RESEARCH OF THE INFLUENCE OF XANTHAN GUM ON RHEOLOGICAL PROPERTIES OF DOUGH AND QUALITY OF BREAD MADE FROM SPROUTED WHEAT GRAIN

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Abstract

The effect of microbial polysaccharide xanthan in the amount of 0.1-0.4% on the rheological characteristics of the dough from sprouted wheat grain and quality indicators of bread was studied. It was found that when xanthan gum is added, the dough's spreading and adhesion strength decreases, and the dough's resilience-elastic and plastic-viscous characteristics improve. Bread made from sprouted wheat grains with the addition of experimental dosages of xanthan has better structural-mechanical and physicochemical properties, as evidenced by higher indicators of crumb compressibility, specific volume, and moisture compared to the control sample. To obtain bread with the best quality indicators, it is recommended to use 0.3% xanthan.

Keywords

sprouted wheat grain bread; xanthan gum; dough; structure; bread quality; adhesion strength; specific volume.

Introduction

One of the effective ways to improve human health is the regular consumption of whole grains as a rich source of physiological and functional ingredients [1–4]. In this regard, it is important to increase the variates of whole wheat bread, the technology of which is based on the maximum usage of the natural potential of grain. It is known that it has a higher content of dietary fibre, antioxidants, minerals, vitamins, and other vital nutrients in comparison with bread made from refined flour. Researchers found that regular whole grain bread consumption leads to reducing the risk of chronic diseases such as diabetes, obesity, cardiovascular diseases, and others [5–9]. In recent years, the demand for food products from sprouted grains, including sprouted wheat, is growing all over the world. It is proved that during grain germination the accumulation of B vitamins, vitamin C, β-carotene, tocopherols, and phenolic compounds are stimulated, and the content of antioxidants increases[10–13]. Hydrolytic enzymatic processes are also activated, which leads to the accumulation of amino acids, reducing sugars, and water-soluble dietary fibre [14], increasing the bioavailability of minerals, as well as

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improving the digestibility of grain biopolymers [15–17]. At the same time, as a result of proteolytic and amylolytic processes, the amount of gluten and its quality decreases, and starch is partially hydrolysed causing the deterioration of the baking properties of grain [18–20]. Bread made from sprouted grain often has a small volume, poorly loosened and dense crumb, which needs to be regulated with the use of baking improvers. To improve the structure of the dough, oxidizing agents are usually used, in particular, ascorbic acid. These substances act directly on gluten proteins, strengthening the gluten network through the formation of disulfide bonds [21,22]. To correct the structure of the dough it is advisable to add the enzyme preparation of glucose oxidase. Under the influence of this substance, glucose is oxidized with the formation of hydrogen peroxide, which is involved in the oxidation of thiol groups of the protein-proteinase complex [23]. The effectiveness of using glucose oxidase together with cytolytic enzymes to improve the structure of the dough and physical-chemical indicators of whole-grain bread has been established [24].

To improve the structural properties of wheat dough, emulsifiers that interact with structural components (proteins, carbohydrates, lipids) to form complex compounds are used. Anionic emulsifiers (esters of diacetyl tartaric acid with mono- and diacylglycerols) interact with wheat flour gluten proteins, strengthening it, and increasing the resilience and elasticity of bread dough. Adding emulsifiers [25] or a complex of emulsifiers with xylanase enzymes [26] positively affects dough rheology and textural properties of whole grain products. An effective way to form necessary viscoplastic and elastic characteristics is the use of hydrocolloids belonging to the class of thickeners (gelling agents). The introduction of cellulose and its derivatives, pectins, carrageenans, and microbial polysaccharides improves the rheological properties of dough and the quality indicators of bread [27]. To stabilize the structure of the dough, the microbial exopolysaccharide xanthan produced by bacteria *Xanthomonas campestris* [28] is effectively used. An important functional characteristic of xanthan gum is the ability to increase the viscosity of aqueous solutions at low concentrations of the drug [29]. It is shown that the introduction of 0.1-0.5% xanthan gum helps to increase the water absorption and gas holding capacity of wheat dough, and increase the specific volume of bread [30,31]. According to [32], the addition of 0.1-0.7% xanthan gum increases gluten elasticity, which results in improving the dough and bread quality indicators. Many authors have proved the importance of the structure-forming role of xanthan in gluten-free dough [33–36]. According to the data presented in [34,35], xanthan has the greatest influence on the viscoelastic properties of gluten-free and protein-free dough in comparison with many other hydrocolloids. Xanthan gum changes the rheological properties of dough from whole wheat flour, increases bread volume, and reduces bread stiffness [37]. However, the impact of adding xanthan gum on the properties of dough and bread made from sprouted wheat grain has not been studied before. The objective of this research is to evaluate the influence of xanthan gum on the dough structure and quality indicators of bread made from sprouted wheat grain. The research was focused on studying the effect of xanthan gum on the resilience-elastic and plastic-viscous characteristics of the dough, the structural-mechanical (crumb compressibility), and physical-chemical (specific volume and moisture) properties of bread.

Methods of research

Materials

Wheat grain (Kharkiv-30 variety, harvest of 2019) was obtained in V. Ya. Yuriev Institute of Plant Breeding. (Kharkiv, Ukraine). Xanthan gum was purchase from CP Kelco ApS", Denmark and pressed baker's yeast obtained from Lviv Yeast TM, Ukraine and table salt from Artemsil TM, Ukraine were used in the research.

Methods of making dough and bread from sprouted wheat grain

- Germination of wheat grain

The washed wheat grain was soaked in water (hydraulic ratio 1:1.5) at a temperature of 20±2°C for 18 hours, then germinated (t= 20±2°C, W= 90±5%) for 24 hours until sprouts appeared (1-2 mm).

- Preparation of model samples for evaluating the rheological properties of dough

Sprouted wheat grain (W=44.0%) was washed with water to remove the contamination products and ground on a laboratory grinder using a matrix with a hole diameter of 2-3 mm. To evaluate the rheological properties of the dough, a model sample was prepared without yeast using xanthan gum in the amount of 0.1, 0.2, 0.3, and 0.4% by the weight of grain (Table 1, samples 1, 2, 3, and 4). A control sample of the dough was prepared without the use of xanthan gum (Table 1, control 1). The amount of water for kneading the dough was calculated based on its moisture (W=47%) and the humidity of the ingredients.

Table 1. The formulations of dough.

Ingredients, g	**Dough samples**									
	Control 1	**Control 2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Ground sprouted wheat grain (W=44%)*	156.0	156.0	156.0	156.0	156.0	156.0	156.0	156.0	156.0	156.0
Baker's pressed yeast	-	3.0	-	-	-	-	3.0	3.0	3.0	3.0
Salt	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Xanthan gum	-	-	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4
Water	to W=47%									

* 156.0 g of sprouted ground grain is obtained from 100 g of dry wheat grain

- Preparation of model samples for evaluating the quality of bread

For the manufacture of experimental samples of bread, the dough (W=47%) was made according to the recipes in Table 1 (Samples 5, 6, 7, and 8). A control sample of bread was prepared in the same way but without xanthan gum (Tab. 1, control 2). The dough was fermented for 90 min. After that, it was divided, shaped, and left to proof at 38±1°C for 35±5 min. The bread was baked at 200±10°C for 30±5 min. All baked bread samples were cooled to room temperature 20±2°C on a cooling rack for 3 hours. Three experimental baking tests were carried out for each bread sample.

Methods of evaluating the rheological properties of dough

The rheological characteristics of sprouted wheat grain dough were determined by the spread of the dough ball and the strength of adhesion. The elasticity, resilience, and viscosity of the dough, determined on Tolstoy's elastoplastometer, were evaluated as well. The spreading of the dough was determined by observing the change in the diameter of a ball of dough (100±0.5 g) during resting [38]. The kneaded dough was formed into balls weighing 100 g. Balls were placed on a glass plate, covered with a windproof cap and placed in a thermostat at a temperature of 30±1°C. The diameter of the dough balls was fixed two times: after forming (initial) and 90 minutes after resting in the thermostat. The adhesion of the dough was determined on an adhesion meter according to the calibration plot of the dependence of the tear-off force of the dough $F_{tear\text{-}off}$ on the stretchability L (cm) [39]. The tear-off forces were calculated per unit area of the contact using the formula:

(1) $$F_{tear\text{-}off}=mg/S_c,\ [F_{tear\text{-}off}]=N/m^2=Pa$$

where, S_c is the contact area, 16 cm^2.

The elasticity, resilience, and viscosity of the dough were determined on a plane-parallel Tolstoy elastoplastometer [39]. The measurement method is based on determining the shear deformation related to the thickness of the sample (Figure 1).

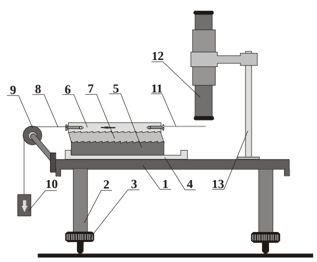

Figure 1. Plane-parallel Tolstoy's elastoplastometer: 1 – table; 2 – table supports; 3 – adjusting screw; 4 – metal stand; 5 – metal plate; 6 – Plexiglas plate; 7 – test sample; 8 – silk thread; 9 – block; 10 – weight; 11 – observation needle; 12 – microscope; 13 - tripod

The dough sample was placed on a metal plate (6) and covered with a plate (7) to which a weight of a fixed mass was attached. The fixed weight value for all dough systems was 50 g, the dough temperature was 20±1°C, and the height of the dough pieces was 8 mm. The first absolute strain value was obtained using a microscope instantly as soon as the load begins to act on the top plate. After that, the value of absolute strain was recorded at intervals of 1 min for 10 min. Follow-up observations were made at intervals of 5 min. After the load was removed, the instantaneous deformation was recorded, and then the instrument readings were taken at the same frequency as during the load. The study was terminated if no change in absolute strain was detected within 30 min. Shear stress (τ, Pa) was determined by the formula:

(2)
$$\tau = \frac{m \cdot g}{F}$$

where m is the weight, *kg*; g – free fall acceleration (9,81 m/s^2); F – plate area, m^2.

The modulus of instantaneous resilience was determined by the formula:

(3)
$$G_r = \frac{\tau}{\gamma_0}$$

here τ is the tangential shear stress, Pa; γ_0 – relative conditionally instantaneous deformation.

The modulus of elasticity is calculated by the formula:

(4)
$$G_{el} = \frac{\tau}{\gamma_{ве}}$$

where τ is the tangential shear stress, Pa; $\gamma_{ве}$ – relative highly elastic deformation.

Plastic viscosity was determined by the formula:

(5)
$$\eta_0^* = \frac{\tau}{tg\alpha},$$

where η_0^* – plastic viscosity, Pa·s; $tg\ \alpha$ – tangent of the slope of the final linear section of the curve to the abscissa axis.

Methods of evaluating bread quality

Structural-mechanical properties (degree of penetration) of the sprouted wheat grain bread were measured on the «Labor» penetrometer by determining the resistance of the breadcrumb to the penetrating indenter (angle 60^0) [39]. To do this, a 4 cm thick sample was cut from the breadcrumbs. Before the analysis, the immersion system was raised to the upper position. The sample was placed on a flat surface of a smooth stand placed on the lifting table of the penetrometer, which was lifted until the immersion body touches the surface of a slice of bread. After pressing the start button for 5 s, the immersion body penetrated the breadcrumb, after which the immersion system was slowed down. The ultimate shear stress of the intact structure σ_0 (Pa), was calculated by Rebinder's formula:

(6)
$$\sigma_0 = k\frac{m \cdot g}{h^2},$$

where m is the mass of the indenter and the device rod acting on the experimental product (minus friction and resistance of the indenter spring), kg; g – free fall acceleration m/s^2; h– cone immersion depth, m; k– indenter constant. The specific volume and moisture content of bread samples was evaluated by the standard methods [38].

Statistical analysis
Experimental data were processed with the use of MS Office Excel spreadsheets. Each test or measurement was performed three times. The statistical significance of the obtained results was determined at $p < 0.05$.

Results and discussion
The results of determining the influence of xanthan gum on the spread of the ball of dough from sprouted wheat grain are presented in Figure 2.

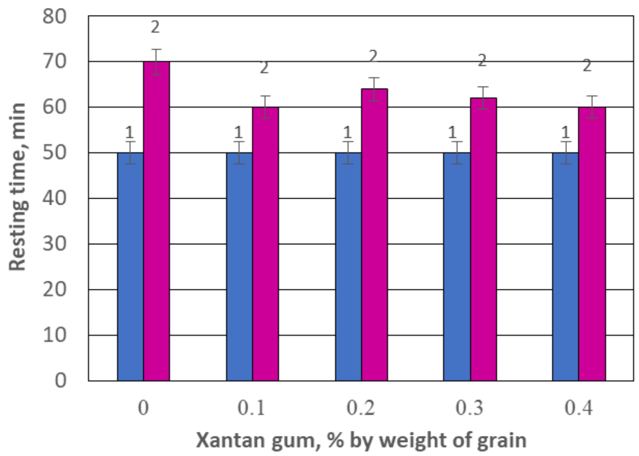

Figure 2. Influence of xanthan gum on the spreading of a ball of dough from sprouted wheat grain:
1 – initial diameter; 2 – diameter after the fermentation process

The obtained results show that with equal initial diameters of dough balls (50 mm) the spread rate of samples with xanthan decreased by 6.0-14.3%, which indicates the strengthening of the dough structure. This is due to the ability of xanthan gum to bind water significantly, contributing to a better structuring of the dough and less dilution, as was previously shown in the works [30,31].

Sprouted wheat dough is characterized by high stickiness, so it was important to study the influence of xanthan gum on its adhesive properties. The results of measuring the strength of the adhesion of the dough are shown in Figure 3.

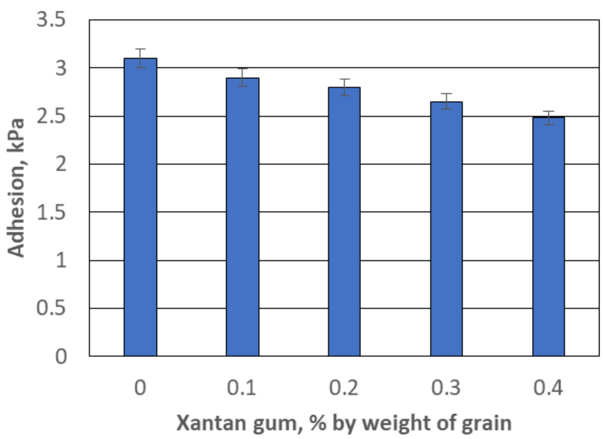

Figure 3. Influence of xanthan gum on the adhesion strength of sprouted wheat grain dough.

It was determined that the addition of xanthan reduces the adhesion strength of the dough by 10.1-21.4%. On the one hand, this is due to its high-water absorption and water retention capacity. On the other hand, anionic polysaccharide xanthan gum forms compounds with flour hydrocolloids, which also helps to reduce the adhesive strength of the dough. According to the results presented in [[40], xanthan gum and gluten form compact complexes using electrostatic interactions. The interaction of xanthan gum with flour proteins is also

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evidenced by data on the strengthening of gluten when adding microbial polysaccharides in an amount of 0.1-0.7% to the flour weight [32]. In addition, xanthan gum can form intermolecular bonds with starch [41,42]. The positive effect of xanthan on the structure of the sprouted wheat grain dough was confirmed by determining its resilience-elastic and plastic-viscous properties on Tolstoy's elastoplastometer (Table 2).

Table 2. Resilience-elastic and plastic-viscous properties of the dough

Indicator	Control sample	Samples of bread with the addition of xanthan gum, % by weight of grain			
		0.1	**0.2**	**0.3**	**0.4**
Modulus of instantaneous resilience, G_r×10^{-2}, Pa	5.00[1]±0.01[2a]	5.4±0.01^a	5.9±0.01^a	6.4±0.02^a	6.8±0.02^a
Modulus of elasticity, G_{el} ×10^{-2}, Pa	6.90±0.02^a	8.0±0.02^a	9.1±0.03^b	10.3±0.03^b	9.3±0.03^b
Plastic viscosity, η_0 ×10^{-3}, Pa·s	9.10±0.02^a	11.0±0.04^b	12.2±0.02^a	13.4±0.04^b	14.0±0.04^b

[1]Means ± [2] standard deviation. Means in a row without a common superscript letter differ statistically (p < 0,05)

According to the obtained data, the addition of 0.1-0.4% xanthan gum contributes to the growth of the dough modulus of instantaneous elasticity by 8.0-36.0%. It should be noted that the modulus of elasticity of the dough with the addition of 0.1-0.3% xanthan gum increases by 15.9-49.3%. Increasing the amount of xanthan gum in the dough to 0.4% reduces the improving effect, but the elastic properties of this sample remain higher than in the control. The plastic viscosity of sprouted wheat grain dough with the addition of xanthan gum also increases through the experiments. These data are consistent with the results of studying the rheological properties of other types of dough in the presence of xanthan gum. For example, the data obtained using the Chopin alveograph indicate an increase in the elasticity of wheat flour dough with the addition of xanthan gum in the amount of 0.1-0.3% and a decrease in it with a biopolymer dosage of more than 0.4% [30]. Other authors [36] using the methods of farinography and rheometry proved the increase in elasticity and viscoelastic properties of gluten-free dough based on rice flour with the addition of xanthan. It was established that the elasticity and viscosity of protein-free dough improve with an increase in the amount of xanthan in it from 0.3 to 0.5% to the mass of corn starch [35]. This tendency of xanthan influence on the rheological properties of sprouted wheat grain dough were also observed during the analysis of structural-mechanical (Figure 4) and physical-chemical (Table 3) properties of bread.

Presented experimental data show (Figure 4) that the introduction of 0.1-0.3% xanthan gum contributes to an increase in the degree of breadcrumbs penetration by 11.3-28.3%, which is caused by improving the elastic characteristics of the dough (Table 2). The degree of penetration of the bread sample with the addition of 0.4% xanthan decreases slightly but remains higher than the control.

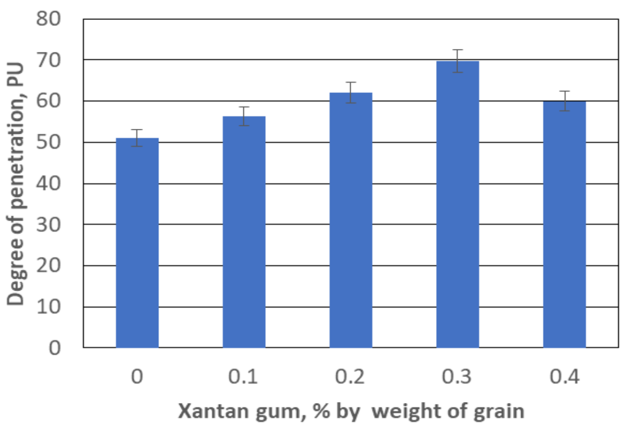

Figure 4. Influence of xanthan gum on the degree of penetration of breadcrumbs.

Table 3 shows the results of determining some physical-chemical indicators of the quality of control and experimental samples of bread from sprouted grain. It was established that the specific volume of bread increases in the presence of xanthan. The presented data show that the largest specific volume was in bread with the addition of 0.1-0.3% xanthan gum.

Table 3. Physical-chemical quality indicators of grain bread with xanthan.

Indicator	**Control sample**	**Samples of bread with the addition of xanthan gum, % by weight of grain**			
		0.1	**0.2**	**0.3**	**0.4**
Specific volume, cm^3/ 100g	$190^1 \pm 2.0^{2a}$	210 ± 4.0^b	230 ± 4.0^b	250 ± 6.0^b	237 ± 5.0^b
Moisture, %	45.0 ± 0.5^a	45.5 ± 0.5^a	45.7 ± 0.9^b	46.0 ± 1.0^b	46.2 ± 1.0^b

[1]Means ± [2] standard deviation. Means in a row without a common superscript letter differ statistically (p < 0,05)

The moisture-absorbing and moisture-retaining abilities of xanthan have a positive effect on the moisture content of bread. A similar effect of xanthan on the specific volume and moisture content of bread was previously established by other authors during the study of its influence on the quality of whole wheat bread [37], bread made from frozen dough [40], Barbari bread [43], protein-free and gluten-free products [35,36].

Impact

The implementation of the obtained results will allow improving the technology of sprouted grain bread and obtaining a healthy product with high consumer properties. This will contribute to the solution of the important social task of improving health of the population. An increase in the dietary intake of whole grain bread as a rich source of many essential nutrients will reduce the risk of the spread of nutritional diseases. During germination, the nutritional profile of grain improves due to the transition of biopolymers into an easily accessible form, as well as an increase in the content and bioavailability of biologically active substances in the grain. However, baking properties of wheat grain deteriorate during germination that negatively affects the appearance of bread and its structure. The study described in this article proposes a way to overcome technological difficulties in forming the structure of bread from sprouted grains based on the use of xanthan polysaccharide, which has the ability to bind water and interact with protein and starch. Our research data show the effectiveness of xanthan for improving the structure of the dough and quality of bread made from germinated wheat grain. As the results of the research showed, the use of xanthan reduces stickiness of the dough from germinated wheat grain and improves its structure. That will optimize the technological process, increase production efficiency and competitiveness of the finished product. The use of whole grain wheat for the production of bread, bypassing its processing into flour, allows a more rational use of valuable grain raw materials, as well as reducing negative impact on the environment.

Conclusions

It was determined that the addition of 0.1-0.4% xanthan gum improves rheological properties of the dough from sprouted wheat grain, namely reducing adhesion, and enhancing the resilience-elastic and plastic-viscous properties. Sprouted wheat grain bread with the addition of xanthan in these dosages has an improved structure, higher moisture, and specific volume. It was also found that the usage of 0.3% xanthan is advisable to obtain bread with the best quality indicators. Future research will focus on determining the effect of xanthan on changing structural-mechanical and physical-chemical quality indicators of sprouted grain bread during storage.

Conflict of interest

There are no conflicts to declare.

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