Advances in Engineering Research, volume 151

International Conference on Smart Solutions for Agriculture (Agro-SMART 2018)

Influence of Flaxseed Flour on Dough Rheology from Wheat-Flaxseed Meal

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***Abstract*—To add new raw materials to the bread recipe in order to increase the nutritional value is associated with the changes of the properties of the dough. First of all, these changes relate to the fermentation processes and rheological properties. Flax can be used for directional modeling of food value of bread. However, the effectiveness of the enrichment of bread, as well as the degree of its influence on the technological properties and fermentation of the dough, depends on the dosage of flax. The objects of the study were flour mixes from wheat flour bakery and flour from oil cake flaxseed in the ratio of 92.5%:7.5%; 90.0%:10.0% and 87.5%:12.5%. Rheological properties of the dough were studied in the Mixolab. There were some established differences in the parameters of the rheological profile of the flour mixtures and fermentation of the dough obtained on their basis. Water absorption capacity increases consequently with the increase of dosage of flaxseed flour, kneading time, the time of the stable state of the dough and its initial acidity. "Viscosity", "Amylolytic Activity" and "Retrogradation" are decreasing. This contributes to a more rapid maturation of the dough and reduces the total duration of its fermentation 1,5 times.**

Keywords—enrichment of bread; flax flour; flour mixes; the dough; biochemical properties; rheological properties

I. INTRODUCTION

Nutritionists consider flax seeds (Linumus itatissimum L.) not only as a source of edible oil, which is rich in α-linolenic acid [1, 2], but also as an additional source of protein [1, 3], soluble and insoluble dietary fibers [4, 5], and lignans [6, 7]. It is the properties of these components of flax seeds and products of their processing which determine the growing popularity of their inclusion in the ingredients of food products and the activity of researching them as raw materials with dietary properties. It has been sorted out that the peptides of flax seed proteins have antioxidant properties [8], and their soluble dietary fibers contribute to the reduction of glucose and cholesterol, specifically when included in the diet of diabetic patients [9–11]. Lignans of flax seeds are involved in the weight, lipid profile and blood pressure regulation [6, 7, 12].

The variability of the composition of the ingredients of linseed oil occurs due to the differences between botanical species and the varieties of this plant [13, 14]. However, the oil of all botanical species and varieties has dietary properties, which include the effect on the functional activity of the membranes of red blood cells, hepatotropic effect, antitumor effect [15, 16], and, above all, the possibility of directed

regulation of the lipid spectrum of blood serum [17] and the associated cardioprotective effect [18]. Mainly, the dietary properties of linseed oil are explained by the high content of α-linolenic acid, but the presence of natural antioxidants, such as fat-soluble vitamins and selenium [2], have a certain value.

Along with the listed positive effects of linseed oil, there is reliable clinical evidence that this product should not be considered as an independent active preparation of fatty acids omega-3 [19]. An excessive enrichment of the diet with α-linolenic acid of linseed oil can lead to a reduced provision in the body's vitamin E supply and deterioration in the overall vitamin status [20].

The ambiguity of clinical data on linseed oil dietary properties was the reason for the emergence of a new scientific research trend, the main purpose of which was to change the thrombogenic and atherogenic characteristics of animal and poultry fats through modification of their diet by the inclusion of the linseed oil or flax seeds [21–23].

However, the traditional direction of research does not give up its position, offering the modification of the daily human diet with inclusion of flax seeds or linseed oil directly into the consumed products. One of the most popular topics concerning this issue is the inclusion of flax seeds processing products in the ingredients, of flour products, mainly of bread [4, 7, 11, 24].

Bread is one of the most convenient products for the nutritional value directed modeling of in order to ensure the preventive effectiveness of the daily diet.

The best-studied way to adjust the nutritional value of bread is its enrichment with dietary fibers in the form of bran or whole grain flour. This criterion fully meets the dietary fiber of flax seeds and flour from flax seeds [25]. Somehow, flaxseed oil, can be considered both as an enriching component and as a plasticizer, because fats in bread technology play an important role, providing the necessary consistency of the dough, the elasticity of the crumb, reducing the rate of staling, and increasing the nutritional value of baked products. At the same time, a number of experimental studies show that the adding of grinded flax seeds into the dough consistence in physiologically significant dosages can lead to a significant deterioration in the taste and flavor of bakery [26], snacks [27], and confectionery products [28]. As a rule, it is caused by the high rate of linseed oil oxidation and determines the need for "veiling" the manifested negative effects in the organoleptic properties of flour products with flax seeds. One of the technological "findings" in this plan was the possibility of nanocapsulation of linseed oil before adding into the ingredients of flour products, including the use of protein-polysaccharide mixture as a material for capsules [29].

The statistics of publications devoted to theoretical and experimental studies of including flax seed processing products into the ingredients of bakery products, indicates the growth of scientific and practical interest to the topic. The scientific literature shows that the inclusion of flax flour in the ingredients of flour mixtures has an effect on the technological properties of the flour and the process of dough formation. However, the available publications do not have enough data to obtain the unambiguous representation of the effect of flax flour on the rheological properties and enzymatic complex of the dough.

Since the properties of the dough as an elastic-viscous-plastic body determine ultimately the technological characteristics of semi-finished products and the quality of finished bread, the aim of this work was to research the effect of the flax flour dosage on the biochemical properties of mixes of wheat and flax flour, on the process of maturation, and on the rheological properties of the dough from mixes of wheat and flax flour.

II. OBJECTS AND METHODS OF RESEARCH

The objects of the research were as follows:

1) flour from oil cake flaxseed (Linum usitatissimum L., Linaceae). It is flax flour that was obtained by a cold pressing of oil flax seeds, with the subsequent grinding oil cake into flour with a dispersion of less than 0.5 mm (Fig. 1). It has a characteristic flavor of flax seeds, light brown. According to the manufacturer's label, nutritional value of 100 g of flax flour includes 36 g of proteins, 10 g of fats, and 9 g of carbohydrates;
2) flour mixes, which were obtained by wheat flour bakery mixing (Triticum aestivum) first grade and flax flour in the ratio of 92.5% : 7.5%; 90.0% : 10.0% and 87.5% : 12.5% (by weight);
3) first grade wheat flour bakery, used as the object of control research in the study of the quality of flour mixes, while studying the rheological properties of the dough and at the stage of analysis of the quality of bread.

The results of experimental studies of flour mixes and bread were received with the help of the methods adopted in the grain processing and baking industry.

a  b 

Fig. 1. Oil cake flaxseed (a) and flour from oil cake flaxseed (b)

The sugar-forming ability of flour mixes was determined by the number of maltose (mg) formed in 1 hour of insisting a water-flour suspension from 10.0±0.1 g of flour mixes and 50 cm3 of water at a temperature of 27 °C.

The acidity of flour mixes was determined by titration of the sample (in the form of water suspension) with 0.1 m sodium

hydroxide solution, with calculation of value of the indicator by the sum of all acid-reacting substances passing into the water.

Water absorption of the flour mixes and rheological properties of dough of experimental compositions were studied by ISO 17718:2013 [30], using the Mixolab device (Chopin Technologies, France) in accordance with the technical description of the device, in the Protocol "Chopin+".

The way the bread looks, crumb condition, taste and smell were determined by organoleptic methods.

The moisture content of the bread crumb was determined by drying the crumb samples weighing 5 g at a temperature of 130±2 °C for 45 minutes, followed by weighing and calculating the value of the indicator in %.

Porosity of bread was determined by acquiring cylindrical clipping of crumb of a certain volume with their subsequent weighing and calculation of the value of the indicator in %.

Data analysis was performed with the SPSS package (SPSS 6.0 for Windows, SPSS Inc., Chicago, IL, USA).

III. RESULTS AND DISCUSSION

A. Biochemical properties of flour mixes

The addition of flax flour should have a significant impact on the biochemical properties of flour mixes and dough fermentation, even based on theoretical prerequisites. In the enzyme complex of products of flax seeds processing the main role is played by the hydrolytic and oxidation-reduction enzymes, which become even more active in the presence of free water. Dough kneading can be taken as an example, including the instrumental study of its rheological properties. Being one of the factors affecting on the structure of the dough, the increasing activity of lipase is of great importance in the bakery production. Including – indirectly: due to the effects, created in the structure of the dough components by hydroperoxides of fatty acids.

Amylases of wheat flour are responsible for the rate of starch hydrolysis and the composition of the resulting products of hydrolysis, providing the microflora of the dough with sugars necessary for the fermentation processes of the dough. In wheat flour with high baking qualities, part of the α-amylases is connected with protein, which limits their amylolytic activity.

The activity of proteolytic enzymes in semi fat flax flour (for example, as used in this work) is slightly lower than the activity of proteolytic enzymes characteristic of wheat flour of good quality. Meanwhile proteolysis is associated with the accumulation of amino acids, and amino acids are the plastic material for the fermentation of microflora and one of the important components of melanoidin formation which occurs during bread baking. But too intense proteolysis of protein substances can lead to a significant change in their structure; induce unlimited swelling and peptization with the transition to the liquid phase of the dough, which causes a decrease in stability of the dough, deterioration of its consistency and elasticity, liquefaction of the dough and deterioration of the quality of finished products.

Regulation of the depth of proteolysis is necessary to achieve optimal rheological properties of the dough, its water absorption capacity, the ratio of free and bound moisture, gas holding capacity of the test pieces at the last stage dough fermentation – proofing. And perhaps also due to the adding raw materials such as the flax flour, rich in dietary fiber and fats. This allows to provide the required quality of bread.

Summarizing the role of enzymes of flour at the maturation of the dough, we can conclude that their relationship and interaction determine a complex of processes that cause the modification of the structural components of semi-finished products at different stages of the process, which allows one to manage the process and form certain physical, chemical and organoleptic quality indicators of the bread.

The main biochemical properties of the flour, reflecting the activity of the enzymatic complex, include sugar-forming ability, acidity and water absorption (Table I). These properties determine the intensity of fermentation of the dough, the course of proofing dough pieces and the quality of the finished bread, and determine the choice of specific preparation modes of the dough.

According to the results of laboratory studies, the first sign, directly dependent on the introduction into the flour mixture of flax flour, is water absorption. Water absorption is known to depend on the particle size and biochemical properties of the flour: larger particles have the property of "additional swelling", and this property is directly related to the content of biopolymers in the flour – proteins and non-starch polysaccharides.

One of the principal important differences of flax flour from wheat bakery flour is that a part of the carbohydrates of flax flour presents quite a lot of water-insoluble high-molecular polysaccharides. They are cellulose and hemicellulose. The other part (according to various estimates, from 2.0% to 6.5% of the flaxseed weight) presents low molecular weight fragments of these polysaccharides, which are soluble in water pentosans. The share of starch in the composition of carbohydrates of flax seeds is only 5.0–7.0%. A characteristic feature of pentosans is the ability to easily peptize in water with the formation of viscous gel slime. The flour from flaxseed cake differs with an even higher content of the particles of the seed coat and by content of insoluble high-molecular polysaccharides and hydrocolloids that can not only absorb moisture well, but also keep it for some time.

The above-mentioned causes the increase in water absorption of flour mixes (from 69.4% to 72.9% with an increase in the proportion of flax flour in flour mixes from 7.5% to 12.5%), and subsequently it should help to slow down the speed of staling bakery.

TABLE I. BIOCHEMICAL PROPERTIES OF FLOUR MIXES

Name of the indicator	Content of flour from oil cake flaxseed in flour mixes			
	0%	*7.5%*	*10.0%*	*12.5%*
Sugar-forming ability, mg maltoses on 10 g of flour (of flour mixes)	195±15	147±14	114±11	86±9
Acidity, degrees	2.0–2.4	3.5–3.8	4.1–4.4	4.6–4.8
Water absorption, %	62.2±7.4	69.4±6.1	71.0±7.5	72.9±7.9

Consequently, when flax flour is introduced in flour mixes, it is possible to predict the increase in the yield of bread by increasing the water absorption of flour mixes.

The sugar-forming ability is due to the presence of α- and ß-amylases in the flour and dough, under the action of which sugars forms from starch. The input of flax flour characterized by a low content of fermentable carbohydrates and the absence of amylolytic enzymes into flour mixes of, which is causes the change in all properties of the carbohydrate-amylase complex. The main consequence of the relative decrease in the proportion of starch in the resulting wheat-flax mixes is the slowing of the processes of saccharification and dextrinization. As a result, the sugar-forming ability, which determines the intensity of gas formation in the dough and the rise of the dough billets during proofing and baking, is reduced.

The increase of titratable acidity significance, observed when a flax flour is added into flour mixes, determines a higher initial acidity of dough and a faster accumulation of acids in the dough during fermentation. Thus, taking into account the fact that the readiness of the dough for baking is determined by the value of titratable acidity, a decrease in the sugar-forming ability, in general, should not significantly affect the overall duration of maturation of the dough.

B. Rheological properties of dough

Dough making begins with kneading (phase 1 – "Formation of the dough") and is accompanied by a complex set of biochemical, microbiological and physico-chemical processes affecting its rheological properties. It is accompanied with the activation of the work of enzymes and processes of hydration of water-insoluble proteins and polysaccharides. There are also processes of dissolution of globulins, albumins and soluble carbohydrates, with their transition to the liquid phase of the dough.

Data of mixolabogram and of radial diagram (Fig. 2) demonstrate sufficiently pronounced differences in the parameters of the rheological profile of the studied indicators, both between the samples of dough from one wheat flour, and between the samples of dough, obtained from flour mixes with different dosage of flax flour, which indicate different speed of the above-mentioned processes and differences in the mechanisms of dough formation.

The increase in water absorption of flour mixes established at the first stage of research at increase of dosage of flax flour is accompanied by natural increase in the formation period of the dough (from 5.58 to 5.77 minutes in options with flax flour, Table II). A longer formation period of the dough corresponds to a higher dosage of flax flour in the flour mixes. Obviously, a higher dosage of a flax flour in the flour mixes requires a longer time for complete hydration of the hydrocolloids.

A longer period of the dough kneading should provide a longer swelling of gluten proteins in the flour mixes. Consequently, this should cause a decrease in the elasticity of gluten and a decrease in the viscosity of the dough. Stability of the dough while adding flour mixes flax flour has decreased from 10.35 minutes (for the dough of wheat flour) to 9.25–9.67 minutes depending on the options of the introduction of flax flour to flour mixes.

The value of the Mixing index of the samples of dough with the addition of flax flour (Fig. 2) was 4 points. This is the testament of the medium stability of dough with the flax flour. The obtained data allows to characterize the flour mixes with flax flour as of medium strength, which will provide bread with a reduced volume in industrial production.

The Gluten+ index is a complex index that characterizes the quality of protein substances in the analyzed samples and reflects the stability of the structure of protein molecules when heated in the dough temperature range 30–60 °C during phase II, during which the liquefaction of the dough takes place. It is believed that the main role in indexing of this indicator is played by prolamin and glutelin fraction of proteins that form gluten while kneading the dough. During the hydration of proteins, glutelin gives elasticity and rigidity, while prolamins provide the extensibility of gluten and dough.

It was noted that the viscosity of the dough decreases, when it is heated to 30–60 °C. That can be explained by the beginning of denaturation of proteins which releasing decrease the water absorbed during the dough kneading. The value of the Viscosity index reflects the intensity of this process.

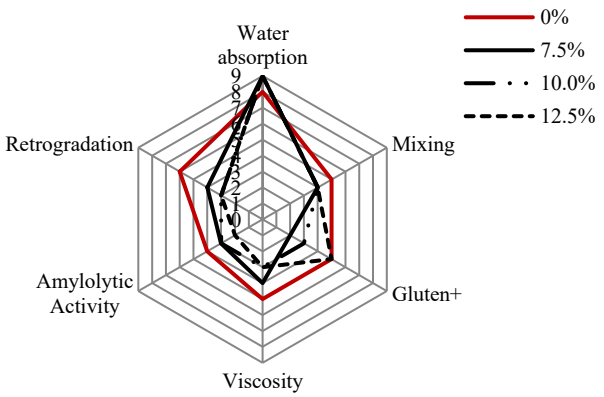

Fig. 2. Radial diagram Mixolab of dough from flour mixes with different doses of flour from oil cake flaxseed (from 0 to 12.5%, in points)

TABLE II. BASIC PARAMETERS: PROTOCOL CHOPIN+

Name and designation of the indicator	Content of flour from oil cake flaxseed in flour mixes			
	0%	*7.5%*	*10.0%*	*12.5%*
Time of formation of dough, minutes	5.27±0.12	5.58±0.16	5.65±0.20	5.77±0.24
Stability of dough, minutes	10.35±0.20	9.25±0.25	9.45±0.32	9.67±0.30
Index «Mixing» (C1)	1.11±0.05	1.11±0.06	1.10±0.04	1.10±0.04
Index «Gluten+» (C2)	0.48±0.03	0.44±0.04	0.44±0.05	0.48±0.04
Index «Viscosity» (C3)	1.71±0.15	1.61±0.13	1.60±0.12	1.62±0.12
Index «Amylolytic Activity» (C4)	1.38±0.21	1.20±0.11	1.17±0.15	1.16±0.15
Index «Retrogradation» (C5)	2.39±0.30	1.78±0.22	1.69±0.20	1.68±0.21

The highest value of the Gluten+ index was the sample of flour mixes with the addition of 12.5% flax flour. The lowest value was the sample with the addition of 7.5% flax flour (2 points), which indicates a more significant liquefaction of the consistency of the dough from these mixes.

Some important processes for the dough formation occur during the exposure of the dough to a temperature range from 30 °C to 60 °C, as starch granules swell (although at this temperature the structure of the starch granules does not change yet), and the action of amylases is reduced to a minimum. However, the leading cause of changes in the consistency of the dough during its mixing and formation is the reorganization of the structure of gluten proteins. First of all, it deals with the changes in the structure of proteins caused by hydrogen bonds breaks. Consequently, the rheological properties of the dough and the quality of the finished bread are determined by the composition and the ratio in the flour mixes of different on solubility and molecular weight fractions of gluten wheat flour – glutenin and gliadin, which determine elastic properties and extensibility of gluten.

Along with the gluten proteins, there is a direct or indirect involvement of other compounds that are in a direct physicochemical interaction with gluten proteins in the formation of gluten frame of the dough under kneading. They are lipids, carbohydrates (in this case, first of all, – pentosans and educated them of mucus), enzymes (amylases wheat flour and flax flour lipoxygenases). Consequently, the adding of flax flour, containing a significant amount of lipids and proteolysis inhibitors, to the composition flour mixes, at a certain dosage can help to strengthen glutelin fraction gluten and increase the viscosity of the dough, as evidenced by the increase in the Gluten+ index compared with the value of this index for wheat flour without additives.

In phase III "Retrogradation", which is characterizes the properties of starch and amylolytic activity of flour or flour mixes, the dough temperature rises from 60 °C to 90 °C. During this phase the destruction of starch granules occurs in the dough, starch gelatinization begins. The viscosity of the dough increases.

7.5% of flax flour or 4 points is the highest value of the Viscosity index established for the dough sample with the addition of flax flour compared with other mixes with different dosages. When the dosage of flax flour to 10.0% and 12.5% increases, the index value decreases, all these correspond well with the increase in the duration of kneading.

There are no amylases in the flax flour, but there is a significant amount of lipolytic enzymes. So a "dilution effect" occurs with the increase in the dosage of flax flour in the flour mixes. In the flour mixes, the proportion of gluten proteins decreases, as well as the content of amylolytic enzymes. This causes a natural decline in the stability of starch paste, fixed in phase IV. Lipolytic activity, on the contrary, increases, and this is accompanied by the appearance of free fat acids and hydroperoxides in the dough.

It should be noted that no clear correlation was found between Viscosity indices and Amylolytic Activity indices. Probably (and this assumption corresponds well with the values of the Mixing index, kneading of the dough), the viscosity of the examined dough samples largely depends on the presence soluble proteins and peripheral particles of flax seeds in flax flour, which contain of non-starch polysaccharides having high hydrophilicity.

Retrogradation is the index that characterizes the carbohydrate-amylase complex of flour and depends on the ratio in the molecules of starch of amylose and amylopectin. This indicator is interconnected with the property of bakery products to resist stale and keep fresh. In the conducted series of studies of the properties of the dough from mixes of wheat and flax flour, the value of this indicator decreases accordingly, the reduce proportion of wheat flour in the mixes.

The research of the rheological characteristics of the dough from the flour mixes of experimental compositions shows that the mixing period (until stability is achieved) increases with the increase of the proportion of flax flour in the flour mixes. In the meantime, the time corresponding to the stable state of the dough slightly increases. Consequently, the use of flax flour in bread production entails the necessity to select special technological modes of dough preparation, proofing and baking.

C. Fermentation of dough and quality of bread

The dough maturation speed, as well as its technological properties, is largely determined by biochemical properties of the flour, in our case of the flour mixes. Therefore, the selection of the dough preparation modes was based on these experimental data. Both the wheat flour dough and the dough from flour mixes were made with the straight dough method.

The main reason to enlarge the volume of water added at the mixing stage to obtain the dough with normal consistency was the increase in water absorption of the flour mixes with a growth in the dosage of the flax flour stated at the research stage

of the rheological properties of the dough. However, high humidity can lead to increased viscosity and stickiness of the dough, and adversely affect the processes of division and rounding of the dough pieces. Then if proofing takes place, poor shape stability of bread can probably appear. Therefore, the baked bread can be expected to have a smaller specific volume and a compacted crumb.

In addition to that, the enzymes of the flour itself are actively involved in the dough fermentation process, during the dough mixing it is supplemented by actions of fermentation microflora enzymes – yeast and lactic acid bacteria. The yeast acts as leavening agents of the dough, producing a significant effect on the rate of gas formation and, as a consequence, the crumb porosity and bread volume. Yeast forms carbon dioxide and alcohol fermenting sugar, flour and maltose formed from flour starch under the action of amylases. In this case, such fermentation by-products as acetic aldehyde, butyl, isobutyl, and amyl alcohol, organic acids and some other substances that give the bread a specific taste and flavor are also produced along with the main product of fermentation (alcohol). Besides, a small amount of alcohol, synthesized by yeast and remaining after baking bread (up to 0.5%), is also necessary to give the bread a characteristic taste and flavor.

Lactic acid bacteria, as a natural component of the fermentation dough microflora, also have a great influence on the taste and flavor of bread, which is largely determined by the ratio of the lactic acid and volatile acids formed during lactic-acid fermentation (their ingredients depend on the constitution of the components of flour). Lactic acid gives the bread a pleasant sour taste, and volatile acids give a specific flavor.

The presence of free fat acids and free amino acids in the flax flour caused the increase of the initial acidity of the dough due to the increased dosage of the flax flour. This fact as well as different rates of starch retrogradation and different rates of fermentation products of hydrolysis by microflora dough, further determined the change in the dynamics of increasing the acidity of the dough from the flour mixes in the fermentation process, that contributed to a more rapid dough maturation and reduce the total duration of its fermentation compared to the wheat flour dough (Table III).

According to the results of the trial laboratory baking and analysis of the baked bread, the porosity reduction and specific bread volume are in a direct correlation with the decrease in the sugar-forming and gas-forming ability of the flour mixes. To a certain extent, the decrease in the porosity and specific volume could be indirectly influenced by polyunsaturated fat acids introduced with the flax flour. There are the hydroperoxides of linoleic and linolenic acids in the flax flour, which oxidize the sulfhydryl groups of proteins with the formation of new disulfide bonds, which determine the strength of the spatial structure of protein molecules of the gluten frame at the stages of the dough maturation and bread baking.

The humidity of baked products rises consequently with the increase in water absorption of flour mixes due to the growing dosage of flax flour. The free fat acids added by the flax flour caused a dynamic increase in the values of titratable acidity of the bread crumb for all variants of the flour mixes.

A slight deterioration of the surface of the bread (slightly rough crust) was noted in variants with dosage of flax flour 10.0% and 12.5%. It is obvious that the high humidity of the dough from flour mixes with the 12.5% addition of flax flour, contributed to a more active flow of microbiological and biochemical processes during the dough maturation. As a result, the pores of the bread crumb were larger and less uniform and thick-walled. Moreover, crumb acquired density and partially lost its elasticity, a specific feature of a wheat bread.

During the process of baking, some other intensive processes also occur, which complete the formation of taste and flavor of bread. Aldehydes and alcohols play an important role in these processes. But the main role in the formation of flavor and taste of the finished bread is given to the reaction of melanoidin formation; which includes the interaction of reduced sugars with amino acids and proteins, colored melanoidins and a variety of volatile components responsible for the flavor of bread. Many of these components are accumulated in the subcortical layer and bread crust. The main role in the oxidation-reduction processes that affect the color of the bread crumb, is fulfilled by polyphenoloxidase, which catalyzies the oxidation of flour tyrosine with the formation of dark-colored melanins, the amount of which determines the darkening of the dough and bread crumb.

Since the content of free tyrosine and the activity of polyphenol oxidase in the dough from mixes of flax and wheat flour is significantly higher than in the wheat flour dough, bread obtained from flour mixes had a darker color of the crumb.

IV. CONCLUSION

The study of the flax flour dosage effect on the biochemical properties of flour mixes and on of maturation and rheological properties of the dough made from wheat-flax seed flour mixes, allows one to predict the behavior of the dough in the process of kneading, fermentation, and proofing.

TABLE III. TECHNOLOGICAL MODES OF DOUGH PREPARATION FROM WHEAT AND FLAX FLOUR MIXES

Name of the process parameter	Content of flour from oil cake flaxseed in flour mixes			
	0%	*7.5%*	*10.0%*	*12.5%*
Temperature of dough, ºC	28–30	28–30	28–30	28–30
Moisture of dough, %	45.0	47.0	48.0	50.0
Initial acidity, degrees	2.0	2.5	3.0	3.5
Time of fermentation of dough, minutes	150	90	60	60
Acidity of the final, degrees	3.0	3.5	4.0	4.5

This makes it possible to adjust the modes of the technological process and the quality of bread in the up-to-date mode.

The results of the research show that the indices of "Viscosity" and "Retrogradation", though the most susceptible to the changes due to the increase in the dosage of flax flour, are as well the most significant in predicting the behavior of the dough and the correction of the technological process modes.

However flax flour has a significant impact not only on the technological properties and the enzymatic complex of dough, but also on the tasting characteristics of baked bread. The crumb becomes darker and even gray when the dosage of flax flour increases, and it even receives a bitter taste at the dosage of 12.5%. That is why it is better not to add flax flour to flour mixes in the amount of more than 10%.

The main purpose of bread enrichment is to add the components to ensure the satisfaction of physiological needs in certain essential nutrients without the necessity to change the human diet. Adding flax flour into the dough within 10% gives the opportunity to use technological parameters which can be easily adjusted to the industrial production conditions, if the necessary conditions for bread enrichment and preservation of bread acceptable taste qualities.

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