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TECHNOLOGY SOLUTIONS IN CASE OF USING CHICKPEA FLOUR IN INDUSTRIAL BAKERY

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Abstract: Chickpea derivatives are very promising flour products for bakery; however, their oligosaccharide content and a distinct bean smell limit their use. This paper contains proposals for various technology solutions for using chickpea flour in bakery. The authors consider such opportunities as: straight dough and sponge dough procedures for making semi-finished products (unbaked loaves), preparation of pregelatinized chickpea flour, micronization of chickpeas and using them together with flaxseed flour and exopolysaccharide. As a result, the authors choose optimal parameters and process modes for the proposed technology solutions.

Keywords: *chickpea micronization, dough rheology, farinogram, flaxseed flour, oligosaccharides*

INTRODUCTION

In order to increase the share of mass-consumption food products fortified with vitamins and mineral substances, including mass-consumption breads, up to 20-25 % of the total industry output, and to ensure supply of locally manufactured products to 80 % of specialized infant food's sector (including dietary: clinical and health nutrition), the following programs have been designed and developed:

- The concept of long-term social and economic development of the Russian Federation till the year 2020 (Approved by the decree of the Government of the Russian Federation, of November 17th 2008, No. 1662-r) [1];
- Basic principles of state policy of the Russian Federation on people's health nutrition till the year 2020 (Approved by the decree of the Government of the Russian Federation, of October 25th 2010, No.1873-r) [2];
- The concept of healthy nutrition of the population of Saratov Region for the period till the year 2020 (Approved by an executive order of the Government of Saratov Region, of December 12th 2012, No.805-P [3].

The research and development efforts of the Russian scientists have been directed toward implementation of the state programs on healthy nutrition.

Chickpea is a very attractive raw material for food industry; however, its content of oligosaccharides limits its use. The researchers from Voronezh State University of Engineering Technology have developed a bakery method for producing bread of increased bioavailability from bio-activated chickpeas; at the same time, the activity of urease goes down during the whole process of peas sprouting and finally reaches a 2-fold reduction [4].

Researchers at Engels Technological Institute believe that producing chickpea isolates and concentrates is promising [5].

The purpose of this study is to consider the opportunity of using a range of various technology solutions for inclusion of chickpea flour ingredients into baking formulas.

The chick proteins are mainly albumins (water-soluble proteins) and globulins (soluble proteins), which averaging 97 % on average. The data of the fractional composition of proteins confirm that the products of chickpea processing can be used in the technology of cooking foods with a low content of gluten [6].

Seeds of chickpea in significant quantities contain (mg/100 g of product) phosphorus - 290, potassium and magnesium - 126. This is one of the few legumes that are favorable for the human body ratio of calcium and phosphorus 1:1.5.

For the chickpea varieties studied, a high content of essential fatty acids, such as linolenic 30 %, linoleic 60 %, oleic 23-28 % is characteristic [6].

The presence of polyunsaturated fatty acids creates conditions for the formation of prostaglandins, preventing the concentration of heavy cholesterol on the walls of blood vessels.

Thanks to the essential amino acids, vitamins, minerals and food fibers contained in chickpeas, it is rightfully considered a "health grain" and recommended for use in therapeutic and preventive nutrition. The high biological value of chickpea (68 %) indicates the balance of its amino acid composition. By its biological value, this culture is superior to lentils and peas. Chickpea is a source of lecithin, riboflavin (B_2), thiamine (B_1), nicotinic and pantothenic acids, choline, selenium, which has an antioxidant effect, increases the body's resistance to cancer [7].

MATERIALS AND METHODS

In the study, we used the following raw materials:
High-quality white wheat flour meeting the requirements of State Standard (GOST) R 52189-2003, wholegrain chickpea from the seeds of Krasnokutsky 36 and Vector flour (according to specifications 9293-001-02068108-2013), flaxseed flour (specifications 9293-011-92001421-08), exopolysaccharide - xanthan gum, sunflower oil (GOST R 52465-2005), sodium chloride (GOST R 51074-2003), drinking water (Sanitary Rules and Standards SanPiN 2.1.4.1074-01), granulated sugar (GOST 21-94), margarine (GOST R 52178-2003).
For the purpose of assessing the impact of chickpea flour on the characteristics of semi-finished products and on the quality of final produce, we kneaded the dough according to formulations presented in Tables 1-3. Based on these process designs, dough was needed in a laboratory doughing machine LABOMIX 1000.

Table 1. *Formulation of dough for bread made of high-quality white wheat flour*

Name of raw material, semi-products and process parameters	Consumption of raw material, process parameters
High-quality white wheat baking flour [kg]	100.0
Compressed yeast [kg]	2.5
Sodium chloride [kg]	1.5
Drinking water [kg]	as per calculation
Initial temperature [ºC]	30.0
Fermentation time [minutes]	150.0
Maximal final *p*H	3.0

Table 2. *Formulation of dough for 'Studenchesky' loaf, with an addition of chickpea flour [7]*

Name of raw material, semi-product and process parameters	Consumption of raw material, process parameters
High-quality white wheat baking flour [kg]	95, 90, 85
Chickpea flour [kg]	5, 10, 15
Compressed yeast [kg]	1.0
Sodium chloride [kg]	1.5
White sugar [kg]	5.0
Table margarine [kg]	4.5
Drinking water [kg]	as per calculation
Initial temperature [ºC]	30.0
Fermentation time [minutes]	180.0
Maximal final *p*H	4.0

* These are different recipes, the quantity of each component of the formulation is selected on the basis of the analysis of the quality of the finished products according to our normative document.

Fermentation of dough was done in the UNOX proofer at 28-30 ºC and ambient air relative humidity of 80-85 %. The prepared dough was balled up, molded and placed for final proofing for around 40-50 minutes. Before oven-loading, the test pieces were manually incised with a knife.

Table 3. *Formulation of dough for the wheat and chickpea loaf, sponge and dough method [8]*

Name of raw material, semi-products and process parameters	**Consumption of raw material, process parameters**
Tight sponge, with pregelatinized chickpea flour	60.0
High-quality white wheat baking flour [kg]	45.0
Compressed yeast [kg]	1.0
Sodium chloride [kg]	1.5
White sugar [kg]	4.0
Table margarine [kg]	3.5
Drinking water [kg]	as per calculation
Initial temperature [ºC]	30.0
Sponge fermentation time [minutes]	150.0
Maximal final *p*H of sponge	4.0
Dough fermentation time [minutes]	70
Maximal final *p*H of dough	4.0

The dough was baked at 220-250 ºC. The baking time was 19-22 minutes.
For micronization method, chickpeas were moistened in advance (from 11.9 up to 28 %) and then processed in an infra-red drier to ensure humidity of 4.5 %. Then, chickpeas were refined in a centrifugal laboratory mill; the sieve grid size was Ø 1 mm.
The experiment versions differed in the amount of chickpea flour added to the sponge and the dough. The control samples were prepared by replacing a part of white wheat flour with chickpea flour in the amount of 5, 10, and 15 % of the total weight of flour.
Dough rheology was measured using 'Brabender' farinograph.
Flavour tests on baked loafs were taken 24 hours after baking, on the laboratory premises of Sensor Technologies JCS, Voronezh State University of Engineering Technology, using odour analyzer MAG-8 with the electronic nose technique [5, 7]; it is an analytical tool comprising a system of low-selectivity sensors with cross-reactive specificity to different substances.
For measurements, an array of 8 sensors was used, based on piezo-quartz bulk acoustic wave (BAW) resonators, with basic oscillation frequency 10.0 MHz and having dissimilar film sorbents on their respective electrodes.
The electrode coatings were chosen in accordance with the task of the *tests (possible emission of different organic compounds from the samples*): polar ones (sensitive to alcohols, aldehydes, ethers, phenols, and other organic compounds): polyvinyl pyrrolidone, high density polyethylene (sensor 1); Triton X-100 (sensor 2); trioctylphosphine oxide (sensor 3), 18-crown-6 (sensor 4), polydiethylene glycol succinate (sensor 5), Tween-40 (sensor 6), 4-aminoantipyrine (sensor 7), dinonyl phthalate (sensor 8) [7].
The measurement time was 120 s; sensor response recording mode - uniform, in 1 sec increments; the optimal sensor response representation algorithm - gradient 3/20 s. The measurement error was 5-7 %.
To measure dynamic viscosity of the semi-product, we used Vicko Tester VT7R rotation viscometer, rotor No. 7, the temperature of the samples at measuring was +38 - +42 °C.

RESULTS AND DISCUSSION

Adding chickpea flour to bakery formulation has its impact upon the quality of semi-product and the final bread. According to our research, in the bread recipe the optimal content of chickpea oil is not more than 5 %, more is observed the enhancement of bean flavor [6]. When kneading dough from low quality wheat flour, an addition of 5-15 % of chickpea flour occasions substantial changes in dough rheology. Dough resistance and stability goes up 2.5-3 times and liquefaction coefficient decreases by 2.5 times, which also has had its impact on valorimetry (Table 4, Figure 1) [9].

However, with the increase of chickpea flour's share to 20 %, dough rheology deteriorates due to smaller amounts of grain gluten while dough liquefaction quickens because of a lesser content of gluten proteins and an increase in water-soluble proteins of chickpea (Figure 2). In the course of the pharynographic test, the following parameters were recorded: resistance to the batch test; Stability of the test; Dilution of dough; Elasticity of the dough; Valorimetric evaluation. The data obtained were subjected to the analysis of variance.

Table 4. *Rheology of white wheat dough with addition of 5, 10, 15, and 20 % of chickpeaflour of Zavolzhsky variety (white wheat bakery flour, 1st grade, of Kalininsk private enterprise)*

No.	Sample	Dough resistance [min]	Dough stability [min]	Dough liquefaction [BU]	Dough elasticity [mm]	Valorimetry [VU]
1	5 %	8.50 b	15.75 c	40.0 a	1.15 b	95.5 b
2	10 %	9.50 b	15.50 bc	45.0 a	1.15 b	96.5 b
3	15 %	8.25 b	8.75 a	60.0 abc	1.20 b	94.5 b
4	20 %	7.25 b	6.00 a	87.5 c	1.15 b	93.5 b
5	Control	3.00a	9.50 a	75.0 bc	0.90 a	87.5 a
	F	9.6*	9.8*	15.5*	8.1*	10.4*
	HCP_{05}	3.21	5.43	13.61	0.16	4.30

*Significance of F-criteria at the error level of 0.5 %

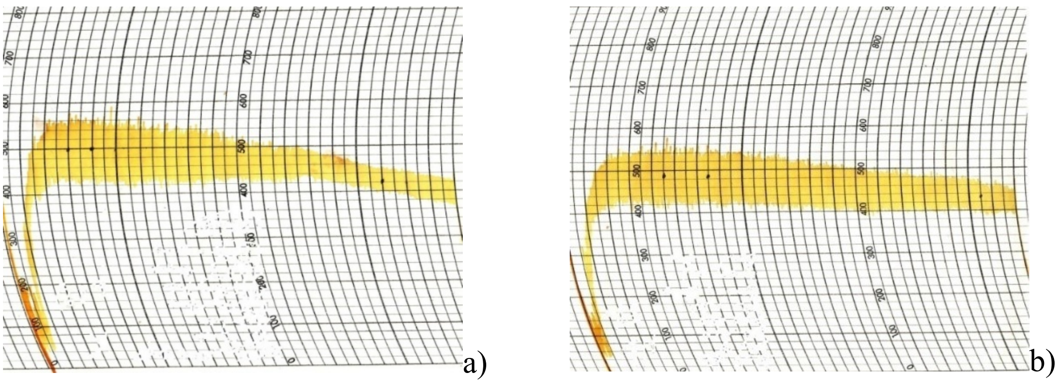


Figure 1. *A farinograph diagram of dough kneaded from white wheat flour, a) trademark 'Selskaya Yarmarka' (control); b) with an addition of flour from Krasnokutsky 28 variety seeds*

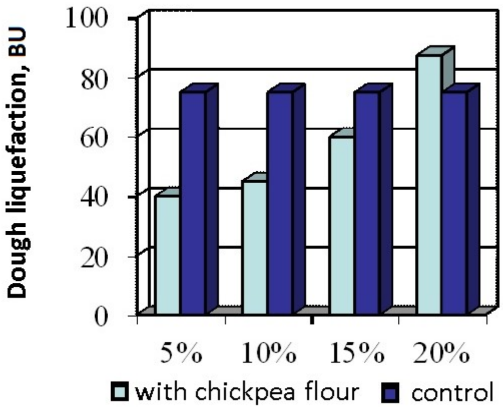


Figure 2. *Chickpea flour effect on the liquefaction index of dough from wheat flour of Kalininsk private enterprise*

When adding 20 % of chickpea flour, liquefaction of the dough accelerates due to the reduced amount of gluten content and the increased amount of water-soluble proteins of the chickpea (Figure 2).

Chickpea proteins solubility fractionation has revealed substantial differences in the content of individual protein fractions (Figure 3), depending on seed variety.

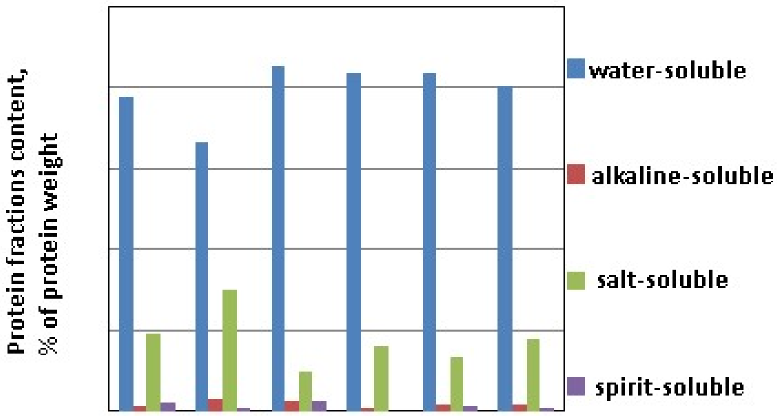


Figure 3. *Chickpea proteins' fractional composition depending on seed variety: 1 - Krasnokutsky 28; 2 - Krasnokutsky 123; 3 - Krasnokutsky 36; 4 - Zavolzhsky; 5 - Vector; 6 - Yubileyny*

Using flour from micronized chickpeas in bakery opens up new and promising opportunities for product diversification.

In the studies by M.K. Sadygova [6, 10], it was shown that with addition of over 5 % of chickpea flour, a pronounced bean smell is observed, porosity deteriorates, and the bread volume decreases [6]. According to the research by V.A. Bukhovets, with the help of heat treatment it is possible to eliminate this problem [11].

The chickpea proteins are mainly albumins (water-soluble proteins) and globulins (salt-soluble proteins), which add up to 97 % on average. The fractional composition data of these proteins confirm that the products of chickpea processing can be used in the technology of cooking foods with low gluten content [12].

Chickpea seeds contain, in significant quantities (mg/100 g of product), phosphorus (290), potassium and magnesium (126). This is one of the few leguminous plants which have a favorable calcium-to-phosphorus ratio for the human body (1:1.5).

For the chickpea varieties studied, high contents of essential fatty acids are characteristic: linolenic (30 %), linoleic (60 %), and oleic (23-28 %) ones [6].

The presence of polyunsaturated fatty acids creates conditions for the formation of prostaglandins, preventing concentrating of heavy cholesterol on the blood vessel walls.

Owing to the essential amino acids, vitamins, minerals and food fibers contained in chickpeas, it is rightly considered a "grain of health" and recommended for use in therapeutic and preventive nutrition. The high biological value of chickpea (68 %) indicates the proper balance of its amino acid composition. By biological value, this culture is superior to lentils and peas. Chickpea is a source of lecithin, riboflavin (B_2), thiamin (B_1), nicotinic and pantothenic acid, choline, selenium, which renders antioxidant effect, increases the body's resistance to oncology diseases [13].

Before seed micronization, one batch of seeds was additionally treated by water steam in order to increase their humidity to 23.9 %. The pre-treated chickpeas were placed in an infrared drier at 130-135 °C for 2 hours in order to reduce humidity down to 12.1 %. The pre-treated chickpeas were refined then in a laboratory mill.

In the study, we used two methods of making dough: straight dough mixing and sponge dough mixing. The experiment variants differed in the content of flour from micronized chickpeas used in the bread formulation (5, 10 and 15 %) (Table 5).

***Table 5**. Experiment variants*

№	White wheat loaf samples	
	straight dough mixing	**sponge dough mixing**
1	control	control
2	with an addition of untreated chickpea flour, 5 %;	with an addition of untreated chickpea flour (10 % - to the sponge, 5 % - to the dough)
3	with an addition of untreated chickpea flour, 10 %;	with an addition of untreated chickpea flour (5 % - to the sponge; 10 % - to the dough)
4	with an addition of untreated chickpea flour, 15 %;	with an addition of micronized chickpea flour (5 % - to the sponge, 10 % - to the dough)
5	with an addition of micronized chickpea flour, 5 %;	with an addition of micronized chickpea flour (10 % - to the sponge, 5 % - to the dough)
6	with an addition of micronized chickpea flour, 10 %;	with an addition of micronized chickpea flour (15 % - to the sponge, 0 % - to the dough)
7	with an addition of micronized chickpea flour, 15 %	with an addition of micronized chickpea flour (0 % - to the sponge, 15 % - to the dough)

Upon baking and cooling of bread, we carried out an assessment of its quality (in points) by the following organoleptic parameters: crust color, porosity, crumb rheology/chewiness/taste/smell. This was found by organoleptic method (human sensors, our sensory organs, sense of smell, vision).

According to Table 6, we see that by all indicators, the sample with 5 % of added pre-treated flour distinctly stands out (94.9 points); on the other hand, the sample with an additionof 10 % of pre-treated flour is a very close "second best".

Table 6. *A comparative assessment of bread made using different dough mixing methods*

Organoleptic indicators	Experiment samples						
	1	2	3	4	5	6	7
Straight dough mixing							
General assessment, points	91.7	92.0	84.7	81.2	94.9	93.8	80.9
Sponge dough mixing							
General assessment, points	90.7	86.0	84.7	93.2	94.9	90.2	91.9

We see from Table 7 that an addition of chickpea flour in the amount of 15 % makes bread's porosity slide. The more chickpea flour finds its way into a bread formulation, the higher is acidity, which is determined by chickpeas' chemical composition.

Table 7. *Physical and chemical quality parameters*

Parameters	1	2	3	4	5	6	7
Straight dough mixing							
Acidity number	1.2± 0.11	3.5± 0.1	3.8± 0.12	5.1± 0.9	3.8± 0.1	5.6± 0.1	5.6± 0.12
Porosity [%]	82.5± 2.1	80.0± 2.9	81.7± 2.7	77.3± 2.9	79.5± 2.3	81.6± 2.7	67.0± 2.8
Sponge dough mixing							
Acidity number	2.4± 0.11	3.0 ± 0.1	3.0± 0.12	2.8 ± 0.9	2.8 ± 0.1	3.1 ± 0.1	2.9± 0.12
Porosity [%]	70.3± 2.1	59.6± 2.9	56.7± 2.7	67.2± 2.9	65.3± 2.3	60.1± 2.7	62.1± 2.8

Using micronized chickpea flour in bakery opens up new and promising opportunities for product diversification. The process of micronization relying on infrared rays leads to a quick and effective warming-up of seeds, due to which moisture in seeds goes out through evaporation, at the same time – because of a very fast heating - the pressure of water vapor increases and intensifies chemical and biological processes in seeds. This is the reason why toxic and anti-nutritional substances in seeds (trypsin, pepsin) are destroyed, protein compounds become denatured, and green starch's structure becomes broken, which contributes to their transformation into a more easily digested form [7].
Bun formulations allow adding 15-20 % of chickpea flour.
To improve the formulation of 'Studenchesky' loaf by using chickpea flour, we took the input parameters as follows: X_1- protein content in baked bread; X_2- chickpea flour content, % of the weight of flour; X_3- the loaf crumb rheology. The criterion of various factors' impact on the quality of baked bread was an integrated assessment of loaf quality, in points (Figure 4).
The optimization demonstrated that a 10 % addition of chickpea flour to the formulation of 'Studenchesky' loaf led to a better crumb rheology and a higher integrated score of the baked bread. For 'Studenchesky' loaf's formulation, a package of normative documentation was duly developed and approved – the specification TU 9115-001-00493497-2010.

$$K = F(X_1, X_2, X_3, X_4)$$

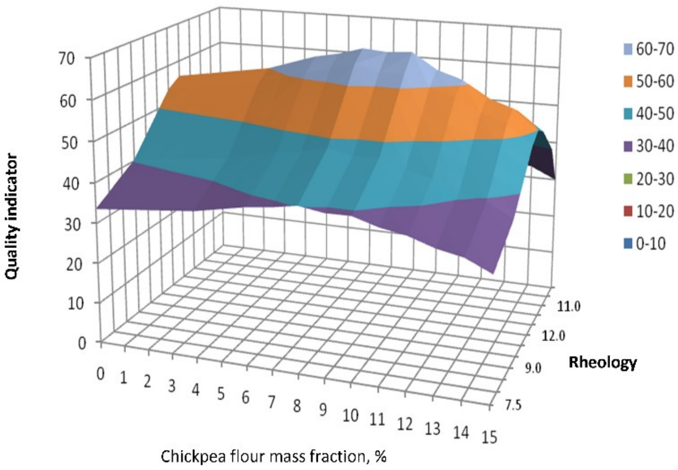
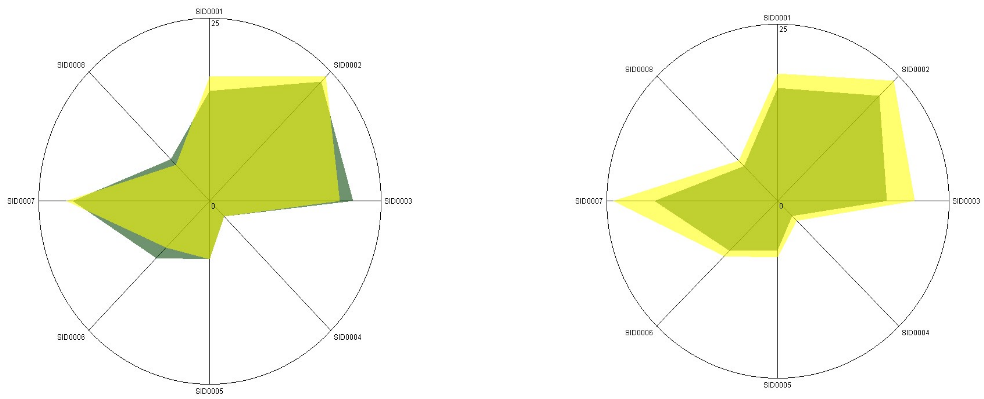


Figure 4. *A correlation between the quality indicator and the percentage of chickpea flour/bread rheology*

In 'Studenchesky' loaf, the addition of chickpea flour in a native form leads to a significant rise in the concentration of nitrogen-containing compounds in the equilibrium gas phase (Figure 5), the content of esters goes up while the content of acids slides down when measured in the air above the sample loaf; at the same time, the amount of nitrogen-containing organic compounds, which are characteristic of chickpeas, does not change. The organoleptic assessment of the smell of the wheat and chickpea loaf (done by end users) showed that they could feel a pleasant nutty scent coming from the baked bread.



a) Relative surface difference: 2.1 % (insignificant)

b) Relative surface difference: 39.3 % (significant)

Figure 5. *Comparison of the kinetic 'visual images' of signals from the array of sensors for the tests: a – 'Studenchesky' loaf with chickpea flour; b – white wheat and chickpea loaf*

In order to improve the nutritional and biological value of the bread, we added 15 % of chickpea flour to the formulation of the wheat and chickpea loaf. For the removal of legume odour, chickpea flour is to be pregelatinized. Due to this process, starch becomes more amenable to the work of amylolytic enzymes of white wheat flour, which, in its turn, leads to a better quality of baked bread.

For the wheat and chickpea loaf's formulation, a package of normative documentation was duly developed and approved – the specifications TU 9115-002-00493497-2010, and patent No. 2429599 was taken out on the method of its production [14]. The economic feasibility, technological expedience and social significance of the proposed formulation and process technology were confirmed by their practical approbation in an industrial environment.

In order to improve the rheology of semi-finished products, *i.e.* to make the dough more structural and prevent its spreadability, we propose the use of flaxseed flour. Since there is no gluten in the chickpea oil, when it is enlarged in the recipe, the semi-finished product spreads, so we recommend a composite mixture with linseed flour, which reduces the spreadability.

To the formulation of 'Studenchesky' loaf we added a composite mixture comprising 15 % of chickpea flour and 5, 10, 15 % of flaxseed flour. The control test, 'Studenchesky' loaf with 15 % of chickpea flour, showed that the unbaked pieces lose their form already in 60 minutes of observation (Figure 6). If additional 5-10 % of flaxseed flour is introduced, we observe an improvement of structural and mechanical properties of unbaked loafs, which leads to a better quality of the end product. On the other hand, we have to point out that in this case, the color of the crumb alters.

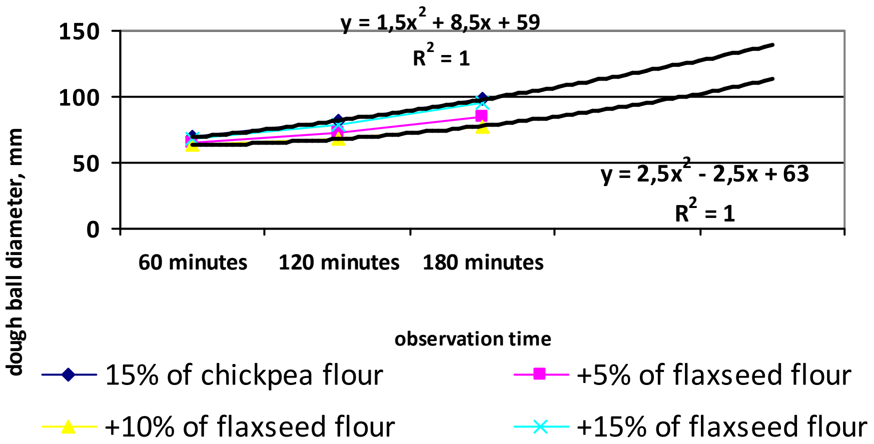


Figure 6. *Dependence of dough ball diameter on composite mixture*

One of the possible technology solutions here is the use of an exopolysaccharide - xanthan gum, which also has a beneficial effect on the rheology of unbaked loafs with the 15 % content of chickpea flour. We added exopolysaccharide in the amount of 1, 1.5 and 2 % of the weight of flour to the formulation of 'Studenchesky' loaf with 15 % of chickpea flour (Table 8).

We compared products with chickpea flour, with the increase of which the dough spreads out. To overcome spreading out, we propose such a technological solution as adding a polysaccharide; its affect on the dough viscosity is shown in Table 8.

Table 8. *Impact of different additives on the viscosity of the system*

Test variant	**Content in the formulation [%]**		**Measurement rate [rpm]**	**Dynamic viscosity [cP]**
	chickpea flour	**exopolysaccharide**		
1 - control test (without additions)	10	-	RPM=30	57500-54000
2	10	1	RPM=12	255400-264500
3	15	-	RPM=12	154900-158000
4	15	1,5	RPM=6	447000-457600
5	20	-	RPM=5	45490-46470
6	20	2	RPM=5	170140-143180

The more chickpea flour and polysaccharide in the formulation, the bigger are changes in the dough rheology, which leads to a decrease in the measurement rate of the viscometer. With 15 and 20 % of chickpea flour in the formulation, the consistency becomes more viscous and the dough dilutes. But it must be noted that the samples with exopolysaccharide showed lower dynamic viscosity if compared with those without exopolysaccharide; the system stabilizes itself, dough dilution is prevented, which leads to a better shape stability of unbaked loafs. So, the conclusion is that adding exopolysaccharide to 'Studenchesky' loaf had a positive effect upon the quality of baked bread.

CONCLUSIONS

Proceeding from the above, we can make a conclusion that the proposed methods of dough processing and chickpea seeds treatment, as well as additional introduction of processing additives allow removing the specific legume odor and reduce the content of anti-nutritional substances of chickpea flour.
The proposed process solutions can be implemented in the conventional technology of baking. The products developed as part of the study demonstrated a better nutritive and biological value and can be recommended for mass consumption with the purpose of enriching people's food ration with plant proteins and micronutrients.

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