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The usage of a binder system for frozen berries in the manufacture of confectionery

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Abstract. The aim of the research was to create binding systems for confectionery using gelling agents. The possibility of using partially hydrolyzed liquid egg white (egg hydrolyzate) in the binding system of gelling agents (egg hydrolyzate - agar (EG-A), egg hydrolyzate - starch (EG-S)) was determined to obtain the required mechanical characteristics when creating coatings, ornaments or fillers in confectionery with whole berries or pieces of fruit. In this regard, a technology has been developed for the hydrolysis of liquid egg white in the presence of an acidic reagent. The best rheological characteristics of the gelling agent from egg white were obtained under the following hydrolysis conditions: egg white: 1% HCl ratio = 1:2, process temperature - 66°C, duration - 40 minutes, the pH of the egg hydrolyzate was 6.53, the amount of dry solids was 11.78%. The newly created systems with agar (E406, Germany), chemically modified food starch (E1442, Germany) and hydrolyzed egg white (egg hydrolyzate) allow to adjust the properties of the coating for quick-frozen berries used in semi-finished confectionaries or cakes. It is established that the coating for quick-frozen berries, which includes a system consisting of 1% E406 and 0.5% egg hydrolyzate, should be carried out in 2 stages. In the first stage, a 10-minute exposure of the coating, which has a tensile strength of 580 g cm^{-2}, allows to create a strong capsule around the berry, which prevents the processes of destruction from proceeding. The second stage is necessary to obtain a uniform surface coating of the semi-finished mix from the berries. In this case, the tensile strength of the coating should be 480 g cm^{-2}. The system created from the E1442 and egg hydrolyzate gelling agents was also used in 2 stages when making cakes, which were subsequently baked at 180 °C. The content of the binding system in the coating applied to the test substrate was 6.9–7.7%, the effective viscosity of the coating was 120–180 Pa s. The content of the binding system in the coating of the surface of the berries in the second stage was 5.2–6.3% with effective viscosity values of 50–90 Pa s. Semi-finished berry products and ready-made baked cakes, produced with developed binding systems, can be stored at -8 °C for 10 to 12 days. After refrigerated storage, the separated moisture was not observed in the test samples. The absence of the phenomenon of syneresis with the indicated proportions of the introduction of gelling agents in coating systems has been established.

Key words: hydrolysis, egg hydrolyzate, binding systems, jellies, confectionery, refrigerated storage.

INTRODUCTION

To maintain the body's physiological needs (Basu & Lyons, 2014), the use of quick-frozen fruits and berries as an independent dish, decoration or as a part of confectionery is associated with the problem of preserving their physico-chemical properties and sensory indices for a long time.

Preservation of color, prevention of deformation of fruit and berry products as part of confectionery can be considered as a promising direction due to the fact that the existing technologies for using of gelling coatings based on various gelling agents allow to maintain high quality of the products no more than 96 hours, which is a significant problem for manufacturers.

Mainly hydrocolloids are used for obtaining food products of gel-like structure. Under certain conditions, polymer molecules of gelling agents are capable of forming a three-dimensional cross-linked network in solutions. In such a system, water is physically bounded, which results in changing the consistency of the product (DeMars & Ziegler, 2001). The gel is a fixed form of a colloidal solution (sol). For the implementation of the process of transition of the sol to the gel, it is necessary that forces between molecules start to act to ensure the formation of intermolecular bonds. This can be done by various methods: reducing the moisture content (due to evaporation), adding substances that contribute to forming of bonds and cross-linking, changing the temperature and adjusting the pH (Dille et al., 2018). Depending on the structure of the gel molecules, the gelling mechanisms differ significantly.

In the manufacture of gelling coatings for confectionery, a limited number of hydrocolloids is used. It is impossible to use thickeners, because the viscous structure formed by them is not able to stabilize spatially the berries and fruit fragments used for decorations.

The selection of ingredients that stabilize the binding systems in the composition of the coatings applied during the production of confectionery on berry raw materials plays an important role, therefore, it is necessary to know the properties that not only coating should have, but also the gelling agents included in the systems. The properties of thickeners and gelling agents can be changed by modifying them (introducing chemically neutral or ionic substituents into the molecule) to produce, for example, various types of starches (Huang et al., 2017; Lee et al., 2017; Naji-Tabasi & Razavi, 2017). According to the results of the analysis of the properties presented on the market of hydrocolloids, we chose agar-agar (E406) and modified corn starch (E1442). To regulate the strength characteristics of binding systems, (Cregut & Rondags, 2013; Han & Han, 2014; Somboon et al., 2014; Riedel et al., 2015; Rioux et al., 2015; Hayashi et al., 2016) additionally hydrolyzed egg white was used.

Studies of agar in combination with other gelling agents are quite extensive (Santagiuliana et al., 2018). They are essential when creating new foods (Sun et al., 2018) with the necessary properties (Li & Nine, 2016; Ellis et al., 2018). In the manufacture of gelling coatings in the confectionery industry, agar is often used because of its distinctive feature - resistance to temperature (Vao et al., 2016) in an acidic environment. This feature makes it possible to store the agar sol during thermostatting at temperatures higher than the gelling temperature for a sufficiently long time. Thus, the possibility of creating the necessary reserve of coating is used. In addition, agar gels are characterized by good sensory properties (Kohyama et al., 2016) and high storage stability with little tendency to syneresis.

Depending on the type and extent of hydrolysis of the properties of starches (Włodarczyk-Stasiak et al., 2017) and their influence on the systems they include (Lin et al., 2018), they can vary widely (Astuti et al., 2018). Virtually all starches exhibit thickener's properties, and gelling properties occur when the polymer chains of starch are joined together to form a three-dimensional network when cooled, which leads to a decrease in its viscosity and an increase in elasticity. Starches that have passed through several stages of hydrolysis have the properties of both cross-linked and esterified starches (Włodarczyk-Stasiak et al., 2017).

When choosing the appropriate type of modified starch, it is necessary to be guided by the knowledge of the effect of chemical treatment on the properties of the binding system formed by it, as well as the recommendations of manufacturers. The properties that are most suitable for the manufacture of gelling coatings that withstand heating - cooling, has the starch E1442, which we used in our study.

In the gastrointestinal tract, ether and ester bonds are easily cleave, and the assimilation of modified starches occurs in the same way as the native (Kim et al., 2017).

Egg white, traditionally used in the food industry, has high solubility, foam-and gelling properties (Duan et al., 2018; Li et al., 2018), has adhesive characteristics, increases stability and viscosity of various bio-organic systems. Moreover, the strength characteristics of systems developed with their use are increased with the raise of processing temperature, exposure time and other factors (Raikos et al., 2007). However, the quantitative limits of the introduction of egg white are limited, since it reduces the sensory properties of the finished product (elastic consistency, color dilution). It was of interest to investigate modified egg white in the composition of the coatings, which in its properties is different from liquid egg white. Large reserve of chicken egg white are formed during the production of mayonnaise, since its production uses yolk, and chicken protein here is a by-product. The by-products appearing in the technological process of the main production are raw materials for obtaining new types of full-fledged products and are not waste to be disposed of.

The use of other types of gelling agents and thickeners is also possible, but this is associated either with a decrease in the quality of the product, or with the complication of implementation and control of technological operations, or with the increased cost of the product (Chen et al., 2015). Therefore, the priority in the research presented below was the creation of a new gelling agent with the desired properties from available and cheap raw materials, the usage of binding systems and the research of the possibility of their application in the confectionery products.

MATERIALS AND METHODS

To create the egg hydrolyzate - agar (EG-A) binding system, the best mode of hydrolysis of egg white in hydrochloric acid solutions with concentrations of 0.4%, 0.6, 0.8, 1.0, 1.2 and 1.4% with liquid egg white: HCl solution ratio = 1: 2 and temperatures of 48, 54, 60, 66, 72 ± 0.5 °C for 50 minutes was determined. The egg white hydrolyzed by us is a jelly of white color The pH value was measured by pH-meter 150-MI, 1-12 pH-electrode (Measuring technique, RU). The dry solids content was determined using a laboratory refractometer of the type RL 3 (Poland).

In the recipe of the coating based on the EG-A binding system, consisting of 0.5% EG and 1% E406, starch caramel acid molasses of Novlyansky starch factory (RU) in the amount of 8, 9, 10, 11, 12, 13, 14 % was included. The dry solids content in the molasses was 78%. Adjustment of the pH of the coatings was carried out in the presence of citric acid at a concentration of 0.2%. Water was added in the amount of 46.2–48.3%. The solids content in the formulations remained constant and was regulated by changing the amount of sugar (from 38.1 to 42.8%). The coating formulations are presented in Table 1.

Table 1. Coating Formulations with EG-A Binding System

S. No.	Component name	Quantity, g for 100 g of embedding			
		No. of recipe of jellifying embedding			
		1	2*Control	3	4
1	Sugar	42.0	40.0	39.6	38.1
2	Molasses	8.0	10.0	12.0	14.0
3	Agar	1.0	1.0	1.0	1.0
4	Egg white	0.5	0.5	0.5	0.5
5	Citric acid	0.2	0.2	0.2	0.2
6	Water	48.3	48.3	46.7	46.2

The change in the mechanical characteristics of the EG depending on the concentration of the chemical reagent, as well as the effect of the content of EG-A on the properties of the coatings, were investigated using a device of the Valent type with umbrella-shaped cap with surface area of 2 cm^2. Mechanical strength of the gel was evaluated as:

$$P = m \cdot S^{-1}, \quad (1)$$

where m – a mass of weight touching the gel surface (stretch), g; S –surface area, to which the pressure is applied, cm^2.

To obtain thermostable, resistant to freeze-defrosting systems, usually use modified starches of various origins (Zhang et al., 2018). Therefore, a coating was developed that combines the properties of thermal stability, the required consistency and durability in the freezing process based on the egg hydrolyzate - starch (EG-S) binding system with 5, 6, 7, 8, 9% E1442 and 0.5% EG recipes. The sugar content in the formulation of the coating ranged from 31.7to 35.7%, citric acid –0.35%, water –58.5%. The coating formulations are presented in Table 2.

Table 2. Coating Formulations with EG-S Binding System

S. No.	Component name	Quantity, g per 100 g of embedding				
		No. of recipe of jellifying embedding				
		1	2	3	4	5
1	Sugar	35.70	34.70	33.70	32.70	31.70
2	Starch	5.00	6.00	7.00	8.00	9.00
3	Egg white	0.50	0.50	0.50	0.50	0.50
4	Citric acid	0.35	0.35	0.35	0.35	0.35
5	Carmin coloring agent	0.05–0.10	0.05–0.10	0.05–0.10	0.05–0.10	0.05–0.10
6	Flavoring agent	0.05–0.10	0.05–0.10	0.05–0.10	0.05–0.10	0.05–0.10
7	Water	58.50	58.50	58.50	58.50	58.50

The effect of the content of the EG-S binding system on the properties of the coating, as well as changes in the properties of the coatings during refrigerated storage, was determined from the values of the effective viscosity coefficient.

Coatings were stored at -8 °C for 12 days. This temperature is used at factories for the refrigerated storage of confectionery or semi-finished products for cakes. Then defrosted and again measured. In the process of research, the force applied to the system varied widely. The mass of the load varied from 8 to 62 g.

Comparison of the effective viscosity values of coatings with different EG-S contents was carried out with a load mass of 36 g. When using a load of smaller mass for coatings with a high content of the binding system, viscosity measurement is difficult because the transit time is quite long and with a larger mass of load for coatings with a low content of the binding system, its transit time is too short, which leads to a significant increase in measurement error.

The essence of the viscosity estimation method of the coating on the rotary viscometer is that the test coating is placed between two brass concentric cylinders of the viscometer – internal and external – and the internal cylinder is rotated. In this case, the internal resistance forces of the material are overcome by external force. The temperature of the investigated coating during the measurements was 20 °C.

The effective viscosity of the coating was calculated for each experiment using the equation: according to the passport for the rotary viscometer PB-8M:

$$\eta_{ef} = \kappa_{\lambda}\frac{M - M_0}{N}, \qquad Pa \cdot s \tag{2}$$

$$K_{\lambda} = \frac{Rg}{8\pi^2\left(\frac{hr_1^2 r_2^2}{r_2^2 - r_1^2} + \frac{r_1^3 r_2^3}{r_2^3 - r_1^3}\right)}, \qquad m^{-1} \cdot s^{-2} \tag{3}$$

where M – the load weight, rotating the cylinder of the viscometer, kg; M_0 the inherent friction of the bearings, which is small and corresponds to the load weight of 0.001 –0.002 kg; N – angular velocity, rad·s^{-1}; κ_{λ} – the instrument constant for a given experience, m^{-1} s^{-2}; R – the pulley radius, R = 0.02235 m; r_1 – radius of the internal cylinder of the viscometer, r_1 = 0.01605 m; r_2 – the radius of the outer cylinder of the viscometer, r_2 = 0.01905 m; h – the height of the cylindrical part of the rotation body, immersed in the product under investigation, m; g – the gravitational acceleration, g = 9.81 m s^{-2}.

The instability of gelling coatings to freezing is manifested in their tendency to syneresis after defrosting, i.e. to the separation of fluid. To assess the tendency to syneresis, frozen coating samples were placed on a funnel with a filter for defrosting, the separated liquid was collected in a graduated test-tube. The amount of separated liquid, related to the mass of the sample, served as a criterion for assessing the tendency of the coating to syneresis after defrosting. The tendency to syneresis was measured after 12 days of storage at -8 °C.

For the manufacture of jelly, frozen fruits and berries grown with the utilization of a plant growth and development stimulator were used (Kremenevskaya et al., 2017). The quick-frozen berries were coated, heat treated (in case of coating with EG-S) and then refrigerated.

The organoleptic estimation of coatings was determined by 7 highly qualified experts using the rating method according to the appearance and condition of the surface, taste and smell, consistency (set 10-point scale), color (5-point scale).

The measurements were performed with five-time repetitions. Statistical processing of the experimental data was performed by the Curve Expert 1.5.0 program at a confidence level of P = 0.95. Statistical processing of the consistency of expert opinions in determining organoleptic indicators was carried out with the STATISTIKA program by calculating the Kendall rank concordance coefficient (W) with subsequent assessment of its significance using the Pearson criterion (Kendall & Stuart, 1973) according to the equation:

$$W = \frac{12S}{m^2(n^3 - n)} \quad (4)$$

where S – the sum of the squares of the differences between the sum of the ranks studied and their arithmetic average; m – the number of experts; n – the number of objects (n = 5).

The consistency of the theoretical and statistical distribution was determined by the Pearson criterion (U) by the expression:

$$U = mwk \quad (5)$$

where $k = a^{-1}$ – the number of degrees of freedom, a –the number of estimated characteristics.

RESULTS AND DISCUSSION

Hydrolysis of liquid egg white

The results of studies related to the determination of the best concentration of the HCl solution during the hydrolysis of liquid egg white were evaluated by the strength (P) of the jelly formed. They are presented in Fig. 1.

As it can be seen from the data presented, the maximum strength of the hydrolysates obtained is observed in the case of the processing of raw materials with a chemical reagent at concentration of 1% in the presented temperature range. The decrease in concentration below 0.3% did not allow to obtain protein jelly, the formation of irregular clots was observed. Increasing the concentration of the reagent above 1.2% led to a significant decrease in the strength of the jelly. In addition, high acid concentrations increase costs.

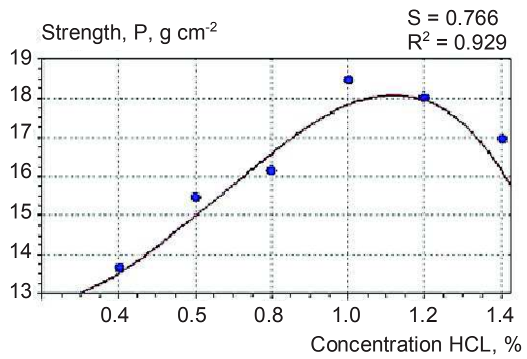

Figure 1. Dependence of the strength of egg hydrolyzed jelly at different concentrations of HCl solutions in the process of hydrolysis at the temperature of 66 °C.
P = 15.4-15.8C + 37.8-19.7, where C –the HCl concentration, where (hereafter): S –Standard deviation, R^2 –correlation coefficient.

The selection of temperature regime is associated with the fact that increasing the temperature intensifies the diffusion, distribution and binding of the reagent, the rate of protein hydrolysis increases, therefore, decreases the time of the process, but can lead to undesirable changes in the finished product. In this case, at the temperature of 72 °C, protein coagulation is observed (coagulation of native egg white happens at temperature of 58–60 °C).

With the optimum HCl concentration and temperatures of 48, 54 and 60 °C, the resulting jelly of white color is less dense, the strength values of which are, respectively, 14.2, 15.8, 16.4 g cm^{-2}. At a temperature of 66 °C, the strength of the jelly reaches 18.4 g cm^{-2}. In connection with the above, the hydrolysis temperature was assumed to be 66°C.

The duration of hydrolyzate exposure is determined by the time required for the formation of strong jellies of white color. Loss of fluidity of a viscous liquid and its transformation into a more or less elastic jelly (broth jell) occurs when bonds form between the side chains of protein macromolecules. These bonds are formed as a result of the interaction of both polar and ionized groups. Protein chains form peculiar spatial three-dimensional frameworks (grids). The best modes allow to carry out the process of rise and gradual ordering in the gelatinizing system of a spatial grid relatively quickly. When conducting research, it was found that the formation of jellies at the reagent concentration of 1%, the process temperature of 66 °C and the raw material and water ratio of 1: 2, begins as early as 15– 20 minutes after the start of the process, and they become stable after an additional 15 minutes away. Therefore, the required time of the process of hydrolysis of egg white under these conditions is 40 minutes. The pH of the hydrolyzate is 7.53, the amount of dry solids is 11.78%.

It is necessary to add that the carrying capacity of the equipment for liquid treatment, the correct management of the process, water consumption for technological needs, the degree of contamination of wastewater depends on the value of the 'raw material: solution' ratio (the so-called liquid coefficient, LC). To increase the carrying capacity of the equipment, liquid processing is advisable to conduct at lower values of the liquid coefficient.

The study of the EG-A binding system

Studies of coatings obtained on the basis of egg hydrolyzate, agar and molasses showed that in order to avoid premature gelation of the finished coating, it is necessary to thermostatize it at a temperature of 66–68 °C before use. The use of the coating should be carried out in the shortest possible time, since the gelling coating based on the proposed system should not be used prematurely because the gel re-formed after melting the coating has extremely low mechanical strength. The effect of the content of the binding system, obtained immediately after production and after reheating on the mechanical strength of the fillings, is presented in Fig. 2.

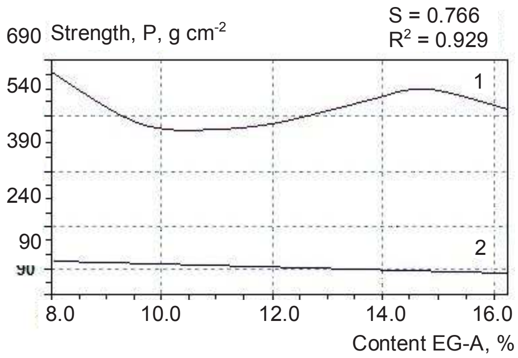

Figure 2. 1 –The effect of the content of the EG-A binding system coating on the mechanical strength; 2 –The effect of repeated heat treatment on the mechanical strength of coatings with different content of the EG-A binding system.

$P_1 = 9701 - 2203C + 173C^2 - 4.44C^3$,

$P_2 = 497 - 94.7C + 7.47C^2 - 0.194C^3$

where (hereafter) C –the content of the binding system in the coating, %.

As it can be seen from the presented data, after repeated heat treatment, the formation of a durable coating of berry raw materials in the production of confectionery is not possible.

The creation of coatings, the content of bound moisture in which is big enough, it lets reduce the cryoscopic temperature of the product and, accordingly, the temperature of the refrigerated storage. Analysis of the temperature curves showed that the cryoscopic temperature of the coating with EG-A is -8 °C. Traditionally, confectioneries are stored at 4 °C. It was of interest to determine the value of the mechanical strength depending on the content of the binding system of the coating at different temperatures of refrigerated storage.

The research results are presented in Fig. 3.

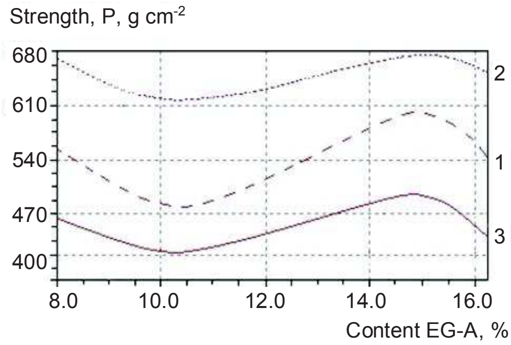

Figure 3. 1 –Dependence of the mechanical strength values of the coatings on the amount of EG-A before refrigerated storage; 2 – Dependence of the mechanical strength values of the coatings on the amount of EG-A binding system at the storage temperature of -8 °C for 12 days; 3 –Dependence of mechanical strength values on the amount of EG-A binding system at the storage temperature of 4 °C for 5 days.

$$P_1 = 9665 - 2246C + 179C^2 - 4.67C^3$$
$$P_2 = 5287 - 1118C + 87.8C^2 - 2.25C^3$$
$$P_3 = 9701 - 2203C + 173C^2 - 4.44C^3$$

Comparing the values of the mechanical strength of the coating samples with EG-A after refrigerated storage with the values of samples that have not been subjected to storage, it can be seen that for all coatings, regardless of the percentage of binding systems introduced into them, the following is observed. The values of mechanical strength increase when stored for 12 days under conditions of near cryoscopic temperature of -8 °C and decrease when stored for 5 days under traditional conditions (4 °C).

The decrease in mechanical strength during storage is typical for jellies, which contain an agar component, and this is mainly due to a violation of the spatial structure of the gel by reducing the properties of the hydrocolloid. Apparently, at near-cryoscopic temperatures, these processes are slowed down; moreover, by reducing the thermalmotion of the molecules, the gelling agent is able to form a more durable gel. The best strength values of all three coating samples are observed when using 14.5% EG-A.

The presence of two maxima on the dependency diagrams of the jelly's mechanical strength on the content of the binding system in the coating can be explained in the first case by matching the optimum sucrose content, in the second - by the pH value. Such changes in the values reflected in the curves are possible due to the introduction of molasses into the binding system. The monosaccharides that make up the molasses have a lower dehydrating capacity than sucrose, therefore, an increase in the molasses content due to a decrease in the sugar content may lead to a decrease in the gel strength. However, the molasses have an acidic reaction of the medium (pH = 4.0–4.5), and the pH value has a significant effect on the strength and optimum temperature of the jellies (i.e., the temperature at which their strength is maximum). Thus, with an increase in the content of molasses by reducing the amount of sugar, the pH of the medium may decrease so much that the strength of the jelly will increase (Gao et al., 2017). It is impossible to completely abandon the use of molasses during the creation of the binding system, since in this case saccharification of the coating during the refrigerated storage may occur.

When gelling frozen fruits (raspberries, cherries) and berries (black currants) with freshly prepared EG-A based coatings and their subsequent storage, phenomena that impair the quality of the product were observed to varying degrees, the main features of which were deformation of the film and oxidation of its surface. An organoleptic evaluation showed that after refrigerated storage, the oxidation of the gelled berries is not observed in all samples of black currant. In samples of raspberries, no oxidation of the fruits is observed in the case of their coating of 14.5% EG-A, and with a decrease or increase in the percentage of the binding system, a slight oxidation occurs. When coating the quick-frozen cherries with a content of 14.5% EG-A, there is a minimal oxidation of the fruits; with 9.5 and 15.5% the maximum oxidation of the samples is observed. Deformation of all types of fruits and berries is not observed after storage in the coating with 14.5% of the binding system and is insignificant for samples at 11.5, 13.5% and 15.5%. For cherries, the deformation at 11.5 and 13.5% was also insignificant, and at 15.5% was strongly pronounced. Color changes and the phenomenon of syneresis for all samples were minimal even at 13.5% of the binding system. The area of the uncovered surface of fruits and berries at 9.5 and 11.5% of the system was 20%, at 13.5 and 15.5% –10%.

The thickness of the coating film with EG-A, which forms on the surface of the fruit or berry, ranges from 0.5 to 1.0 mm. Moreover, the formation of a thinner film is characteristic for coatings with lower strength. A sample having a 15.5% of binding system has a crumbly consistency. There are difficulties with filling of raspberries. Raspberries are one of most sensitive fruits and most quickly deteriorating. Also, it has a high water content and due the binding effect may suffer. For sure, the hairy surface will affect the filling as well. The surface of the berry is not fully covered, possibly due to the high surface tension coefficient of the 'hairy' surface of the raspberry. The appearance of the empty surface deteriorates during storage and the surface dries out.

When strictly follow the technology of coating quick-frozen fruits and berries (with an exposure after coating for up to 10 minutes for gelation), it may be obtained a product that does not change its consumption properties when stored at –8°C for 12 days. As the first layer, a coating with 0.5% hydrolyzed egg white, 1.0% agar and 13.0% molasses (strength of 580 g cm^{-2}) was used, for the second layer, a coating with 0.5% hydrolyzed egg white was used, 1.0% agar and 10.0% molasses (strength of 480 g cm^{-2}). The first layer creates a solid capsule around the fruits and berries, preventing the processes of destruction from proceeding, the second layer allows to obtain a uniform coating.

EG-S based binding system study

When creating a system with the addition of hydroxypropyl distarch phosphate, the coating is with a viscous gelled structure, and has thermostable properties being resistant to freeze-defroster cycles. The effect of the EG-S binding system on the viscous properties of the coating is shown in Fig. 4.

For non-Newtonian fluids, viscosity is not a constant, but a function of the force applied to the system. In the process of freezing and refrigerated storage, the viscosity of the coatings slightly increases. This may be due to partial extraction of solutes into the aqueous phase during freezing or with partial drying of the coating during storage. The change in the dependence of the effective viscosity coefficient of the coatings on the amount of EG-S after refrigerated storage is similar. The deviation of values is no more than 5%. The resistance of the coatings to freezing and refrigerated storage was determined indirectly by the value of syneresis. The graph based on the measurement results is presented in Fig. 5.

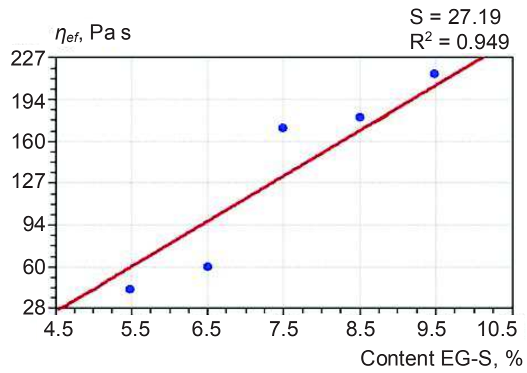

Figure 4. Dependence of the effective viscosity (η_{ef}) coefficient of coatings on the amount of EG-S applied before refrigerated storage.
$\eta = 181 + 45C$

It can be seen that the introduction of the binding system in the amount of 7.5 and 9.5% prevents the process of syneresis and practically no moisture is released. The use of binding systems in confectionery production allowed to develop technologies of products' coating using quick-frozen fruits and berries as decoration.

Fruits and berries covered with EG-S, pre-placed on a test basis, and baked. All coatings used showed thermal stability properties for 10–15 minutes at a temperature of 200–220 °C. The finished products were stored at a temperature of -8 °C for 10 to 12 days. Then determined the condition of the berries. For all types of fruits and berries, the best performance was achieved with the use of 7.5 and 8.5% binding systems - no browning, deformation of the fruit, uncoated surface of the fruit and wetting of the test substrate. The maximum changes were found at 5.5% and 9.5% EG-S. When making a binding system in an amount of more than 8.5%, the viscosity of the coatingincreases and its uniform distribution over the surface of the dough piece, especially fruits, is significantly hampered. In addition, a further increase in the content of starch in the coating adversely affects its taste. When making the system in an amount of less than 5.5%, there is a strong wetting of the dough base and deformation of the fruit during baking. The optimal content of the binding system in the coating: for the top layer - 5.2–6.3% (easily distributed over the surface of fruit, the viscosity is 50–90 Pa s); for the lower layer - 6.9–7.7% (dense enough so that the fruit would

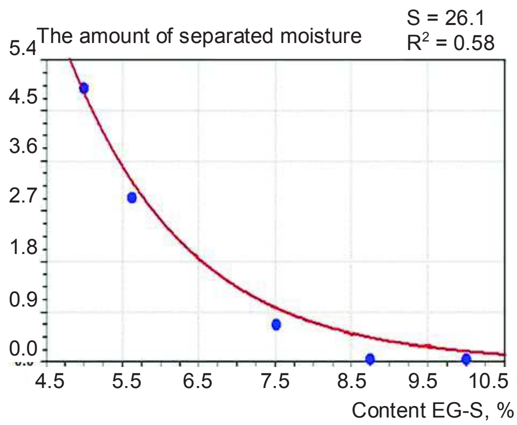

Figure 5. Dependence of the amount of separated moisture (M) of the filling after freezing with a different amount of the binding system.
$M = 386e^{-0.795C}$

remain on its surface in a state of indifferent equilibrium, the viscosity is 120–180 Pa s).

Organoleptic studies have shown that the surface of the coatings in all samples before and after refrigerated storage was glossy. The consistency of the samples with a 5.5% binding system had the structure of a thick jelly (berry starch drink) (short droplet type), with 6.5% and higher - a soft jelly. The aroma in all samples was intense, specific to fruits and berries, the taste is sour, pleasant The scoring of the cakes by experts is presented in Table 3.

Table 3. Tasting sheet of the cakes with the EG-S binding system

S.No.	Expert	Taste, smell	Consistency and appearance	Colour
1	1	8	7	4
2	2	8	7	3
3	3	8	7	5
4	4	7	8	3
5	5	7	8	5
6	6	7	8	5
7	7	8	7	4

Statistical studies of the organoleptic evaluation of confectionery by experts showed a strong consistency of expert opinion, since the value of the concordance U was 0.75, which exceeds the threshold value (w > 0.7). Its calculated significance by the Pearson criterion is 10.5. The critical values of the Pearson correlation at 2 degrees of freedom, 1 and 5% significance levels are, respectively, 9.210 and 5.991, which is less than the calculated value. This suggests that, at a significance level of 1%, the estimated coefficient of concordance can be taken as significant.

The use of binding systems in the production of confectionery has allowed the development of coating technologies for products made using quick-frozen fruit and berry products.

CONCLUSIONS

Research related to obtaining new products from resources, which are usually disposed of or part of them is used in a limited food sector, seems to be relevant. With minimal investment and the simplicity of the production technology, it is possible to obtain ingredients with specified properties, which, in turn, directly change the properties of products produced with their use.

It was established that hydrolysis of liquid egg white at the concentration of 1% HCl solution, the process temperature of 66 °C, the raw material and water ratio of 1: 2 for 40 minutes allows to obtain a product with strength characteristics.

The obtained data of the mechanical strength of various binding systems, which included hydrolyzed egg white, made it possible to develop a coating technology for quick-frozen berries for confectionery. At first, the fruits and berries are immersed in the system with EG-A, characterized by high strength values (570–590 g cm^{-2}). Then, the gelatinized berries are covered with a new coating layer, which has lower strength indices (470–490 g cm^{-2}). The first layer creates a solid capsule around the berries, preventing the processes of destruction from proceeding, the second layer allows to obtain a uniform coating.

The use of the technology described above allowed us to obtain a product that did not change its consumption properties when stored at -8 °C for 12 days. Moreover, the condition of the product stored under the proposed modes (-8 °C 12 days) was better than the product stored under the traditional modes (120 hours at 4 ± 2 °C).

In case of using a binding system made of egg white ingredient and modified starch in the coating, the coating with a binding system content of 5.5–6.5%, having an effective viscosity of 45–60 Pa s was used for the upper layer. The EG-S binding systems with such indicator values allow the coating to be easily distributed over the surface of the fruit or berry, including quick-frozen raw materials. For the lower layer, it is better to use EG-S with a binder content of 7.2–7.6%, having a sufficiently thick texture (130–180 Pa s), so that the fruit remains on its surface in a state of indifferent equilibrium. Coatings with EG-S have thermostable properties and can be used for coating berry and fruit raw materials in confectionery developed for 10–15 minutes at a temperature of 200–220 °C. Finished products can be stored at near-cryoscopic temperatures for 10–12 days, while maintaining high consumer properties.

When conducting organoleptic studies by experts, the high quality of the presented samples was revealed. The high convergence of the results suggests the correctness of the statistical study.

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