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ASSESSMENT OF THE EFFECT OF ROSEHIP POWDER ON THE STRUCTURAL AND MECHANICAL PROPERTIES OF WHEAT DOUGH AND BREAD

The object of research is dough and bread made from wheat flour with the addition of rosehip powder. Its use in bread technology is considered as a promising direction for improving the quality of dough and finished products due to the natural content of biologically active substances in rosehip. The problem of insufficient knowledge of the effect of whole rosehip powder on the structural and mechanical properties of dough and bread is solved by conducting comprehensive studies using modern methods. According to the results of farinographic studies, it was found that the introduction of 2–8% rosehip powder contributes to an increase in the water absorption capacity of the dough and an extension of its formation time. At the same time, an increase in dough stability by 13.8–32.3% and a decrease in the degree of dilution by 6.6–18.0% compared to the control sample are observed, which indicates the strengthening of the structural and mechanical properties of the dough and its increased resistance to mechanical stress during kneading. Alveographic analysis also confirmed the strengthening of the dough structure: its tenacity increases, extensibility decreases, and the specific work of deformation increases by 5.3–21.1%. This is due to the strengthening of the gluten complex of wheat flour under the action of ascorbic acid, non-starch polysaccharides and polyphenolic compounds contained in rosehip powder.

It was established that the introduction of rosehip powder in an amount of 2–6% of the flour mass contributed to the improvement of the structure of the products, which is manifested in an increase in the specific volume of bread by 12.0–22.8% and a decrease in the hardness of its crumb by 14.1–28.2%. Increasing the additive content to 8% leads to a decrease in the improving effect, but the experimental indicators remain higher than the control ones.

The results obtained can be used in the practice of baking production during the development of bread technology with increased nutritional value and quality.

Keywords: *bread, dough, rosehip powder, structural and mechanical properties, specific volume.*

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1. Introduction

Bread, as one of the key products of daily consumption, plays an important role in shaping the diets of the population of many countries of the world. Over the centuries, bread technologies have been created and continue to be improved by introducing new solutions. The current trend in the development of baking technologies is the focus on health-promoting types of bread. Of particular interest in this regard is the involvement of natural plant raw materials in the technological process, the properties of which allow not only to enhance the nutritional profile of bread, but also to improve its quality. In view of this, in recent years, the attention of researchers has been drawn to rosehip processing products. Rosehip (*Rosa* L.) is a perennial plant of the *Rosaceae* family, which is widely distributed in Europe, Asia, and North America. Since ancient times, it has been known as a medicinal plant and remains a symbol of health and youth in many cultures of the world. Rose hips are a powerful source of flavoring and biologically active substances, which determines their high value as raw materials for the production of a wide range of healthy food products, including bread. They are characterized by a high content of a wide range of antioxidants [1], valuable fatty acids [2], vitamins, minerals [3], etc. Such a composition determines pronounced biological properties, in particular antioxidant, immunomodulatory, anti-inflammatory and general strengthening and other effects [4, 5]. The well-known therapeutic effect of rose hips is primarily based on the high content of vitamin C, the concentration of which in its fruits significantly exceeds that of blueberries, lemons and oranges [6]. The reduced form of vitamin C is ascorbic acid, which is one of the most effective improvers of oxidative action. In the dough, under the action of ascorbate oxidase, ascorbic acid is converted to dehydroascorbic acid and acts as a powerful oxidant of thiol groups of gluten proteins. Such "crosslinking" through the formation of disulfide bonds contributes to the strengthening of the gluten framework. This provides an increase in the resistance of the dough to deformation, improvement of gas-holding capacity and strengthening of the dough structure, increase in the volume of bread and improvement of the crumb structure [7, 8]. Therefore, in baking, rosehip products are considered not only as a source of biologically active compounds, but also as an alternative to synthetic ascorbic acid. In works [9, 10] using farinographic, extensographic and rheofermentographic research methods, it was established that the introduction of 0.5–2.5% powder from the

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pulp of rosehip fruits contributes to an increase in the water-absorbing capacity of the dough, an increase in its stability and a decrease in extensibility. The authors attribute this to the complex effect caused by the action of vitamin C and dietary fiber powder. To improve the volume and porosity of bread, the authors recommend using it in the dough preparation process in an amount of 1.5–2.0%. In work [11], it is recommended to add 2.5% rosehip pulp powder to reduce the adhesion and stretchability of dough from whole grain flour. However, these studies used small dosages of rosehip pulp powder, which do not allow to significantly increase the nutritional value of bread. In works [12, 13], it was established that the addition of defatted rosehip powder in an amount of 5–15% of the flour mass increases the dough stability, but the intensity of gas formation decreases. This leads to a decrease in the specific volume of bread from 4.09 to 2.67 cm^3/g at the maximum dosage level of the powder. The content of antioxidants in bread also increases. However, the structural and mechanical properties of dough and bread have not been studied sufficiently.

The effect of rosehip fruit oil on the quality of rye-wheat bread has been studied, in particular on the physicochemical, structural and mechanical and organoleptic indicators depending on its dosage [14]. It has been proven that the introduction of 3–5% of oil contributes to the improvement of porosity, specific volume and dimensional stability of products, which is associated with the activation of the fermentation microflora of the dough under the influence of biologically active components.

It has been shown that the introduction of 2–6% of rosehip fruit meal (a secondary product in the production of rosehip oil) contributes to the intensification of fermentation processes, an increase in the gas-holding capacity of the dough, and an improvement in its structure and quality of bread [15, 16]. These researches were conducted on rye-wheat dough.

The authors of [17] showed that it is advisable to use rosehip seed flour in an amount of up to 5%, since higher dosages worsen the quality of the products. Other researchers in [18] proposed to include a larger amount of rosehip seed powder (10%) in the recipe in order to improve the rheological properties of the dough and the chemical composition of the bread. In [19], on the contrary, a decrease in the textural characteristics of the products and their specific volume was shown when 3–5% of rosehip seed powder was added due to the formation of a denser and less elastic bread crumb. In research [20], the main attention was paid to increasing the antioxidant activity and optimizing recipes with rosehip seed powder, without a detailed analysis of the rheological parameters of the dough and bread quality.

For maximum use of rosehip nutrients, it is advisable to use whole fruit powders in baking. The authors of [21] showed that when using compositions containing 15% chestnut flour and 0.5–3% powder from whole ground rose hips, the rheological profile of the dough is significantly improved, which is manifested in an increase in dough stability. However, it was used rose hips powder in a mixture with other non-traditional raw materials, which does not allow to isolate its effect on the dough system and product structure.

Thus, the analysis of literary sources indicates the presence of researches devoted to the use of various rose hips processing products in baking and their effect on technological processes and the quality of finished products. At the same time, the available data are not sufficiently systematized, and the issue of the effect of whole rose hips powder on the structural and mechanical properties of dough and bread remains insufficiently covered.

In view of this, researches aimed at determining the influence of powder obtained from whole rose hips on the formation of the structure of dough and bread from wheat flour are relevant.

The object of research was dough and bread from wheat flour with the addition of rosehip powder.

The aim of research is to assess the influence of rosehip powder on the structural and mechanical properties of dough and bread from wheat flour, which will further allow to substantiate effective technological solutions in the development of bread technology using it.

To achieve the aim, the following objectives were formulated:

1) to determine the influence of rosehip powder on the structural and mechanical characteristics of dough;

2) to determine the influence of rosehip powder on the structural and mechanical properties of bread.

2. Materials and Methods

2.1. Characteristics of the raw materials used in the researches

The first-grade wheat flour (SE Novopokrovsky Bakery Plant, Ukraine), whole rosehip powder (Company "Mu Eco", Ukraine), pressed baker's yeast (TM Lviv Yeast, Ukraine), table salt (TM Sarkara, Ukraine) were used.

The appearance of rosehip powder is shown in Fig. 1.

Fig. 1. Appearance of rosehip powder

The content of nutrients, dietary fiber (non-starch polysaccharides and lignin) and vitamin C in rosehip powder is given in Table 1.

Table 1

Chemical composition of rosehip powder

Substance	Mass fraction of a substance
Proteins, g	4.1
Fats, g	3.5
Carbohydrates, g	59.3
including mono- and disaccharides	14.8
starch	0.3
non-starch polysaccharides	44.2
Lignin, g	16.0
Vitamin C, mg/100 g	280.0

2.2. Methods of studying the structural and mechanical properties of dough

To study the structural and mechanical properties of dough, the following were used:

– model systems made from first-grade wheat flour (control sample);

– samples with partial replacement of flour with rosehip powder in the amount of 2, 4, 6 and 8% of the flour mass.

The structural and mechanical properties of dough were determined using a farinograph (Brabender, Germany) according to DSTU 4111.1-2002 and an alveograph (Chopin, France) according to DSTU 4111.4-2002.

2.3. Preparation of bread test samples

Bread samples were prepared in a single-phase method. The dough was kneaded in a KitchenAid (USA) dough mixer until a homogeneous consistency was obtained. The recipe of the control sample included first grade wheat flour (100%), pressed baking yeast (3%), table salt (1.5%) and water. In the experimental samples, 2, 4, 6 and 8% of wheat flour was replaced with rosehip powder.

The kneaded dough was subjected to ripening for 180 min at a temperature of 30 ± 2°C. The fermented dough was divided into pieces, shaped and proofed in a proofing cabinet for 40 min at a temperature of 35 ± 2°C and a relative humidity of 80 ± 5%. Baking of dough blanks was carried out in a UNOX (Italy) convection oven at a temperature of 210 ± 10°C with humidification of the baking chamber. The duration of bread baking was 25 ± 2 min.

2.4. Methods for studying bread quality indicators

Bread quality indicators were determined after it was completely cooled (3 hours after baking). The specific volume of bread (cm^3/100 g) was calculated as the ratio of the product volume to its mass. The volume of products (cm^3) was determined by measuring the volume of grain displaced by the bread from a volume measure [22].

The textural properties of the bread crumb (hardness) were determined using a TA.XTplus Texture Analyser (Stable Micro Systems, Great Britain) equipped with a cylindrical probe P/36R. The crumb hardness was determined as the maximum compression force of bread crumb samples, expressed in grams [23].

2.5. Statistical processing of research results

The results of three parallel measurements were statistically processed using the Fisher-Student test at a confidence level of $p = 0.95$. The MS Excel 2016 application package (USA) was used to process experimental data.

3. Results and Discussion

3.1. Determination of the effect of rosehip powder on the structural and mechanical properties of dough

The results of studying the effect of rosehip powder on the structural and mechanical properties of dough according to farinogram data (Table 2) showed that its addition contributed to:

– some increase in the water absorption capacity of the dough;

– an extension of its formation time from 2.0 in the control to 2.9 min at a dosage of 8%. This is probably due to the fact that rosehip powder contains a significant amount of cellulose, hemicelluloses, and pectin substances that actively bind water. As a result, the dough requires more moisture to achieve the required consistency.

Table 2

The effect of rosehip powder on the structural and mechanical properties of wheat dough according to farinogram data ($n = 3$; $\sigma = 3–5\%$)

Indicator	Control sample	Samples with replacement of wheat flour with rosehip powder, %			
		2	4	6	8
Water absorption capacity, %	61.3	62.0	62.5	62.8	63.4
Dough development time, min	2.0	2.2	2.4	2.7	2.9
Stability, min	6.5	7.4	7.7	8.0	8.6
Softening degree, farinograph units	61	57	55	52	50

It was also found that the dough stability increased by 13.8–32.3% and its dilution decreased by 6.6–18.0%, respectively. This is evidence of the strengthening of the gluten complex due to ascorbic acid, which acts as a natural improver and oxidizes the sulfhydryl groups of proteins, contributing to the formation of disulfide bonds. There is also a mechanical "reinforcing" effect of rosehip fiber particles, which stabilize the structure. Gluten strengthening can be facilitated by the formation of protein-polysaccharide complexes of non-starch polysaccharides of rosehip powder with wheat flour proteins [24]. It is also known that rosehip contains a significant amount of polyphenols [25], and the formation of protein-phenol interactions is also the cause of gluten strengthening, as shown in [26, 27].

Thus, the results of farinographic analysis showed that the addition of rosehip powder in an amount of 2–8% instead of flour led to an improvement in the structural and mechanical properties of the dough.

The tendency to strengthen the dough structure with the addition of rosehip powder was also observed during alveographic measurements (Table 3).

Table 3

The effect of rosehip powder on the structural and mechanical characteristics of the dough according to alveogram data ($n = 3$; $\sigma = 3–5\%$)

Indicators	Control sample	Samples with replacement of wheat flour with rosehip powder, %			
		2	4	6	8
Dough tenacity (P), mm	80.0	85.0	90.0	95.0	100.0
Dough extensibility (L), mm	100.0	90.0	85.0	75.0	70.0
P/L ratio	0.80	0.92	1.05	1.27	1.43
Specific deformation work, W, $\times 10^{-4}$ J/g	190.0	200.0	210.0	220.0	230.0

Thus, the tenacity index (P) increased from 80 mm in the control to 100 mm with the addition of 8% rosehip powder (by 25.0%). This indicates an increase in the ability of wheat dough to resist deformation. In the presence of the experimental additive, the dough extensibility index (L) significantly decreased, indicating a decrease in the ability to stretch. A decrease in dough extensibility is characteristic of dough systems with increased stiffness and elasticity, in which the gluten becomes stronger. Along with this, an increase in the P/L ratio was observed from 0.8 in the control to 1.43 with the addition of 8% rosehip powder. This indicated that the addition of the experimental additive led to the formation of a stronger dough with significant resistance to stretching. The introduction of rosehip powder in experimental quantities contributed to an increase in the specific work of deformation (W) by 5.3–21.1%, which also indicated a strengthening of the structure of the dough system.

The detected effects are probably due to the action of a combination of factors considered above when discussing the results of farinographic studies, namely the presence and features of the interaction of ascorbic acid, polyphenols and non-starch polysaccharides of rosehip powder with gluten proteins.

3.2. Determination of the effect of rosehip powder on the structural and mechanical properties of wheat bread

The use of rosehip powder in an amount of 2–8% of the flour mass significantly affected the quality indicators of bread. Its introduction contributes to an improvement in the volume of bread, which, judging by Fig. 2, increases significantly with the addition of 2–6%, and with the introduction of 8% the positive effect is somewhat reduced.

The structure of bread is indirectly characterized by the specific volume index. The results of the influence of rosehip powder on this index of bread are shown in Fig. 3.

The data in Fig. 3 show that the addition of rosehip powder in an amount of 2–6% led to an increase in the specific volume of bread compared to the control sample by 12.0–22.8%. On the one hand, this is due to the strengthening of the gluten framework, which contributed to the retention of a larger amount of carbon dioxide during fermentation. On the other hand, the presence of biologically active substances in the powder probably causes the activation of alcoholic fermentation, and, consequently, the amount of accumulated CO_2. Further increase in the dosage of rosehip powder to 8% led to a decrease in the specific volume of bread compared to samples containing 4–6% of the additive, but exceeded the value of the specific volume in the control sample. This is explained by the excessive content of non-gluten components, which disrupt the continuity of the gluten matrix and limit its ability to retain gas.

The positive effect of rosehip powder on the structural and mechanical properties of bread was established when determining its effect on the hardness index of its crumb (Fig. 4).

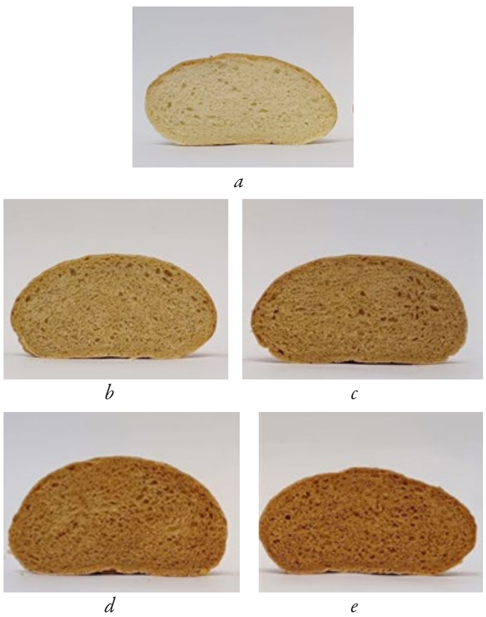

Fig. 2. Wheat bread: *a* – without additive (control); *b*, *c*, *d*, *e* – with replacement of wheat flour with 2, 4, 6, 8% rosehip powder

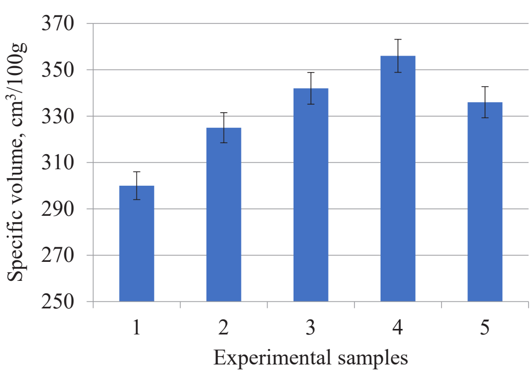

Fig. 3. Specific volume of bread: 1 – without additive (control); 2, 3, 4, 5 – with replacement of wheat flour with 2, 4, 6, 8% rosehip powder

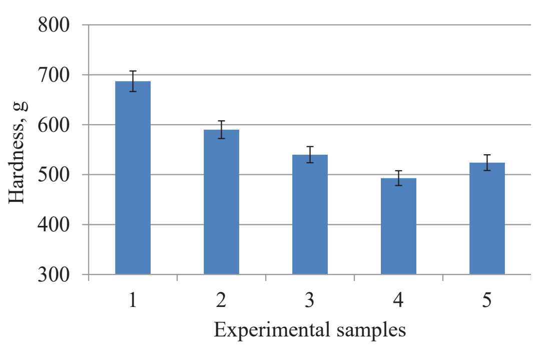

Fig. 4. Bread crumb hardness: 1 – without additive (control); 2, 3, 4, 5 – with replacement of wheat flour with 2, 4, 6, 8% rosehip powder

As can be seen from the results illustrated in Fig. 4, the change in bread crumb hardness with the addition of 2–8% rosehip powder has a nonlinear nature and is due to the complex action of physicochemical factors. With the addition of 2–6%, a decrease in bread crumb hardness by 14.1–28.2% is observed. This, as in the case of the specific volume of bread, is associated with the strengthening of the gluten framework, the improvement of the gas-holding capacity of the dough and the formation of more developed crumb porosity under the action of the powder components. At the same time, the dietary fiber of rose hips helps retain moisture, which increases the elasticity of the crumb. Further increase in the dosage of the additive to 8% leads to an increase in hardness, although it remains lower than in the control sample. This is probably due to a significant amount of non-starch polysaccharides, their competition with gluten proteins and starch for moisture, and the compaction of the bread structure.

3.3. Limitations and directions of research development

The obtained experimental results partially explain a previously insufficiently covered aspect, since they allow to establish the regularities of the influence of rosehip powder on the structural and mechanical properties of dough and bread made from wheat flour. However, the research has certain limitations due to the use of only first-grade flour, which complicates the transfer of the results obtained to other types and grades of flour. In further researches, it is advisable to optimize the technological parameters of bread production with rosehip powder and assess its nutritional and biological value.

4. Conclusions

1. It has been found that the introduction of rosehip powder in an amount of 2–8% of the flour mass contributes to the improvement of the structural and mechanical properties of the dough. The water absorption capacity increases, the stability rises by 13.8–32.3%, the softening decreases by 6.6–18.0%, and the tenacity of the dough increases by 25.0% and the specific work of deformation by 5.3–21.1% while simultaneously reducing the extensibility.
2. It has been found that the introduction of rosehip powder in an amount of 2–6% of the flour mass contributes to an increase in the specific volume of bread by 12.0–22.8%, a decrease in the hardness of its crumb by 14.1–28.2%. Further increase in the content of the additive leads to a decrease in the improving effect.

Conflict of interest

The authors declare that they have no conflict of interest regarding this research, including financial, personal, authorship or other nature, which could affect the research and its results presented in this article.

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Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented paper.

Authors' contributions

Bohdan Bilash: Conceptualization, Data curation, Formal analysis, Investigation, Validation, Writing – original draft, Writing – review and editing, Resources; ***Olga Samokhvalova***: Conceptualization, Methodology, Writing – review and editing, Supervision; ***Svitlana Oliinyk***: Conceptualization, Methodology, Formal analysis, Investigation, Validation, Writing – original draft, Writing – review and editing; ***Olena Bolkhovitina***: Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review and editing; ***Nataliia Cherevychna***: Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review and editing.

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