

## INFLUENCE OF DIETARY SUPPLEMENT BASED ON HEME IRON ON DOUGH PROPERTIES AND QUALITY OF ANTIANEMIC CUPCAKES

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### Abstract

Providing the diet of all segments of the population with sufficient organic iron is an urgent problem today. The work aims to study the effect of a dietary supplement based on heme iron on the properties of gluten, dough, and the quality of antianemic cupcakes.

Test samples of prescription compositions of cupcakes were obtained by co-administration of a dietary supplement with ferrous iron ("Redham" from the blood of slaughter animals) and esters of citric acid, mono-, and di-glycerides of fatty acids. The content of gluten in the test samples, its elasticity, elongation, hydration ability was determined by the mechanical method. The microstructure of the study objects was determined by microscopy. The viscosity of the dough was measured on a rotary viscometer with a controlled shear rate, the value of which depends on the speed and the size of the gap between the cylinders, in one of which was placed the test samples. The strength of adhesion of model samples of the test was investigated on the device of Boris Nikolaev, where the force of separation, attributed to the contact area, is realized. The alkalinity of the cupcakes was determined by acid titration, the specific volume of the cupcakes - by measuring the volume of bulk filler extruded by the product, and then dividing the volume of the product by its weight. The process of hardening of cupcakes was controlled by changing the structural and mechanical properties of

the crumb, determined using a penetrometer AP-4/1, and its brittleness. Given the daily requirement of an adult in iron, we created prototypes of cupcakes with the introduction of dietary supplement "Redham" in the amount of 4, and 6% of the total mass.

The addition of "Redham" to cupcakes deteriorate the rheological properties of gluten, dough and contributes to the production of finished products in a reduced volume, with a too dense crumb, less resistant to hardening. To improve the quality of cupcakes with a mass fraction of "Redham" with 4 and 6%, we used citric acid esters, and mono- and diglycerides of fatty acids, which were pre-mixed with a dietary powder additive. As a result, the value of the brittleness index in the samples increased by 1.48 and 1.44 times, respectively, the total deformation of the crumb after 7 days of storage - by 1.1 and 1.2 times, respectively, and the specific volume of products increases by 1.1 times.

Obtained flour confectionery products characterized by the content of ferrous iron can be recommended for mass (4% "Redham" content), and therapeutic and prophylactic (6% "Redham" content) consumption, which should be confirmed with a further clinical studies.

**Key words:** Flour confectionery, Dietary supplement, Ferrous iron, Surfactant, Quality and safety indicators.

## 1. Introduction

One of the current challenges today is to provide the diet of all segments of the population with sufficient organic iron, the deficiency of which or the inability of the body to absorb and accumulate it in sufficient quantities cause iron deficiency, which can lead to iron deficiency anemia [1].

Flour confectionery products are the most popular products among all groups of the population, which is why these products are the most convenient for the correction of nutritional and biological values, in particular, the iron content.

The effectiveness of the use of dietary supplements based on heme iron has been confirmed. Thus, scientists have developed some dietary supplements based on food blood, and plant raw materials - "Redham", "Kalgem", "Phytogem" and proved that the introduction of these additives in fruit and berry fillings and replicated iris contributes to the enrichment of heme iron and allows to expand the range of this product for mass and therapeutic and prophylactic purposes [2, 3].

Dietary supplement (DS) "Redham", which is obtained by drying with mixed heat (MH drying) from the blood of cattle and dried crushed rose hips [4], has a dispersion  $10 - 30 \times 10^{-6}$  m, certain functional and technological properties and due to the content of easily digestible ferrous iron provides a given physiological direction of food products.

Dietary supplements that contain heme iron are widely used to enrich different groups of foods. However, their inclusion in flour confectionery products affects the quality of finished products such as taste, porosity, color, moisture content of the crumb, etc. Therefore, to establish the possibility of using a DS "Redham" as an enrichment of flour confectionery, it is necessary to take into account the prescription composition, the optimal dosage, and method of application.

The aim of the work is a scientific study of the effect of a dietary supplement based on heme iron on the properties of gluten, dough, and the quality of cakes of antianemic direction.

## 2. Materials and Methods

To create experimental recipe compositions for cupcakes, the technology of nut cake was used as a base [5]. Test samples were obtained by adding a DS "Redham" to wheat flour in the amount of 4, 6, and 8 % of the total weight.

The content of gluten in the test samples, its elasticity, elongation, hydration ability was determined by the mechanical method. Microstructure of the study objects

was determined by microscopy. Viscosity of the dough was measured on a rotary viscometer with a controlled shear rate, the value of which depends on the speed and the size of the gap between the cylinders, in one of which was placed the test samples [6].

Strength of adhesion of model samples of the test was investigated on the device of Boris Nikolaev, where the force of separation, attributed to the contact area, is realized. The alkalinity of the cupcakes was determined by acid titration, the specific volume of the cupcakes - by measuring the volume of bulk filler extruded by the product, and then dividing the volume of the product by its weight. Process of hardening of cupcakes was controlled by changing the structural and mechanical properties of the crumb, and determined using a penetrometer AP-4/1, and its brittleness. Given the daily requirement of an adult in iron, we created prototypes of cupcakes with the introduction of dietary supplement "Redham" in the amounts of 4 and 6% of the total mass [7, 8].

## 3. Results and Discussion

According to the norms of the physiological needs of the population in minerals, the daily requirement of an adult for iron is on average 15 mg for men and 17 mg for women. Of this amount, at least 2 mg should be heme iron [1]. The main requirements for iron-containing additives are that they should not: give food products foreign taste, odor, color; accelerate spoilage of products during storage, and should dissolve well in an acidic environment; to form iron salts capable of transitioning into an ionic form available for assimilation; and the particle size of reduced iron should be 5 - 10  $\mu$ m [9].

Given the above information, appropriate calculations were made for the mass fraction of DS "Redham" in the recipe composition of cupcakes, which allows you to make heme iron in flour confectionery depending on their recommended physiological purpose: for mass consumption (1 - 2 mg heme iron/100 g product), therapeutic and prophylactic purposes (2 - 3 mg of heme iron/100 g of product), and for therapeutic purposes (3 - 4 mg of heme iron/100 g of product).

Taking into account this information and the content of heme iron in DS "Redham" (in the amount of 0.55 g/kg), the mass fractions of this dietary supplement - 4, 6, and 8% by weight of the recipe composition of cupcakes (or 12, 18, and 24% by weight of wheat flour), which allow enriching flour with ferrous flour, depending on the purpose.

Given this, the selected dosages of DS "Redham" to some extent will affect the structural and mechanical properties of the dough and the quality of the cakes, which depends primarily on its effect on the properties

of gluten. Therefore, at the first stage, the gluten content, its elasticity, elongation, hydration ability when adding DS «Redham» were investigated (Table 1).

As can be seen from the table. 1, the addition of DS “Redham” leads to a decrease in the content of crude gluten both after  $20 \times 60$  s after kneading the dough (8 - 17%) and after  $180 \times 60$  s its autolysis (6 - 13%), and its strengthening.

From the obtained data it turns out that the denatured proteins of the blood of cattle and fiber of rose hips in the composition of DS “Redham” do not participate in the formation of gluten, so its yield is reduced.

The hydration capacity of gluten proteins in the dough with DS “Redham” decreases and is confirmed by the data obtained on the device IDK, and by elongation. Reduction of gluten spreading with “Redham” is probably associated with slowing of proteolysis under the influence of iron ions.

Strengthening of gluten is also facilitated by the presence of fiber contained in the additive due to rosehip powder (4% by weight of the prescription composition of the additive (0.4%)), its hydrophilicity. The spread of gluten washed from the dough with DS “Redham” is also reduced. This is since the associative ability of the molecules of denatured protein DS “Redham” to water molecules is less pronounced than native vegetable proteins, which contributes to the redistribution of moisture in the system. The data obtained are the basis for predicting a reduced volume

of cupcakes with the addition, especially with the maximum dosage (8%) of DS “Redham” in the recipe composition.

The next stage of research was to determine the effect of selected dosages of DS “Redham” on the properties of the finished product (Table 2).

As can be seen from Table 2, the maximum dosage of DS “Redham”, which is 8% by weight of the prescription composition, has a negative effect on the organoleptic properties of cupcakes: the products acquire a foreign taste, smell, color.

The data obtained show that during the heat treatment there is a transition of part of ferrous iron to trivalent, which gives a grayish-brown color of the cake crumb. In addition, iron reacts with sulfur, which is released from the sulfur-containing amino acids of egg white during a heat, resulting in the formation of ferrous sulfate and giving a grayish crumb to the cake.

Table 2 data indicates that the specific volume of cakes is reduced by 2 - 10.4% compared with the control in the samples with the addition of DS “Redham”, which is associated with the replacement of flour with an additive that harms the properties of gluten, has low moisture and fat retention capacity, due to which the compaction of the structure of the finished product.

The alkalinity of cupcakes increases with increasing dosage of DS “Redham”, due to its pH value, which is 7.5 versus 5.9 in wheat flour [10]. The amount

**Table 1. The effect of DS “Redham” on the quantity and quality of gluten**

Indicator	Premium wheat flour - control	The value of the indicator in the test with DS “Redham”, % by weight of the prescription composition		
		4	6	8
<b>Crude gluten content, %:</b>				
Initial	28.7 ± 2.2	26.3 ± 2.2	24.9 ± 2.2	23.8 ± 2.2
Terminal	30.1 ± 3	28.2 ± 2.2	27.2 ± 2.2	26.2 ± 2.2
<b>Hydration, %:</b>				
Initial	175 ± 17	171 ± 17	165 ± 16	160 ± 16
Terminal	209 ± 20	201 ± 20	198 ± 18	194 ± 19
<b>Elasticity, units device:</b>				
Initial	65 ± 6	62 ± 6	60 ± 6	58 ± 5
Terminal	75 ± 7	73 ± 7	71 ± 7	69 ± 6
<b>Elongation, cm:</b>				
Initial	9 ± 0.9	9 ± 0.9	8 ± 0.8	7 ± 0.7
Terminal	15 ± 1	14 ± 1	13 ± 1	12 ± 1
<b>Elongation, s</b>				
Initial	22 ± 2	20 ± 2	19 ± 1	18 ± 1
Terminal	35 ± 3	31 ± 3	30 ± 3	27 ± 2.5
<b>Dry gluten content, %:</b>				
Initial	10.3 ± 1.1	9.2 ± 0.9	8.6 ± 0.8	7.7 ± 0.7
Terminal	9 ± 0.9	9 ± 0.9	8.4 ± 0.8	7.5 ± 0.5

**Table 2. The impact of DD "Redham" on the quality of cupcakes**

Indicator	Nut Cupcake - control	Cupcake with DS «Redham», % by weight of the prescription composition		
		4	6	8
<b>Appearance</b>	The product is the correct shape of the cake, the surface is smooth, sprinkled with powdered sugar	The product is the correct shape of the cake, the surface is smooth	The product is the correct shape of the cake, the surface is smooth, the volume of the product is slightly reduced	The product is the correct shape of the cake, the surface is smooth, the volume of the product is reduced
<b>Taste</b>	Pleasant vanilla-nut, without extraneous flavors	Pleasant vanilla-nut, without extraneous flavors	Pleasant vanilla-nut, with a slight taste of the additive	An extraneous bitter taste appears
<b>Scent</b>	Pleasant vanilla-nut, without foreign odors	Pleasant vanilla-nut, without foreign odors	Pleasant vanilla-nut, with a light aroma	Pleasant vanilla-nut, with a light aroma
<b>Color</b>	The crust is brown, ruddy, the pulp is yellow	The crust is brown, the pulp is light brown	The crust is brown chocolate, the crumb is brown	The crust is brown, the pulp is dark brown
<b>Consistence</b>	The pulp is fine-grained, dense, baked, without traces of impermeability, the section shows evenly distributed nuts	The pulp is fine-grained, dense, baked, without traces of impurity, the section shows evenly distributed nuts	The pulp is fine-grained, dense, baked, without traces of impurities, the section shows evenly distributed nuts	The pulp is fine-grained, dense, baked, without traces of impurities, the section shows evenly distributed nuts
<b>Specific volume, cm<sup>3</sup>/100 g</b>	250.2 ± 25	242 ± 20.1	237 ± 23	224 ± 20.1
<b>Alkalinity, deg.</b>	2 ± 0,1	2 ± 0.1	2.2 ± 0.2	2.4 ± 0.2
<b>The content of ferrous iron, %:</b>				
<b>Before baking</b>	-	38 ± 3.1	40 ± 4	42 ± 4.1
<b>After baking</b>	-	32 ± 3.1	30 ± 3	27 ± 2
<b>Crumbliness of crumb, %</b>				
<b>In 1 day</b>	0.90 ± 0.08	1 ± 0.1	1.3 ± 0.1	1.9 ± 0.1
<b>In 7 days</b>	4.9 ± 0.4	6.7 ± 0.5	7.2 ± 0.5	7.8 ± 0.5
<b>Total deformation of the crumb, units penetrometer</b>				
<b>In 1 day</b>	142 ± 14	142 ± 14	142 ± 14	142 ± 13.5
<b>In 7 days</b>	132 ± 13	123 ± 12	115 ± 11	106 ± 10.5
<b>The amount of ferrous iron, %:</b>				
<b>In 1 day</b>	-	32 ± 1	30 ± 3	26 ± 2
<b>In 7 days</b>	-	30 ± 1	28 ± 2	23 ± 2

of ferrous iron during the baking of cakes with DS "Redham" is reduced by 16 - 35%, which is associated with the transformation of its share under the action of temperature (at a crust of 140 °C), and oxidative processes. However, the stability of iron from significant losses is partially provided by β-carotene contained in rosehip powder.

Addition of DS "Redham" reduces the shelf life of the fragility of cupcakes by 1.1 - 1.2 times, and the total deformation of the crumb by 7 - 20%. During storage, the loss of ferrous iron is 20%. Thus, it should be noted that the introduction of DS "Redham" in the recipe of cupcakes negatively affects the rheological properties of gluten, dough and leads to finished products of reduced volume, with a too dense crumb, less resistant to hardening compared to the control

sample. Given this, to improve the quality of flour confectionery products with DS "Redham" in dosages of 4 and 6% by weight of the prescription mixture, it may be appropriate to use improvers with a directed technological function - surfactant.

In order to improve the structural and mechanical properties of the dough and the quality of the finished products using DS "Redham", citric acid ester mono-, diglyceride of fatty acids was selected. According to the recommendations of the literature and the manufacturer, the optimal dosage of surfactants for flour confectionery is 1% by weight of the prescription composition.

The peculiarities of the proposed recipe for cupcakes, including the combined use of DS "Redham" and surfactants, determined the need to clarify the effect

of surfactants on the particles of dietary supplements, and, consequently, the safety of ferrous iron during heat treatment and storage.

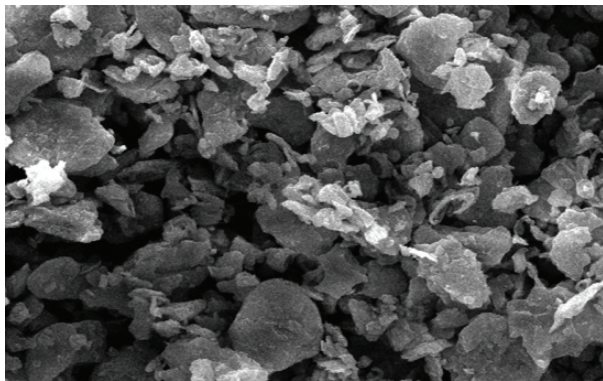
It should be noted that surfactants contain antioxidants -  $\alpha$ -tocopherol 0.3%, ascorbyl palmitate 0.3%, which is an important factor in stabilizing divalent iron in the supplement.

Model systems were selected for the experiment, which consists of the ratio of DS "Redham" and surfactant

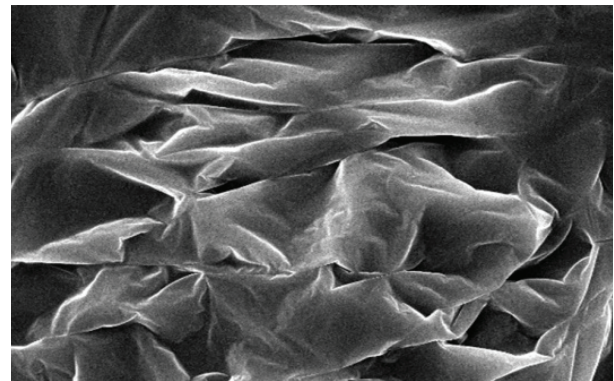
as 4 : 1 or 6 : 1, which corresponds to the number of components in the recipe composition of cupcakes with 4 and 6% additives, respectively.

The structure of model systems was studied by microscopic method - Figure 1.

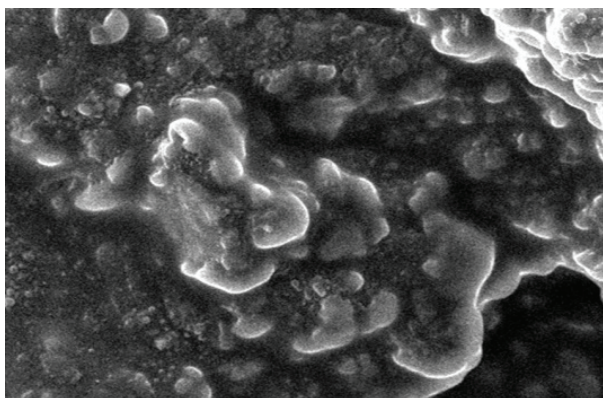
As can be seen from Figure 1, when comparing the particles of DS "Redham" and with the addition of surfactants, regardless of their ratio, there is a wrapping of each particle or aggregated particles with a surfactant.



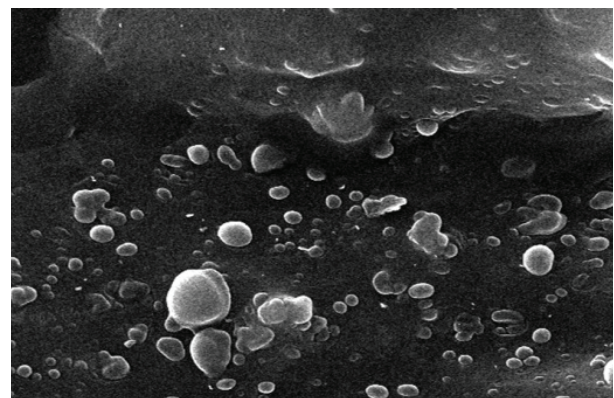
DS particles "Redgem"  
( $\times 200$ )



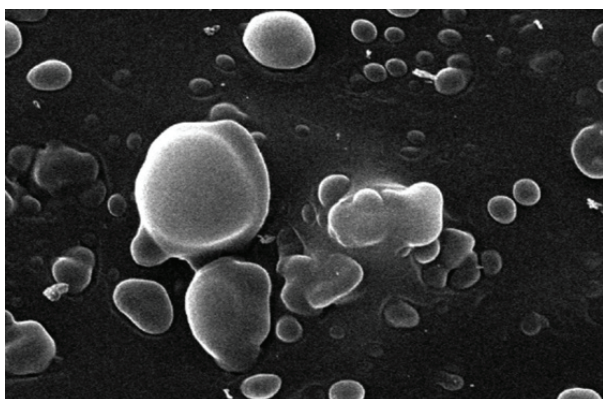
Surfactant (freeze-dried)  
( $\times 750$ )



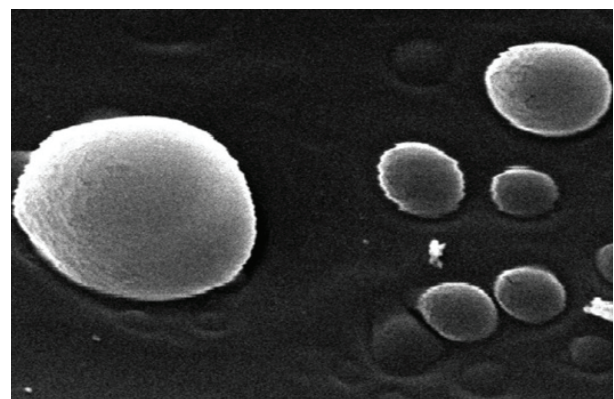
Suspension DS "Redham" and emulsifier  
(4 : 1) ( $\times 200$ )



Suspension DS "Redham" and emulsifier  
(4 : 1) ( $\times 1000$ )



Suspension DS "Redham" and emulsifier  
(4 : 1) ( $\times 3000$ )



Suspension DS "Redham" and emulsifier  
(4 : 1) ( $\times 10000$ )

**Figure 1. Microstructure of DS particles "Redham" with emulsifier**

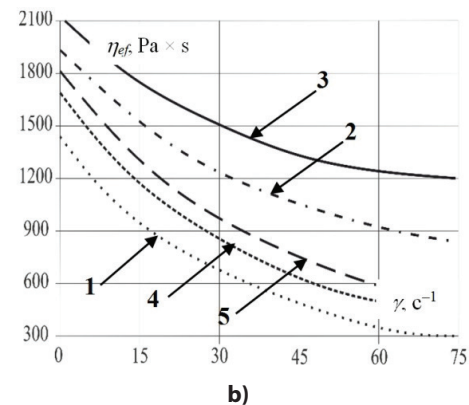
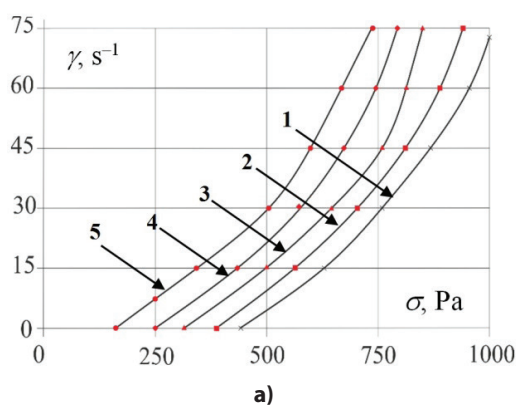
By gradually enlarging the image of the structure of an individual particle of the additive, it is shown that a surfactant shell is formed on its surface, which tightly covers it in volume, preventing the effects of oxygen.

In Figure 1 is shown an image of a surfactant, which was pre-dried by the method of microstructural studies. As can be seen, the substance forms a film after drying, and, therefore, in the native state at the specified ratio contributes to the envelopment of each particle of the additive, preventing oxidative or thermal transformation. The action of surfactants can be explained from the following positions: first, the surface of DS particles of "Redham" is characterized by the presence of hydrophobic groups formed during thermal coagulation of protein molecules in cattle, so there are hydrophobic interactions of nonpolar (hydrophobic) groups of protein on the surface and the hydrophobic end of the surfactant, which is an ester of citric acid, mono-, diglyceride of fatty acids; secondly, DS "Redham" has formed during MH drying capillary-porous structure, which provides penetration and retention of the surface and pores of the pasty surfactant; third, the irregularity and looseness of the DS Redham particle shape without surfactants increases the activation energy, which causes poor interaction between the particles, while its spherical shape with surfactants helps to reduce the specific interaction surface at maximum volume.

The purpose of further research was to study the improving effect of surfactants on the properties of the dough and the quality of cakes with DS "Redham".

Investigated the effect of DS "Redham" and surfactants on the structural and mechanical characteristics of the dough are resented in Figure 2.

As can be seen from Figure 2, the dough with DS "Redham" with the addition of surfactants has a value of the shear stress of 1.8 times greater than that of the control sample.

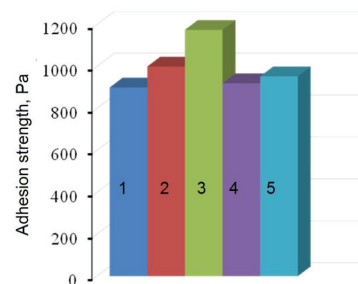


**Figure 2. Limit shear stress (a) and dynamic viscosity of the dough (b): 1 - control; 2 - with 4% DD "Redham"; 3 - with 4% DD "Redham" and emulsifier; 4 - with 6% DD "Redham" and emulsifier**

A similar trend is observed for the viscosity of the dough, which is associated with a low value of moisture-retaining and emulsifying ability of the additive, which causes thinning of the dough, but the addition of anionic surfactants reduces the negative impact of the additive and strengthens almost intact structure 1.7 - 2.3 times compared to the test without surfactants. This is since the introduction of surfactants, which have hydrophilic and hydrophobic components, changes the internal structure of the dough, its strength increases, and approaches the value of the control.

Thus, the results of the study of structural and mechanical properties of the dough with DS "Redham" and surfactants showed that the addition increases the viscosity of the semi-finished product, the improver forms a thicker consistency of the dough, which will affect the consistency of the crumb and the finished product.

In addition to the shear stress and viscosity of the dough, an important technological factor is its adhesion, which requires the selection of the material of the work surface for the formation of dough blanks and baking products. The results of the study of the adhesion strength of the dough for cupcakes are shown in Figure 3.



**Figure 3. Adhesion strength of the dough for cupcakes: 1 - control; 2 - with 4% DD "Redham"; 3 - with 4% DD "Redham" and emulsifier; 4 - with 6% DD "Redham" and emulsifier**

As can be seen from Figure 3, the addition of DS "Redham" leads to the formation of a sticky structure of the dough, which is 1.1 - 1.3 times stronger than the control value.

The selected dosage of surfactants, which has a "crosslinking" effect on the dough, allows to give it an anti-adhesive character at the level of the control sample, which is an important aspect of technology and can predict the quality of finished products with the joint use of DS "Redham" and surfactants.

Therefore, the next stage of research was to study the effect of combined dosing of DS "Redham" and surfactants on the quality of finished products (Table 3).

As can be seen from the Table 3, the addition of surfactants significantly improves the quality of cakes, especially - the specific volume, consistency, resistance to hardening. The value of the brittleness in cakes with DS "Redham" 4 and 6% by weight of the prescription mixture and surfactants increases by 1.48 and 1.44 times, respectively, the total deformation of the crumb after 7 days of storage - 1.1 and 1.2 times respectively. Currently, the specific volume of products increases 1.1 times from the sample that does not contain surfactants, and close to the control (Figure 4).

However, the main advantage of the application of surfactants is the effect on the safety of ferrous iron during baking, which is 2.6 and 3.5%, which is 6.2 and 7.1 times more than the samples with DS "Redham"

without the introduction of surfactants.



a)



b)



c)

**Figure 4. Cupcakes with addition (sectional view):**  
a - cocoa powder; b - DS "Redgem";  
c - DS "Redham" and surfactants

**Table 3. Influence of DS "Redham" and surfactants on the properties of cupcakes**

Indicator	Cupcakes with DS "Redham", % by weight of the prescription composition, and surfactants	
	4	6
<b>Appearance</b>	Product volume at the control level	Product volume at the control level
<b>Taste and smell</b>	Pleasant vanilla-nut, without extraneous flavors	Pleasant vanilla-nut, with a light taste of the additive resembling cocoa powder
<b>Color</b>	The crust is brown, the pulp is light brown	The crust is brown chocolate, the crumb is brown chocolate
<b>Consistence</b>	The pulp is fine-grained, dense, baked, without traces of impermeability, the section shows evenly distributed nuts	The pulp is fine-grained, dense, baked, without traces of impermeability, the section shows evenly distributed nuts
<b>Specific volume, cm<sup>3</sup>/100 g</b>	252.2 ± 20.1	250 ± 23.1
<b>The amount of ferrous iron, %:</b>		
<b>Before baking</b>	38 ± 3.1	40 ± 3.1
<b>After baking</b>	37 ± 3.1	38.6 ± 3
<b>Crumb fragility, %:</b>		
<b>In 1 day</b>	1 ± 0.1	1.3 ± 0.1
<b>In 7 days</b>	4.5 ± 0.4	5 ± 0.4
<b>General deformation of the crumb, units penetrometer:</b>		
<b>In 1 day</b>	144 ± 10.5	145 ± 11.5
<b>In 7 days</b>	130 ± 11.5	135 ± 11.5
<b>The amount of ferrous iron, %:</b>		
<b>In 1 day</b>	37 ± 3.1	38.6 ± 3
<b>In 7 days</b>	36.5 ± 3	37.5 ± 3

#### 4. Conclusions

- As a result of the conducted researches the expediency of using DS "Redham" and ester of citric acid and mono-, diglycerides of fatty acids in the technology of cakes of antianemic direction was confirmed.
- It was found that the optimal weight of the recipe composition of cupcakes is the dosage of DS "Redham" in the amount of 4 and 6% and ester of citric acid and mono-, diglycerides of fatty acids in the amount of 1 %.
- Experimentally confirmed the feasibility of using as a technological method of pre-mixing DS "Redham"» and surfactants before adding to the recipe composition of the dough, which allows to wrap the additive particles with surfactant in the dough, stabilize rheological properties and increase its resistance to thinning, help reduce losses ferrous iron during baking and storage of products.
- The obtained flour confectionery products are characterized by high-quality indicators and the content of ferrous iron can be recommended for mass (4% DS "Redham") and therapeutic and prophylactic (6% DS "Redham") consumption, respectively.

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