

Effects of various raw ingredients on bread quality

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Abstract. The purpose of the current research is to study the mechanisms behind how various raw ingredients affect the quality of bread. The objects of the research were the flour used in making the bread (consisting of gluten at 28.5%, and with an ash content of 0.55), with no added fats; tap water or activated water (treated in a USTA-0.4/22 OM ultrasonic processor (Volna, Russia), operating at a frequency of 22 ± 1.65 kHz and at 30% of maximum output power (400W) for mixing dough); and plant extract additives based on stevioside and fucoidan (fully replacing the sugar). Included in the analysis were the effects of using activated water and combined plant extract additives on organoleptic qualities (appearance, crust colour, crumb condition, taste, stickiness during mastication, and friability), as well as the physical and chemical qualities (moisture content, porosity, and acidity). Yeast activity was studied in dough which had been produced using activated water and combined plant extract additives. An Altami-136T optical microscope (Altami, Russia) was used to study the activity of yeast cells. The effects of activated water and combined plant extract additives were analysed by examining the microstructure. Microscopic studies were carried out using a Jeol JEM-2100 electron microscope (Jeol Ltd, Japan). The results confirm that activated water and combined plant extract additives may be used to improve the quality of fresh bread.

Key words: bread, bakery products, activated water, sweeteners, bound water, storage

INTRODUCTION

An important issue in the manufacture of bread and baked goods is the consistency of the products. Very often, the ingredients used are quite dissimilar in terms of their properties, making it difficult to produce high-quality bread. For centuries, researchers have looked for ways to improve the quality of bread. Today, lactic acid bacteria (LAB), which produce a series of metabolites which have a positive effect on the texture of bread, are widely used in fermentation. Exopolysaccharides produced by LAB have the potential to replace more expensive hydrocolloids which are used as bread improvers (Arendt et al., 2007).

In addition to this method of influencing the dough's integral components, there is a growing trend which uses additives in the baking industry in order to achieve the optimum quality in terms of the technological properties of dough and the quality of the finished bread (Rosell et al., 2001). The interaction between sourdough and a number of additives such as exogenous enzymes and non-starch polysaccharides has been evaluated (Corsetti et al., 2000; Di Cagno et al., 2003). Researchers recommend the use of emulsifiers, hydrocolloids, and enzymes as additional methods to improve the quality of

bread. This improves the rheological properties of the dough and the quality of the finished bread, and stabilises its technological parameters (Sciarini et al., 2012).

Whatever improvement methods have been used by researchers (emulsifiers, enzymes, microbial ferments, complex enriching additive, influence on dough components, etc), everything ultimately depends on the dough's components, the interactions between those components, and their structure (McClements, 2007). The structure of the crumb is one of bread's fundamental quality characteristics. There is a direct relationship between the crumb structure, appearance, and the volume of finished products (Zghal et al., 1999), as well as their structure and texture (Pylar, 1988). Therefore we can conclude that a knowledge of bread structure makes it possible to exert an influence on its properties and quality.

MATERIALS AND METHODS

Bread ingredients

The raw materials for making bread and bakery products:

- wheat flour (gluten 28.5%, with an ash content of 0.55), produced by Grigorovich Bread Products Plant OJSC, Chelyabinsk City, Russia.

- activated water obtained using an ultrasonic processor, the USTA-0.4/22 OM (Volna, Russia), operating at a frequency of 22 ± 1.65 kHz and at 30% of maximum output power (400 W). The mechanism of ultrasonic cavitation in liquid systems occurs due to the formation of a high temperature and pressure shock waves (Naumenko & Kalinina, 2016). Physical effects include changes in viscosity, a dispersed state, and the strength of the colloidal system; chemical effects are linked, as a rule, to thermal mass exchange (Krasulya et al., 2015).

- a combined plant extract additive (CPEA) consisting of fucoidan and stevia derivative products (El'piner, 1963; Usov 2001; Shtrigul, 2009; Shestakov et al, 2013). Stevia is quite a well known natural sweetener, one which is recommended for diabetic nutrition. It can be used as a source of food in various forms – such as dried leaves and decoctions of those leaves, extracts, syrups or stevioside (a powder with stevia glycosides to be as purified as possible). Fucoidan is a sulphated heteropolysaccharide which is found in oceanic brown algae and in some echinoderms.

- a stevia solution prepared from stevioside powder (0.14% of flour weight), to which a calculated amount of 98 °C water was added and steeped for fifteen minutes. After steeping, the solution was filtered, cooled, and used at 35 °C. The stevioside infusion method eliminated the undesirable bitter aftertaste.

The main component of fucoidan molecules is the remains of sulfated α -L-fucose. Fucoidans are typically composed of other monosaccharides: galactose, mannose, xylose, uronic acids, and acetyl groups.

The bread was made using the recipes shown in Table 1. When using activated water, traditional bread recipes were used.

Bread making

All of the samples that were studied were prepared using a straight dough process. A laboratory test was carried out on bread baking with a mass of 300 g and a temperature of 220 °C (Naumenko & Kalinina, 2016).

The raw materials underwent preliminary preparation. The flour was sifted and weighed on an automatic scale. Cake yeast was removed from its packaging. To ensure the even distribution of the yeast cells in the dough, the yeast was dissolved in water in yeast blending machines. The yeast suspension was prepared using one part yeast to two parts water at a temperature of 30 °C. Salt was dissolved before it was added. The water temperature did not exceed 40 °C.

Table 1. Dough recipes

Ingredients, g	Bread	Reference sample	Bread with sugar completely replaced by fucoidan	Bread with sugar completely replaced by stevioside and fucoidan	Bread with sugar completely replaced by stevia syrup and fucoidan
Flour	1,000	1,000	1,000	1,000	1,000
CPEA, consisting of stevia and fucoidan derivative products	-	-	1	1	1
Vegetable oil	-	140	140	140	140
Sugar	-	10	-	-	-
Salt	15	15	15	15	15
Yeast	20	20	20	20	20

The dough was mixed in one stage with all ingredients and the water according to the recipes. The dough's temperature after mixing was 31 ± 1 °C. During fermentation, the dough was punched down twice, at sixty minutes after the start of fermentation and again after two hours; the total duration of the dough fermentation process was 170 minutes.

The division of the dough for bread consisted of the following actions: the division of dough into pieces; its placing into pans; and the final proofing of product samples. The dough was divided into pieces using a dough-cutting machine.

The final proofing was carried out at room temperature (between 35–40 °C) and at a relative humidity level of between 70–75%. The proofing time for the formed pieces was sixty minutes.

The bread was cooled for three hours before being packed in plastic film, and then stored at a temperature of 2 ± 2 °C for 72 hours. Tests were carried out three and 72 hours after baking.

Research methods

The status of freshness was monitored, based on changes in organoleptic parameters (appearance, crust colour, crumb condition, taste, stickiness during mastication, and friability), and physical and chemical parameters (moisture content, swelling capacity, and friability).

The moisture content levels in the mass were determined by drying the test samples at a temperature of 130 °C for a period of forty minutes; the swelling capacity of the soft part of the bread was determined by the amount of water which was absorbed by this area of the bread within a period of five minutes (in terms of millilitres of water for each gram of dry matter (DM)); the friability, indicated as a percentage figure, was determined

according to the number of individual crumbs which were formed after shaking test samples of the soft part of the bread for fifteen minutes at a rotational speed of between 190–250 rpm.

Yeast activity was assessed using microscopy with an Altami-136T optical microscope (Altami, Russia). The microstructure was analysed using the microscopic studies that had been carried out with a Jeol JEM-2100 electron microscope (Jeol Ltd, Japan).

The baking of the bread and other bakery goods using various recipes, and studies of each product sample, were carried out in triplicate. A mathematical analysis was carried out on the results using generally accepted methods of statistical analysis, with the results being expressed as an arithmetical mean (M) and its standard deviation (m). Statistically significant differences amongst the groups were established using the Kruskal-Wallis criteria. In order to be able to detect statistically significant differences between two compared groups, the Manna-Whitney criteria (U) were used. Differences were deemed significant where $p < 0.05$. Statistical interconnections were studied using a non-parametric correlational analysis, calculating the coefficients of the correlation of rankings according to Spearman (Rs).

RESULTS AND DISCUSSION

In order to evaluate the role of water in bread quality, samples were baked in which the dough was first prepared using tap water (the reference sample), and then using activated water.

The organoleptic evaluation of the studied samples suggests that the activated water and complex herbal supplements had a pronounced effect on the appearance, crust colour, crumb state, taste, stickiness during mastication, and friability.

Those samples which had been produced using activated water showed increased volume as well as a more developed, authentic, and thin-walled porosity, and high consumer appeal. Activated water influenced various quality indicators such as appearance, and the nature of the porosity, elasticity, and 'crumb chewability'. No significant changes in the flavour, aroma and/or colour of the products' crumbs were noted.

Those samples which were produced with the plant-extract additive can be characterised as having increased volume, a regular shape, and a slightly convex crust. A sufficiently uniform, thin-walled porosity with round-shaped pores enhances the customer appeal of the samples being studied, whilst the soft, elastic, and well-chewed crumb makes it even more attractive. It should also be noted that the bread samples which had been produced with sugar completely replaced by fucoidan were insufficiently sweet; those bread samples for which the sugar was completely replaced by stevioside and fucoidan had a sweet taste with a bitter aftertaste; and those bread samples for which sugar was completely replaced by stevia syrup and fucoidan had a typical, balanced taste.

When the physical and chemical parameters were checked, it was discovered that after the bread had cooled to room temperature (after three hours), the samples studied were almost the same in terms of moisture content, but different in terms of swelling capacity and friability (Table 2).

The friability of bread which had been produced with activated water was 0.7% less than that of the reference sample, and its swelling capacity was higher by 0.9 ml per 1g of DM. Differences between the values of the reference sample and those of bread which had been produced with activated water could be due to the intensified activity of the yeast and a more intensively developed protein matrix (Fig. 1).

Table 2. Changes in the physical and chemical parameters of the bread and bakery products samples during storage (3 hours)*

Studied samples	Moisture content, %	Crumb porosity, %	Crumb acidity, %	Friability, %	Swelling capacity, ml g ⁻¹ of DM
Bread					
Reference	42.5 ± 0.1	73.0 ± 0.1	2.5 ± 0.2	5.6 ± 0.1	6.8 ± 0.2
Using activated water	43.2 ± 0.2	76.4 ± 0.3	2.9 ± 0.1	4.9 ± 0.2	7.7 ± 0.1
Bread with additives					
Reference	35.8 ± 0.2	74 ± 0.1	1.8 ± 0.2	4.4 ± 0.2	7.8 ± 0.2
Bread with sugar completely replaced by fucoidan	34.5 ± 0.1	83 ± 0.2	1.7 ± 0.2	3.7 ± 0.1	8.7 ± 0.2
Bread with sugar completely replaced by stevioside and fucoidan	37.6 ± 0.1	84 ± 0.1	1.6 ± 0.2	3.8 ± 0.1	9.1 ± 0.2
Bread with sugar completely replaced by stevia and fucoidan syrup	41.2 ± 0.2	82 ± 0.2	1.6 ± 0.2	3.9 ± 0.1	9.0 ± 0.2

*Results were obtained using generally accepted methods of statistical analysis and expressed as an arithmetical average and its standard deviation. Differences were deemed significant at $p < 0.05$

The structure of the samples is characterised by a large number of oval-shaped particles whose characteristics correspond to grains of starch. The grain surface is smooth and free of cracks, grooves, or pores. In the microstructure of the reference samples, equal proportions can be found both of large and fine grains of starch. The starch is present in the form of round or elliptical-shaped grains. Individual grains are slightly deformed.

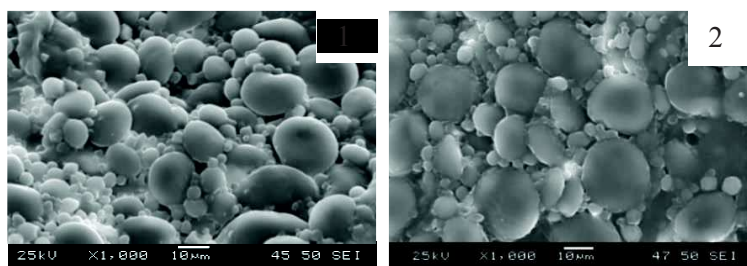


Figure 1. Dough microstructure: 1 – reference sample; 2 – sample using activated water.

Those samples which had been produced using activated water contain much fewer grains of starch. Swollen, significantly increased-size grains of starch predominate. The protein matrix is more distinct and developed. Some small starch grains have attached protein particles which make them angular. Large grains of starch have protein attached to them. Those protein particles which are attached to the fine grains of starch make them angular and faceted. Sometimes the protein matrix surrounds an entire group of starch grains in individual structural units. Fine starch grains, of which there are few, are interconnected by a protein web. The swollen protein matrix envelops the starch grains.

The bread with additives also differed positively from the reference samples. All of the test samples which had additives also had an increased crumb porosity of 8–10%. The crumb moisture mass fraction and the acidity of the test samples differed slightly. There was a decline in the friability of between 0.5–0.7% and an increase in the swelling index by 0.9–1.3 ml per 1g of DM. The CPEA which was added served to enhance the number of yeast cells, accelerating its maturation, and making the dough-making process more intensive as evidenced by the results of the study on the dough reference and test-sample microstructure (Fig. 2).

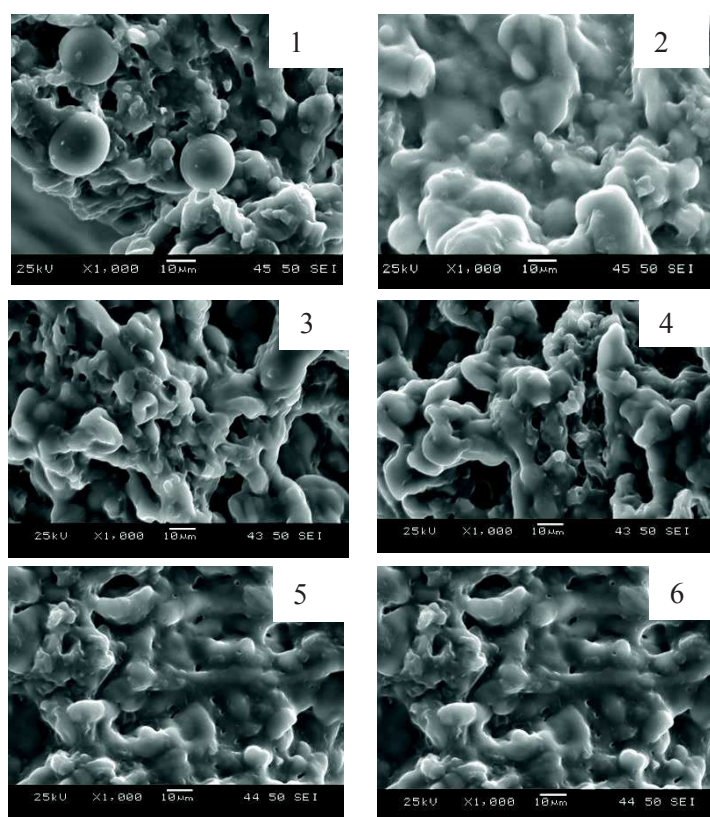


Figure 2. The microstructure of the bread crumb after 3 hours of storage: 1 – reference sample; 2 – sample using of activated water; 3 – reference for the bread with additives; 4 – bread with sugar completely replaced by fucoidan; 5 – bread with sugar completely replaced by stevioside and fucoidan; 6 – bread with sugar completely replaced by stevia syrup and fucoidan.

The baking process sets the sponge-like crumb texture in bread by creating a hierarchical structure of gas cells, from the macro to the micro scale within the bread crumb (Liu & Scanlon, 2003). The crumb structure in the test samples (bread made using activated water and samples with additives) is characterised by pores that are limited by the interporous walls which compose the spongy skeleton. A microscopic examination of the crumb's interporous walls shows that they consist of a solid mass of protein (gluten) which has coagulated in the baking process with the swollen, partially gelatinised starch grains embedded in it, as described in Rosell et al. (2001).

The starch grains in the pore walls are somewhat elongated, arranged parallel to their plane, and surrounded by a mass of coagulated protein. Only a few starch grains are in direct contact with each other, which is confirmed by other researchers (Semin et al., 2009). Protein coagulated substances form a spatially continuous phase of the bread crumb, and starch grains are only embedded in this system. This structure may be presented as a swollen, elastic jelly. The hard-to-distinguish, interporous walls consist of a solid mass of gluten (the protein coagulated in baking). In the test samples the entire surface of the starch grains is closely adjacent to the mass of coagulated protein, which means that no sharp, clearly visible boundary between them can be observed.

Results from the use of activated water and various ingredients (fucoidan, stevioside and fucoidan, and stevia and fucoidan syrup) were obtained from studying the bread samples after a period of 72 hours (Table 3).

Bread which was produced using activated water had significantly lower levels of friability than with the control sample, and the swelling capacity was significantly higher. The bread which was produced with additives also showed a positive deviation from the control samples. All test samples which included additives showed increased swelling capacity and a less pronounced intensity when it came to moisture loss in comparison to the control samples.

Table 3. Changes in the physical and chemical parameters of the bread and bakery products samples after storage (72 hours)

Studied samples	Moisture content, %	Crumb porosity, %	Friability, %	Swelling capacity, ml g ⁻¹ (d.m.)
Bread				
Reference	40.5 ± 0.2	66.0 ± 0.2	17.4 ± 0.1	3.2 ± 0.1
Using activated water	41.8* ± 0.2	71.0 ± 0.2	13.4* ± 0.2	4.5* ± 0.2
Bread with additives				
Reference	34.6 ± 0.1	74.6 ± 0.2	12.8 ± 0.2	4.6 ± 0.2
Bread with sugar completely replaced by fucoidan	33.5* ± 0.2	76.2 ± 0.2	11.2* ± 0.1	6.7* ± 0.1
Bread with sugar completely replaced by stevioside and fucoidan	36.6* ± 0.1	78 ± 0.2	10.8* ± 0.1	7.1* ± 0.2
Bread with sugar completely replaced by stevia syrup and fucoidan	41.6* ± 0.1	78.2 ± 0.1	10.3* ± 0.1	7.3* ± 0.2

* significant differences ($p < 0.05$) in comparison to reference

All of the test samples showed an increased moisture content reading in comparison with the control samples, which could help to preserve the quality of stored bread. In

general, high water content in bread has been reported to increase its shelf life (Rogers et al., 1988; He & Hosney, 1990) and to delay starch retrogradation (Andreu et al., 1999).

In the control samples, a partial transfer takes place from starch to a crystalline state, with an accompanying thickening of its structure. In the test samples (using activated water and the plant extract additives) this process occurs noticeably more slowly due to the formation of a more developed protein matrix during dough preparation. This also conforms to the data which was received in regard to changes to crumb friability and swelling capacity in baked goods during storage (Goryacheva et al., 1983; Schiraldi et al., 1996; Karim et al., 2000; Haros et al., 2002; Xie et al., 2004). The data which was obtained confirms well to the results from the study of dough microstructures in the control samples and test samples (Fig. 3).

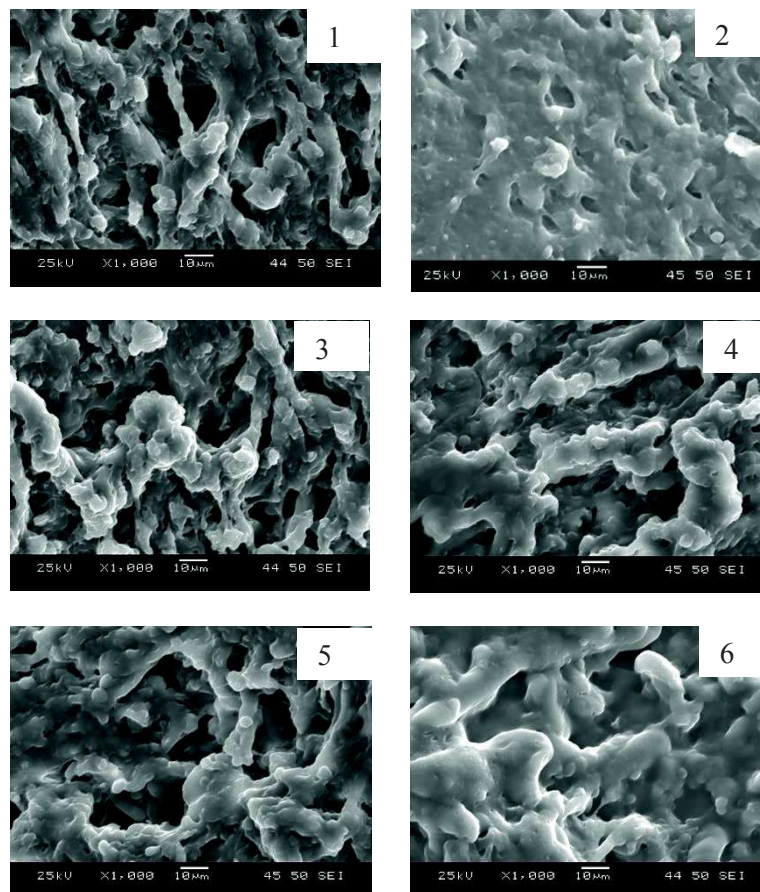


Figure 3. The microstructure of the bread crumb after 72 hours storage: 1 – control sample; 2 – sample using activated water; 3 – control for the bread with additives; 4 – bread with sugar completely replaced by fucoidan; 5 – bread with sugar completely replaced by stevioside and fucoidan; 6 – bread with sugar completely replaced by stevia syrup and fucoidan.

In the control sample's microstructure, interior layers of air can be clearly seen, which may indicate a decrease in the volume of starch granules in connection with the

formation of crystalline starch structures. The sample which used activated water has a more uniform, amorphous crumb structure, with a smaller number of interior air layers.

Also typical for the crumb structure of bread which has been made with fucoidan fully replacing sugar is the formation of pores that are limited by interporous walls which make up the spongy skeleton. The structures shown in those samples which had been produced using stevioside and with fucoidan fully replacing sugar, and in bread which had used stevia syrup with fucoidan fully replacing sugar, contain noticeable differences. For example, with the sample which was produced using stevioside and with fucoidan fully replacing sugar, it is possible to distinguish the starch granules and to determine the size of the pores. The microstructure of bread which has been produced with stevia syrup and with fucoidan fully replacing sugar can be described, as before, as a puffy, non-structured jelly with barely discernible interporous walls.

CONCLUSIONS

The use of activated water enhances the accumulation of yeast cells, the development of protein matrix, and a more complete expansion of starch granules. Thanks to this, the bread has high consumer appeal, a beautiful appearance, increased volume, and a uniform, thin-walled porosity. The friability index significantly decreases, which also has a positive effect on the bread's organoleptic characteristics. Studies of the microstructure both of the dough and the finished product (following three hours of storage) confirm the organoleptic, physical, and chemical results. The test samples consist of a solid mass of protein (gluten) which has coagulated during baking, with swollen, partially gelatinised starch granules embedded in it. Those samples which were produced with activated water have even more greatly developed gluten.

The results of the study indicate a positive effect on the quality of the samples during storage (over the course of 72 hours). Bread which was produced with activated water had significantly lower levels of friability than did the control sample, and the swelling capacity was significantly higher. The resulting data is explained by the presence in those samples which were produced with activated water of a more uniform, amorphous crumb structure, with a decreased quantity of interior air layers. This is consistent with the data from Semin et al., (2009). This was also seen in other studies (Barcenas & Rosell, 2005; Brennan et al., 1996).

The use of various ingredients (fucoidan, stevioside, stevia syrup, and fucoidan) in bread production intensifies the dough-making process, makes the yeast cells accumulate more actively, and develops the protein matrix, which eventually has a positive effect on the quality of the finished product. All of those test samples which were produced with additives showed increased crumb porosity. A decrease in friability and an increase in swelling capacity were observed.

The results obtained were positive ones, and these were also maintained in the test samples during storage (over the course of 72 hours). The resulting data from a microscopic study of the crumb structure both from the control samples and the test samples leads one to the conclusion that changes in the microstructure of the control sample during storage occur with more intensity and, furthermore, an air layer forms around a portion of the pore surface which may result in the increased friability of the product. The full replacement of sugar with stevia syrup and fucoidan slows the staling

process most effectively, something that is confirmed by the less intensive changes in the microstructure.

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