UDC 664.654; 664.655
DOI: 10.15587/1729-4061.2023.278799

FORMATION OF THE QUALITY AND SHELF LIFE OF BREAD THROUGH THE ADDITION OF ROWANBERRY POWDER

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The object of the study is bread made from medium rye flour enriched with rowan powder. The study is devoted to the formation of quality and increase of the shelf life of bread. The technology of obtaining powder from Sorbus aucuparia involves freezing fruits, preliminary dehydration by osmotic dehydration, drying and grinding. It was found that rowan powder contains the highest amount of potassium (860 mg/100 g) and 6.7 % crude fiber. Rowan powder contains 1.72 mg/100 g of vitamin C, which gives it antioxidant properties. The experimental samples of bread from medium rye flour were made by the liquid sponge method. Rowan powder was added to samples D1, D2, and D3 in an amount of 5, 10, and 15 %, respectively. The control sample (C) was made according to a standard recipe. The analysis of the physicochemical parameters of bread quality showed that with an increase in the amount of rowan powder added, the acidity of the samples increased, but did not exceed the standard values. Rowan powder did not significantly affect the moisture content of the bread crumb. With the addition of 5 and 15 % powders, the moisture content was 46.7 and 46.6 %, respectively. In sample D2, which contained 10 % rowan powder, the moisture content was the lowest – 45.9 %. The effect of rowan powders on the storage ability of rye flour bread was investigated. It was found that mold appeared on the surface of sample C on the 5th day of storage. In the sample with a rowan powder content of 5 % – on the 12th day of storage, with a powder content of 10 % – on the 21st day of storage. On sample D3, mold was observed on the 16th day of storage. These results indicate that rowan powder can be used as a natural preservative that can significantly increase the shelf life of rye flour bread

Keywords: enriched bread, rowan powder, gluten-free component, shelf life, bread molding

Received date 28.03.2023
Accepted date 02.06.2023
Published date 30.06.2023

How to Cite: *Samilyk, M., Demidova, E., Nazarenko, Y., Tymoshenko, A., Ryzhkova, T., Severin, R., Hnoievyi, I., Yatsenko, I. (2023). Formation of the quality and shelf life of bread through the additive of powder from rowanberry. Eastern-European Journal of Enterprise Technologies, 3 (11 (123)), 42–49. doi: https://doi.org/10.15587/1729-4061.2023.278799*

1. Introduction

Bread is one of the main food products [1]. This product is a source of macronutrients (carbohydrates, proteins) and microelements (vitamins, minerals) [2]. At the same time, bread is deficient in vitamin C, iron, calcium, pectin, and other functional components. To balance the chemical composition, bread is enriched with various additives with functional properties. The addition of various fillers and additives affects the biochemical processes of yeast cell development, fermentation, dough maturation and baking.

Various herbal additives are added to bakery products to reduce the glycemic index and improve their taste [3]. For consumers, it is important that bread has not only good taste but also high nutritional value [4]. To increase the demand for their products, bread producers are trying to create not just a traditional product, but to give it additional functional properties [5]. It is worth noting that bread made from whole grain flour is more beneficial. This is due to the fact that food products made from refined flour are one of the main causes of diabetes, gastrointestinal diseases, and other metabolic disorders [6]. The beneficial effects associated with the consumption of whole wheat flour products are explained by the high content of dietary fiber in their composition [7]. In order to improve the functional properties of bakery products, they are enriched with various biologically active components [8].

Bread is not resistant to mold development caused by mycelial fungi of the genus *Penicillium*. Due to its high moisture content (more than 40 %) and water activity (approximately 0.94–0.97), bread spoils very quickly at room temperature. Its shelf life is only 36 hours.

Therefore, research on the development of technology of rye flour bread with an extended shelf life and increased biological value is very relevant.

2. Literature review and problem statement

Bread made from rye flour is worth noting for its beneficial effects on the body. Rye contains the largest amount of dietary fiber, as well as a wide range of biologically active compounds [9]. Rye flour bread contains B vitamins. Dietary fiber in rye flour consists of arabinoxylan, cellulose, β-glucan, fructans, and lignin. Lignin is an important functional component, the content of which can change during the processing of rye bread. This is due to the biochemical and microbiological processes that occur during bread making [10]. The composition of rye sourdough bread can be changed to meet different nutritional needs [11]. Although rye flour bread contains more dietary fiber than other types of bread, its content does not meet even 10 % of the daily requirement.

The consumption of rye bread is constantly growing due to the nutritional value and high bioavailability of its components, as well as lower gluten content. Rye flour is often combined with other types of flour. A study has shown that the addition of barley flour to rye bread increases the content of dietary fiber and antioxidant activity [12].

Enrichment of rye bread with berries and fruits, vegetables, seeds, and non-traditional types of flour is an effective method of increasing its biological value [13]. However, the introduction of such additives can affect the development of undesirable microflora and reduce the shelf life.

The paper [14] presents the rationale for the use of 25 % Jerusalem artichoke powder by weight of flour in bread production. The resulting product had high consumer properties, increased content of total protein, pectin substances, calcium, phosphorus, and other functional components. The addition of fruit powders from *Amelanchier alnifolia* berries to rye bread led to a significant increase in their polyphenol content and antioxidant activity compared to control products [15]. The proposed technology of rye bread enrichment with 3 % *Amelanchier alnifolia* powders allows extending the shelf life of bread, preventing the appearance of mold [16]. The use of these types of raw materials can significantly increase its cost, as they are not common in many regions.

The positive impact of bread enriched with various additives on health promotion and prevention of non-communicable diseases associated with lifestyle has been proven [17]. Eating bread enriched with tomato pomace reduces lipid levels in the body [18]. Bread enriched with curcumin is better absorbed by the body [19]. To enrich bread, secondary raw materials are often used, which are formed during the processing of grain (buckwheat husks, oatmeal, wheat bran and seed waste), berries, and fruits. These types of raw materials have a unique chemical composition and high biological value and are used to produce powders as carriers of dietary fiber [20]. At the same time, typical technologies for producing plant powders are energy-intensive, which can affect the cost of bakery products. Since the main process is drying, it is worth developing measures to rationalize it. In addition to having a positive effect on the human body, dietary fiber has a high moisture retention capacity. This prevents bread from staling, and as a result, the shelf life of the product is extended [21, 22]. The source of dietary fiber is vegetables (carrots, cabbage, cactus), fruits (apple, grapes, orange, mango), cereals (wheat, rye, oats) and seeds (cocoa beans, coffee beans) [23]. The work [24] investigated the effect of high-fiber powders (buckwheat, beet, and flaxseed) on the rheological properties of dough and quality indicators of rye-wheat bread. The research resulted in bread with good physicochemical properties, denser crumb, and enriched with dietary fiber. A positive effect on the rheological properties of the dough and the organoleptic quality of bread can also be obtained when using beer and buckwheat groats to enrich bread [25]. However, secondary raw materials can negatively affect the organoleptic properties of bread.

The analyzed technological solutions also affect the organoleptic, physical and chemical properties, and biological value of bread, but do not increase its shelf life. To increase the shelf life of bread and prevent its microbiological spoilage, preservatives (mainly sorbate and propionate salt) are added [26]. Such additives have a negative impact on the human body. The development of microorganisms in bread can be controlled by using aseptic packaging, ultraviolet irradiation, pasteurization, and ingredients that prevent mold development [27]. The implementation of the above measures to increase the shelf life of bread is more expensive than the product itself, and therefore not widely used in industrial conditions.

Such ingredients include processed products of various types of rowan. Numerous studies of the antiradical properties of rowan show that it has a large amount of phenolic acids that can prevent rapid spoilage of products [28]. The feasibility of using rowan fruits to prevent the development of mold in breads has been considered [29].

The technology of wheat bread using *Sorbus aucuparia* rowan powder has already been developed and substantiated. No defects in taste, odor, or shape were found in bread with the addition of 10 % powder. When rowan powders are added, the bread preparation time is reduced by 30 minutes compared to the classical straight dough method and by 120–150 minutes compared to the sponge and dough method. The shelf life of bread using the proposed technology is 15 days [30].

The analysis of various sources [28, 29] of information and the results of our own research [30] confirm the positive effect of rowan powders on some properties of bread and its storage ability. However, no studies have been found on its effect on the quality indicators of bread made from medium rye flour produced by the liquid sponge method.

3. The aim and objectives of the study

The aim of the work is to form the quality and increase the shelf life of rye flour bread enriched with *Sorbus aucuparia* powder. This will substantiate the feasibility of using rowanberry powder in the production technology of rye flour bread.

To achieve the aim, the following objectives were set:

– to analyze the mineral composition, vitamin C and crude fiber content in *Sorbus aucuparia* powders;

– to analyze the content of vitamin C and crude fiber in *Sorbus aucuparia* powders;

– to study the effect of *Sorbus aucuparia* powder on the formation of quality indicators of rye flour bread (organoleptic, physico-chemical, microbiological);

– to analyze the effect of *Sorbus aucuparia* powder on the shelf life of rye flour bread.

4. Materials and methods of research

The object of the study is the technology of making enriched bread from medium rye flour. According to the proposed research hypothesis, adding a gluten-free component, *Sorbus aucuparia* powder, to the dough will help enrich bread with vitamins, minerals, dietary fibers and increase its shelf life. Such assumptions are taken on the basis of generally known information about the chemical composition of rowan.

Rowan powders were produced by a method that provides for preliminary freezing and osmotic dehydration of fruits. Fruits of wild *Sorbus aucuparia* were collected in October 2022 in the Sumy region, Ukraine. The washed and sorted fruits were first frozen. After defrosting, they were partially dehydrated in a supersaturated sucrose solution (70 %) by osmotic dehydration. The duration of dehydration was 1 hour at 50±5 °C (water duty – 1). The process was carried out using a laboratory unit, the design of which was developed independently [31].

The production of experimental bread was carried out by the sponge and dough forming method using medium rye flour. Liquid starters were used, made from a mixture of pure cultures of lactic bacteria strains *L. plantarum-30*, *L. casei-26*, *L. fermenti-34* and a mixture of pure cultures of yeasts *S. minor* chornorichenskyi and *S. cerevisiae L-1*. The ready developed dough was left for 40 min (35±5 °C) and baked for 50 min in an electric oven at 225±5 °C.

Experimental samples were made according to the developed formulation (Table 1). Rowan powder was added to samples D1, D2, D3 in an amount of 5, 10 and 15 %, respectively. The control sample (C) was produced according to the standard formulation.

Table 1

Recipe of bread from medium rye flour

Name of raw materials, semi-finished products and process indicators	Dough	Consumption of raw materials for dough preparation, kg			
		Sample 1 (C)	Sample 2 (D1)	Sample 3 (D2)	Sample 4 (D3)
Liquid sourdough	0.58	1.16	1.16	1.16	1.16
Flour in sourdough for dough	–	0.34	0.34	0.34	0.34
Medium rye flour	0.16	1.02	0.969	0.918	0.867
Salt	–	0.02	0.02	0.02	0.02
Yeast	–	0.002	0.002	0.002	0,002
Rowan powder	–	–	0.051	0.102	0.153
Total	0.74	2.542	2.542	2.542	2.542

The mass content of trace elements in the studied samples of rowan powders was analyzed using an SEM and EDS detector based on an SEO-SEM Inspect S50-B microscope (AZtecOne with an X-MaxN20 dispersive spectrometer). Samples for the study were pressed into tablets 2 mm in diameter with a ground outer surface. To prevent surface charge accumulation in the electron-probe experiment, dielectric samples were coated with a thin layer (30–50 nm) of silver.

Vitamin C content in the experimental powder samples was studied by high-performance liquid chromatography on a liquid chromatograph (Agilent Technologies 1200, UV-Vis Abs detector, detection at λ=240 and 300 nm, C18 column (Zorbax SB-C18 4.6×150 mm, 5 μm)). The following mobile phase was used: methanol and 0.02M KH_2PO_4 solution (20:80). Isocratic treatment with an elution rate of 1 ml/min and an analytical column temperature of 40 °C was used. The injection volume was 20 μl. The samples were extracted by adding the mobile phase (20 ml) to the liquid samples (5 ml). The obtained samples were centrifuged three times (OPN-12 centrifuge) at 10,000 rpm for 10 minutes. The extracts were filtered using an Agilent 0.45 μm PTFE filter.

The fiber content was determined by Wind's method. A powder sample weighing 2.5 g was introduced into a 250 cm^3 conical flask with a reflux condenser, a solution of 50 cm^3 sulfuric acid (mass fraction of 1.25 %) and 0.2 cm^3 amyl alcohol was added and the flask contents were heated until they slightly boiled. After 30 minutes of acid hydrolysis, the flask was disconnected from the cooler, cooled and its contents were neutralized with a 33 % sodium hydroxide solution in the presence of phenolphthalein. After neutralization, a 33 % sodium hydroxide solution was added in a volume of 1.70 cm^3 to form the required dense medium in the reaction flask. After 30 min of dense hydrolysis, the contents of the flask were quantitatively transferred to a dry filter preweighed with a weighing bottle placed on a Büchner funnel. In order to prevent the fiber particles from remaining on the funnel walls, they were washed onto the filter with a washer. The fiber was washed on the filter with hot water at a weak vacuum using a Komovsky pump, then with 2 % acetic acid solution and again with hot water. The fiber was dried on the filter by letting air in. The last traces of moisture were removed by treating the fiber with a 5 cm^3 alcohol-ether mixture (1:1) for 2 minutes, which was then filtered into a cooled Büchner flask. The air-dry filter with fiber is carefully lifted with a sharp spatula, folded in quadruple and transferred to the weighing bottle where the filter was previously dried. Drying is carried out on the VNIIHP – HF device at 160 °C for 10 minutes.

After determining the mass of the pre-dried filter and weighing bottle before and after filtering, the fiber content in the sample in grams is calculated, and then in mass fractions (%) in terms of dry matter.

The content of crude fiber (X) in mass fractions (%) in terms of absolutely dry matter is calculated by the formula:

$$x=\frac{(m_1-m_2)\cdot 100\cdot 100}{m\cdot(100-W)}, \quad (1)$$

where m_1 – mass of the weighing bottle with fiber and filter, g; m_2 – mass of the weighing bottle with filter, g; m – mass of the product sample, g.

The final result was the arithmetic mean of two parallel determinations. Allowable discrepancies between the two results of parallel determinations should not exceed ±0.15 %.

Bread acidity was determined by the arbitration method. Crumbled bread weighing 25 g was mixed in a 500 cm^3 milk bottle and 250 cm^3 distilled water of room temperature was added in portions from the volumetric flask when stirring. The bottles were carefully corked, shaken for 2 min and allowed to stand for 10 min. After that, the suspension was shaken again for 2 min and left at rest for 8 min.

The supernates were filtered through gauze into a dry beaker. 50 ml of the filtrate was taken with a Mohr pipette into 200–250 cm^3 conical flasks. The sample was titrated with 0.1 N NaOH solution in the presence of 2–3 drops of 1 % alcoholic phenolphthalein solution to obtain a faint beige coloration, which didn't disappear within 1 minute. Bread acidity A_b (in degrees) was calculated according to the formula:

$$A_b=2\cdot K\cdot V, \quad (2)$$

where K is the correction factor to the titer of 0.1 N alkali solution; V is the volume of 0.1 N NaOH solution, ml.

Bread humidity was determined by drying in a SESH-3M oven. For this purpose, the bread crumb was thoroughly crushed with a knife and quickly weighed. Two portions of 5 g each were placed in pre-dried and weighed metal weighing bottles, accurate to 0.01 g. Samples of the crumb in open weighing bottles were placed in a SESH-3M cabinet heated to 130 °C for 45 minutes. After drying, the weighing bottles were removed, covered with lids and cooled in a desiccator. The cooled weighing bottles were weighed and the difference between the weight before and after drying was used to determine the moisture content of the crumb, expressing it as a percentage of the sample taken. The final result was given as the arithmetic mean of the two determinations.

To determine the shelf life, the samples were stored at room temperature, without light access in polyethylene bags for 21 days.

5. Results of the study of rye flour bread enriched with *Sorbus aucuparia* powder

5. 1. Results of the analysis of the mineral composition of powders from *Sorbus aucuparia*

The mineral composition of rowan powders has been studied in order to identify trace elements that can improve the functional properties of bread. The results of the analysis of the mass ratio of mineral substances in powders from rowan fruits are presented in Fig. 1.

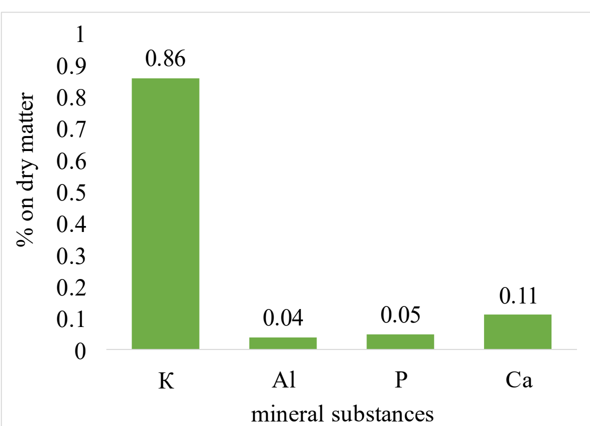

Fig. 1. Mineral composition of *Sorbus aucuparia* powder

The analysis showed that rowan powders contain the following minerals, mg per 100 g: potassium – 860, calcium – 110, phosphorus – 50 and aluminum – 40. The daily human need for K is 2–2.7 g, and with an intellectual load increases to 5 g. Thus, eating 100 g of bread enriched with rowan powder provides 4.3 % of the daily requirement for potassium. Increasing the content of this element in the composition of bread will have a positive effect on its functional properties.

5. 2. Results of the study of vitamin C and crude fiber content in powders from *Sorbus aucuparia*

Vitamin C stimulates the launch of immune processes, and also has antioxidant properties, so its content in rowan powders was studied. In addition, the fiber content of the powders was examined.

The results of the study are presented in Table 2.

Table 2

Results of the analysis of vitamin C and fiber content in rowan powders

Indicator	Value
Vitamin C content, **mg**/100 g	1.72
Crude fiber content, **%**	6.7

It was found that rowan powders processed by the method of freezing and osmotic dehydration contain a small amount (1.72 mg/100 g) of ascorbic acid, which is 2.5 % of the daily requirement of the body. The crude fiber content of rowan powders is 6.7 % (6.7 g per 100 g of powder), while rye flour contains 0.6–2.1 % fiber. The introduction of rowan powder into the recipe of rye flour bread will significantly increase the content of dietary fiber in the finished product. The introduction of rowan powders into the recipe of rye flour bread will improve its functional properties.

5. 3. Results of the study of the effect of *Sorbus aucuparia* powder on bread quality indicators

The organoleptic, some physicochemical and microbiological quality indicators of bread enriched with rowan powder were investigated.

It is worth noting that the consistency of dough pieces with an increase in the amount of rowan powder in the recipe became vaguer. The volume decreased, which is explained by the introduction of the gluten-free component. The proofing time of all dough samples was the same.

The organoleptic evaluation showed that sample D3, which contained 15 % powder, had a bitter taste and a slightly darker color compared to other samples (Fig. 2, *d*).

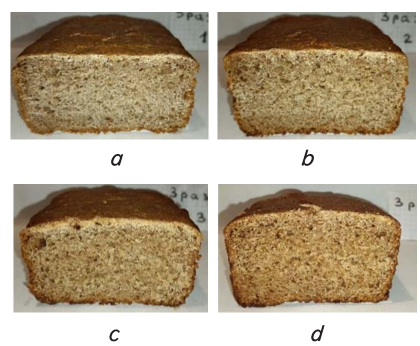

Fig. 2. Bread made from rye flour: *a* – sample C; *b* – sample D1; *c* – sample D2; *d* – sample D3

The surface of all experimental samples was uniform. The color of the crust was brown, the crumb was slightly moist to the touch. The shape of the samples is correct, rectangular, not blurry, without blobs, and consistent with the type of product. The crust is free of cracks and tears. The color of the crust is brown. The color of the crumb is uniform in the samples. The crumb is not sticky or moist to the touch. The porosity structure is medium to large, uniform. The pore wall thickness is medium. At the same time, no voids or seals were found in any sample. The taste and odor of the control sample and sample D1 corresponded to the normative indicators, without foreign flavors. Sample D2 had a pleasant rowan aroma and flavor, not sour. The taste of sample D3 was more pronounced with an intense rowan flavor.

Some physicochemical parameters of the quality of bread enriched with rowan powder were analyzed. The results are presented in Table 3.

Table 3

Results of the analysis of physicochemical parameters of bread made from rye flour

Name of indicators	Normative value	Sample			
		1 (C)	D1	D2	D3
Crumb acidity, degree	8.0–12.0	7.6	7.9	8.1	8.4
Crumb moisture content, %	46.0–51.0	46.0	46.7	45.9	46.6

The acidity of the control sample, which did not contain additives, was 0.4 degrees below the standard value. When 5 % rowan was added, the moisture content of the crumb increased by 0.7 % compared to the sample without additives. When 10 % of rowan powder was added, the moisture content decreased to 45.9 %. In samples with 15 % rowan powder, the moisture content practically did not differ from the samples to which 5 % powder was added. Thus, it is found that adding rowanberry powders has no significant effect on the change in humidity of the finished product.

Bread made of rye and a mixture of rye and wheat flour (with a shelf life of more than three days) is controlled by microbiological indicators at the end of the established shelf life. Therefore, on the 4th day of storage, microbiological parameters of the quality of rye flour bread enriched with rowan powders were analyzed (Table 4).

Table 4

Microbiological parameters of rye flour bread

Name of indicators	Normative value	Sample			
		1 (C)	D1	D2	D3
Number of mesophilic aerobic microorganisms, CFU per 1 g, no more than	$1.0\cdot10^3$	$4.0\cdot10^1$	$2.0\cdot10^1$	$1.0\cdot10^1$	$1.0\cdot10^1$
Mold fungi, CFU per 1 g, no more than	$1.0\cdot10^2$	Not found			

The analysis showed that rowan powder does not cause the development of microflora in finished products. After the expiration date (more than 72 hours), the number of mesophilic microorganisms exceeded the norm in the control sample C and the sample with 5 % rowan powder D1. With an increase in the content of rowan powder to 10 and 15 %, mesophilic aerobic microorganisms and mold were not detected in rye flour bread.

5. 4. Results of the study of bread storage capacity

The shelf life of unpackaged rye flour bread is only 36 hours, packaged bread – no more than 72 hours. Given the antioxidant [32] properties of rowan and rowan powders, the shelf life of enriched rye flour bread was investigated. Since mold is considered the main cause of bread spoilage, we studied its development until it appeared in the experimental samples. The first signs of mold on the control sample (without the additive) appeared on the 5th day of storage. In the sample with a 5 % rowan powder content – on the 12th day of storage, with a powder content of 10 % – on the 21st day of storage. On the sample with a 15 % rowan powder content, mold was observed on the 16th day of storage.

The appearance of the experimental samples on the 21st day of storage is shown in Fig. 3.

a *b* *c* *d*

Fig. 3. Bread made from rye flour on the 21st day of storage: *a* – sample C; *b* – sample D1; *c* – sample D2; *d* – sample D3

These results indicate that rowan powder can be used as a natural preservative that can significantly increase the shelf life of rye flour bread.

6. Discussion of the results of the study of bread enriched with *Sorbus aucuparia* powder

The analysis of the mineral composition of rowan powder (Fig. 1) showed the highest content of potassium (860 mg/100 g) and calcium (110 mg/100 g). The study [33] showed the highest content of these elements in the fruits of *S. aucuparia*. The same researchers showed the content of Mg, Cu, Zn, Mn in rowan fruits, which were not found during the presented experiment. At the same time, the experiment showed the content of Al (40 mg/100 g) in rowan powders, which was not found in the fruits during the study [33]. Potassium is present in all body tissues and is essential for normal cell functioning. It normalizes the metabolism, acid-base and water-salt balance in the body. Therefore, enriching bread with rowan powder will give the product additional functional properties.

It is known that rowan contains 3 times more ascorbic acid than oranges [34]. According to Mrkonjic[35], rowan fruits contain approximately 0.1 mg/g (dry matter) of vitamin C. According to other studies [32], the content of vitamin C in fruits, depending on the rowan variety, varied from 18 to 189 mg per 100 g of raw material. Analysis of powders made from wild rowan fruits (Table 2) showed that they contain 1.72 mg/100 g. The daily recommended intake of vitamin C is about 60 mg. And 5–7 mg per day prevents scurvy [36]. Adding rowan powders to bread will partially enrich it with ascorbic acid.

The daily fiber requirement in the body is 20–30 grams. The powders contained 6.7 g per 100 g of crude fiber (Table 2), which is 22–33 % of the daily requirement. The fiber contained in flour and powders helps to cleanse the body of toxic substances and improves metabolic processes.

The results (Table 3) showed that the acidity of the experimental bread samples D1, D2, D3 was within the normal range. With an increase in the amount of rowan powder added, the acidity increased, which is explained by the content of organic acids in the composition of rowan [35]. It was found that the addition of rowan powders does not lead to a significant decrease in moisture content, which has a positive effect on the process of dough fermentation. With an increase in the moisture content of semi-finished products, the activity of homofermentative bacteria increases and, accordingly, the accumulation of lactic acid increases. In the process of lactic acid fermentation, lactic and acetic acids are produced by lactic acid bacteria (resulting in an increase in the acidity of finished products), alcohol, aromatic compounds (forming the taste of finished products) and a small amount of carbon dioxide. As a result, bread acquires a delicate milky flavor with a slight sourness.

Microbiological analysis of the samples showed that the addition of rowan powders inhibits mold development. The shelf life of bread is increased (up to 20 days). This is confirmed by previous research results [28–30].

The disadvantage of this study is that there is no specialized equipment for osmotic dehydration. In industrial conditions, it is difficult to maintain the necessary modes of berry dehydration without such equipment. However, the design of an apparatus for osmotic dehydration has already been developed [31], and this development is currently being patented.

The limitations of this study include the fact that in the process of osmotic dehydration, a derivative product (waste sugar solution) is formed. It is recommended to use it to enrich sugar-containing food products. To implement the proposed method, the production of rowan powders and processing of osmotic solutions should be carried out within the same enterprise.

Further research will be aimed at the possibility of using other wild berries (sea buckthorn, viburnum, elderberry) in the enrichment technology of bread from medium rye flour.

7. Conclusions

1. The analysis of the mineral composition of *Sorbus aucuparia* powders showed the highest content of potassium (860 mg/100 g). Consuming bread enriched with rowanberry powder can improve the metabolism of the body due to the functional action of K.

2. Ascorbic acid powders contain 1.72 mg/100 g of ascorbic acid, which has antioxidant properties and a positive effect on the immune system. Enrichment of bread with rowan powders will significantly increase dietary fiber content due to the high crude fiber content in rowan powders (6.7 %).

3. According to organoleptic properties, bread enriched with rowanberry powders met the normative requirements. Bitterness was felt only when 15 % powders were used in the formulation. The sample with 10 % rowanberry powders was chosen as the best one. With this amount of the additive, there were normal physico-chemical (acidity and crumb moisture) and microbiological parameters of rye flour bread quality.

4. It was found that the introduction of 10 % rowanberry powders into the recipe of rye flour bread can increase its shelf life up to 20 days.

Conflict of interest

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

Funding

The study was conducted within the scientific and technical work under the state order for scientific and technical (experimental) developments and scientific and technical products “Development of technologies for complex processing of vegetable raw materials for food products” (No. DZ / 125 - 2022 dated September 23, 2022).

Data availability

The manuscript has no related data.

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