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DEVELOPMENT OF BREAD TECHNOLOGY WITH HIGH BIOLOGICAL VALUE AND INCREASED SHELF LIFE

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As an additive to bread, it is proposed to use a powder made from derivatives of Sorbus aucuparia mountain ash processing. The powder production technology involves freezing fruits, preliminary dehydration by osmotic dehydration, drying in an infrared dryer and grinding. The technology of bread with an extended shelf life and increased biological value has been developed, and some of its physical and chemical properties have been studied. To determine the feasibility of using powders from Sorbus aucuparia processing derivatives, their amino acid spectrum was analyzed by the chromatographic method. 17 amino acids in the amount of 7.43 g/100 g were identified, 7 of which are essential (valine, leucine, isoleucine, lysine, methionine, threonine, phenylalanine) in the amount of 1.84 g/100 g. The highest concentration of the total number of amino acids is glutamic acid (1.57 g/100 g), which gives the powders the properties of natural preservatives, increases the storage capacity of bread. The experiment showed that adding 20 % powder from Sorbus aucuparia processing derivatives to wheat flour bread allows at least doubling its shelf life. However, such an amount of additive affects the porosity of the bread and its organoleptic properties. Therefore, a sample was made with the addition of 10 % powder, and no defects in taste, smell and shape of bread with the addition of mountain ash powder were found. When using the developed technology, the time for making bread is reduced by 30 minutes compared to the classic straight dough method and by 120–150 minutes compared to the sponge dough method. The shelf life of bread according to the proposed technology is 15 days

Keywords: enriched bread, dehydration, Sorbus aucuparia processing derivatives, infrared drying, glutamic acid

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1. Introduction

Bread is an important staple in the diet of most people. It is a source of carbohydrates, proteins, vitamins and minerals. However, the most sought-after wheat flour baked goods are high in calories and low in biological value. This is explained by the fact that for their production mainly fine flour is used, which, when refined, loses a large amount of useful nutrients. It is also known that bread is susceptible to mold growth and has a short shelf life at room temperature (3–7 days) [1]. In order to increase the shelf life of bread and prevent its microbiological spoilage, various additives, such as potassium sorbate and propionate, are added to the recipe [2]. However, food additives obtained through a chemical process can cause allergic reactions and have other negative effects on the human body. Therefore, research on the development of bread technology with an extended shelf life and a higher biological value is extremely relevant.

2. Literature review and problem statement

In [3], it was shown that refined flour and bread made from it practically do not contain whole grains, and, accordingly, dietary fibers. Among dietary risk factors worldwide, low consumption of whole grains has been noted as the second risk factor for mortality. According to the results of studies [4], it was found that wheat flour products do not contain A, C, D vitamins, and carotenoids. They contain small amounts of calcium, B vitamins, tocopherols and dietary fiber. However, it is known that eating bread made from unrefined flour can lead to undesirable consequences. In unrefined flour after baking bread, harmful microflora may remain, leading to indigestion. The coarse structure of flour is well digested only in the absence of stomach disorders, and coarse fibers can increase the acidity of gastric juice. Therefore, whole grain bread is not recommended for certain diseases.

The world uses a wide variety of food additives to improve the quality of bakery products, giving them additional functional properties [5]. The best way to increase the biological value of bread is to enrich it with natural additives based on vegetable raw materials. In vegetable raw materials, with proper heat treatment, vitamins, macro- and microelements, dietary fiber, antioxidants and other biologically active substances are preserved. Such raw materials include wild berries, which have a rich chemical composition and are affordable. In addition, wild berries are grown without the use of various plant protection products, pesticides and other chemicals, and therefore are safe [6]. To develop dietary types of bread, soy products are used, since they have low energy and high biological value, as well as a low glycemic index [7].

In order to increase the shelf life due to antioxidant properties, it is recommended to use viburnum meal as an additive in the production of bakery products [8]. The addition of 2 % viburnum meal powder prevents the appearance of mold for 6 days. However, by using artificial preservatives, bread can be stored for up to 30 days. Sea buckthorn products are effective functional fillers in the production of bread and confectionery [9]. It has been proven that the addition of sea buckthorn powders can increase the biological value of bread, but there are no studies on the effect of the additive on the bread's storage capacity. Numerous studies of the antiradical properties of mountain ash show that it has a large amount of phenolic acids, which can prevent quick spoilage of products [10]. It was found that wild berries had a higher content of phenols. However, it has not been studied whether these properties change after processing. The expediency of using mountain ash fruits, dried in an electric dryer and ground into powder, to prevent the development of mold in bread was considered [11]. The first appearance of mold in samples with mountain ash powders was observed already on the 7–9th day (depending on the amount of additive).

It has been found that powders are the optimal form of bread additives, since they are conveniently blended with other components [12]. Osmotic dehydration is one of the methods of preliminary preparation of raw materials before drying, which makes it possible to improve the quality of dried raw materials and preserve their sensory properties and biological value [13]. Osmotic dehydration is a process used to partially release water from plant tissues by immersion in a hypertonic solution to reduce moisture prior to the drying process [14]. Compared to other moisture removal methods, osmotic dehydration preserves color, aroma, nutrient content, and flavor compounds [15].

Previous studies, presented above, of the possibility of using some wild berries (viburnum, sea buckthorn, mountain ash) showed a positive effect on some properties of bread. The use of good raw material processing technology will significantly increase the biological value of the final product. Therefore, the development of bread technology using wild raw materials is an urgent issue and requires additional research. There is a large number of studies on the functional properties of *Aronia melanocarpa* fruits, juice, meal and powder, but there is almost no information on the properties of *Sorbus aucuparia*. Therefore, *Sorbus aucuparia* mountain ash derivatives were chosen as raw materials for the production of additives with functional properties.

3. The aim and objectives of the study

The aim of the study is to develop a bread technology using *Sorbus aucuparia* mountain ash powder. This will extend the shelf life of bread and increase its biological value.

To achieve the aim, the following objectives should be accomplished:

– to analyze the amino acid spectrum of powders from *Sorbus aucuparia* processing derivatives;

– to analyze the effect of the powder from *Sorbus aucuparia* processing derivatives on the storage capacity of bread;

– to evaluate the organoleptic properties of bread samples with powder from *Sorbus aucuparia* processing derivatives;

– to investigate the effect of the powder from *Sorbus aucuparia* processing derivatives on the physical and chemical parameters of bread;

– to develop a flowchart for the production of bread with an extended shelf life.

4. Materials and methods

The object of this study is the technology of making enriched bread. According to the proposed research hypothesis, the addition of powders made from derivatives of *Sorbus aucuparia* processing to the dough will contribute to the enrichment of bread with amino acids and increase its shelf life. Such assumptions are accepted on the basis of well-known information on the chemical composition of mountain ash.

The *Sorbus aucuparia* mountain ash derivatives were first frozen and partially dehydrated in a hypertonic sugar solution (70 %) by osmotic dehydration for 1 hour. Partially dehydrated berries were separated from the osmotic solution and sent for drying in an infrared laboratory dryer at a temperature of 50 °C. Dried berry derivatives were ground into powders using an LZM-1 laboratory disk mill to a fineness that ensured the complete passage of the material through a braided brass sieve No. 045 (0.45 mm) (Fig. 1).

a *b*

Fig. 1. *Sorbus aucuparia*: *a* — mountain ash; *b* — powder

To determine the biological value of mountain ash powder, an analysis of its amino acid spectrum was performed. Identification of the amino acid spectrum was performed by ion exchange column chromatography using a «BIOTRONIK» amino acid analyzer (Germany).

The production of prototypes was performed by the steamless method according to the recipe presented in Table 1.

Table 1

Recipe for wheat flour bread, kg/100 kg of flour

Raw material	Control	Sample 1	Sample 2
Highest-grade wheat flour	100.0	80.0	90.0
Powder from mountain ash processing derivatives	–	20	10
Dry baker's yeast	1.0	1.0	1.0
Salt	1.5	1.5	1.5
Sugar	2.0	–	–
Sunflower oil	2.0	2.0	2.0
Water	24.5	24.5	24.5
Total	130.0	130.0	130.0

The main task was to find out whether it is possible to replace part of the flour with mountain ash powder, so that the recipe for all components, except for sugar, is the same. Regarding the second question, due to osmotic dehydration, part of the acids goes into the solution, therefore, no deterioration in the taste of bread with the addition of 10 % powders was found.

Sugar was not used in the formulation of samples prepared with the addition of mountain ash powder (sample 1, sample 2), since it is sufficiently replaced by sugars contained in mountain ash processing derivatives due to the interaction of mountain ash fruits with an osmotic solution (70 % sucrose solution).

At the first stage of the study, only a control sample and sample 1 were made with the addition of 20 % mountain ash powder.

The organoleptic evaluation showed that the sample with the additive had a too pronounced bitter taste and smell of mountain ash, in addition, the bread was viscous and poorly suited for baking. It was obvious that the recipe needed to be adjusted.

At the same time, the effect of powder addition on mold processes was investigated.

Since, when analyzing various sources of information, no studies were found on the use of osmotic dehydration as a method of processing mountain ash. There was an assumption that sucrose would promote the development of harmful microflora.

At the second stage, sample 2 was made with the addition of 10 % mountain ash powder.

At the same time, an organoleptic evaluation of the samples (control, sample 2) was carried out and their physicochemical parameters (acidity, porosity, mass fraction of moisture) were studied. To determine the shelf life, the samples were stored at room temperature, without access to light in plastic bags for 15 days.

5. Results of the study of bread technology using *Sorbus aucuparia* mountain ash powder

5. 1. Results of the study of the amino acid spectrum of the powder

Analysis of the amino acid spectrum of the powder made from derivatives of *Sorbus aucuparia* processing showed the presence of 17 amino acids (Fig. 2) in the amount of 7.43 g/100 g.

Mountain ash powder contained 7 essential amino acids, g/100 g: valine (0.29), leucine (0.47), isoleucine (0.26), lysine (0.23), methionine (0.03), threonine (0.28), phenylalanine (0.28). The highest concentration of all amino acids was glutamic acid (1.57 g/100 g). As a result of the enzymatic conversion of glutamic acid under the action of the enzyme glutamate decarboxylase, it turns into γ-aminobutyric acid, which is the most important mediator of the inhibition process in brain neurons. In addition, glutamic acid enhances taste sensations, creating a «feeling of satisfaction». The bitter taste is especially enhanced. Derivatives of glutamic acid have a stabilizing effect during storage. It is added in the form of the E620 additive to canned food, food concentrates, culinary products to enhance their taste and fats to extend the shelf life.

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

The shelf life of bread is an important indicator that determines its consumer quality. Therefore, at the next stage of the study, the storage capacity of bread with the addition of 20 and 10 % powder from *Sorbus aucuparia* processing derivatives was analyzed. Since mold is considered the main cause of bread spoilage, its development was studied for 15 days. The results are presented in Fig. 3.

The experiment showed that the addition of 10 and 20 % powder from *Sorbus aucuparia* processing derivatives to wheat flour bread allows at least a twofold increase in its shelf life.

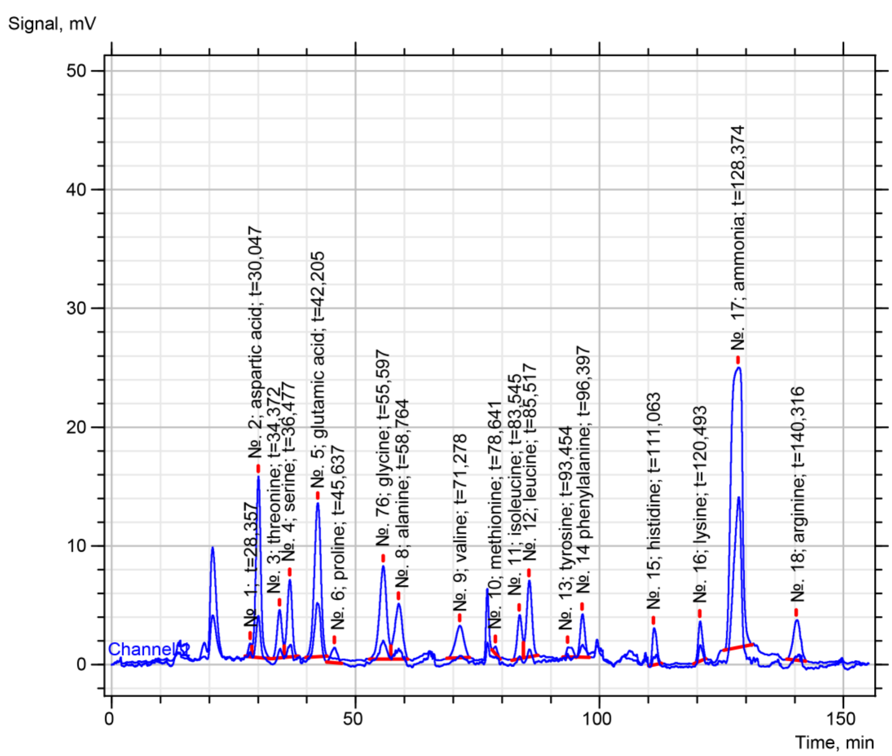

Fig. 2. Amino acid spectrum of *Sorbus aucuparia* powder

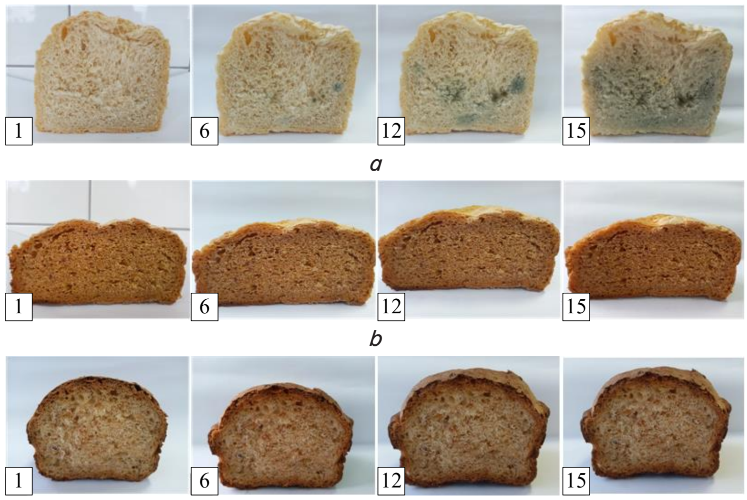

Fig. 3. Photos of samples for 1, 6, 12 and 15 days of storage: *a* — control; *b* — sample 1; *c* — sample 2

Considering these results, the expediency of using powders from Sorbus aucuparia processing derivatives to extend the shelf life of bread is obvious. However, to determine the optimal bread recipe, an analysis of its organoleptic and physico-chemical parameters was carried out.

5. 3. Results of the analysis of organoleptic parameters of bread

The organoleptic evaluation of the studied samples showed that the addition of 20 % powder from *Sorbus aucuparia* processing derivatives negatively affects the taste of bread. This amount of additive affects the porosity of bread. Sample 1 had a bitter taste caused by glutamic and sorbic acids contained in mountain ash. Therefore, the sample with the addition of 10 % powder from *Sorbus aucuparia* derivatives was recognized as the best.

An organoleptic evaluation of the studied samples was also carried out. Sample 1 had a rectangular vague shape. The sample surface is uneven. The color of the crust is brown, the crumb is somewhat moist to the touch. The taste is expressed with an intense smell of mountain ash. By almost all indications, bread with the addition of 20 % powder was of poorer quality than bread without additives. The shape of sample 2 is regular, rectangular, not vague, without sagging, corresponds to the type of product. The crust is free of cracks. The color of the crust of the control sample is light brown, and that of sample 2 is brown. The color of the crumb in both samples is uniform. The crumb is not sticky or moist to the touch. In sample 2, small inclusions of the added additive are observed. The porosity structure is medium to large, uniform. The wall thickness is medium. At the same time, voids and seals were not found in any of the samples. The taste and smell of the control sample corresponded to the normative indicators, without foreign flavor. Sample 2 had a pleasant mountain ash aroma, the taste was normal, not sour.

5. 4. Results of the analysis of the physico-chemical parameters of bread

During the study of the sample with the addition of 10 % powder from *Sorbus aucuparia* processing derivatives, no defects in taste, smell and shape were detected. The physico-chemical parameters of bread with the addition of 20 % powder from *Sorbus aucuparia* processing derivatives were not studied, since the results of the organoleptic evaluation showed that such an amount of the additive negatively affects the consumer characteristics of the bread.

An analysis of some physico-chemical indicators of bread was also carried out. The results are presented in Table 2.

Table 2

Results of the analysis of the physico-chemical parameters of bread

Indicators	Control	Sample 2
Baking shrinkage, %	13.81	13.63
Crumb acidity, deg	2.0	3.8
Crumb moisture content, %	39.4	39.3
Crumb porosity, %	69.5	71.9
Bread crumbliness index, %	22.6	15.1

5. 5. Development of a flowchart for the production of bread with an extended shelf life

The flowchart of bread production with increased biological value and extended shelf life has been developed (Fig. 4).

According to the proposed flowchart, the dough is prepared by the straight dough method in one phase. Before kneading the dough, dry yeast is activated. To do this, 50 % of purified water provided by the recipe is heated to 35–45 °C and mixed with salt. After complete dissolution of the salt, yeast is added in an amount of 1 % by weight of the flour. In parallel, the rest of the water (50 % of that prescribed by the formula) is mixed with the powder from *Sorbus aucuparia* processing derivatives. The resulting suspension is added to the yeast suspension. Due to the nutrients contained in the mountain ash powder and acting as a nutrient medium for yeast, their activation occurs already 3–5 minutes after mixing. At the same time, intracellular enzymes are synthesized, and the process of substrate dissimilation is accelerated. Yeast productivity grows, and the fermentation activity increases. The surface of the mixture foams, gas bubbles are observed and a characteristic yeasty smell appears. Thus, the activation time is halved, there is no need to increase the amount of yeast, which is usually characteristic of the straight dough method. The activated mixture is added to the flour, after which the next operation begins – kneading the dough. The kneaded dough ferments at room temperature (at least 20 °C). Fermentation occurs within 2–2.5 hours. The fermented dough is punched, divided into pieces and rounded. Rounded dough pieces are proofed for 30 minutes. The proofed pieces are given the necessary shape, after which they are placed in baking dishes and left for final proofing for 20 minutes. During this stage, the starch in the flour is broken down into sugars, which are consumed by the yeast. The yeast then forms bubbles of carbon dioxide suspended in the gluten structure of the dough. The purpose of the final proofing is to create an optimal dough structure to maximize the rise of the bread during baking. Baking was carried out for 50 min at a temperature of 220–230 °C.

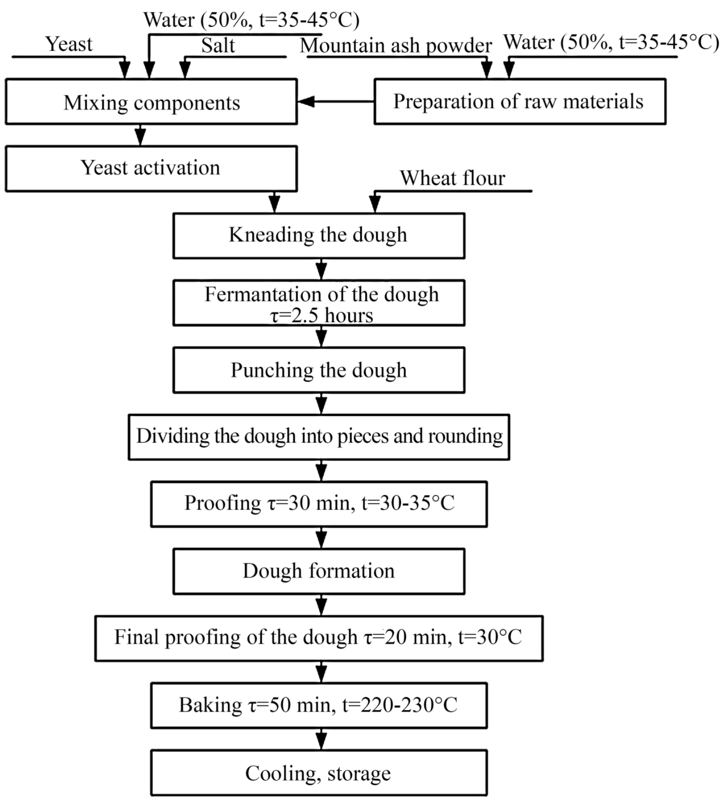

Fig. 4. Flowchart for the production of bread with an extended shelf life

When using the developed technology, the cooking time is reduced by 30 minutes compared to the classic straight dough method and by 120–150 minutes compared to the sponge dough method.

6. Discussion of the results of the study of the effect of mountain ash powder on the quality of bread

The results of the analysis of the amino acid spectrum of the powder suggest that the powder from *Sorbus aucuparia* processing derivatives can become a natural preservative that will not only increase the biological value of finished products, but also increase their shelf life.

From literary sources it is known that the fruits of *Sorbus aucuparia* contain a large amount of useful nutrients. Therefore, it can be assumed that in addition to amino acids, bread is also enriched with dietary fiber, minerals and vitamins. The proposed fruit processing technology allows you to preserve their biological value as much as possible. This issue requires further study and is the goal of future research.

The study showed that the addition of 10 % powder from derivatives of *Sorbus aucuparia* processing to flour made it possible to obtain bread with good organoleptic (Fig. 3) and physicochemical parameters (Table 2). Similar results were obtained by other scientists who introduced pineapple pomace, fenugreek fibers, chokeberry, apples, cranberries, carrots, cocoa, and flax into bread recipes [16–18]. These results are explained by the fact that the minerals, vitamins and acids contained in the mountain ash powder are a good breeding ground for yeast. As a result, they develop faster and positively affect the quality of the dough.

An analysis of the physicochemical parameters of bread showed that the addition of powder from derivatives of *Sorbus aucuparia* processing does not lead to a decrease. An increase in acidity helps to improve the storage capacity of bread, inhibiting the development of harmful microorganisms. The humidity of both samples is almost the same (difference of 0.1 %), slightly below the standard values. This may be due to the method of bread production. However, such humidity will contribute to better storage of bread. An increase in the porosity of the crumb can be caused by an increase in the amount of minerals, vitamins and acids contained in the powders. These nutrients stimulate the development of yeast, better splitting sucrose into alcohol and CO_2. In this case, the dough is loosened, the number and size of pores increase. Products with greater porosity are better absorbed and retain freshness longer. The ability to reduce the crumbliness of bread can be explained by enveloping partially gelatinized starch grains and slowing down their compaction due to the crystallization of amylose and amylopectin.

Gelatinized starch grains give off water, decrease in volume, and there is a process of their transition from an amorphous state to an initial crystalline state, i.e. starch retrogradation. The sucrose contained in powders reduces the gelatinization rate of starch.

The analysis of storage stability and the study of organoleptic and physico-chemical indicators of bread quality confirmed the effectiveness of including 10 % powder from *Sorbus aucuparia* processing derivatives in the wheat bread recipe.

A feature of the proposed technology is a unique method of processing mountain ash, which allows preserving the biological value of fruits. Freezing reduces the bitterness of fruits, osmotic dehydration – partially dehydrates them, reducing the total drying time. Since dehydration is carried out in a concentrated sugar solution, the taste properties of the powder are improved, and the color is preserved.

The proposed solutions for the use of mountain ash powder can be used both for straight dough and sponge dough baking methods.

It was found that the addition of mountain ash powder increases the shelf life up to 15 days. Obviously, this is due to the antioxidant properties of mountain ash, the presence of glutamic acid in its composition. Other authors have also shown that *Aronia melanocarpa* chokeberry has a high antiradical activity.

The limitations of this study include the fact that there is no specialized equipment for osmotic dehydration. In industrial conditions, without such equipment, it is difficult to maintain the necessary modes of berry dehydration. But the design of the osmotic dehydration device has already been developed [13], now this development is being patented.

Subsequent studies will be aimed at studying the biological value of bread with the addition of 10 % powder from *Sorbus aucuparia* processing derivatives regarding the possibility of using other wild berries (sea buckthorn, viburnum, elderberry) in this technology.

7. Conclusions

1. According to the results of the analysis of the amino acid spectrum of powders from *Sorbus aucuparia* processing derivatives, it was found that they contain 17 amino acids, 7 of which are essential. Thus, when they are added, bread is enriched, its biological value increases.

2. It was found that glutamic acid, contained in the powder from derivatives of *Sorbus aucuparia* processing in the amount of 1.57 g/100 g, affects bread as a preservative and prevents the development of mold.

3. It was found that the addition of 10 % powder from *Sorbus aucuparia* processing derivatives has a positive effect on the organoleptic properties of bread, giving it a pleasant mountain ash aroma.

4. With the introduction of 10 % powder from *Sorbus aucuparia* processing derivatives into the bread recipe, its physical and chemical parameters practically do not differ from those of bread made without additives.

5. According to the proposed flowchart, the shelf life of bread can be increased up to 15 days, while the time of bread preparation is reduced (by 30 minutes with the straight dough method and by 120 minutes with the sponge dough one).

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