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Advantages of electric resistance method for baking bread and flour confectionery products of functional purpose

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Abstract. In this paper we studied the effect of the baking method on the preservation of beta-carotene in two types of products: pan wheat bread and sponge cake. Five sources of beta-carotene were used in the study, three of which are commercially available samples, and the two others are experimental samples of supramolecular complexes of beta-carotene with alpha- and beta-cyclodextrins in powder form (molecular ratio 1: 1). Bread and sponge cake were baked by convective and electric resistance methods. The values of temperature and current flowing through the dough were monitored during electric resistance baking. The beta-carotene content was measured in the dough after kneading, in the cake batter after mixing and in the finished products after baking and cooling. The beta-carotene content was evaluated by spectrophotometry after extraction. The control samples of bread and sponge cake were baked without adding beta-carotene. Different sources of beta-carotene exhibited varying stability in bread and sponge cake. Bread samples baked by the electric resistance method with addition of supramolecular complexes had minimum losses of beta-carotene. Electric resistance baking ensured lower losses of beta-carotene in bread and sponge cake samples.

Key words: beta-carotene, bread, electric resistance baking, sponge cake, supramolecular chemistry.

INTRODUCTION

The development of the modern food industry is characterized by the creation of new types of products with high nutritional value intended for dietary and functional purposes. It explains an interest in methods of processing raw materials that allow to preserve the maximum possible amount of useful nutrients and to obtain a high-quality product that meets modern safety standards.

Integrity of functional ingredients in consumer products can be achieved in several ways. One of them is microencapsulation. It is used to reduce the loss of nutritional value of food, to increase the stability of the properties of microingredients, etc. (Gonçalves et al., 2016; Sepelevs & Reineccius, 2018; Baranenko et al., 2019) Starches, sugars, cellulose, lipids, animal and vegetable proteins, surfactants are mainly used as encapsulating materials (Nik et al., 2011; Trentin A.et al., 2011; Zabodalova et al., 2014; Yi et al., 2015). Another method is creation of supramolecular inclusion complexes. Formation of an inclusion complex affects physicochemical properties of the embedded molecule. Therefore, supramolecular complexes are obtained in order to enhance or alter any of the physicochemical properties of so-called guest substances (Mercader-Ros et al., 2010; Jin Z.-Y., 2013; Kurkov & Loftsson, 2013; Mangolim et al., 2014; Rudometova & Nikiforova, 2016).

Degradation of labile substances can also be reduced by the use of gentle technological processing modes (Strizhevskaya et al., 2019). One of these methods of bread baking is based on the use of the electric resistance (ER) heating method instead of the traditional convective heating (C) method. ER baking is characterized by a high heating rate and a lower maximum process temperature, reaching up to 100 °C (Derde et al., 2014), while C baking is carried out at a temperature of the air in the oven up to 180–240 °C (Sidorenko et al., 2012). Due to the lower temperatures and the shorter duration of the ER process baking allows to preserve useful nutrients of bread to a greater extent (Popov et al., 2012; Javkina et al., 2014), as well as to obtain functional products, reducing the loss of functional ingredients (Yalaletdinova, 2010).

An increased preservation of functional microingredients can be achieved by combining several technological methods simultaneously. A special case of such combination is the use of various stabilized forms of functional ingredients and ER baking. Such a combined method can be used, for example, to reduce the beta-carotene loss in bread and flour confectionery products.

Beta-carotene is a food supplement, used in the food industry as food dye E160a, it is also included in the list of functional food ingredients. Beta-carotene has great potential for use in functional foods as a precursor of vitamin A (retinol) (Rodriguez-Amay et al., 2011; Kumar & Kumar, 2012; Naumova & Kozubtsev, 2016). However, a significant disadvantage of beta-carotene is its liability to collapse under the influence of light, oxygen and high temperatures (Rudometova et al., 2018; Mérillon, 2019).

The aim of this paper was to study the influence of the baking method and stabilizing additives on the loss of beta-carotene during baking. In order to achieve this goal a series of experiments in C and ER baking with various types of beta-carotene was set up.

MATERIALS AND METHODS

Beta-carotene

In this paper the following sources of beta-carotene were used:

– water-dispersible suspension of beta-carotene with the content of coloring substances 1.6%;

– fat-soluble suspension of beta-carotene with the content of coloring substances 2.0%;

– water-soluble food-grade beta-carotene with the content of coloring substances 2.0%;

– experimental supramolecular complex of beta-carotene: beta-cyclodextrin (β-CD) with a molecular ratio of 1:1 and with the content of coloring substances 30% (Rudometova et al., 2018; Rudometova & Kulishova, 2018);

– experimental supramolecular complex of beta-carotene: alpha-cyclodextrin (α-CD) with a molecular ratio of 1:1 and with the content of coloring substances 25% (Rudometova et al., 2018; Rudometova & Kulishova, 2018).

Beta-carotene dosage selection

Beta-carotene dosage selection was based on the recommended daily allowance and the color intensity of the end product acceptable for consumer (MR 2.3.1.2432-08, 2008).

We have chosen a dosage of 20 mg of beta-carotene which, taking into account the inaccuracy and baking losses, will be 25–35% of the daily intake in the finished product. Along with that the product will be classified as fortified food (European Commission, 2006; Watson, 2017), and according to the results of preliminary experiments its coloration will not be excessive.

Bread making technology

A straight-dough preparation method was used. The processes were carried out in the following sequence:

– weighing components, heating water to 36 °C;

– mixing yeast with flour, dissolving salt in a portion of water, embedding beta-carotene;

– dosing components into the bowl of the dough mixing machine;

– kneading dough in a dough mixing machine (Bear Varimixer Teddy);

– fermentation of the dough for 2 hours, at 35 °C, with manual punching after 1 hour and 20 minutes (proofing cabinet Miwe Aero, model AE 6.06.04, Germany);

– cutting dough and forming dough pieces;

– proofing dough in a proofing cabinet at temperature of 40 °C and at relative humidity of 80% for 1 hour (Miwe Klima, type MGT, Germany);

– baking dough using two methods, namely, the convective one in the oven (Miwe Aero, model AE 6.06.04, Germany) and the electric resistance method in the laboratory ER oven;

– cooling the bread.

The dough formula is shown in Table 1.

Table 1. The dough formula

Ingredients	The mass of ingredients, g
Wheat flour 1st grade	500.0 ± 1.00
Salt	5.0 ± 0.10
Instant yeast	2.5 ± 0.10
Water	315.0 ± 2.00
Beta-carotene	$20 \times 10^{-3} \pm 0.01$

The list of used sources of beta-carotene, as well as the method of their embedding in the bread formula is shown in Table 2.

Table 2. The used sources of beta-carotene

Type of additive	Beta-carotene dosage, mg	Application method	Sample name
Water-dispersible suspension, 1.6%	20	water dispersion	B1
Fat-soluble suspension, 2.0%			B2
Liquid Water-Soluble Beta-Carotene, 2.0%			B3
Supramolecular complex α-CD: beta-carotene (molecular ratio 1:1)			B4
Supramolecular complex β-CD: beta-carotene (molecular ratio 1:1)			B5

For successful baking a round piece of dough with a mass of 230 ± 1 g was formed, its edges were cut off so that to obtain area of 50 mm that will ensure close contact of the piece of dough with electrodes. The forming scheme is shown in Fig. 1. The dough sample had a mass of 150 ± 5 g. The inaccuracy is explained by the difficulty of simultaneously observing the weight of the dough sample and the required distance between the vertical edges.

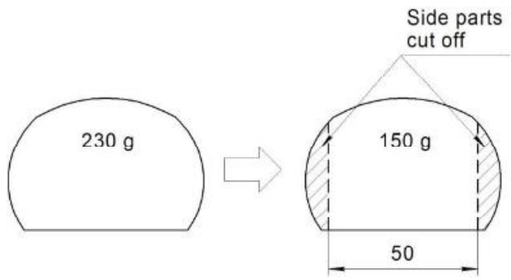

Figure 1. The forming scheme of the dough sample.

The dough sample was placed in the electric resistance oven so that the cut edges had close contact with electrodes.

In parallel with ER baking a bread sample from the same dough of the same mass was baked by C baking method at a temperature of 210 °C for 25 minutes.

After baking, bread samples were cooled at room temperature for 1 hour.

Sponge-cake baking technology

The sponge cake batter formula is shown in Table 3.

The sponge cake batter was prepared as follows. The mixture of salt, eggs and sugar was whipped for 10 minutes using stand mixer KitchenAid Artisan; in the process of whipping the mixture increased in volume by 2–3 times. Egg whites and egg yolks were not separated before whipping. In order to increase the batter conductivity and to speed up the ER baking process some amount of salt was added to the formula.

After whipping, the flour was added evenly into the mixture so that to avoid formation of lumps.

Table 3. The sponge cake batter formula

Ingredients	The mass of ingredients, g
Eggs	253 ± 5.00
Sugar	150 ± 1.00
Premium wheat flour	160 ± 1.00
Salt	1.0 ± 0.100
Beta-carotene	$20\times10^{-3} \pm 0.01$

The list of used sources of beta-carotene, as well as the way of their embedding in the sponge cake batter formula, is shown in Table 4.

Table 4. The list of sources of beta-carotene used in the sponge cake batter

Type of additive	Beta-carotene dosage, mg	Application method	Sample name
Water-dispersible suspension, 1.6%	20	mixing with eggs	SC1
Fat-soluble suspension, 2.0%			SC2
Liquid Water-Soluble Beta-Carotene, 2.0%			SC3
Supramolecular complex α-CD: beta-carotene (molecular ratio 1:1)			SC4
Supramolecular complex β-CD: beta-carotene (molecular ratio 1:1)			SC5
Supramolecular complex β-CD: beta-carotene (molecular ratio 1:1)		mixing with flour	SC6

Beta-carotene and eggs were whipped until the beta-carotene sample was evenly mixed.

The viscous medium of eggs prevents even distribution of the supramolecular complex in powder form, while there is no such problem when dispersing complex in water (as in the case of bread dough). It can cause a decrease in intensity and uniformity of color in the finished product. In order to compare two different ways of complex embedding, the sample SC6 was added to the sponge cake experiment plan.

Embedding of beta-carotene into the flour in the sample SC6 was carried out in several stages before mixing. Initially, beta-carotene in powder form was mixed with part of the flour with the same volume ratio, and the mixing was carried out until the mixture was evenly colored. At the next stage, a double volume of flour was added to the mixture, and the mixing was carried out again until color was even, and so on until the beta-carotene sample was completely mixed with flour.

After mixing, the baking mold for the ER baking method and the one for the C baking method were filled with batter. The weight of batter in the ER baking mold was 107 g.

Convective baking was carried out in a Miwe Aero oven, model AE 6.06.04, Germany, at a temperature of 180 °C for 19 minutes in a mold with a diameter of 300 mm and a height of the sponge layer of 30 mm.

After baking, the sponge cake was cooled at room temperature.

Electric resistance oven used for experiments

Baking samples of bread and sponge cake was carried out in a specially designed installation. The installation casing is a box, open at the top and equipped with a hinged bottom. The casing is made of monolithic sheet polycarbonate with a thickness of 8 mm. Two electrodes from sheet stainless steel AISI 304 with a thickness of 2 mm are installed in the grooves inside the casing. Dimensions of the internal chamber of the installation are 100×50×100 mm (L: W: H). The hinged bottom allows to remove the baked sample from the bottom without deformation, which is very important, because crustless bread and sponge cake are easily deformed. The installation drawing is shown in Fig. 2.

Baking of bread dough and sponge cake samples after proofing was carried out at a voltage of 220 V, a frequency of 50 Hz. During baking current flowing through the dough sample was measured using an IEK 266 C ammeter and the dough and the batter temperature was measured using a chromel-alumel DTPK011-07 / 1.5 thermocouple. The thermocouple was connected to an analog input module, which was connected to a personal computer via the RS-485 - USB interface. Data from the input module was processed in MasterScada in real time. The thermocouple was installed in the dough sample at a certain point, in the center, at a height of 45 ± 5 mm from the chamber bottom. Baking was stopped at the moment when current reached a minimum and remained constant for 10 s. According to the data obtained, the duration of bread baking was about 120 seconds and the duration of sponge cake baking was about 600 s.

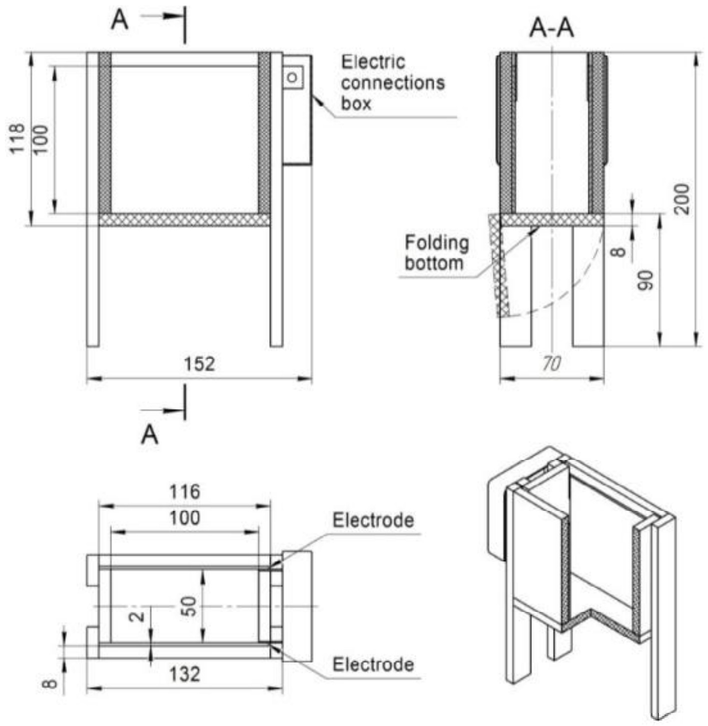

Figure 2. Drawing of the installation for electric resistance baking.

Extraction of beta-carotene from bread

5 g of sample (with an accuracy of 0.001 g) were mixed with quartz sand in a 1:1 mass ratio. The resulting mixture was ground in a ceramic mortar for 10 minutes, with addition of 10 cm^3 of solvent (chloroform). Then the mixture was filtered into a 250 cm^3 conical flask; the resulting precipitate was transferred to the mortar. The procedure was repeated until the sample was completely discolored.

Extraction of beta-carotene from sponge cake

2 g of the sample (with an accuracy of 0.001 g) were placed in a 100 cm^3 conical flask, where 30 cm^3 of solvent (chloroform) were added. Extraction was performed in a Bandelin Sonorex ultrasonic bath at room temperature at an installed power of 128 W for 30 minutes. The mixture was then filtered into a 250 cm^3 conical flask, and the resulting precipitate was transferred back. The procedure was repeated until the sample was completely discolored.

Determination of beta-carotene content

The optical density of the resulting combined solutions was determined. The measurement was carried out on a SHIMADZU UV-1800 double-beam scanning spectrophotometer in the wavelength range of 300–700 nm against the solvent.

Mass fraction of beta-carotene in the object of study (in mg g^{-1}) was calculated according to the formula, referred to in the reference source (Socaciu, 2007; European Commission, 2012).

Organoleptic analysis of bread and sponge cake

The organoleptic parameters were evaluated by a group of three tasters in accordance with GOST R 58233 (State Standard of the Russian Federation, 2018). The organoleptic properties of bread and sponge cake baked by C and ER methods were evaluated on a 5-point scale, the accuracy of the point evaluation was 0.1 points.

Evaluation of bread samples was carried out according to the following parameters: the state of the bread surface (smoothness, presence of tears, lumps, etc.), the color of the crumb (taking into account the introduction of beta-carotene as a dye), porosity (thin-walled or thick-walled, uniform, etc.), crumb consistency (tenderness, mellowness, dryness, etc.), bread aroma, crumb taste (State Standard of the Russian Federation, 2018).

Evaluation of sponge cake samples was carried out according to the following parameters: external appearance (smoothness, presence of tears, cracks, etc.), crumb color (taking into account the introduction of beta-carotene as a dye), consistency (softness, elasticity, dryness), crumb taste, aroma (Popov et al., 2014).

Since bread and sponge cake samples prepared by ER baking lacked a crust, the taste and color of samples obtained by different baking methods were evaluated only by crumb.

Statistical data processing

All experimental measurements were performed three times. Analysis of variance (one-way ANOVA) of the obtained data was carried out by Microsoft Excel with a significant difference at $P \leq 0.05$. Some of the parameters were compared using the Fisher test. Graphical dependencies were obtained using Microsoft Excel software.

RESULTS AND DISCUSSION

Dynamics of changes in the current strength and temperature during ER baking of bread and sponge cake

Fig. 3 shows experimental data on changes in the current strength and temperature when baking bread. Dynamics of the current strength is complex, which can be explained by thermal and physicochemical processes occurring in the dough during baking. At the beginning of bread baking, an increase in the current strength occurs due to an increase in the degree of dissociation of salts and acids and transition of soluble substances to the liquid phase. Subsequently, the current strength decreases somewhat, which the authors attribute to the swelling of the protein and carbohydrate components of the dough. Insignificant repeat increase in the current strength can be caused by denaturation of proteins and release of moisture, resulting in a short-term increase of conductivity. Further decrease in the current strength is associated with the evaporation of moisture from the dough and the decrease in conductivity, which is confirmed by the data from the authors (Sidorenko et al., 2012).

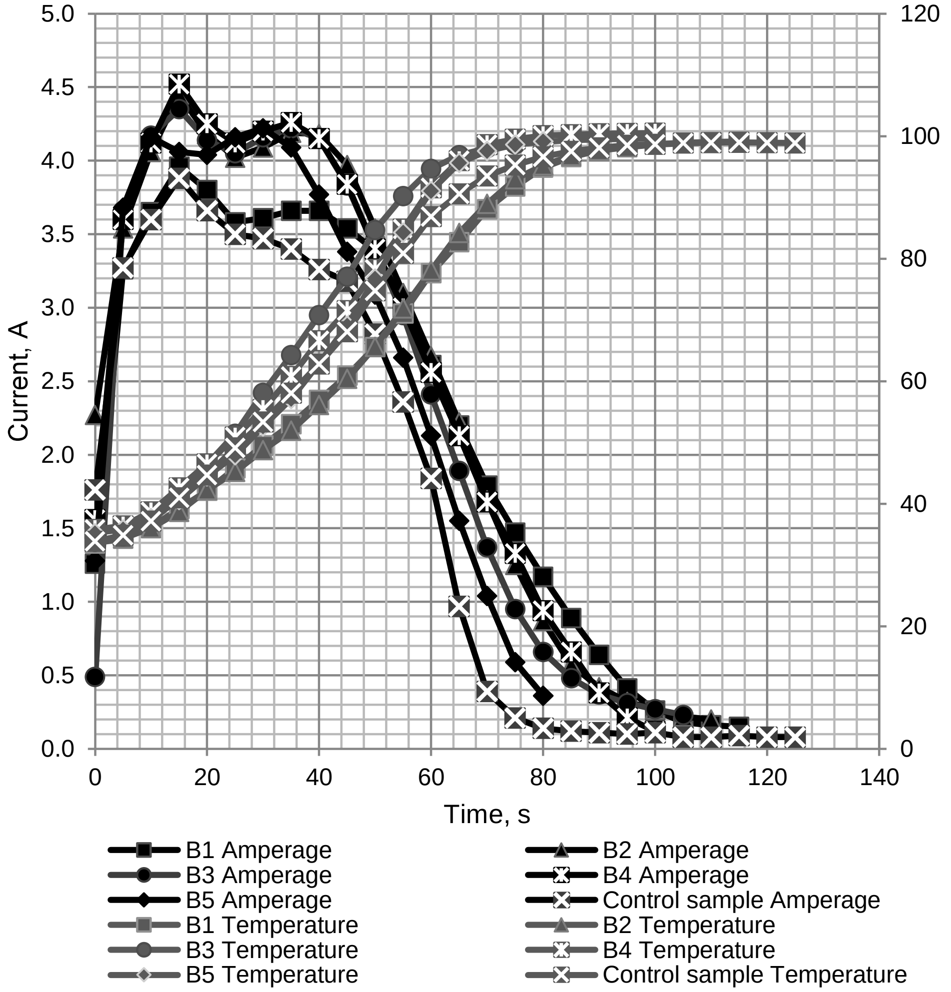

Figure 3. Experimental data on changes in current strength and temperature during ER baking of bread

The sample is heated almost linearly up to a temperature of 80–90 °C, smoothly going to a plateau at 98–99 °C. Analysis shows that experimental curves are similar and generally vary slightly. The scatter of current strength values can be explained by an inaccuracy in the current measurements, as well as by inevitable fluctuations in humidity, the mass of dough samples, the contact area between the dough and electrodes and the degree of proofing of dough samples. The combined influence of these factors, however minor they are, can lead to differences in the maximum current strength among experiments. Consequently, differences in the dynamics of changes in the current strength affect the heating rate of the dough sample in various experiments.

Figs 4 and 5 show experimental data on changes in the current strength and temperature during baking of sponge cake. It should be noted that, compared with bread, the dynamics of changes in the current strength during baking of sponge cake are less complex.

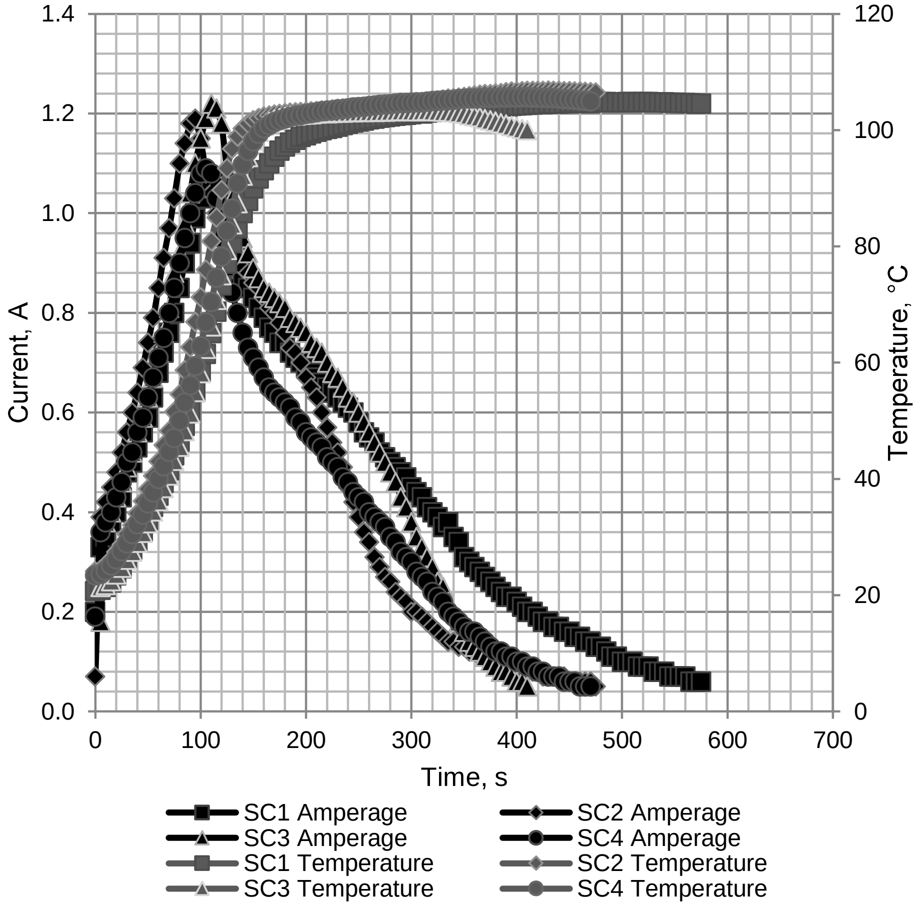

Figure 4. Experimental data on changes in current strength and temperature during ER baking of sponge cake, samples SC1–SC4.

The curve is a single peak function. The initial increase in the current strength to a maximum can be caused by an increase in conductivity due to an increase in temperature of the sponge cake batter. Upon reaching a temperature close to 100 °C, a decrease in the current strength is presumably caused by the evaporation of moisture from sponge cake and a decrease in the overall conductivity of the sponge cake batter.

The dynamics of changes in the temperature of sponge cake is close to the ones of yeast dough, with the exception of the maximum process temperature, which reaches 105 °C in sponge cake. Scatter of the maximum current strength during baking observed in experiments can be explained by the ammeter error, as well as by the difference in the composition of the eggs in different batches, whose intrinsic conductivity significantly affects the overall conductivity of sponge cake.

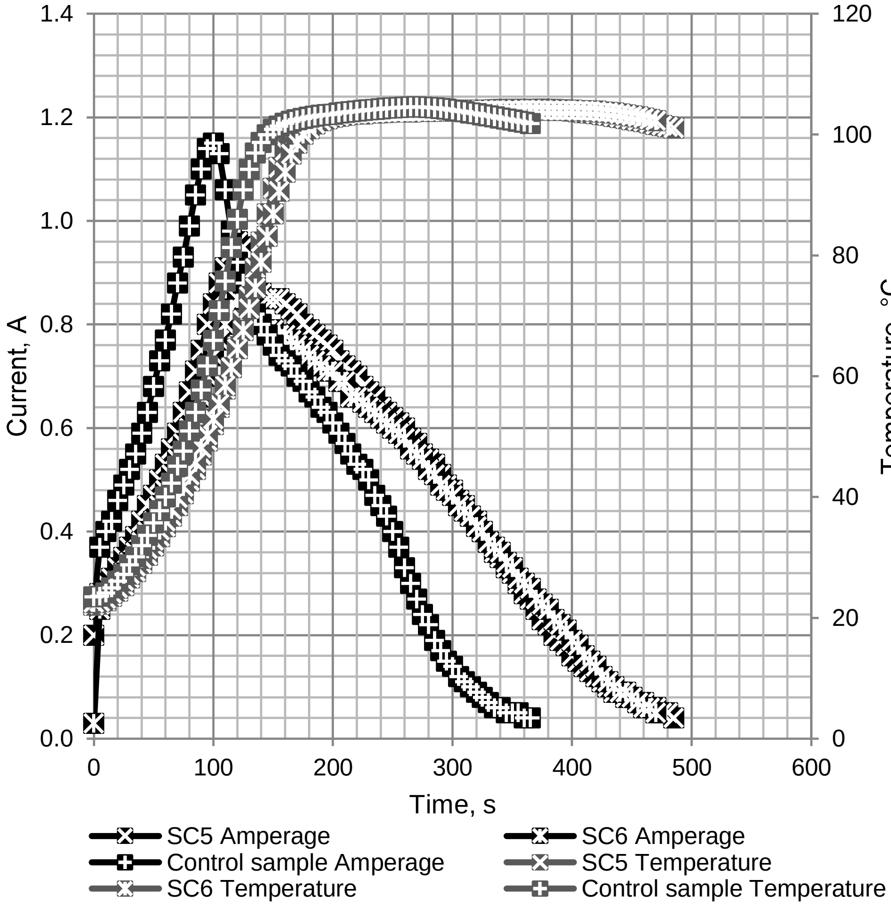

Figure 5. Experimental data on changes in current strength and temperature during ER baking of sponge cake, samples SC5–SC6 and control sample.

Selection of the extraction method

Beta-carotene extraction methods based on literature sources (Schierle et al., 2004; State Standard of the Russian Federation, 2010) require either a complex process or a large amount of equipment. Some studies have been conducted to develop a rapid method of extracting beta-carotene. Those are methods of Quı'lez (method 1) and U. Schweiggert (method 2) (Quílez et al., 2003; Schweiggert et al., 2005). We have tested these methods of sample preparation on sample B1 (Table 5).

Table 5. Efficiency of beta-carotene extraction by two methods

Method	The initial amount of beta-carotene, mg	The content of beta-carotene in the finished product, mg
1	20.10 ± 0.1	2.22 ± 0.2
2	20.00 ± 0.1	7.31 ± 0.1

However, as can be seen from the results obtained, these extraction methods do not provide complete extraction of coloring substances from the samples, which leads to unreliable results of the beta-carotene content. Therefore, we have developed the extraction methods described in the Materials and Methods section.

Beta-carotene content in bread and sponge cake samples

Fig. 6 shows data on the content of beta-carotene in mg g^{-1} of the final product in samples of bread obtained by two baking methods. It should be noted that in the control samples (prepared without adding beta-carotene) no significant amount of beta-carotene was found.

Data analysis shows that beta-carotene is lost in all bread samples during baking. However, these losses are less than those recorded by the authors (Rogers et al., 1993; Ranhotra et al., 1995). This significant difference can be explained by the fact that the authors used samples of stabilized beta-carotene developed more than 30 years ago, and during this time progress in improving the stability of beta-carotene has stepped forward.

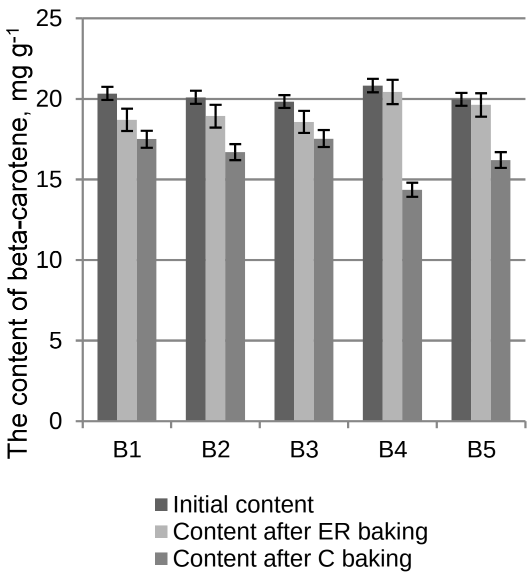

Figure 6. Beta-carotene content in bread samples.

Statistically significant differences in the samples prepared by different baking methods were observed in the samples with the addition of supramolecular complexes and fat-soluble beta-carotene. Close values of beta-carotene losses were observed for samples B1, B2 and B3 obtained using emulsified forms of beta-carotene, which are more stable during convective baking than supramolecular complexes. Perhaps this is due to the presence of an emulsifier and a fatty phase in carotene-containing additives.

The higher preservation of beta-carotene in the samples obtained by ER baking can be explained by the different temperatures and duration of baking of the samples: during ER baking, the product temperature did not exceed 100 °C, while C baking was carried out at a temperature of 210 °C. In addition, only the outer layers of bread were exposed to higher temperatures during C baking. Thus, the difference in beta-carotene losses between the samples is explained only by the losses in the crust, and taking into account the fact that the fraction of crust in the mass of the product is relatively small and does not exceed 30%, a slight difference fits completely into these facts.

According to the experimental data obtained, it can therefore be concluded that the greatest stability of beta-carotene during baking can be achieved by combining technological parameters and using a stabilized form of beta-carotene, for example, supramolecular forms of beta-carotene and ER baking.

Fig. 7 shows data on beta-carotene content in mg g^{-1} of the final product in sponge cakes prepared by two baking methods.

Statistically significant differences in sponge cake samples prepared by different baking methods were observed when adding supramolecular complexes and fat-soluble beta-carotene (samples SC4, SC5, SC6. SC2, respectively).

The same as bread samples, sponge cake samples with supramolecular complexes were characterized by greater losses than samples with emulsified sources of beta-carotene during convective baking.

Comparison of losses in samples SC5 and SC6, in which the same source of beta-carotene is used, but the application method is different, allows us to conclude that, in addition to the baking method and to the form of carotene, the method of introduction of additives also affects the preservation.

The influence of the baking method as a whole can be explained by the same factors as those in bread baking process: lower temperature, process duration and a decrease in losses in the surface layer due to the absence of crust.

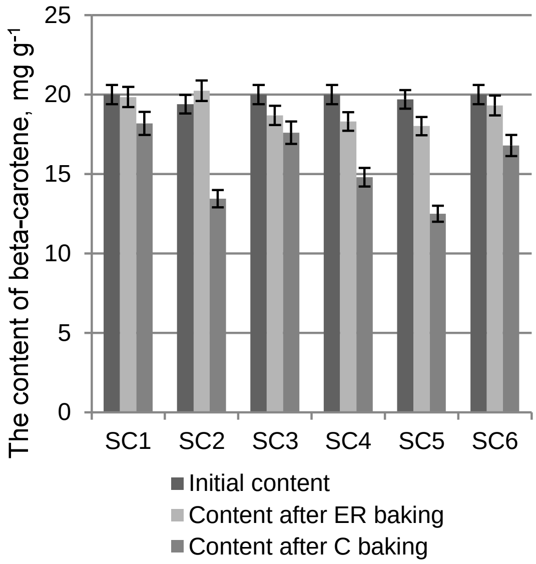

Figure 7. Beta-carotene content in sponge cake samples.

Organoleptic analysis of bread and sponge cake

Organoleptic parameters of bread are shown in the Table 6.

Table 6. Sensory characteristics of bread

Sample		State of the bread surface	Color of the crumb	Porosity	Crumb consistency	Bread aroma	Crumb taste
B1	ER	4.80 ± 0.16	4.77 ± 0.05	4.00 ± 0.08	4.17 ± 0.09	3.27 ± 0.05	3.87 ± 0.05
	C	4.73 ± 0.12	4.80 ± 0.16	4.47 ± 0.09	4.13 ± 0.05	4.80 ± 0.08	3.70 ± 0.12
	F	0.21	0.08	28.00*	0.20	529.00*	4.50
B2	ER	4.80 ± 0.16	4.83 ± 0.12	3.97 ± 0.21	4.17 ± 0.05	3.33 ± 0.12	4.63 ± 0.17
	C	4.77 ± 0.09	4.87 ± 0.09	4.47 ± 0.12	4.20 ± 0.16	4.83 ± 0.05	4.53 ± 0.12
	F	0.06	0.09	8.65*	0.08	253.00*	0.45
B3	ER	4.83 ± 0.12	4.87 ± 0.19	3.93 ± 0.12	4.30 ± 0.08	3.17 ± 0.17	3.73 ± 0.17
	C	4.77 ± 0.12	4.93 ± 0.09	4.47 ± 0.09	4.27 ± 0.12	4.87 ± 0.12	3.77 ± 0.09
	F	0.29	0.20	23.30*	0.10	130.00*	0.06
B4	ER	4.73 ± 0.19	3.90 ± 0.08	4.17 ± 0.05	4.27 ± 0.09	3.40 ± 0.08	4.83 ± 0.12
	C	4.83 ± 0.17	3.83 ± 0.12	4.37 ± 0.05	4.43 ± 0.09	4.83 ± 0.05	4.87 ± 0.05
	F	0.31	0.40	18.00*	3.10	462.00*	0.13
B5	ER	4.93 ± 0.09	3.73 ± 0.19	3.80 ± 0.14	4.33 ± 0.12	3.23 ± 0.09	4.83 ± 0.09
	C	4.73 ± 0.12	3.70 ± 0.08	4.53 ± 0.09	4.40 ± 0.08	4.73 ± 0.05	4.80 ± 0.08
	F	3.30	0.05	37.20*	0.40	405.00*	0.14

* means unacceptance of the hypothesis (a significant difference in the results at the level of 0.05); calculated value of the *F-criterion*. The tabular value of the *F-criterionis* 7.71.

There were no statistically significant differences in crumb shape, taste and consistency between samples of different baking methods. However, there is a statistically significant difference in the aroma indices, which may be due to the fact that during ER baking the temperature of the dough does not reach sufficient values for the Maillard reactions to occur.

Nature of porosity is conditioned by the geometric shape of the bread prepared by two baking methods and having the same weight: the form for ER baking is narrower and higher than the standard baking form.

Also there is a significant difference in the color intensity between the samples with different sources of beta-carotene: the samples with the addition of supramolecular complexes are less colored, which is caused by their physicochemical properties (Rudometova et al., 2018; Rudometova & Kulishova, 2018).

Organoleptic parameters of sponge cake are shown in the Table 7.

Table 7. Sensory characteristics of sponge cake

Sample		External appearance	Crumb color	Consistency	Crumb taste	Aroma
SC1	ER	4.83 ± 0.09	4.80 ± 0.08	4.63 ± 0.05	4.43 ± 0.05	3.90 ± 0.14
	C	4.93 ± 0.05	4.9 ± 0.08	4.53 ± 0.12	4.47 ± 0.12	4.9 ± 0.08
	F	1.80	1.50	1.13	0.13	75.00*
SC2	ER	4.80 ± 0.14	4.80 ± 0.08	4.53 ± 0.05	4.77 ± 0.09	4.17 ± 0.05
	C	4.83 ± 0.09	4.87 ± 0.05	4.40 ± 0.08	4.67 ± 0.05	4.83 ± 0.05
	F	0.08	1.00	4.00	1.80	200.00*
SC3	ER	4.70 ± 0.08	4.73 ± 0.09	4.73 ± 0.09	4.77 ± 0.12	3.93 ± 0.12
	C	4.83 ± 0.12	4.87 ± 0.05	4.60 ± 0.08	4.80 ± 0.08	4.87 ± 0.05
	F	1.60	3.20	2.29	0.10	98.00*
SC4	ER	4.80 ± 0.08	3.50 ± 0.08	4.67 ± 0.12	4.83 ± 0.05	4.00 ± 0.14
	C	4.90 ± 0.08	3.37 ± 0.05	4.40 ± 0.08	4.73 ± 0.12	4.87 ± 0.09
	F	1.50	4.00	6.40	1.13	52.00*
SC5	ER	4.73 ± 0.05	3.27 ± 0.12	4.67 ± 0.12	4.77 ± 0.12	4.03 ± 0.12
	C	4.77 ± 0.09	3.23 ± 0.12	4.63 ± 0.12	4.80 ± 0.08	4.97 ± 0.05
	F	0.20	0.07	0.07	0.10	98.00*
SC6	ER	4.77 ± 0.12	4.27 ± 0.12	4.60 ± 0.14	4.73 ± 0.12	4.03 ± 0.12
	C	4.83 ± 0.12	4.20 ± 0.16	4.70 ± 0.08	4.83 ± 0.09	4.93 ± 0.09
	F	0.29	0.21	0.75	0.83	66.28*

* means unacceptance of the hypothesis (a significant difference in the results at the level of 0.05); calculated value of the *F-criterion*. The tabular value of the *F-criterionis* 7.71.

According to the results of the organoleptic evaluation of sponge cake samples prepared by different baking methods, no statistically significant differences were found in the external appearance, crumb color, crumb consistency and taste. A significant difference is observed in the aroma of the samples, which is due to the absence of melanoid-forming products in the sponge cake prepared by ER baking.

There is a difference in color saturation between samples with different sources of beta-carotene; samples with supramolecular complexes are less intensely colored. It should be noted that the color intensity is influenced by the method of beta-carotene addition, which is confirmed by the different mean values of the color intensity in samples SC5 and SC6.

CONCLUSION

The use of electric resistance baking in the production of crustless bread and sponge cakes allows for better preservation of the embedded beta-carotene in bread and sponge cake batter samples. Thus, combination of the ER baking method and the use of stabilized forms of beta-carotene, such as supramolecular complexes, for example, allow to obtain functional bread and flour confectionery products with minimal loss of useful nutrients. Furthermore, the use of ER baking instead of the traditional method does not significantly affect the organoleptic characteristics of crumb in the finished products.

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