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ARTICLE

Influence of biologically active raw materials on rheological properties of flour confectionery products

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ABSTRACT New achievements in science, food technologies and medicine call for sounder, scientifically proven nutrition. Food must be functional being aimed at preventing numerous diseases, improving performance capacity and health. Cereals, in particular bakery and confectionery, have the highest potential to be modified to get functional properties. Currently the assortment of this daily food has been actively enlarged. Therefore, the purpose of this work is to improve the production technology of the national flour confectionery "Chak-chak" using biologically active raw materials of the Republic of Bashkortostan. As the result of the conducted studies the ratio of the main ingredients and biologically active raw materials (bee pollen, honey and oat talkan) in flour confectionery as well as production parameters are improved. Therefore, the developed product (chak-chak with bee products and oat talkan), having no analogues, can find its place among other flour confectionery goods.
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Introduction

Many manufacturers, guided by current trends in the development of the healthy food market, are focused on the production of functional products (Siro et al. 2008). Domestic production of functional food products is mainly based on enriched vitamins, minerals, dietary fibers and lower energy value (Kinyuru et al. 2015). One of the most promising goods to be modified in this way is cereals, including flour confectionery (Šebečić et al. 2007; Okpala and Ofoedu 2018; Tugush et al. 2018; Saleh et al. 2019). Biologically active raw materials added to their formulas will provide higher number of important nutrients required to the daily intake.

The fundamental point is to find the optimal proportions of non-traditional ingredients. Besides solving the main task of increasing the nutritional and biological value of products, it is possible to improve their production technology, make organoleptic, physico-chemical and structural-mechanical properties of finished products better, and extend their shelf life (Šebečić et al. 2007; Rumiantseva et al. 2012; Leonova et al. 2018).

Currently, it has become relevant to study the possible use of non-traditional raw materials being able to increase nutritional value of products in manufacturing flour confectionery goods. There is a developed formula of cereal bars with a high content of protein and vitamins based on soy protein, wheat germ and oat, enriched with ascorbic acid and α-tocopherol (Amjid et al. 2013). Some works are devoted to the development of flour confectionery goods with a high content of dietary fibers. It is done by adding oat flour, amaranth, soy flour and carob flour (Arghire et al. 2016). Gluten-free snacks with amaranth, orach and quinoa seed flour were also studied (Codină et al. 2019).

When developing new types of flour confectionery goods with specified properties and composition to optimize the production process, it is necessary to monitor the technological parameters as well as rheological characteristics of raw materials and semi-finished products (Codină et al. 2019). Flour confectionery goods production is associated with processing of bound-dispersion systems and the formation of coagulate, mixed and condense-crystallized structures. Rheology allows to control structural and mechanical properties as well as the quality of products by adding additives, changing modes and methods of mechanical and technological processing (Novotni et al. 2009; Munteanu et al. 2016; Gabitov et al. 2018).

There is a study on the effect of the plantain seed powder on the structural and mechanical properties of flour confectionery goods, in particular hard-dough biscuits. The main physical and chemical indicators, organoleptic characteristics, spreading coefficient, volume and texture were determined. The additive used helped to increase the spreading behavior of cookies and reduce their volume and density (Krystyjan et al. 2018).

There are studies on the influence of various dietary fibers on the rheology of semi-finished products for bread and bakery products. The dough rheological properties are examined with a farinograph (Brabender, Germany) and a texture analyzer (Stable Micro Systems, UK). It was found that inulin added to the formula affects the dough consistency, elasticity and adhesion. When dextrin is included, the viscosity increases, but it does not have a significant impact on other dough properties (Novotni et al. 2007).

The influence of bee pollen on the quality of flour confectionery goods is also studied. The increased dosage of bee pollen is found to improve structural and mechanical properties of bakery, such as volume, structure, consistency and crust color (Conte et al. 2018).

In the light of the foregoing, the research goal is to assess the impact of oat talkan and bee products on structural, mechanical and technological properties of finished and semi-finished products as well as to improve the chak-chak formula with biologically active raw materials as oat talkan, honey and bee pollen.

Materials and methods

The research is carried out in the scientific research laboratories of the Bashkir State Agrarian University, the Bashkir Agricultural Research Institute and the Research Institute of the Baking Industry.

The investigation is based on traditional and special chemical, physico-chemical, structural and mechanical methods to study properties of raw materials, semi-finished and finished products. Physico-chemical and organoleptic quality indicators of products are recognized according to the Russian Sate Standard GOST 5897-90. Organoleptic evaluation is conducted using a 30-point scale. The quality of the product is estimated by the total assessment. 30-25 points correspond to the excellent product quality, 24-20 points as good and 19-10 points as satisfactory.

Flour humidity was determined in accordance with State All-Union Standard (GOST) 9404-88 using an electric SESH-3M drying cabinet, in which the drying chamber temperature is up to 150 °C. The cabinet has a temperature controller that creates drying temperature and keeps the heat in the working zone at 130-140 °C (accurate within ±2 °C). Humidity is determined in two parallel hangers. Two clean dried metal weighing bottles are removed from the desiccator and weighed with an error of no more than 0.01 g. The product isolated from the average sample according to GOST 27668 for determining humidity is thoroughly shaked in the container and selected from different places. Then, it is put in each weighing bottle of a product batch weight with the mass of (5.00 ± 0.01) g. After that the weighing bottles are covered with lids and placed in the desiccator. When the temperature in the drying cabinet reaches 130 °C, the thermometer is turned off and the oven is heated to 140 °C. Then the thermometer is turned on, and open weighing bottles with batch weight of the product are quickly placed into the cabinet upon the removed lids. Empty cabinet slots are filled with empty weighing bottles. The product is dried for 40 min from the moment the temperature of 130 °C was re-created. It is allowed not to heat the drying cabinet to 140 °C, if after its full loading the temperature of 130 °C is re-created within 5-10 min. After drying, the weighing bottles with the product are removed from the cabinet with crucible tongs, closed with lids and transferred to the desiccator for complete cooling for about 20 min (but no more than 2 hours). Cooled weighing bottles are weighed with an error of no more than 0.01 g and placed in the desiccator until the analysis results are processed.

Product humidity (X) as a percentage is calculated using the Formula 1:

$$X = 100\ \frac{m_1 - m_2}{m_2}$$

where m_1 is the mass of flour and bran weight batch before drying (g); m_2 is the mass of flour and bran weight batch after drying (g).

The effect of bee pollen, honey and oat talkan on the structural and mechanical properties of semi-finished products as dough is studied on fried semi-finished chak-chak and syrup. The structural and mechanical properties were analyzed with «ST-2 structure meter». Chak-chak wheat dough kneading parameters are determined with an information measuring complex, including Farinograph-E (Brabender, Germany), a kneading trough, a programmable thermostat and a personal computer.

Strength test determination is based on finding the extreme load on the "Knife" indenter. The product placed on the table is loaded at 10g/s after being touched in the middle with a force of 10 g.

Syrup viscosity test method is based on finding the loading force on the "Disk" indenter when it is introduced into the prepared syrup sample to a depth of 4 mm at 0.5 mm/s after the contact force of 5 g. The maximum value of the loading force F_c expressed in grams is interpreted as the compressive strength of the paste. Then the position of the indenter is fixed for 5 s and the indenter is extracted from the product at a distance of 45 mm at 0.5 mm/s with the maximum tension force of the paste Ft.

Table 1. Significance test results for the syrup model coefficients.

Standard (RMS) beta coefficient deviation	Coefficients	Standard error	t-statistics	P-value	Lower endpoint (95% confidence interval)	Upper endpoint (95% confidence interval)
a_0	50.51746	0.613	82.447	0.000	49.303	51.731
a_1	-0.52421	0.028	-18.558	0.000	-0.580	-0.468
a_2	-0.29575	0.023	-12.725	0.000	-0.342	-0.250
a_3	0.004341	0.000	14.373	0.000	0.004	0.005
a_4	-0.00032	0.000	-1.082	0.282	-0.001	0.000
a_5	0.002566	0.000	9.638	0.000	0.002	0.003
a_6	-0.00019	0.000	-15.398	0.000	0.000	0.000
a_7	1.71 E-05	0,000	1.723	0.088	0.000	0.000

Chak-chak wheat dough kneading parameters are found with the help of an information measuring complex, including Farinograph-E (Brabender, Germany), a kneading trough, a programmable thermostat and a personal computer. Dough properties are tested with farinograph by kneading wheat flour with oat talkan. Dough consistency of 500 ± 20 f.u. is received by estimating the required amount of water. The farinograph operation procedure and principle: a flour sample of 300 g on a 14% moisture basis is placed in a mixing bowl and stirred for 1 min. Then water is added from the right front corner of the buret for 25 s. (Rumiantseva et al. 2012). The dynamics of rheological behavior of the chak-chak dough with a rational dosage of 6% of oat talkan and the control sample without oat talkan during kneading is tested on the Brabender Farinograph-E. During the analysis, the dough development time and strength are recorded.

Determination of dough formation time

Dough formation time (min) is the difference between the time of adding water and the time when the first signs of a decrease in consistency appear. In cases where farinogram shows two maxima, the value of the higher maximum is used to measure the time of dough formation. The arithmetic mean value of the dough formation time is accepted as a result and is calculated according to two farinograms with a rounding to 0.5 min, provided that the difference between the two results does not exceed 1 min for values of the dough formation time up to 4 min or 25% of their average value for values of the dough formation time more than 4 min.

Determination of dough resistance

Dough resistance (min) is calculated within the accuracy up to 0.5 min as the time difference between the points, at which the upper limit of the farinogram crosses for the first time and re-crosses the line 500 UF. This value characterizes dough resistance to mixing. If the actual maximum consistency deviates from the 500 UF line, but not more than ± 20 UF (9.1), then the line corresponding to the actual consistency must be used for the reading.

Experimental samples of chak-chak are made according to the traditional formula modified by replacing wheat with 2-12% of oat talkan. The control samples are without oat talkan. The syrup to dress chak-chak is made of bee pollen used instead of sugar in the amount of 25 to 100%. Results are compared with the control sample of the syrup without bee pollen.

Results

Nonlinear multi-dimensional statistical models are used to optimize the ratio of the chak-chak ingredients and the syrup.

Chak-chak and syrup formula improvement based on mathematical models

Nonlinear multi-dimensional statistical models are developed to evaluate the effect of bee products and oat talkan on the organoleptic and physico-chemical properties of chak-chak (Gabitov et al. 2018, 2018b). A similar method of optimizing flour confectionery recipes is used to improve the formulation of bakery products. The mathematical model is applied to the baking process. A mathematical model completely related to the change in the volume output is developed (Zhang and Datta 2006).

At the first stage, the syrup formulation is optimized with the addition of bee pollen (see Table 1). The response function for the syrup viscosity is represented by the dependence:

$$z(x,y)_1 = a_0 + a_1(x - 50) + a_2(y - 57{,}5) + a_3(x - 50)^2 + a_4(y - 57{,}5)^2 + a_5(x - 50)(y - 57{,}5) + a_6(x - 50)^3 + a_7(y - 57{,}5)^3$$

where x is the mass fraction of bee pollen, y is the time that 1 quart (946 cm^3) of the substance comes out of the

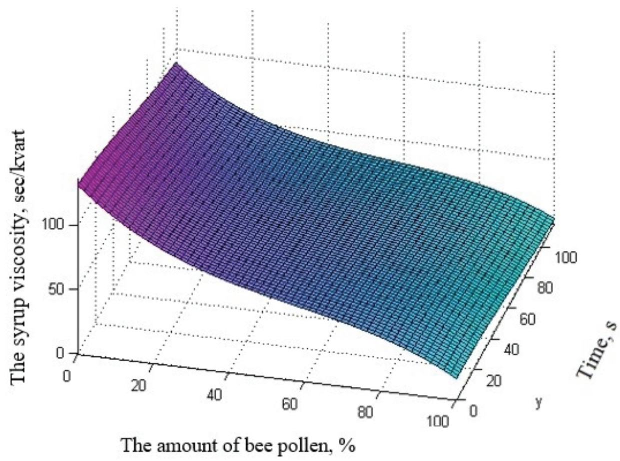

Figure 1. Effect of the bee polen dosage on the syrup viscosity.

filled funnel. The coefficient of multiple correlation= 0,99534175. The observed value of Fisher's F-criterion is 1705,.392471.

The multi-criteria optimization with one explanatory parameter is described by the generalized desirability function D (Kirillova and Kanevskaia 2017; Tugush et al. 2018). The optimal dosage of oat talkan is determined according to physical and chemical properties. The generalized desirability function D is the proportional average of individual indicators.

$$D = \sqrt[n]{d_1 d_2 ... d_n}$$

where is the individual desirability *i* indicator, n is the number of indicators. "Desirability" d refers to a desired level of the indicator. The d value of can vary from 0 to 1.

Since there are unilateral restrictions on the indicators, the desirability function has the form:

$$d_i = exp\,(-e^{-y_i})$$

where is some dimensionless quantity associated with the natural exponent (*x*).

The values of dimensional (natural) exponents (*x*) indicating the quality of semi-finished and finished products can be changed in dimensionless (*y*) at the nonlinear relationship according to the formula:

$$y_i = a_0 + a_1 x_i + a_2 x_i^2 + a_3 x_i^3 \qquad \text{(eq. a)}$$

Having twice logged the equation, we obtain an expression for y_i

$$y_i = ln\ \frac{1}{ln\frac{1}{d_i}}$$

Substituting the values into the equation (eq. a), we get:

$$a_0 + a_1 x_i + a_2 x_i^2 + a_3 x_i^3 = ln\frac{1}{ln\frac{1}{d_i}} \qquad \text{(eq. b)}$$

Let's make a system of equations for the known values of *x* and *d*. Solving the system together, we find the values of the coefficients a_0, a_1, a_2 and a_3. As the result, there is an equation of the nonlinear dependence between the studied parameter and dimensionless values. According to this equation, one can find *y* for any *x*, and then the desirability index according to the Formula 2 (Kirillova and Kanevskaia 2017; Tugush et al. 2018). Assessment scales for dimensional indicators of chak-chak and biscuit semi-finished product are given in Tables 2 and 3.

"Excellent", "good", "satisfactory" and "poor" rates for organoleptic indicators of quality correspond to 25, 20, 10 and 5 score values. Substituting these values in the formula (eq. b), we get:

$$\begin{cases} a_0 + 25a_1 + 25^2 a_2 + 25^3 a_3 = ln\frac{1}{ln\frac{1}{d_i}} \\ a_0 + 20a_1 + 20^2 a_2 + 20^3 a_3 = ln\frac{1}{ln\frac{1}{d_i}} \\ a_0 + 10a_1 + 10^2 a_2 + 10^3 a_3 = ln\frac{1}{ln\frac{1}{d_i}} \\ a_0 + 5a_1 + 5^2 a_2 + 5^3 a_3 = ln\frac{1}{ln\frac{1}{d_i}} \end{cases}$$

Table 2. Chak-chak dimensional indicators and standard assessment criteria based on the desirability scale.

Quality gradations	Desirability scale	Density (kg/m3)	Moisture weight (%)	Water absorption (%)	Total sugar weight (%)	Fat weight (%)	Organoleptic indicators
1	2	3	4	5	6	7	8
Excellent	0.80 ≤ *d* < 1.00	< 48	< 12	> 180	< 28	< 14	> 25
Good	0.63 ≤ *d* < 0.80	> 48	> 12	< 180	>28	> 14	< 25
Satisfactory	0.37 ≤ *d* < 0.63	> 50	> 15	< 170	> 30	> 16	< 20
Poor	0.20 ≤ *d* < 0.37	> 52	> 17	< 150	> 32	> 18	< 10
Very poor	0.00 ≤ *d* < 0.20	> 54	> 18	< 140	> 34	> 20	< 5

Table 3. Equation coefficients of the nonlinear dependence between product properties and the dimensionless indicators of the standard evaluation based on the desirability scale.

Indicator name	Equation coefficients			
	a_0	a_1	a_2	a_3
Chak-chak				
Density (kg/m3)	-832.969	50.58465	-1.01489	0.006733813
Moisture weight (%)	1.753842	0.014651	0.006439	-0.000785284
Water absorption (%)	-145.942	2.739339	-0.01731	3.69272E-05
Total sugar weight (%)	-173.36	18.06974	-0.61086	0.006733813
Fat weight (%)	-21.6347	4.925181	-0.32804	0.006733813
Organoleptic quality indicators	-1.3186	0.219421	-0.01165	0.000295418

The equation of the nonlinear dependence between the texture indicator and the dimensionless value of the standard evaluation based on the desirability scale will be as follows:
The calculation results are shown in Table 3. Natural

$$y_1 = -1.31 + 0.21x_1 + -0.01x_1^2 + 0.002x_1^3$$

and generalized quality indicators of chak-chakby the desirability function as well as the corresponding values are presented in Figure 2 and Table 4.

It is established that the generalized desirability function has the greatest value for samples 1-4.

Hence, the best amount of oat talkan for chak-chak is no more than 6%. Therefore, further studies were carried out on products with 6% of oat talkan.

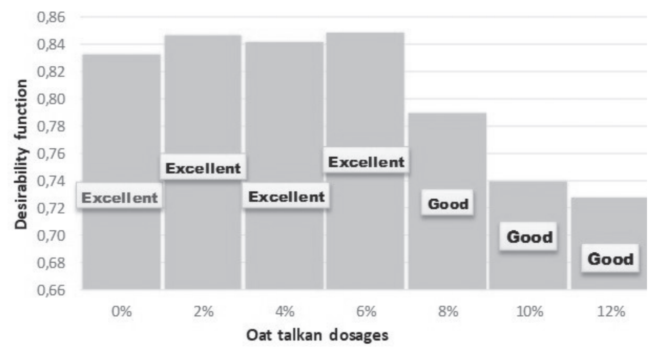

Figure 2. Chak-chak values by the desirability function at different oat talkan dosages.

Table 4. Natural and generalized chak-chak indicators by the desirability function.

Samples	Natural values responses						Individual desirability responses						Generalized desirability function D	Evaluation according to the desirability scale
	Density (kg/m3)	Moisture weight (%)	Water absorption (%)	Total sugar weight (%)	Fat weight (%)	Organoleptic quality indicators	Density (kg/m3)	Moisture weight (%)	Water absorption, (%)	Total sugar weight (%)	Fat weight (%)	Organoleptic quality indicators		
	x_1	x_2	x_3	x_4	x_5	x_6	d_1	d_2	d_3	d_4	d_5	d_6		
No. 1.	46.33	10.23	204.8	28.0	14.0	23,00	0.85	0.84	1.00	0.80	0.80	0.73	0.83	excellent
No. 2.	47.67	7.28	202.7	28.4	13.8	26,00	0.82	0.86	1.00	0.78	0.81	0.83	0.85	excellent
No. 3.	48.07	10.34	201.5	28.7	12.7	26,00	0.80	0.84	0.99	0.76	0.85	0.83	0.84	excellent
No. 4.	48.57	10.40	199.1	29.0	12.0	26,00	0.76	0.84	0.99	0.73	0.86	0.83	0.85	excellent
No. 5.	49.17	10.44	196.2	29.1	12.2	21,00	0.72	0.84	0.98	0.72	0.86	0.66	0.79	good
No. 6.	49.93	10.51	195.1	29.3	11.9	16,00	0.64	0.83	0.98	0.70	0.86	0.52	0.74	good
No. 7.	50.10	10.54	193.2	29.6	11.8	16,00	0.62	0.83	0.96	0.67	0.86	0.52	0.73	good

Sample No. 1.: control. Samples No. 2., No. 3., No. 4., No. 5., No. 6., and No. 7. are chak-chak with 2%, 4%, 6%, 8%, 10% and 12% of oat talkan, respectively.

Influence of oat talkan and bee products on structural and mechanical properties of chak-chak

Structural and mechanical properties of chak-chak dough are extremely important for the formation and subsequent roasting of semi-finished products (Muratova and Smolikhina 2013). The research results of the oat talkan effect on the dough properties are shown in Figures 3, 4. Similar methods to determine the rheological characteristics of flour and dough using a farinograph and a mixograph are widely used in researches to optimize the formula of bakery products (Munteanu et al. 2016). Particular parameters of the dough for confectionery products were studied using the farinograph. The data obtained are presented in the Table 5.

It is found that the dough development time of the control sample is 5.3 min, its resistance to mixing is 17.6 min. The score (an indicator of the flour "strength") is 200. The dough development time with oat talkan is shorter and amounts to 4.6 min. The dough resistance to mixing is longer by 18.1 min. At the same time, the dough with oat talkan has more homogeneous structure compared to the control sample. Therefore, it can be concluded that oat talkan accelerates the gluten development and the technological process of chak-chak production.

Table 5. Dough for confectionery products parameters

No.	Parameters	Control	Chak-chak with oat talkan
1	Wheat flour moisture content (%)	14.0	14.0
2	Dough formation time (min)	5.3	4.6
3	Resistance (min)	17.6	18.1
4	Consistency (FU)	580	550
5	Water absorption (%)	59	62

Influence of Oat Talkan on the Technological Process of Making Chak-Chak

To determine the effect of oat talkan on the production process, the time to fry dough pieces of chak-chak duration in deep fat is analyzed. During the studies, goods with 6% of oat talkan have been manufactured. The control samples of chak-chak are made according to the traditional recipe. The readiness of the chak-chak dough pieces is identified by humidity and appearance. The moisture content after frying was 8.9-9%. The results are shown in Figure 3.

It is found that the color of the dough pieces with oat talkan becomes golden brown in 2-3 min, while the control sample is still corn-colored. Moreover, the moisture content of the dough pieces with oat talkan decreases to 9% at the 3rd minute of roasting that indicates the readiness of the product.

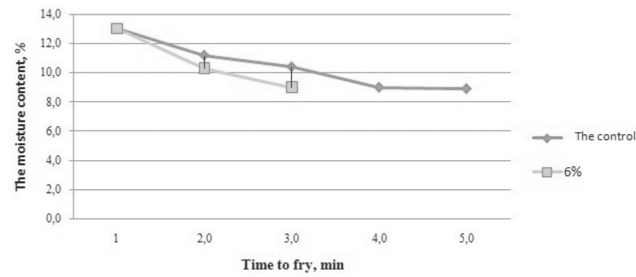

Figure 3. The effect of oat talkan on the time to fry chak-chak dough pieces.

Thus, the addition of oat talkan reduces the duration of frying by 2 min compared to the control sample. It can result from higher content of dietary fibers in oat talkan that provide acceleration of heat and moisture exchange processes.

Influence of oat talkan on structural and mechanical properties of fried semi-finished products of chak-chak

In the course of studies, the influence of different dosages of oat talkan on the density of fried dough pieces of chak-chak is identified. To conduct the study, fried semi-finished products of chak-chak with a dosage of oat talkan from 0 to 12% (in 2% increments) are used. The results are shown in Figure 4.

The dough height-diameter ratio increases in proportion to the amount of oat talkan. This demonstrates lower dough firmness.

The next stage of the research is the study of the structural and mechanical properties of deep-fried semi-finished chak-chak. The studies are carried out using the «ST-2 structure meter». During the study, 6 goods with

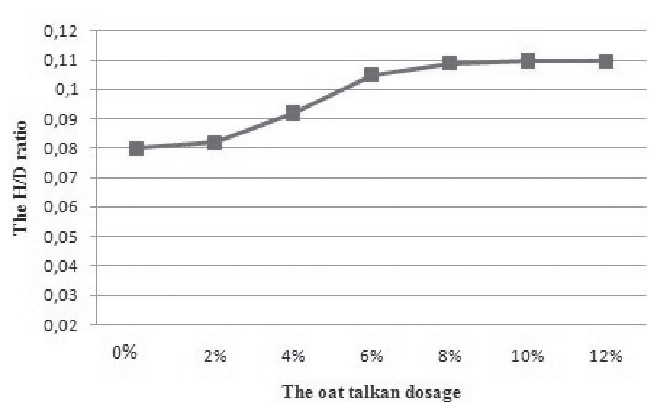

Figure 4. The height-diameter ratio of fried semi-finished products of chak-chak.

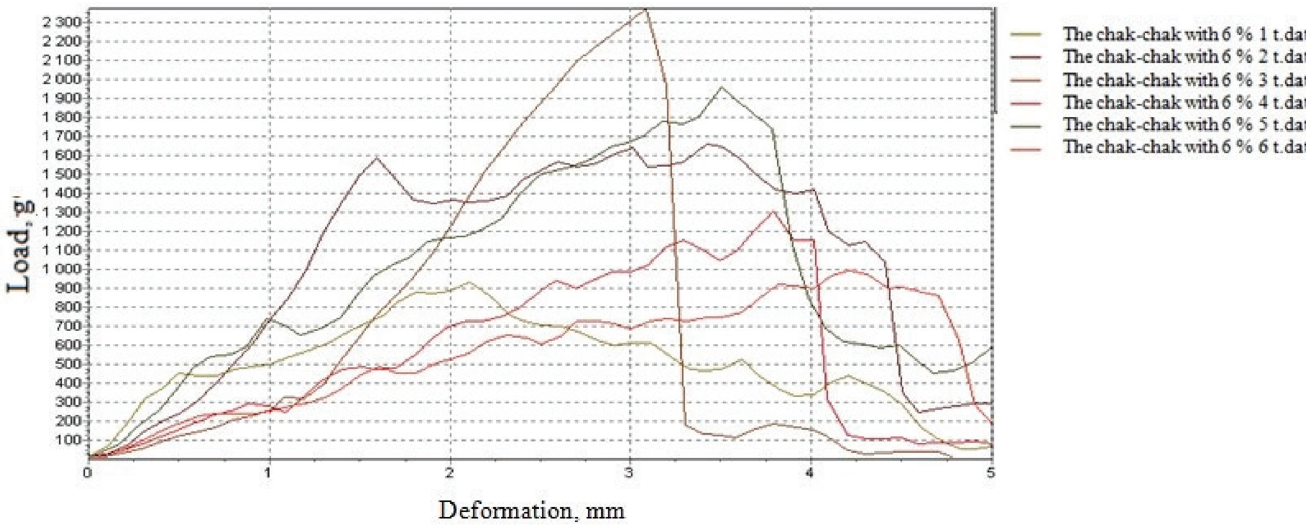

Figure 5. Assessing the strength of fried semi-finished chak-chak (the control sample).

6% of oat talkan from each batch and the control sample are selected. The strength and fragility of semi-finished products are examined with the help of the "Knife" indenter. The results are presented in Figures 5, 6.

The resulting data makes it possible to evaluate the structure and consistency of fried semi-finished products. The control samples are found to have a denser structure and less developed texture than the products with talkan. There is an increase in the volume of fried semi-finished chak-chak with talkan. Also, according to the data received, the fragility of products when adding oat talkan to the formula, is higher that is a positive property for this type of flour confectionery products.

Based on the conducted research, it can be concluded that oat talkan improves the consistency and structure of fried semi-finished chak-chak, which is why its addition to the chak-chak formula is reasonable. Chakkaravarthi et al. (2009) studied the rheological parameters of dough and fried semi-finished confectionery jalebi using a rheometer with a controlled voltage. Similar studies of the influence of various non-traditional raw materials on the structural and mechanical properties of flour confectionery and bakery were conducted by researchers (Thakur and Nanda 2018, 2019; Saleh et al. 2019).

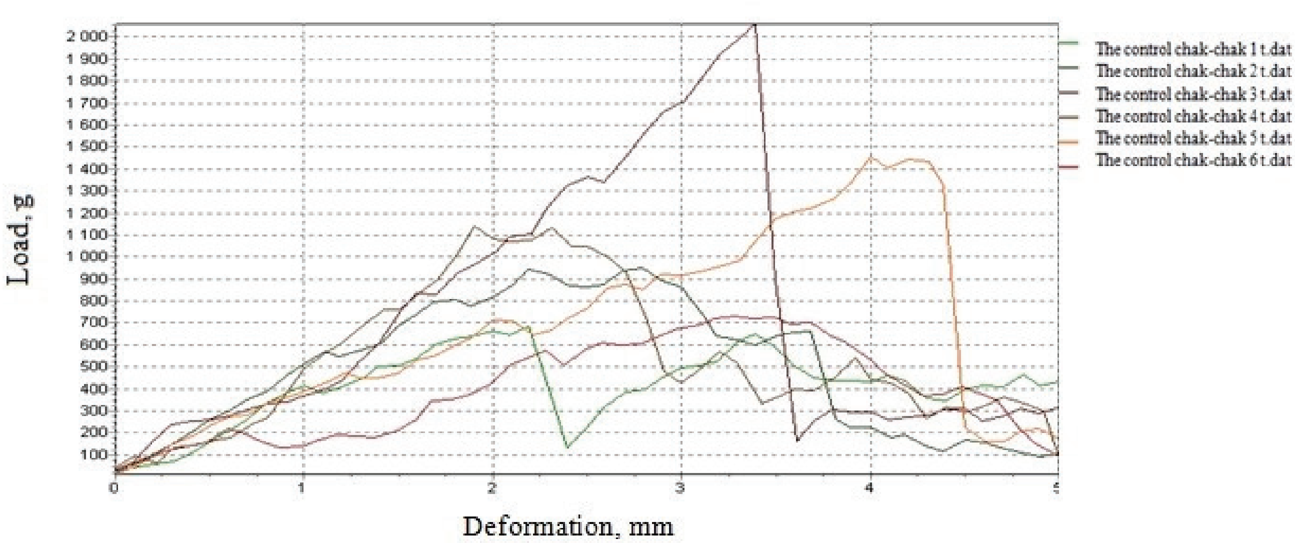

Figure 6. Evaluating the strength of fried semi-finished chak-chak with 6% of oat talkan

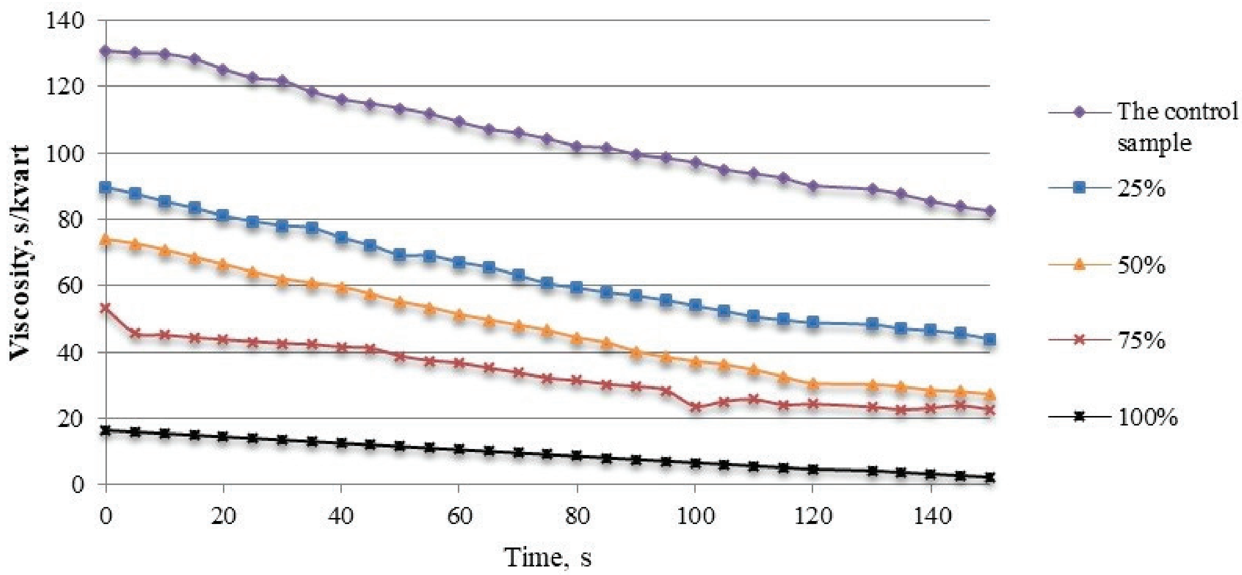

Figure 7. Dependence of the syrup viscosity on bee pollen content.

Development of a syrup formula for Chak-Chak with bee pollen

Since chak-chak is a high-calorie product, one of the goals of this work is to reduce the amount of sugar in the chak-chak syrup formula. Therefore, sugar in the syrup formula is replaced with bee pollen in the amount of 25%, 50%, 75%, and 100% of the sugar mass.

We identified the effect of the bee pollen dosage on the organoleptic characteristics of the syrup. With added bee pollen the color of the syrup becomes deep golden. There is also a pleasant taste and flavor pertinent to honey and bee pollen. There is also an organoleptic evaluation of the syrup with different dosages of bee pollen (results not shown).

It is found that the syrup with 25% of bee pollen has the highest organoleptic score being 30 points. It corresponds to the "excellent" assessment. With higher dosage of bee pollen there is a further change in the syrup color to brown and bitter taste. It is unacceptable for this type of finishing product.

To test the effect of bee pollen on the structural and mechanical properties of the syrup, its viscosity is examined. The results presented in Figure 7 clearly demonstrate the dependence of the syrup flow time in the March funnel on the dosage of bee pollen.

Bee pollen added to the syrup is found to reduce its viscosity. It can complicate the process of finishing the end product. To confirm the received results the strength characteristics and the syrup viscosity are analyzed on the «ST-2 structure meter» using the "Disk" indenter. It is conducted at 33 °C. The results are shown in Figure 8.

It is established that introducing the indenter in the control sample of the syrup requires more force than the indentation in the syrup with bee pollen. The results indicate a decrease in the syrup viscosity when bee pollen is added. Obviously, this is due to vitamins, minerals and amino acids in bee pollen that prevent the sucrose crystallization.

Discussion

The chak-chak product is authentic and has no analogues in the world. At the same time in many countries attempts have been made to improve the quality and properties of traditional flour confectionery goods by including bee products and different cereals.

There are a number of researches devoted to the change of rheological properties of flour confectionery under the influence of introduced ingredients. Thus, the influence of different flour from different varieties of flax seeds on rheological properties of wheat flour is studied. The rheological properties are evaluated by the Mixolab device. The dough microstructure is evaluated by epifluorescence light microscopy. Higher dosage of flaxseed flour brings in an increase in water absorption capacity and stability of the dough (Codină and Mironeasa 2016).

There are papers that study factors influencing the rheological characteristics of the dough, the effect of different additives as well as the interaction of ingredients. The most frequently used methods of rheological tests and their relation to the product functionality are also

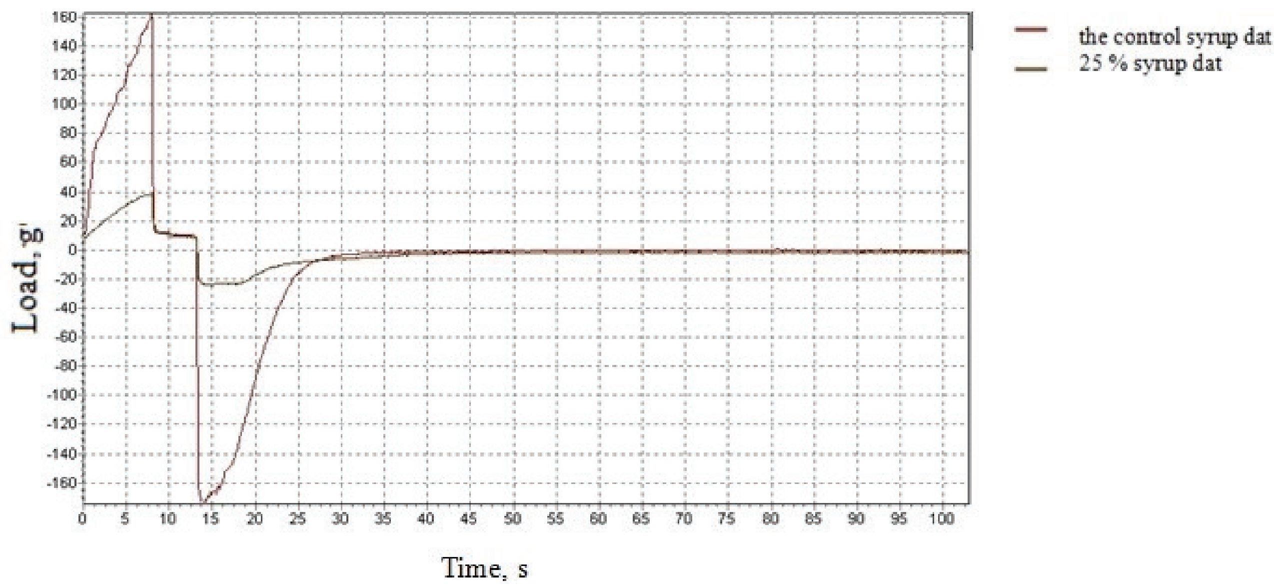

Figure 8. Effect of the bee pollen on the syrup viscosity.

analyzed (Amjid et al. 2013).

Studies on optimizing the content of iron (FE) and oligofructose (OF) in order to get wheat flour dough with the best rheological properties using the methodology of the response surface (RSM) are conducted. The rheological properties of the dough are tested with farinograph, alveograph, amylograph, falling number and rheofermentometer. Added iron and oligofructose are found to improve the structure of the product. With higher levels of oligofructose, water absorption, dough strength, its extensibility, the falling number, the temperature at high viscosity are significantly lower (Codină et al. 2019).

There are also a number of research works aimed at optimizing bakery and flour confectionery goods using the methodology of the response surface (Zhang and Datta 2006; Arghire et al. 2016; Munteanu et al. 2016; Tugush et al. 2018) and the desirability function (Zhang and Datta 2006; Myers et al. 2016; Tugush et al. 2018; Kilic et al. 2019). At the same time, the formula component optimization by creating mathematical models for the developed product has not been carried out. Therefore, we have developed nonlinear, multiple regression models based on the received data, natural and generalized desirability values. These provided the evidence base to justify practicability of ingredient introduction.

There is a work (Krystyjan et al. 2015), devoted to the study of the bee pollen influence on the qualitative properties of flour confectionery goods. Studies prove that bee pollen does not affect the fat content of cookies. However, there was a small but significant increase in the protein and mineral content of the product. Basically, the data obtained by other researchers indicate that the addition of processed cereal products, bee pollen and other bee products increases the biological and nutritional value of the end good that is also confirmed by our results.

Conclusions

As the result of the conducted studies nonlinear multidimensional statistical models are developed. The formula of chak-chak with oat talkan and the syrup with sugar replaced by bee pollen is optimized. The rational dosages are found to be as follows: wheat flour replaced with oat talkan in the amount of 6% (in the chak-chak formula) and sugar replaced with bee pollen in the amount of no more than 25% (in the syrup recipe).

The influence of oat talkan and bee products on the structural and mechanical properties of semi-finished products and finished products, as well as on the parameters of the manufacturing process is identified. When adding oat talkan to the chak-chak formula, the dough development time is reduced by 4.5 min, while the dough stability during kneading is increased by 1.5 min. Compared to the control sample, the products with oat talkan have a more aerated structure and developed porosity. There is an increase in the volume of fried semi-finished chak-chak with talkan. The addition of bee pollen is found to reduce the syrup viscosity.

It is found to be reasonable to use bee products and oat talkan in the chak-chak formula to improve the structural and mechanical properties of the product and reduce the production process by accelerated time for dough development and dough pieces frying.

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