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COMPLEX QUALITY INDICATOR OF SUGARS AND SUGAR SUBSTITUTES AND THEIR USE IN THE PRODUCTION OF CONFECTIONERY PRODUCTS

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Abstract: *The paper presents the results of calculation on the basis of the basic principles of theoretical qualimetry of the complex index of quality of sugars and sugar substitutes. When evaluating sugars according to the complex indicator as the differential indicators, there were selected sweetness, glycemic index, solubility and melting point, caloric content, which have the greatest influence on the organoleptic, technological and physiological parameters of sugar quality. When calculating the complex index of sugar substitutes, it was suggested to introduce three indicators: the heat dissolution, water activity and the degree of tolerance. According to the selected indicators, which values have been transformed into a 10-point scale, profilograms have been constructed. Formulas of calculating the complex quality index were developed taking into account the validating factors of each indicator determined by the Delphi method. The calculation of the complex index of sugars' quality showed a significant advantage of tagatose and the expediency of its use in the manufacture of confectionery products. The calculation of the complex index of quality of sugar substitutes showed that the highest score was registered by erythritol, fact that determines the expediency of its use in the manufacture of confectionery products with dietary function. The calculation showed the following values of the complex index of sugars' quality – sucrose, glucose, fructose, maltose, lactose, tagatose, trehalose: 0.53, 0.46, 0.72, 0.44, 0.26, 0.81, 0.44, 0.47 respectively, and sugar substitutes – sorbitol, xylitol, isomaltotol, maltitol, erythritol, lactitol: 0.34, 0.42, 0.37, 0.47, 0.86, 0. 37 respectively. The article describes the sorption-desorption properties of various groups of confectionery products using sugars and sugar substitutes.*

Keywords: theoretical qualimetry, complex index, Delphi method, differential indicators

1. Introduction

Today food products for special purposes are in great demand in the world. According to the Codex Alimentarius food products for special purpose are divided into functional items that have health properties and dietary products intended for nutrition for people with different diseases who are unable to consume original products [1].

Carbohydrates are of great importance for human life – they are a source of energy and perform very important physiological functions: regulatory, toning, protective, adsorption. According to IUPAC nomenclature carbohydrates are divided into simple (monosaccharides) and complex (oligo - and polysaccharides) [2]. Mono - and disaccharides form a group of carbohydrates called sugars. It should be noted that the experts of the Food and agriculture organization of the UN (FAO) and the World Health Organization (WHO) use the term "sugars" referring to mono - and disaccharides [1]. The suffix "ose" is present in the title of sugars like: sucrose, glucose, fructose, lactulose, etc. According to the international standard CODEX STAN 212-1999 the group of sugars include: white sugar, powdered sugar, yellow sugar, brown sugar, glucose anhydrous, glucose crystalline hydrate, the powder of glucose, glucose syrup, dry glucose syrup, lactose, fructose, raw sugar from sugar cane [3].

All sugars have a sweet taste and in food production have structure functions which mean that they participate in the formation of disperse structures with coagulation, crystal and coagulating-crystalline properties. In the manufacture of confectionery sugars participate in the formation of amorphous, crystalline, gel-like, pasty, cream structure [4].

In the manufacture of confectionery for dietetic purpose sugar substitutes are used instead of sugar. Substances with a sweet taste that by organoleptic, physico-chemical and structural-mechanical indicators can replace sugar in food products belong to the group of sweeteners. According to the rules of nomenclature of IUPAC (international Union of pure and applied chemistry), formulated in 1996, polyols, acrospires, hydrogenated carbohydrates which are synonyms of one class of derivatives of carbohydrates belong to sugar substitutes. All sweeteners have the suffix "-tol": sorbitol, xylitol, lactitol and other [2].

The "sugar substitutes", "acrospires", "hydrogenated carbohydrates", "polyols" are the synonyms of one subclass of derived of carbohydrates. The alcohol group is presented in the compounds (-CH_2OH), which replaces the carbonyl group (-C=O) in aldoses and ketoses of different sugars. As polyols do not have a carbonyl group, they can't form a cyclic structure which is characteristic for monosaccharides and disaccharides, so they are usually depicted in Fischer projections. Sugar substitutes do not participate in the reaction of melanoyodin formation, because they have no reductive properties [5].

All sugar substitutes-polyols are obtained by catalytic hydrogenation of the corresponding carbohydrates. Sorbitol is produced from glucose, xylitol – from D-xylose, isomalt - from sucrose, lactitol - from lactose, maltitol - from maltose. Erythritol is the only sugar substitutes, which is obtained not by catalytic hydrogenation of carbohydrates but by microbial synthesis. As microorganisms, osmophilic yeast and fungi Pollinis, Trigonopsis, or Torulopsis are used [4].

This work is dedicated to the assessment of the quality of sugars and sugar substitutes by the integrated indicator of quality. While determination by a integrated indicator, the sweetness, glycemic index, solubility, melting point, calorific value were selected as the quality differential indicators, which have the greatest influence on organoleptic, technological and physiological indicators of the quality of the product.

The *sweetness* has an important functional role in the manufacturing of confectionery products. Sweetness is estimated relatively to sucrose, which sweetness is taken as 1 unit of sweets [6].

The *glycemic index* in recent years has become the main indicator of the quality of food, especially for dietetic purpose. The concept of glycemic index was first introduced in 1981 by Dr. David Jenkins, a Professor at the University of Toronto in Canada in order to determine what meals are the most beneficial for people with diabetes. The impact of food on glucose levels in the blood is determined by the glycemic index (GI). The lower the ability of foods to raise glucose level in blood, the more favorable their effect on insuline and the lower risk of developing diabetes, cardiovascular disease, obesity [7].

Solubility has a great importance in assessing the quality of sugars by an integrated measure. Most sugars are well soluble in water, with increasing temperature the solubility increases. Solubility is accompanied by the destruction of the crystal structure, hydrogen bonds with water molecules in aqueous solutions as well as the internal and intermolecular hydrogen bonds, which strength will depend on the concentration of carbohydrate solutions and temperature. The ability of carbohydrates to dissolve determines their effect on structure formation processes of various food products of amorphous, crystalline, prescriptive, spumy structure [8, 9].

The Melting point is the temperature at which a crystalline solid turns into liquid state, which affects energy costs, that is, with the increase of the melting temperature the amount of energy increases that is required to transfer the food product into the liquid state [8].

Calorific value is an important indicator of the assessment. It is the amount of energy (Kcal, kJ) that is released in the human organism from food products to ensure physiological functions [10].

When calculating the integrated indicator of the quality of the sugar substitutes, it was suggested to introduce three indicators: the heat of dissolution, water activity and degree of tolerance in addition to differential metrics which were used in assessing the quality of sugars (solubility, melting point, calorie, sweetness, glycemic index).

The *heat of solution* is of great importance as teplophisic characteristics, affects the organoleptic characteristics, so the consumption of sorbitol, xylitol and especially erythritol there is a strong cooling effect [4].

Water activity is of great importance when storing products and it describes the hygroscopic properties and microbiological stability of the product [8].

The *degree of tolerance* is important in assessing the quality of polyols. Polyols can cause undesirable gastro-intestinal disorders (laxative effect) when used by sensitive persons, so excessive consumption can cause gastrointestinal complications. There are limitations to an amount of consumption of polyols. So it is shown in the Codex Alimentarius that if in the consumption of the food product it is assimilated more than 20 grams of polyols, the product must contain a marking that it has laxative effect [11]

2. Matherials and methods

The solubility of sugars was determined by the mass of the substance that can dissolve in 100 g of solvent at a certain temperature to make the solution saturated [8].

The melting point was determined using a capillary method using a device which consists of a heat-resistant round-bottom flask of 100-150 ml with a long neck; heat-resistant glass test tube which is inserted in a flask so that it does not reach its bottom by 1 cm; capillary tubing made of non-durable glass with 0.9 – 1.1 mm in diameter; mercury thermometer with a price division of 0.5 ° C; heating sources - gas burner, electric heater. The flask is charged at ¾ with a suitable liquid, for example, with distilled water (for substances with T_{mel} to 80 ° C), vaseline or silicone oil, concentrated sulfuric acid (for substances with T_{mel} from 80 to 260 ° C), a solution of three parts of potassium sulfate in seven parts of concentrated sulfuric acid (for substances with T_{mel}> 260 ° C). The difference between definitions should not exceed 1°C. The beginning of melting is the appearance of the first droplet of liquid and the end - the complete transition of matter into a liquid state. This temperature range (range T_{mel}) must not exceed 2°C [9].

Energy value was determined taking into account the amount of energy released from 1g of the product, taking into account the content of proteins, fats and carbohydrates [10].

Sweetness was determined by the organoleptic method using sensory analysis. In the evaluation of organoleptic parameters from 12 to 15 experts participated [12].

Determination of the glycemic index involves testing by people with normal weight index and tolerance to glucose and food consumption on an empty stomach (two hour's break after the last meal) with the absence of physical activity. It is desirable to conduct testing at 10 o'clock in the morning after a 10-14 hour rest break. It is also recommended when taking a certain amount of food or white bread, if it is chosen as the standard, drink them with a standard amount of water, which is 250 ml. When using glucose as a standard, firstly it must be dissolved in 250 ml of water. Duration of consumption of liquid food products should be 5-10 minutes, and solid and semi-hard - 10 - 20 minutes. The first measurement of blood glucose should be done exactly 15 minutes after consuming the first portion of food or the first drink of the beverage. Sweetness of glucose and high osmotic pressure of its aqueous solutions can lead to a decrease in stomach activity, and therefore, as a standard, instead of glucose, sometimes white (wheat) bread is used. Another advantage of white bread is that its consumption results in an increased insulin response.

The value of glycemic indexes for white bread (GI_b) is higher than the value of GI_g ($GI_b = 100/73\ GI_g$). It is also appropriate to obtain at least two values of GI for each person [13].

The heat of solution is determined using calorimetry [14].

Water activity and sorption-desorption properties are investigated on a Mac-Ben device, according to sorption-desorption curves. The method is used to obtain information about the kinetics of the determination of sorption equilibrium and sorption capacities at different media humidity (steam vapor activity). Measurements are carried out on the vacuum balances of Mac-Ben with a quartz spiral, sensitivity of it is at least 1 milligram / mm. Deformation of the spiral is recorded using a catheter KM.-9 with an accuracy of ~ 0.01 mm. The method of measurement is as follows: a sample of an adhesive in the form of an individual film or film on a substrate weighing at least 100 mg is reinforced on a quartz spiral, which is placed in a sorption column. After thermostating at a given temperature for 30-40 minutes, the system is vacuumed to a residual pressure of 10-5 mm.m.c. with the continuous registration of the desorption process of volatile components from the sample to the determination of the constant weight of the sorbent [8].

Integrated indicator of quality was calculated according to the basic principles of qualimetry [15].

3. Results and discussion

In this work, a comparison of the quality of sugars: sucrose, glucose, maltose, lactose, tagatose, trehalose, lactulose is conducted by an integrated measure (Table 1), which takes into account physic-chemical properties.

Table 1

Basic physical and chemical parameters of sugars

Name of sugar	Solubility at 293 K (20 ° C),%	Glycemic index (GI),%	Caloric content		Melting point		Sweetness, unit
			kJ / g	kcal/g	К	°C	
	P_1	P_2	P_3		P_4		P_5
Saccharose	69.00	68.00	16.75	4.00	453.00	180.00	1.00
Glucose	47.00	100.00	16.75	4.00	419.00	146.00	0.80
Fructose	**78.00**	20.00	16.75	4.00	**377.00**	**104.00**	**1.50**
Maltose	47.00	105.00	16.75	4.00	381.00	108.00	0.40
Lactose	16.00	45.00	16.75	4.00	525.00	252.00	0.35
Tagatose	58.00	**3.00**	**6.28**	**1.50**	407.00	134.00	0.92
Trehalose	68.90	72.00	14.49	3.46	483.50	210.50	0.45
Lactulose	75.20	46.00	16.75	4.00	442.00	169.00	0.50

Analysis of the data indicates that all indicators have different units of measure. To calculate the integrated indicator of quality according to the basic principles of qualimetry differential indicators it should be transformed to the same scale of measurement. It was decided to transform the indicators into ten-point scale.

Profile grapgics were built due to the obtained data (Fig. 1), which area of characterizes the overall quality of sugars.

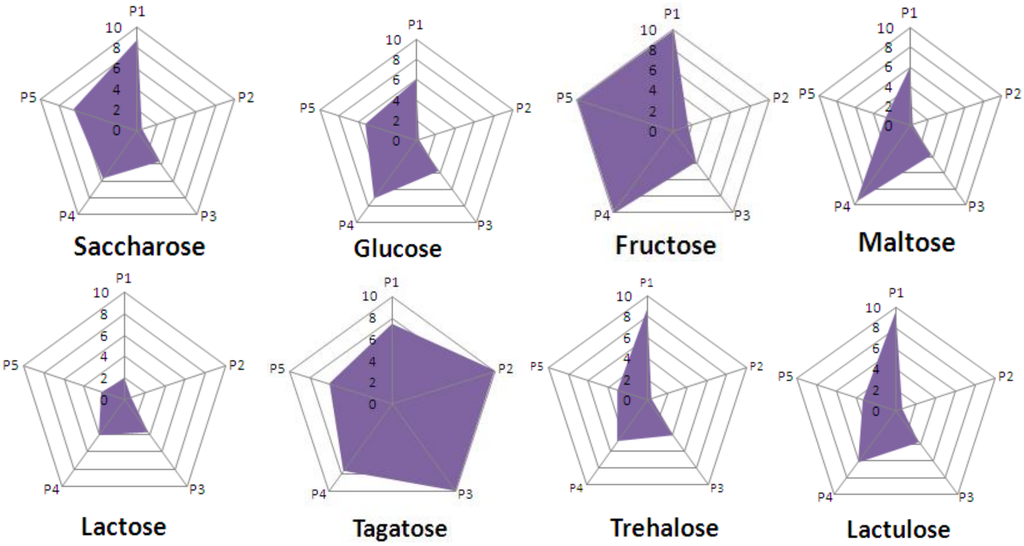

Fig. 1. The profile graphics of indicators of quality of sugars

Analysis of profile graphics shows that the largest area has tagatose, and the lowest – lactose. Each individual indicator has different influence on the overall assessment of the quality of the product. The validityt of influence of indicators on overall quality is not taken into account in profile graphics. According to the basic principles of quality control the influence of individual indicators on the quality was determined taking into account the validity coefficients. There are many methods of determining the validity coefficients. We decided to determine the validity factors by the method of Delphi. The condition for determining the validitycoefficients is:

$$\sum_{i=1}^{m} M_i = const \qquad (1)$$

In our case, the validity factors were determined according to the following formula:

$$M_1 + M_2 + M_3 + M_4 + M_5 = 1 \qquad (2)$$

Table 3 shows the definition of the validity coefficients by the method of Delphi (round II)

Table 2

Definition of validity factors

Expert number	The value of the validity factor					Sum of the validity coefficients
	M_1	M_2	M_3	M_4	M_5	
The first expert	0.20	0.15	0.25	0.20	0.20	1.00
The second expert	0.20	0.15	0.25	0.15	0.25	1.00
The third expert	0.15	0.20	0.20	0.15	0.30	1.00
The fourth expert	0.25	0.15	0.20	0.15	0.25	1.00
The fifth expert	0.20	0.10	0.20	0.20	0.25	1.00
The sixth expert	0.10	0.20	0.25	0.20	0.25	1.00
The seventh expert	0.30	0.10	0.25	0.10	0.25	1.00
The eighth expert	0.25	0.15	0.25	0.10	0.25	1.00
The ninth expert	0.20	0.15	0.25	0.15	0.25	1.00
A tenth expert	0.20	0.15	0.24	0.16	0.25	1.00
The average value	0.20	0.15	0.24	0.16	0.25	1.00

The average point was taken into account in the calculation of the integrated indicator, which was carried out according to the following formula:

$$K_0^1 = M_1 \frac{P_1}{P_1^б} + M_2 \frac{P_2}{P_2^б} + M_3 \frac{P_3}{P_3^б} + M_4 \frac{P_4}{P_4^б} + M_5 \frac{P_5}{P_5^б} \qquad (2)$$

where M_1, M_2, M_3, M_4, M_5 – the value of the validity factors of the indicator

$P_1^б$, $P_2^б$, $P_3^б$, $P_4^б$, $P_5^б$ – the values of the corresponding indicators in the baseline sample, which equals 10 points

P_1, P_2, P_3, P_4 , P_5 the corresponding value from the profile graphics.

Using the data in profile graphics and Table 2 integrated indicators of the quality of sugars were calculated according to the formula (2) whiche values are given in the Table 3.

Table 3

The value of the integrated indicator of quality of sugars

Name of sugar	The value of the integrated indicator of quality
Saccharose	0.53
Glucose	0.46
Fructose	0.72
Maltose	0.44
Lactose	0.26
Tagatose	**0.81**
Trehalose	0.44
Lactulose	0.47

Quality assessment by an integrated indicator showed significant benefits of tagatose relatively to other sugars.

A comparison of the quality of sugar substitutes: sorbitol, xylitol, maltitol, isomaltitol, lactitol, erythritol by an integrated indicator is made. Main physico-chemical parameters are given in the Table 4. Profile graphics are built due to the obtained data (Fig. 2).

Table 4

Main physical-chemical properties of sugar substitutes

Name of sugar substitute	Solubility at 293 K (20 °C),%	Glycemic index (GI),%	Caloric content		Melting point		Sweet-ness, unit	The heat of solution kJ/kg	Water activity	Tolerance, g/day
			kJ/g	kcal/g	K	°C				
	P_1	P_2	P_3		P_4		P_5	P_6	P_7	P_8
Sorbitol	**75.0**	9.0	8.62	2.6	373.0	100.0	0.6	-110	0.72	24
Xylitol	58.0	8.0	17.01	4.06	**367.0**	**94.0**	0.6	-153	0.82	60
Isomaltitol	24.5	9.0	10.05	2.4	419.0	146.0	0.55	-39	0.88	66
Maltitol	65.0	36.0	10.05	2.4	421.0	148.0	**0.9**	**-23**	0.85	87
Erythritol	37.0	**0.2**	**2.09**	**0.5**	399.0	126.0	0.65	-192	**0.91**	**132**
Lactitol	55.0	2.0	10.05	2.4	423.0	150.0	0.35	-65	0.90	54

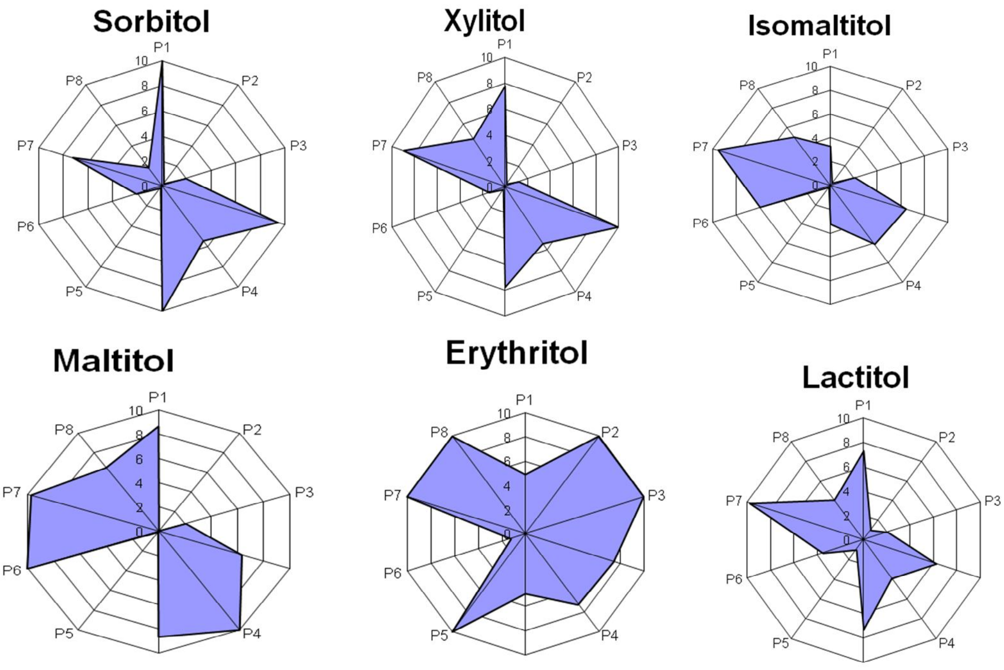

Fig. 2. The profile graphics of quality of sugar substitutes

Analysis of profile graphics shows that the most square takes erythritol, and the less – sorbitol. Table 5 shows the validity factors that were determined by the method of Delphi.

Table 5

Definition of validity factors

Expert number	**The value of the validity factor**								**Sum of the validity coefficients**
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**M_8**	
The first expert	0.1	0.35	0.2	0.03	0.15	0.01	0.05	0.11	1.00
The second expert	0.1	0.25	0.1	0.05	0.2	0.05	0.15	0.1	1.00
The third expert	0.1	0.2	0.2	0.05	0.1	0.05	0.1	0.2	1.00
The fourth expert	0.2	0.15	0.1	0.08	0.05	0.05	0.05	0.32	1.00
The fifth expert	0.1	0.3	0.2	0.02	0.05	0.08	0.15	0.1	1.00
The sixth expert	0.1	0.25	0.3	0.04	0.1	0.08	0.1	0.03	1.00
The seventh expert	0.05	0.15	0.2	0.1	0.15	0.03	0.08	0.24	1.00
The eighth expert	0.1	0.4	0.1	0.05	0.05	0.02	0.1	0.18	1.00
The ninth expert	0.05	0.3	0.2	0.03	0.1	0.03	0.14	0.15	1.00
A tenth expert	0.1	0.15	0.4	0.05	0.05	0.1	0.08	0.07	1.00
The average value	0.1	0.25	0.2	0.05	0.1	0.05	0.1	0.15	1.00

Taking into account the validity coefficients an integrated indicator of the quality of sugar substitute is counted according to the formula (4) (Table. 8).

$$K_0^1 = M_1 \frac{P_1}{P_1^б} + M_2 \frac{P_2}{P_2^б} + M_3 \frac{P_3}{P_3^б} + M_4 \frac{P_4}{P_4^б} + M_5 \frac{P_5}{P_5^б} + M_6 \frac{P_6}{P_6^б} + M_7 \frac{P_7}{P_7^б} + M_8 \frac{P_8}{P_8^б} \quad (4)$$

where M_1, M_2, M_3, M_4, M_5, M_6, M_7, M_8 – the values of the validity factors of the indicator;

$P_1^б$, $P_2^б$, $P_3^б$, $P_4^б$, $P_5^б$, $P_6^б$, $P_7^б$, $P_8^б$ – the values of the corresponding indicators in the baseline sample, which equals 10 points

P_1, P_2, P_3, P_4, P_5, P_6, P_7, P_8 – the corresponding values from the profile graphics.

Table 6

The value of the integrated indicator of the quality of sugar substitutes

Name of sugar substitute	**The value of the integrated indicator of the quality**
Sorbitol	0.34
Xylitol	0.42
Isomaltitol	0.37
Maltitol	0.47
Erythritol	**0.86**
Lactitol	0.37

Analysis of the data showed that the highest mark was registered by erythritol.

Studies have shown a significant outgrowth of Tagatose among sugars and erythritol among sugar substitutes.

D-tagatose (tagatose) is a monosaccharide identified in chemical nomenclature (CAS) by formula $C_6H_{12}O_6$. Tagatose is a white crystalline powder similar to sucrose. Tagatose is found in nature in various fruit, milk and other products.

In the United States tagatose received GRAS status ("recognized as safe") in October, 2001. In December, 2005 tagatose was approved for use in the EU as an innovative food ingredient. Tagatose promotes the growth of lactobacillus and lactic acid bacteria in the human body, and also has prebiotics action. Tagatose is characterized by a low glycemic index, which is equal to 3 %. Long-term consumption of tagatose lowers the level of glucose and blood cholesterol, reducing the risk of obesity, diabetes. In addition, it is considered to be potentially useful in the treatment of anemia, hemophilia, infertility has crioprotector and antioxidant properties [16, 17].

Erythritol is one of the most promising substitutes of a new generation. In the environment erythritol is in plant foods: pear, melon, grape. In the human body erythritol also contains, in particular in blood serum, tissues of the eye. Erythritol is an inhibitor of the breakdown of red blood cells, induced by diazole compounds, reduces vascular damage caused by hyperglycemia. A positive feature of erythritol is also that it belongs to the prebiotics. This poliol does not cause any gastrointestinal complications and loose stools. Erythritol is absorbed in the small intestine by passive diffusion. Erythritol is get by the microbiological synthesis, using such microorganisms Trigonopsis, Torulopsis, Pollinis. Cultivation of microorganisms is carried out in an aqueous medium at a pH from 3 to 6 and a temperature of 35...38°C for 3 to 8 days. Carbohydrates (e.g., glucose, sucrose), nitrogenous substances (malt extract, urea), inorganic salts of potassium, calcium, iron are used for the cultivation of microorganisms [18, 19].

However, in the manufacture of confectionery products, their technological properties and the possibility of their use in the manufacture of confectionery products of various structures are of great importance. An important characteristic of the quality of confectionery products during storage is their sorption-desorption properties.

At the National University of Food Technologies, Kyiv, the innovative technology of chewing caramel of dietic-functional purpose on the basis of the monosaccharide tagatose is developed, that deserves the label "product with reduced calorie" and reduced glicemicity. Studies have shown that chewing caramel with tagatose quickly lose chewing properties during storage, therefore, in order to maintain organoleptic characteristics, that is, chewing effect, and the structure, polyols maltitol and glycerol were proposed to enter in the formulation of the product [20].

Studies have shown that despite the high value of the complex quality index of tagatose, chewing caramel that is made on its basis, while stored quickly loses chewing properties, therefore, in order to preserve the necessary chewing effect and the desired structure, it was proposed to introduce polyol maltitol to the formulation of the product, the complex quality index of which is rather low, but the technological properties of maltitol will improve the quality of chewing caramel on tagatose. The study of sorption-desorption samples of chewing caramel, made according to the traditional recipe on sucrose and using the proposed composition on tagatose and maltitol (Table 7) was carried out.

Table 7

The value of the equilibrium humidity content in chewing caramel by zones of sorption isotherms

Kind of chewing caramel on	The value of equilibrium humidity, %					
	First zone φ = 0 … 25% a_w = 0.0 … 0.25		Second zone φ = 25 … 75 % a_w = 0.25 … 0.75		Third zone φ = 75 … 100 % a_w = 0.75 … 1.0	
	sorption	desorption	sorption	desorption	sorption	desorption
sucrose	0.0…0.0	11.0…13.0	0.0…13.0	13.0…24.1	8.0…75.0	24.1…75.0
tagatose-maltitol	0.0…0.0	11.0…13.0	0.0…8.0	13.0…35.6	8.0…85.4	35.6…85.4

Experiments have shown that the equilibrium humidity content in caramel produced on a mixture of tagatose-maltitol with a_w = 0.75 equals 8%, as well as for caramel produced on sucrose, but the initial humidity content of the finished caramel using tagatose is 8.1%. This suggests that during storage of caramel there was a slight humidity separation, which affects the reduction of the chewing effect by increasing the degree of crystallinity of the structure.

The calculation of the complex quality index has shown good indicators for fructose, but from a technological point of view, fructose is a hygroscopic substance, so its use in confectionery products greatly increases sorption properties. For example, in the production of candy caramel, using only fructose and molasses as anticrystallizer, moisture absorption during storage is significantly increased (Table 8) and when developing new confectionery products, it is necessary to introduce substances with low hygroscopicity into the prescription composition. Among a number of polyols, isomalt and maltitol during storage do not absorb moisture, therefore, recipe mixes of isomalt-fructose and maltitol-fructose were developed in the production of candy caramel. The use of sugar substitutes and fructose in the manufacture of confectionery products can reduce their caloric content and glycemicity, which will allow consuming them by patients with diabetes, as well as providing products with prebiotic properties. In new samples of caramel, sorption-desorption properties were investigated (Table 8).

Table 8

The value of the equilibrium humidity content of candy caramel by zones of sorption isotherms

Kind of caramel on	The value of equilibrium humidity, %					
	First zone φ = 0 … 25% a_w = 0.0 … 0.25		Second zone φ = 25 … 75 % a_w = 0.25 … 0.75		Third zone φ = 75 … 100 % a_w = 0.75 … 1.0	
	sorption	desorption	sorption	desorption	sorption	desorption
fructose	0.0 – 0.0	9.0-17.0	0.0-11.0	17.0-30.0	11.0-125.0	3.0 -125.0
isomalt-fructose	0.0 – 0.0	8.0-16.0	0.0-2.5	16.0-18.0	2.5-133.0	18.0 – 133.0
maltitol-fructose	0.0 – 0.0	7.5-14.0	0.0-3.5	10.0-14.0	3.5-154.0	10.0 – 154.0

Analysis of data shows that caramel on fructose will greatly absorb moisture, because the humidity according to the recipe is 2 - 4%, and equilibrium humidity is 11%. The use of polyols can reduce equilibrium humidity to moisture according to recipes, so such caramel will retain the necessary properties throughout the expiration date.

We conducted a complex of studies about the use of sugar substitutes and sugars in the production of marshmallows, among which the use of mixtures of isomalt-fructose and maltitol-fructose allowed to obtain a good quality product. The determination of the behavior of new samples of marshmallows during storage was very important, so their sorption-desorption properties were investigated (Table 9).

Table 9

The value of the equilibrium humidity content of marshmallow by zones of sorption isotherms

Kind of marshmallow on	The value of equilibrium humidity, %					
	First zone φ = 0 … 25% a_w = 0.0 … 0.25		Second zone φ = 25 … 75 % a_w = 0.25 … 0.75		Third zone φ = 75 … 100 % a_w = 0.75 … 1.0	
	sorption	desorption	sorption	desorption	sorption	desorption
sucrose	0.0 – 0.0	0.0 – 1.0	1.0 - 10.0	12.0-40.0	10.0-130.0	40.0-130.0
isomalt-fructose	0.0 – 0.0	0.0 – 1.0	1.0 - 33.0	9.0-40.0	33.0-163.0	40.0-163.0
maltitol-fructose	0.0 – 0.0	0.0 - 1.0	1.0 - 31.0	11.0-37.0	31.0-158.0	37.0-158.0

Analysis of the data shows that new samples of marshmallow will largely absorb moisture, since the humidity according to the recipe is 18 - 20%, and the equilibrium moisture content of the new samples is 31 - 33%, therefore, such marshmallow in the process of storage will absorb moisture, which leads to the need to pack marshmallow in a waterproof container.The complex of researches on the rational use of erythritol in the production of cakes is conducted in Nuft. The aim was to get a cake based on erythritol that deserves the label "product with reduced calories" and "reduced glycemicity". However, erythritol has a high heat of dissolution (-192 kJ/kg), which influences on the organoleptic properties, i.e. provides unwanted cooling effect. Experiments have shown that the elimination of the cooling effect may be when changing the temperature and duration of baking cake. Traditional temperature of baking for the cake with sucrose is 453 K (180 °C), cooking duration is 30 min. Experiments showed that the temperature of baking cake with erythritol must be 413 K (140 °C), and the duration of baking must be increased by 50 % to reach 45-50 min [21].

The study of sorption-desorption properties of samples of cakes made on the basis of erythritol was conducted. A sample on sucrose was choosen as a control sample (Table 10).

Table 10

The value of the equilibrium humidity content of cakes by zones of sorption isotherms

Kind of cake on	The value of equilibrium humidity, %					
	First zone φ = 0 … 25% a_w = 0.0 … 0.25		Second zone φ = 25 … 75 % a_w = 0.25 … 0.75		Third zone φ = 75 … 100 % a_w = 0.75 … 1.0	
	sorption	desorption	sorption	desorption	sorption	desorption
sucrose	0.0 – 0.0	3.1 – 1.8	0.0-11.6	3.1 – 26.98	11.6-52.0	29.98-52.0
erythritol	0.0 – 0.0	2.8 – 3.95	0.0-9.0	3.95 – 79.3	9.0 – 102.18	79.3 – 102.18

According to the obtained data (Table 12), it is determined that at P / P_0 = 0.75 the equilibrium moisture content of cake based on the sucrose is 11.6%, on the basis of the erythritol - 9.0, which is significantly less than the moisture content of the finished cakes (W = 25 ... 27%), this indicates that when storing all samples will lose moisture, that is, will undergo the process of drawing, therefore, to preserve the necessary properties of products, they must be packed.

4. Conclusion

Research showed the feasibility of determining the assessment of quality of sugars and sugar substitutes by the integrated indicator taking into account the basic principles of quality control. The expediency of calculation of the integrated indicator of quality of sugars by such differential parameters such as solubility, caloric value, glycemic index, sweetness, melting point was justified. The calculation of the integrated indicator of sugar substitutes was carried out by solubility, caloric value, glycemic index, sweetness, melting point, water activity, degree of tolerance and heat of solution. When assessing quality for the integrated indicator the validity factors were taken into account and they were determined by the method of the expert survey after Delphi. It was established that sugar tagatose has the highest value of the integrated indicator of quality (K=0.81). It is established that the sugar substitute erythritol has the highest value of the integrated indicator of quality (K=0.86). The obtained data for the calculation the complex quality index increase the interest to the use of tagatose and erythritol in the manufacture of confectionery, but it is necessary to take into account the technological properties of sugars and sugar substitutes in the manufacture of each individual product. So, tagatose may be used in the production of chewing caramel in a mixture with maltitol. Studies of sorption-desorption properties have shown that such caramel will insignificantly lose moisture and get stale. The widespread distribution of confectionery products was made because of isomalt and maltitol in a mixture with fructose, for example, lollipop caramel and marshmallow were produced using various recipe compositions. Designed samples of candy caramel, according to the data of sorption isotherms, will have high quality during the guaranteed expiration date, and marshmallow absorb moisture, which requires considerable attention when packaging products and the approach to the type of packaging in general. The use of erythritol in the production of cakes significantly affects the quality of the product, so when stored, they will lose moisture and get stale, but it significantly reduces the caloric content of the product and improves its healing properties, therefore, such products require careful packaging to maintain the required quality.

5. References

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