic physical and chemical parameters than sucrose.

Table 2

Determination of weight coefficients in equation (1)

Expert number	The value of the validity factor					Sum of the validity coefficients
	M_1	M_2	M_3	M_4	M_5	
Expert 1	0.20	0.15	0.25	0.20	0.20	1.00
Expert 2	0.20	0.15	0.25	0.15	0.25	1.00
Expert 3	0.15	0.20	0.20	0.15	0.30	1.00
Expert 4	0.25	0.15	0.20	0.15	0.25	1.00
Expert 5	0.20	0.10	0.20	0.20	0.25	1.00
Expert 6	0.10	0.20	0.25	0.20	0.25	1.00
Expert 7	0.30	0.10	0.25	0.10	0.25	1.00
Expert 8	0.25	0.15	0.25	0.10	0.25	1.00
Expert 9	0.20	0.15	0.25	0.15	0.25	1.00
Expert 10	0.20	0.15	0.24	0.16	0.25	1.00
Mean	0.20	0.15	0.24	0.16	0.25	1.00

Table 3

The value of the integrated indicator of quality

Name of sample	Integrated indicator of quality	An assessment of the complex quality index
Sucrose	0.60	satisfactory
Fructose	0.82	good
Isomaltitol	0.66	satisfactory
Maltitol	0.71	satisfactory

Technology of production of candy caramel based on sweeteners. According to traditional technology, the main raw material for the production of candy caramel is white crystalline sugar (saccharose) and starch molasses, which are used in the ratio of 1:0.5. In developing the technology of candy caramel for dietary-functional purpose, it was decided to remove starch molasses from the prescription composition, due to the fact that its composition includes glucose (GI = 100%) and maltose (GI = 105%).

On fig. 2 it is shown the technological scheme of production of candy caramel with dietary function of CIF and CMF. In the samples monosaccharide fructose was used in an optimum amount of 10% for improvement of technological and organoleptic properties. Further increase in the content of fructose in caramel leads to an increase in hygroscopicity.

According to the technological scheme, in the preparation of caramel syrup at the first stage, 30% of water was added to the mass of the mixture in the case of use of isomaltitol and 10% water to the mass of the mixture, if maltitol was used. Taking into account the solubility of polyols, such quantities are optimal. Then the syrup was boiled up to the content of dry matter 80−85%. At the second stage, the preparation of caramel mass with a mass fraction of moisture of 2.0 ± 1.0% was made, the final boiling point of caramel mass was 150 °C. At the third stage, the prepared caramel mass was cooled to a temperature of 85 °C and citric acid was injected in an amount of 0,6%. Atthe next stages, caramel was formed by casting into silicone molds, then it was cooled and wrapped into packing material.

Research of quality indicators of candy caramel. It has been noted above that the use of sweeteners as functional replacements of sugars in foods may cause variations in physical-chemical parameters of the system due to changes in the phase behavior of the sample. This can happen both during the manufacturing process and during the storage of the final product, usually with a negative effect on the storage time.

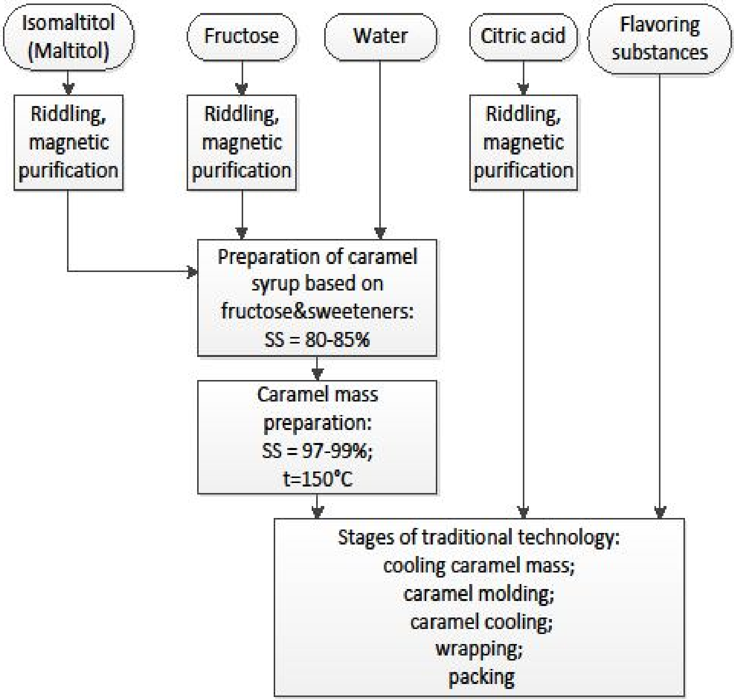

Fig. 2. Technological scheme of candy caramel with dietetic and functional properties manufacture

In view of this, the technology of replacing sugars with sweeteners requires study and control of the following processes [5]:

– crystallization;
– browning;
– structure, bulk and viscosity;
– hygroscopicityand moisture migration;
– effects on colligative properties.

The compliance of the physical-chemical characteristics of the finished product, in which sugar is replaced by a sweetener, to a product without replacement, is usually a criterion for achieving the adequacy of the substitution.

Physical and chemical properties. In the table 4 the physical-chemical indicators of investigated samples are compared with the control.

Table 4

Physicochemical properties of candy caramels

Properties	Control	CIF	CMF
Mass fraction of moisture, %, not more	2.2	2.1	2.2
Mass fraction of reducing substances, %, not more	20.0	6.5	5.8
Acidity, in terms of citric acid, degrees, no less	10.0	15.3	15.8

Data of the table 4 indicate that samples of candy caramel, manufactured according to the advanced technology, contain from 3.0 to 3.4 times less reductive substances than the control sample manufactured according to the traditional technology. However, studies have shown that such caramel does not lose its properties during storage.

Structural-mechanical properties. The structural and mechanical properties of caramel mass are of great importance in the technological process of producing caramel, as shown in table 5.

Table 5

Structural-mechanical properties of caramel's mass

Caramel's mass	Spreading, cm^2/g	Specific volume, $cm^3/100$ g	Density, g/ cm^3	Strength, kgs
Control	2.28	86.1	1.16	138
CIF	2.40	89.3	1.12	124
CMF	2.55	91.1	1.10	95

When comparing the structural-mechanical properties of developed samples with a control sample, no significant differences were found. However, it is clear from the table that the use of polyols contributes to an increase in the spread of caramel mass. This may be due to a reduction viscosity in the caramel mass due to syrups made on the basis of polyols and the absence of dextrin that is presented in the syrup. It should be noted that more fluid masses of caramel are better formed by the casting method.

Isotherm of adsorption-desorption of moisture. According to table 4, CIF and CMF samples have a relatively low content of reducing agents. In [23] it was noted that the low content of reducing agents can lead to crystallization of candy caramel during storage. To study this issue, we studied the isotherms of adsorption and desorption of moisture (fig. 3). The resulting isotherms have the same type for these products as for samples on sugar substitutes and sugar.

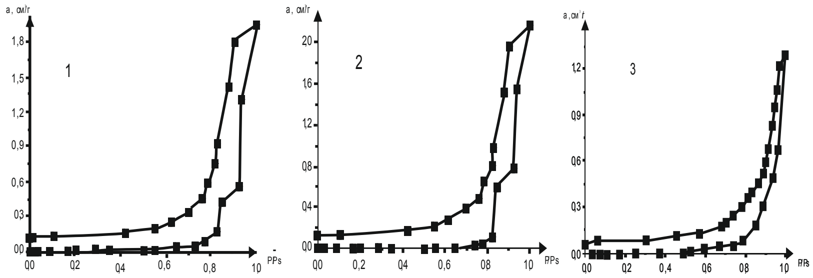

Fig. 3. Isotherm of adsorption-desorption of moisture:
1 – CIF; 2 – CMF; 3 – Control

The value of the equilibrium moisture content of caramel at equilibrium relative humidity 70% and 75% is given in table 6. The analysis of the data showed that the equilibrium moisture content of the caramel produced on the basis of the mixture of sweetener& fructose at a_w = 0.75 is 2.0−2.5%, which corresponds to the required humidity of 3.0 ± 1.0, which is indicated in the formulation. This indicates compliance with the necessary conditions for storing the equilibrium moisture content when storing caramel. However, it should be noted the expediency of wrapped caramel.

Table 6

The value of the equilibrium relative humidity of candy caramel at RH=70% and RH=75% of sorption isotherms

Sample	The value of equilibrium relative humidity RH, %	
	70 (a_w = 0.7)	75 (a_w = 0.75)
Control	2.7	3.0
CIF	2.3	2.5
CMF	1.9	2.0

Indicator of glycemicity and energy value. The use of polyols in caramel technology can greatly reduce their glucose and caloric content. To prove this fact, calculations of the glycemic index and the energy value of the developed caramel samples were compared with the control sample (table 7).

Table 7

Indicator of glycemicity and energy value of caramel

Sample	Index of glycemicity		Energy	
	unit	decrease, %	kkal/g	decrease, %
Control	69.7	–	369.4	–
CIF	10.1	85.6	248.6	32.7
CMF	33.5	51.9	247.4	33.1

In [24], the concept of "reduced glycemicity was defined, which means that the glycemic index is reduced by 25%. The obtained values of decrease of the index of glycemicity at the level of 50−80% (table 5), allow to confirm the achievement status "products with reduced glycemicity" by the studied samples.

Calculated energy value showed more than 30% decrease in value. This is enough to mark samples of CIF and KMF as "products with reduced caloric content". The presented facts confirm the possibility of using candy caramel samples for consumption by all groups of people, including patients with diabetes mellitus. Thus, according to the obtained characteristics, samples of CIF and KMF deserve the marking of "Dietary-functional food product".

On the basis of the research, new types of candy caramel were developed "Fruit lightness" on the basis of the CIF sample and "Nasoloda" based on the CMF sample, which were tastedby the Specialized Industry Tasting Commission and were highly appreciated.

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

1) the technology of production of candy caramel for dietary-functional purpose was developed on the basis of a mixture of sugar isomalt and maltitol with fructose without the use of starch molasses in the formulation;

2) physico-chemical properties of candy caramel indicate that the content of reducing agents in CIF and CMF samples was 6.5% and 6.7%, respectively, which is more than 3 times less than in caramel based on saccharose and starch molasses;

3) the study of isoterms of adsorption-desorption of moisture showed that the equilibrium humidity at a_w=0.70–0.75 varies within 2.0–2.5%, which does not contribute to the violation of the amorphous structure during storage, despite the reduced content of reducing agents;

4) the calculation of glycemic and energy values indicates that new types of caramel deserve the labeling of "product with reduced glycemicity" and "low calorie product".

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