UDC 664.66.016.8
DOI: 10.15587/1729-4061.2024.297772

ESTABLISHING THE CHARACTER AND SHARE OF CHANGES IN NUTRIENTS DURING THE PRODUCTION OF BREAD WITH THE ADDITION OF DOG ROSE SYRUP

In the daily diet, bread is an excellent carrier of nutrients to replenish the body. In this direction, as an additive, dog rose syrup (DRS) can be indispensable for the production of a wide range of bakery products. One of the factors limiting the widespread use of DRS in baking production is the insufficient knowledge of its biological value and changes in the share of nutrients in the technological process. Therefore, the purpose of the study is to analyze the nutritional value, vitamin and mineral composition of wheat flour "Azamatli-95" of the first grade (A95WF), DRS from the variety "R.canina", and bread with the addition of DRS. It was found that with the addition of 5, 10 and 15 % DRS to A95WF in bread samples, the content in g/100 g significantly increases: glucose (0.09±0.05), fructose (0.15±0.08), sucrose (0.02±0.01) and phenolic compounds (0.38±0.1); in mg/100 g: beta-carotene (0.152±0.076), vitamin C (33.6±16.3), potassium (40.07±20.03), magnesium (36.49±18.25), phosphorus (20.94±10.47); in µg/100 g: iron (128.86±64.43) and zinc (18.95±9.47) and the content in g/100 g slightly increases: starch, proteins and raffinose (0.01±0.01), cellulose (0.04±0.02), pectin substances (0.03±0.01); in mg/100 g: thiamine (0.006±0.003), riboflavin (0.013±0.006), niacin (0.015±0.008), calcium (5.39±2.7), sodium (1.25±0.62), sulfur (5.99±2.99); in µg/100 g: iodine (0.42±0.21), cobalt (0.62±0.31) with deviation from the best bread with the addition of 10 % DRS to A95WF. The resulting regression equations (AE<7 %) make it possible to predict and establish a relationship between the shares of changes in significantly changing nutrients, vitamins and minerals in the technological process and the increase in their content in bread

Keywords: wheat flour, rosehip syrup, bread with the additive, ascorbic acid, phenolic compounds, beta-carotene

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Received date 15.11.2023
Accepted date 29.01.2024
Published date 28.02.2024

How to Cite: *Omarov, Y., Bayramov, E., Haciyeva, A., Gurbanova, S., Aslanova, M., İsmayılov, M., Nabiyev, A. (2024). Establishing the character and share of changes in nutrients during the production of bread with the addition of dog rose syrup. Eastern-European Journal of Enterprise Technologies, 1 (11 (127)), 6–19. doi: https://doi.org/10.15587/1729-4061.2024.297772*

1. Introduction

Recently, under the influence of anthropogenic and technogenic factors, the state of the ecosystem has deteriorated throughout the world. This affects the processes of photosynthesis in plants, including wheat, which are the main raw materials for the production of daily food products. In turn, this negatively affects human health and the consumption of normal foods. This affects the processes of photosynthesis in plants, which are the main raw materials for the production of daily food products. This is forcing the rapid development of the food industry to meet the growing daily demand for varied and organic food products. At the same time, due to population growth, shrinking arable land and climate change, the food crisis is becoming a serious problem. Therefore, the use of natural resources, mainly through plants with a high content of bioactive compounds, is of great importance to solve this problem.

The human body can be replenished with necessary nutrients mainly through the product, which is an integral part of food [1]. In the human diet, the main product is bread, which can be used as a good carrier of nutrients [2]. The World Health Organization (WHO) recommends an intake of 400 grams of bread per day, to have the carbohydrates needed to serve as an energy source. However, according to the State Statistics Committee of Azerbaijan (SSCA), per capita bread consumption is set at 380 g/day [3]. Although the population's bread consumption in some countries may be higher or lower than recommended [4]. Bread satisfies the body's need for energy by 30 % [5]. The rest of the body nutrients needs should be provided by other foods, primarily fruits and vegetables [6]. Some of these are indispensable for the production of a wide range of food products due to their chemical composition and biochemical properties [7].

However, in the population, not everyone has fruits and vegetables in their diet. Therefore, with a high probability we can say that in the human body, there is a lack of nutrients, which eventually leads to a disease of the body. Besides, the question of what is the optimal level of fruit and vegetable intake to reduce the risk of chronic diseases and premature death is still unanswered. This is reflected by the fact that recommendations for dietary intake vary globally. For example, current recommendations for fruit and vegetable intake range from at least 400 g/day by the World Cancer Research Fund, the WHO, and in England, to 500 g/day in Sweden, to 600 g/day in Denmark, 650–750 g/day in Norway, and 640–800 g/day in the USA [8]. Increasing the intake of fruits and vegetables to the recommended level may result in a noticeable and measurable effect, as well as improve mental well-being [9]. The most appropriate and effective in this direction is dog rose, which is rich in mono- and disaccharides, vitamins, minerals, carotene, pectin, phenolic compounds, dietary fiber, etc. [10].

It has been observed that dog rose is one of the ten most famous medicinal plants, contains a large amount of vitamin C (VC), so it is commonly used for the prevention and treatment of colds, flu, VC deficiency, and for the prevention of diseases [11].

The paper [12] showed that an important group of biologically active ingredients of rose hips are phenolic compounds, including hydrolyzable tannins, flavonoids, catechins and anthocyanins, phenolic acids and some oligomeric and monomeric phenolic compounds. Extracts from rose hips *R. Canina* have anti-inflammatory and antinociceptive activity *in vivo* [13]. The study of phenolic compounds in wild roses showed that the total content of phenols in rose hips significantly depends on the species, while the total content of flavonoids was the same for all studied species [14]. The inclusion of foods rich in phenolic compounds in dough significantly increases the antioxidant capacity of bread [15]. Rose hips have been found to contain various minerals, mainly phosphorus, potassium, calcium, magnesium, manganese, and zinc. The content and mineral composition of rose hips depends on the type and environmental conditions [16]. The benefits of nutrients, vitamins, and minerals for the human body are widely described in the work [17].

The deterioration of the ecology in the world has increased the level of food contamination, and stress damages the mechanisms of self-regulation of the body, leading to an increase in negative trends in the state of public health [18]. In this regard, the enrichment of bread by adding raw materials rich in nutrients to the recipe will prevent the development of unwanted diseases in the human body and at the same times expand the range of bakery products.

Improving the health, performance, and livelihoods of all age groups through quality and safe food is the main goal of all governments.

Modern technologies should ensure the production of high-grade bread products. In this regard, the widespread use of local raw materials and their inclusion in technological processes remain insufficiently resolved problems [19].

Therefore, a comprehensive analysis of changes in the nutritional value, mineral and vitamin compositions of dog rose syrup (DRS), wheat flour (WF), and finished products – bread with the addition of DRS in the technological process is necessary to further substantiate the development of technology for the production of innovative types of bakery products that expand the range of products and satisfy various consumer preferences. Upon consumer's expectations concerning bread, higher organoleptic qualities, including biological value, are one of the important factors affecting its acceptability for the consumer [20].

Thus, the use of rosehip products as a source of biologically active substances, including VC, as well as phenolic compounds with antioxidant and antimicrobial properties, minerals and other components that determine the nutritional and biological value for baking bread is very relevant.

2. Literature review and problem statement

The paper [21] presents the results of a study of the effect of rosehip flour (RF) on water absorption and the degree of softening into wheat dough, as well as the organoleptic parameters of bread. The incorporation of RF into wheat dough resulted in a decrease in water absorption and degree of softening, and the lowest results were found in the sample with 15 % RF added. Dough stability was found to be higher in the samples containing RF, with the highest value reported for the sample with 5 % RF. Dough and bread color characteristics decreased with increasing the RF quantity. The substitution of WF with RF resulted in a decrease in volume, specific volume, height/diameter ratio and baking loss of wheat bread. In the sensory assessment, bread samples with RF in terms of some properties such as crust color, aroma and taste had higher scores than the control sample. This paper did not study the use of RF to increase the biological value, nor did it establish the nature and share of changes in nutrients in the technological process of preparing bread with the addition of RF.

The paper [22] presents the results of a study of the effect of rosehip seed powder on the quality of bread. It is shown that it reduces the volume and height of the loaf, increases the hardness and chewiness of bread, and reduces the brightness of the bread crumb. Rosehip seed powder can be used up to a level of 5 % without adversely affecting the technological and organoleptic qualities of bread. This paper only investigated the effect of rosehip seed powder on the organoleptic properties of bread and states that the powder can also be used above 10 % to enhance the dietary fiber content of bread, but in this case further studies are needed to improve the technological quality of bread. This paper did not study the use of rosehip seed powder to increase the biological value; the nature and share of changes in nutrients in the technological process of preparing bread with the addition of rosehip seed powder were not determined.

The paper [23] presents the results of research on the effect of rosehip powder on the approximate composition, farinographic properties of dough and physicochemical characteristics of bread. It is shown that rosehip powder (Rp) has a higher ash, carbohydrates and fiber content, as well as a lower moisture and protein content compared to wheat flour and the VC content of 420±16.09 mg/100 g. Direct analysis of the composition showed a decrease in moisture, protein content and wet gluten, as well as an increase in ash, carbohydrates and fiber content in flour mixtures compared to WF. Farinographic properties were positively influenced by the Rp addition and high fiber content in flour mixtures.

Adding Rp to 2.5 % to the mass of WF increases the water absorption of flour mixtures from 58.20 % (WF) to 61.90 % (2.5 % Rp), bread height from 100.10±0.14 mm (WF) to 115.50±0.14 mm (1.5 % Rp), specific volume of bread from 142.82 cm^3/100 g (WF) to 174.46 cm^3/100 g (1.5 % Rp), crumb moisture from 41.81±0.40 % (WF) to 43.92±0.15 % (2.0 % Rp), crumb porosity from 87.75±1.06 % (WF) to 89.40±0.57 % (2.5 % Rp). The dough stability increased with the addition of 0.5–1.0 % Rp, then decreased slightly. In this paper, Rp was used only as a substitute for synthetic VC. No other nutrients, vitamins, and minerals were considered as a bread fortifier. Therefore, along with studying the composition, farinographic properties of the dough and the physicochemical characteristics of bread with the addition of Rp, it is also necessary to study the nature and proportion of changes in nutrients, vitamins and minerals in the technological process of preparing bread with the addition. This will not only improve the organoleptic properties, but also increase the biological potential of bread and may bring health benefits.

The paper [24] presents the results of research on the influence of extracts from rosehip and hawthorn on the biotechnological properties of yeast and lactic acid bacteria, the intensity of microbiological processes during the fermentation of flour semi-products and the quality of wheat bread. The possibility of reducing the duration of the technological cycle by 60–90 minutes without deteriorating the quality of the finished product has been shown. In this paper, extracts from rosehip and hawthorn were used as an alternative to preservatives and other food additives to extend the shelf life and increase the microbiological stability of the product during storage. However, the question of the nature and proportion of changes in nutrients, vitamins and minerals in order to increase the biological value of bread with additives is not considered.

The paper [25] presents the results of research on the content and composition of bioactive compounds in autochthonous rose hips (R. pendulina, R. spinosissima and R. Gallica) and their comparison with the content of bioactive compounds in some cultivars (“Violacea”, “Splendens”, “Poppius”, “Fruhlingsmorgen”, “Fruhlingsduft”, “Sigle Cherry”, “Harstad”, “Bourgogne” and “Mount Everest”) derived from these main species. It is shown that the content of bioactive compounds in modern cultivars is lower than in old cultivars and original rose hip species included in this study, with some exceptions. The content of VC, organic acids and carotenoids was determined, and a hierarchical cluster analysis of their content was carried out. The results obtained are similar to the results of [14], which showed the organic acids content of five rose hips, including R. gallica, containing up to 47.6 g/kg dry weight of citric acid, which exceeds the total content of organic acids in this research. The content of vitamin C in five rose hips R.canina, R.dumalis, R.gallica, R.dumalis subsp. boissieri and R.hirtissima grown in Turkey ranged from 0.66 g/kg dry weight to 1.60 g/kg dry weight. This work shows that further research is needed to understand the aroma active components in the volatile fractions of rose hips. However, this work did not study the nature and proportion of changes in nutrients, vitamins and minerals in the technological process of bread production. The reason for such a high content is presumably that the roses from that study grew in the wild in Turkey where they were exposed to greater stress factors than the samples analyzed for this study, which grew in a maintained park with optimal growth conditions.

The paper [26] presents the results of research on replacing VC with acerola powder (AP). It is shown that AP had similar effects to VC. When adding VC and AP to WF (less than 0.01 % w/w), they increase water absorption, dough holding time (DDT), dough stability and softening, as well as the height and specific volume of bread, reduce its hardness without changing the crumb or crust color. In all versions of the research, the effect of AP was smaller compared to VC. The disadvantage of this paper is that the nature and share of changes in VC in the technological process of bread production have not been studied.

The paper [27] presents the results of research on the influence of ascorbic acid on the foaming capacity, emulsifiablity, and dynamic viscosity of gluten. It is shown that when adding VC, the bubbles in gluten decreased in size with an increase in the VC content from 0 to 3 %, and became larger when the VC content was 4 %. Therefore, VC could modulate the microstructure of the gluten protein network. The addition of ascorbic acid results in the formation of disulfide bonds, which help strengthen the gluten network. The foaming capacity of gluten increased significantly within a VC content of 0 to 2 %, then kept relatively stable within 2 % to 4 %, and finally rose significantly from 4 % to 5 %. The foaming stability showed different changes with the ascorbic acid content increasing from 0 to 5 %, slightly decreasing within the VC content of 0 to 1 %, then decreasing significantly within 1 % to 2 %, keeping stable within 2 % to 4 %, and slightly rising within 4 % to 5 %. VC inhibited the emulsification of gluten. Adding VC to gluten protein leads to an increase in the content of the sulfydryl group and high molecular weight glutenin, and content decrease of the disulfide bond. One of the most widely used oxidants for this purpose has been potassium bromate. However, its use in bakery products is currently forbidden in many countries due to its carcinogenic effects. However, this paper did not study the nature and proportion of changes in the VC content in the technological process of bread preparation.

The paper [28] presents the results of research on replacing synthetic VC with Rp. It is shown that when adding Rp to WF, the dough resistance to extension, R, in Brabender Units (BU), increased from 330±1.41 BU (control) to 995±1.41 BU (2.5 % w/w Rp) for a resting time of 90 min. The gelatinization temperature of the dough increased from 61.0 °C (control) to 62.9 °C (2.5 % w/w Rp). The volume of gases retained in the dough increased in bread with up to 2.0 % w/w Rp and afterwards decreased. The sensory properties of the bread, e. g., external appearance, volume, flavor, and taste, received higher total scores than the control bread. According to the results presented in this work, the optimum concentration of Rp was 1.5 % w/w. The results obtained are similar to the results of [26]. However, the paper [28] also did not study the nature and share of changes in the nutritional value of rose hips and its processed products as a fortifier for bread products.

Thus, bread products are a necessary daily product in the human diet, and do not fully enrich the body with nutrients, vitamins and minerals. Analysis of literature data confirms that the nutritional value of rose hips and its processed products has been sufficiently studied. However, the problem is that the nature and proportion of changes in nutrients, vitamins and minerals in the technological process of preparing bread with the addition of DRS have not been established. In addition, there has been insufficient research into the use of rosehip and its products, especially rosehip syrup, in baking.

Therefore, to further substantiate the development of technology for the production of new types of bread products, expanding the range of products and satisfying different consumer preferences, a comprehensive analysis on establishing the nature and share of changes in the nutritional value, vitamins and minerals of raw materials, i.e. WF, DRS and bread with the addition of DRS in the technological process of bread preparation is necessary.

3. The aim and objectives of the study

The aim of the study is to establish the nature and share of changes in nutrients, vitamins and minerals in the technological process of preparing bread with the addition of dog rose syrup. This will allow for correct adjustments when enriching bread with rosehip syrup.

To achieve the aim, the following objectives are accomplished:

– to analyze the nutritional substances of wheat flour, dog rosehip syrup and bread with additives;

– to analyze the vitamins of wheat flour, dog rosehip syrup and bread with additives;

– to analyze the minerals of wheat flour, dog rosehip syrup and bread with additives.

4. Materials and methods

The objects of the research are WF, DRS and bread with the addition of DRS. The main hypothesis of the research is that establishing the nature of changes in nutritional value, vitamins and minerals in the technological process of making bread will make it possible to determine or select the share of reduction in their content. The use of DRS in the production of baked goods from WF will increase their biological value, expand the range, raw material base and the use of non-traditional raw materials. However, it should be borne in mind that the quality indicators of DRS and WF vary depending on the region of growth and cultivation.

The first-grade flour from the “Azamatli-95” wheat variety was used, obtained in the selection process carried out at the Azerbaijan Scientific Research Institute of Agriculture (ASRİA). The variety has been included in the State Register of Selection achievements of the Republic of Azerbaijan in 2005 and is protected by patent No. 00086 [29].

To increase the biological value of bread, DRS was added to WF in amounts of 5, 10 and 15 % by weight of flour, and it was determined how significant the nature and share of changes in nutrients, vitamins and minerals are in the technological process of preparing bread with the additive.

The methods of the research: theoretical studies – comparative analysis of the literature resources, experimental studies – experiments based on the GOST standards. The research was carried out at the “Food Engineering and Expertise” department of the Azerbaijan Technological University, “Ganja-Deyirman”, Ganja “NEON” enterprises, and at the laboratories of the Georgian Research Institute and the ASRİA.

At the Hyper Gold Amina market in Ganja, pressed yeast of the “Azermaya” trademark (AZS GOST 171-81) with a moisture content of 75 % and salt of the “Azeriduz” trademark (Azerbaijan) with a moisture content of 3 % were purchased.

Ripe rose hips of the species “*R.canina*” were used as enrichment agents. As wild rose is widespread and grows in the mountainous zones of Azerbaijan and is economically profitable. Rose hips were purchased at the “Ganja Sabati” market.

The gluten amount in the first-grade flour of the Azamatli-95 (A95) wheat variety was defined according to the GOST standards, extensibility was measured on a ruler [30], gluten deformation index (GDI) in the “IDK-1M” device [31], moisture in the flour using the Pfeuffer HE-50 device (Germany), its color in the “R3-TBMS-M” device, the falling number (FN) was found using the “Hagberg-Perten” device (Switzerland).

The suitability of flour for baking was determined by a sample of bread made in the laboratory [32].

During the preparation of flour for production, it was sifted and cleaned of ferromagnetic impurities. As the dry matter of the flour changes depending on humidity, the flour corresponding to 960 g of the dry matter mass was taken.

For uniform distribution of yeast and salt in the flour, they were used in liquid form.

Pressed yeasts were finely chopped, dissolved in water in a ratio of 1:3, and used as a suspension in the preparation of a tight sponge.

Salt was dissolved in water in a ratio of 1:4 and added to wheat flour as a solution during dough kneading.

DRS was prepared as follows. The fruits are prewashed, sorted, and cleaned of impurities: the legs are cut off and the sepals are removed, then rinsed with clean water. To reduce the loss of VC, fresh rose hips are added immediately to rapidly boiling water [33]. The amount of water is 10–15 % by weight of fresh rose hips. Stirring, the mass is boiled for 10 minutes. Left to infuse for 10 minutes. Then crushed and rubbed through a metal sieve. Then, a 1–2 % suspension of bentonite is added to clarify the juice. The clarified juice is filtered, separated from the sediment, and transferred to clean containers. Rosehip juice is evaporated in a vacuum apparatus brand MZS-320M to obtain 50 % dry matter. The resulting syrup, after cooling to room temperature, is stored at 0–1 °C. The syrup had a light pink color. The amount of dry matter of DRS was determined on an MA-871 digital refractometer (Romania).

Before using the syrup, it was diluted in water used for dough kneading. The water consumption for diluting the syrup to the options was 30.56, 60.73 and 91.09 g, respectively. This is necessary for the quick and even distribution of the syrup in the flour when kneading the dough [34].

To prepare samples of bread with a natural additive, DRS was added to WF of the first-grade Azamatli-95 in a ratio of 5, 10 and 15 %.

Bread was prepared according to the following opti-ons (Table 1).

The dough was prepared in two stages on the tight sponge. The consumption of raw materials for the preparation of dough using the pre-enzyme method according to the production conditions was calculated in Microsoft Excel 2016 using the appropriate formulas [32].

Table 2 shows the consumption of raw materials for the preparation of wheat flour dough with a moisture content of 14 % with a content of 960 g of dry matter.

Table 1

Options for preparation of bakery products

Options	Products	Amount of additives, %	Abbreviations
Control	Azamatli-95 (A95) wheat flour (WF)	0	A95WF
I	Azamatli-95 wheat flour (A95WF)+dog rose syrup (DRS)	5	A95WF-DRS5
II		10	A95WF-DRS10
III		15	A95WF-DRS15

Table 2

Consumption of raw materials for the preparation of wheat flour dough with a moisture content of 14 % with a content of 960 g of dry matter

Raw materials and semi-finished products	Consumption of raw materials by stages, g								Moisture content, %
	Control		Option I		Option II		Option III		
			A95WF- DRS5		A95WF- DRS10		A95WF- DRS15		
	Tight sponge	Dough	Tight sponge	Dough	Tight sponge	Dough	Tight sponge	Dough	
1-grade wheat flour	502.3	614	502.3	614	502.3	614	502.3	614	14.0
Yeast suspension	6.7	–	6.7	–	6.7	–	6.7	–	93.75
Salt solution	–	6.44	–	6.44	–	6.44	–	6.44	74.78
Dog rose syrup	–	–	–	55.81	–	111.63	–	167.44	50.0
Water for kneading	256.3	332.20	256.3	326.22	256.2	320.24	256.32	314.26	100
Tight sponge	765.3	765.3	765.3	765.3	765.3	765.3	765.3	765.3	43.5
Dough	–	1717.9	–	1767.8	–	1817.6	–	1867.4	44.0

Technological modes and parameters were also adapted to production conditions. The temperature of the dough after kneading should be 32 °C, and the temperature of the water used for kneading the dough should not exceed 45 °C. During the experiment, the temperature of the flour was t_f=24 °C.

First, a tight sponge was made, then the dough was kneaded. Dough and tight sponge were prepared in a B20 (China) spiral kneading machine with a multi-speed drive.

To prepare a tight sponge, the yeast suspension and a certain amount of water were poured into the pot according to the recipe (Table 2), mixed, then the flour was added and kneaded for 5 minutes until a homogeneous mass was obtained (mixing shaft speed 100 RPM). The kneaded tight sponge was weighed, the temperature was measured and then placed into a thermostat to ferment for 240 minutes. The air temperature in the thermostat was (31±1) °C and the relative humidity was 80–85 %. The fermentation of the tight sponge was controlled by its final acidity and doubling in volume. The moisture content of the tight sponge was 43.5 %.

To prepare the dough, the rest of the flour and water, salt solution and DRS were added to the tight sponge in the pot and kneaded for 10 minutes until a homogeneous mass was obtained (mixing shaft speed: at the beginning of 6 minutes – stirring at 100 RPM, then 4 minutes – kneading at 166 RPM). The kneaded dough was weighed, the temperature was measured and then placed into a thermostat at (31±1) °C for 60 minutes for fermentation. The relative humidity in the thermostat was 80–85 %. After 30 minutes of fermentation, the dough was again kneaded for 2 minutes (mixing shaft speed 100 RPM). The fermentation of the dough was controlled by its final acidity and doubling in volume. The moisture content of the dough was 44 %.

After the end of the fermentation period, the dough was divided into three equal pieces. The dough pieces were formed manually on the table. Two dough pieces were given an elongated (baton-like) shape, and the third was given a spherical shape.

Elongated dough pieces (for baking in molds) were placed in metal molds pre-greased with vegetable oil. The dough with a spherical shape (for baking hearth bread) was placed on a round metal plate.

The molds and the plate were placed into a thermostat together with the dough, where it was ripened at a temperature of 35–40 °C and relative humidity of 75–85 %. As the ripening period depends on many factors, it is not limited, i. e. it can be increased or decreased. The end of the ripening was organoleptically determined by the condition and appearance of the dough.

After the ripening period finished, first, one mold and the plate and after 5 min, the other mold containing the prepared dough were placed in the oven. Bread samples were baked in the oven at 220–230 °C after moisturization in the baking chamber. Dough pieces were baked in molds for 32 min, and on a sheet for 30 min.

After the bread samples were baked, water was sprinkled on their upper crust and weighed.

The quality of the bread samples was assessed after cooling, within 8 hours after baking.

The total protein in the studied objects was determined using the Kjeldahl method. Protein indices for flour, bread, and DRS were found to be 5.83, 5.7, and 6.25, respectively [35].

Vitamin contents were studied using a high-performance liquid chromatograph Shimadzu LC-20 Prominence (Germany). The ash amount was defined in the muffle furnace (Turkey).

Phenolic compounds were determined on a high-performance liquid chromatograph ProStar-MS 500 (Varian, USA).

Pectin, cellulose, and carbohydrates were determined according to the manual [36].

The mineral substances were quantified using the atomic absorption spectrometer AAnalyst 400 (Perkin Elmer, USA).

The drying method 930.15 [37] was used to determine the moisture content of bread, which was 43.8, 43.8, 44.0, and 43.9 % for the control, options I, II, and III, respectively.

The results were developed statistically with the one-way analysis of variance (ANOVA). Analyses of variance to the correlations between the options were performed using Microsoft Excel 2016 at a significance level of $p<0.05$ [38].

5. Results of a scientific and experimental study of the possibility of using dog rose syrup to increase the nutritional value of bread

5. 1. Analysis of food substances of dog rose syrup, wheat flour and bread with additives

The following indices were determined for the wheat flour: fresh gluten amount – 31.6±0.1 %, extensibility – 9.5±0.5 cm, GDI – 77.8±0.4 units, moisture in the flour – 14±0.1 %, color – 52.5 units, ash content – 0.6 %, FN – 265±5.0 sec.

The scope of this paper was to increase the biological value of bread by adding DRS. For baking bread samples with additives to A95WF, DRS was added in the amount of 5, 10 and 15 %, which were compared with the control bread.

In the course of experimental studies to study the nature and share of changes in the content of nutrients, mineral and vitamin compositions in the technological process of making bread, the best option in terms of organoleptic indicators was bread A95WF-DRS10 made with the addition of DRS in an amount of 10 % by weight of flour (option II).

Table 4 presents a comparative analysis of the nutritional value indicators of first-grade A95WF, DRS and samples of bread with additives.

Table 4

Comparative analysis of the nutritional value indicators of the first-grade A95WF, DRS, and samples of bread with additives (g/100 g)

Indices	Abbre-viated	First-grade A95WF	DRS	Change in indices*, %	Samples of bread by options			
					Control	I	II	III
Starch	Sta	57.4	0.08	–28±0.22	41.20	41.20	41.21	41.21
Proteins	Pro	11.6	0.1	–25±0.18	8.68	8.68	8.69	8.69
Glucose	Glu	0.08	2.0	–55±0.16	0.04	0.08	0.13	0.17
Fructose	Fru	0.04	3.4	–55±0.16	0.02	0.09	0.17	0.25
Sucrose	Suc	0.18	0.4	–55±0.16	0.08	0.09	0.10	0.11
Raffinose	Raf	0.55	0.16	–55±0.16	0.25	0.25	0.25	0.26
Cellulose	Cel	0.4	0.45	–24±0.68	0.30	0.32	0.34	0.35
Pectin substances	Pec	0.1	0.26	0.00	0.10	0.11	0.13	0.14
Phenolic compounds	Phen	0.1	0.76	0.00	0.10	0.37	0.48	0.58

*Note: * – the change share of indices during the technological process*

Table 4 shows that the nutritional value indicators in all samples of bread A95WF-DRS5, A95WF-DRS10, and A95WF-DRS15 were higher than those of the control sample. When DRS was added to A95WF, among the carbohydrates in bread samples with the additive, the content of glucose, fructose and sucrose increased significantly. Compared to the control bread, the share of changes in their content in the bread samples A95WF-DRS5, A95WF-DRS10, A95WF-DRS15 was (g/100 g): glucose – 0.09±0.05, fructose – 0.15±0.08, sucrose – 0.02±0.01.

Table 4 shows that in comparison with the control bread, in all samples of bread A95WF-DRS5, A95WF-DRS10 and A95WF-DRS15 the content of phenolic compounds increased significantly. Compared to the control bread, the share of change in the content of phenolic compounds in bread samples A95WF-DRS5, A95WF-DRS10, A95WF-DRS15 was 0.38±0.1 g/100 g.

When DRS was added to A95WF, among carbohydrates the content of starch, proteins and raffinose slightly increased, and in all samples of bread A95WF-DRS5, A95WF-DRS10, and A95WF-DRS15 it was almost at the same level as in the control bread. The share of change in their content was 0.01±0.01 g/100 g. In bread samples with the additive, the content of cellulose and pectin substances also slightly increased, the proportion of change of which was 0.04±0.02 and 0.03±0.01 g/100 g, respectively.

5. 2. Analysis of vitamins of dog rose syrup, wheat flour and bread with additives

Table 5 presents the results of a comparative analysis of vitamins of the first-grade A95WF, DRS and samples of bread with additives.

Table 5 shows that the content of vitamins in all samples of bread A95WF-DRS5, A95WF-DRS10, and A95WF-DRS15 were higher than in the control bread. When DRS was added to A95WF, the content of beta-carotene and VC significantly increased in bread samples with the additive. When DRS was added to WF, the beta-carotene content in the control bread was 0.01 mg/100 g, and in bread samples A95WF-DRS5, A95WF-DRS10 and A95WF-DRS15 it was 0.086, 0.162 and 0.239 mg/100 g; and the VC content was 16.4, 33.6 and 49.9 mg/100 g, respectively. Compared with the control bread, in the bread samples A95WF-DRS5, A95WF-DRS10, and A95WF-DRS15, the share of change in the content of beta-carotene was 0.152±0.076 mg/100 g, and VC – 33.6±16.3 mg/100 g.

When DRS was added to A95WF, in all bread samples A95WF-DRS5, A95WF-DRS10, and A95WF-DRS15, the content of thiamine, riboflavin, and niacin increased slightly and was almost at the same level as in the control bread. Compared to the control bread, the share of changes in their content in bread samples with the additive was (mg/100 g): thiamine – 0.006±0.003, riboflavin – 0.013±0.006, niacin – 0.015±0.008.

Table 5

Vitamins of the first-grade A95WF, DRS, and samples of bread with additives (mg/100 g)

Indices	Abbre-viated	First-grade A95WF	DRS	Change in indices*, %	Samples of bread by options			
					Control	I	II	III
Thiamine	B1	0.38	0.08	–34±0.9	0.247	0.250	0.253	0.255
Riboflavin	B2	0.30	0.17	–24±0.6	0.226	0.233	0.239	0.245
Niacin	PP	1.54	0.20	–24±0.7	1.160	1.167	1.175	1.182
β-carotene	Car	0.01	1.70	–9±0.8	0.010	0.086	0.162	0.239
Vitamin C	VC	0.00	640	–47±0.5	0.000	16.4	33.60	49.90

*Note: * – the change share of indices during the technological process*

5. 3. Analysis of minerals of dog rose syrup, wheat flour and bread with additives

Table 6 presents a comparative analysis of the minerals of first-grade A95WF, DRS, and samples of bread with an additive.

Table 6

Minerals of first-grade A95WF, DRS, and samples of bread with additives (per 100 g of product)

Indices	Abbreviated	First-grade A95WF	DRS	Change in indices*, %	Samples of bread by options			
					Control	I	II	III
Macroelements, mg								
Potassium	K	280	528	–24±0.12	212.46	232.50	252.53	272.56
Calcium	Ca	38	48	+12±0.21	42.64	45.33	48.03	50.72
Magnesium	Mg	95	420	–13±0.10	82.56	100.80	119.05	137.30
Sodium	Na	5	12.5	×168±0.2	582.41	583.04	583.66	584.29
Sulfur	S	75	80	–25±0.12	56.16	59.16	62.15	65.15
Phosphorus	P	310	280	–25±0.22	231.82	242.29	252.76	263.23
Microelements, µg								
Iron	Fe	1600	1400	–7±0.96	1472.64	1537.07	1601.50	1665.92
Zinc	Zn	784	250	–24±0.21	594.19	603.67	613.14	622.61
Iodine	I	4.2	5.6	–24±0.96	3.15	3.36	3.57	3.78
Cobalt	Co	3.4	7.8	–21±0.13	2.68	2.99	3.30	3.60

*Note: * – the change share of indices during the technologicalprocess*

Table 6 shows that compared with the control bread, the content of minerals in all samples of bread A95WF-DRS5, A95WF-DRS10 and A95WF-DRS15 was higher than that of the control bread. When DRS was added to A95WF, among the macronutrients in bread samples A95WF-DRS5, A95WF-DRS10, and A95WF-DRS15, the content of potassium, magnesium, and phosphorus increased significantly. At the same time, the share of changes in their content in bread samples with the additive was (mg/100 g): potassium – 40.07±20.03, magnesium – 36.49±18.25, phosphorus – 20.94±10.47. However, the content of calcium, sodium and sulfur slightly increased. Simultaneously, the share of changes in their content in bread samples with the additive was (mg/100 g): calcium – 5.39±2.7, sodium – 1.25±0.62, sulfur – 5.99±2.99. In all samples of bread A95WF-DRS5, A95WF-DRS10, A95WF-DRS15, the content and share of sodium change was almost at the same level as in the control bread.

Table 6 shows that, compared with the control bread, in all bread samples A95WF-DRS5, A95WF-DRS10, A95WF-DRS15, among the macronutrients the content of iron and zinc significantly increased. At the same time, the share of changes in their content was (µg/100 g): iron – 128.86±64.43, zinc – 18.95±9.47. However, the content of iodine and cobalt increased slightly. At the same time, the share of changes in their content was (µg/100 g): iodine – 0.42±0.21, cobalt – 0.62±0.31.

To predict the nature and share of changes of significantly changing nutrients, vitamins and minerals, regression equations were obtained.

The main characteristics of the significantly varying nutritional values of the bread samples are shown in Table 7.

The dependence of the content of significantly changing nutrients in the technological process of preparing bread samples on the amount of DRS added to A95WF was studied (Table 7). Pairwise linear regression was chosen for glucose, fructose and sucrose, and a parabolic trend was chosen for phenolic compounds ($p<0.05$).

Table 7

Main characteristics of significantly varying nutritional values of bread samples

Indices	Range of indicators change, g/100 g	Regression equations	Correlation coefficient R2	Approxi- mation error, AE, %
Glu	0.04–0.17	y=0.0088x+0.039	0.9979	2.29
Fru	0.02–0.25	y=0.0154x+0.017	0.999	5.21
Suc	0.08–0.12	y=0.00198x+0.0799	0.9986	0.35
Phen	0.1–0.58	y=0.0017x2+0.0565x+0.108	0,991	4.89
Car	0.01–0.239	y=0.01526x+0.0098	0.9999	0.62
C	0–49.9	y=3.338x–0.06	0.9999	0.61
K	212.46–272.56	y=4.004x+212.491	0.9999	0.0032
Mg	82.56–137.3	y=3.649x+82.557	0.9999	0.0025
P	231.82–263.23	y=2.084x+232.036	0.9997	0.0749
Fe	1472.64–1665.9	y=12.8842x+1472.646	0.9999	0.0005
Zn	594.19–622.61	y=1.894x+594.189	0.9999	0.0022

Linear regression for phenolic compounds was not suitable because the approximation error was 19.44 %. Since the error is greater than 7 %, it is not desirable to use the linear equation as a regression. Therefore, in our study for phenolic compounds, a parabolic equation was chosen.

The parameters of all regression equations were estimated by the least squares method. The statistical significance of the equations was tested using the correlation coefficient and Fisher's test ($F>F_{tab}$).

6. Discussion of the experimental results of the research of the share for changes in nutrients DRS, WF and bread with the additive

Data in Table 4 show that DRS is rich in glucose, fructose, sucrose and phenolic compounds, which are important for the human body, compared to wheat flour. And wheat flour is not very rich in nutrients. That is why dog rose syrup was used in the production of bread.

Table 4 shows that when DRS was added to A95WF, the content of glucose, fructose, sucrose and phenolic compounds significantly increased in bread samples with the additions A95WF-DRS5, A95WF-DRS10, A95WF-DRS15 compared to the control bread.

As can be seen from Table 4, the content of glucose, fructose and sucrose in WF is very small (0.08, 0.04 and 0.18 g/100 g, respectively), and in DRS it is higher (2.0, 3.4 and 0.4 g/100 g, respectively). When DRS was added to WF, after baking in the control bread, the glucose, fructose and sucrose contents were 0.04, 0.02 and 0.08 g/100 g, respectively. In bread samples A95WF-DRS5, A95WF-DRS10 and A95WF-DRS15, the glucose content was 0.08, 0.13 and 0.17 g/100 g, fructose – 0.09, 0.17 and 0.25 g/100 g, and sucrose – 0.09, 0.10 and 0.11 g/100 g, respectively. The raffinose content in WF was 0.55 g/100 g, and in DRS – 0.16 g/100 g. When adding DRS to A95WF, the raffinose content in the control bread was 0.25 g/100 g, and in bread samples A95WF- DRS5, A95WF-DRS10 and A95WF-DRS15 changed from 0.25 to 0.26 g/100 g. At the same time, the raffinose content increased slightly.

It is known that the fermentation of the dough begins as an end product with hexose, especially with glucose under the action of yeast. Table 4 shows that the enrichment of flour with glucose, fructose, and sucrose creates conditions for a quick and organized fermentation process. The paper [39] cites that according to [40], sugar is responsible for promoting golden brown crusts, improved crumb textures and moisture retention in the crumb.

The content of cellulose in A95WF and DRS was 0.4 and 0.45 g/100 g, respectively (Table 4). When DRS was added to A95WF, the cellulose content in bread samples A95WF-DRS5, A95WF-DRS10 and A95WF-DRS15 increased slightly from 0.30 to 0.35 g/100 g compared to the control bread. The paper [39] also cited that the presence of dietary cellulose reduces the risk of oxidative stress associated with cardiovascular disease. However, increasing the amount of cellulose is not always desirable. The paper [41] cites that cellulose can weaken the gluten matrix and reduce its ability to retain gases. This leads to a decrease in the volume of bread. Since in our study, when adding DRS to WF, the amount of cellulose in bread samples increases slightly, this will not lead to a decrease in bread volume.

Pectin substances, which create conditions for the formation of aromatic substances during dough fermentation, are 0.1 g/100 g in WF, and 0.26 g/100 g in DRS. When DRS was added to A95WF, the content of pectin substances in bread samples A95WF-DRS5, A95WF-DRS10 and A95WF-DRS15 increased slightly from 0.10 to 0.14 g/100 g compared to the control bread. During the hydrolysis of pectin substances, as representatives of heteropolysaccharides, along with galacturonic acid, other simple monosaccharides are formed: glucose, arabinose, mannose, rhamnose, etc. The formation of a pleasant burnt aroma of bread is associated with the transformation of hexose into hydroxymethylfurfural or methylfurfural under the influence of heat during baking bread. Heat also produces furfural from pentoses.

By adding DRS to A95WF, it is possible to increase the content of phenolic compounds, i.e. polyphenols in dough for enriching bread products. Compared to DRS, WF has very few phenolic compounds.

From Table 4, it can be seen that the TPC of DRS is 760 mg/100 g and is consistent with these studies. Data in Table 4 demonstrate that during the baking process, phenolic compounds are not only preserved, but their total content increases: in the control bread it was 0.10 g/100 g, and in bread samples A95WF-DRS5, A95WF-DRS10 and A95WF-DRS15 it was 0.37, 0.48 and 0.58 g/100 g, respectively.

When DRS was added to A95WF, it was found that during the baking process, phenolic compounds were not only preserved in bread samples but their total content increased. This is consistent with the work of [42], where baking was shown to increase the amount of phenolic compounds in breads, cookies and muffins.

Table 4 shows that among the nutrients in A95WF, starch is contained significantly more and amounts to 57.4 g/100 g. This is an easily digestible carbohydrate that creates conditions for the development of diseases (for example, diabetes, obesity, etc.). However, DRS contains only 0.08 g/100 g of starch. When adding DRS to WF in bread samples A95WF-DRS5, A95WF-DRS10, A95WF-DRS15, the starch content decreases in the technological process of bread preparation by 28±0.22 % and is in the range of 41.20–41.21 g/100 g.

It was found that the protein content of WF is 11.6 g/100 g, and that of DRS is 0.1 g/100 g. When adding DRS to WF in bread samples A95WF-DRS5, A95WF-DRS10, A95WF-DRS15, the content of protein substances decreases in the technological process of bread preparation by 25±0.18 % and is in the range of 8.68–8.69 g/100 g.

Thus, when adding DRS to WF, the content of starch, proteins, raffinose, cellulose and pectin substances in all bread samples A95WF-DRS5, A95WF-DRS10, A95WF-DRS15 increased slightly and was almost at the same level, close to the control bread: 41.2–41.21, 8.68–8.69, 0.25–0.26, 0.32–0.35 and 0.11–0.14 g/100 g, respectively (Table 4).

It was found that the parameters of all models of significantly changing nutrients in the technological process are statistically significant (Table 7). The obtained estimates of the regression equations allow us to use them for forecasting. The correlation coefficients show that the relationship between the content of nutrients in bread samples with additives and the amount of DRS added to A95WF is very high. Since the values of the approximation errors are less than 7 %, this indicates a good quality of the models found.

A comparative analysis of vitamins revealed the absence of VC in the first-grade wheat flour and the control sample of bread (Table 5). Data in Table 5 demonstrate that there was very little beta-carotene in the first-grade wheat flour and the control sample of bread. Compared to first-grade A95WF, the contents of beta-carotene and VC were higher in DRS, while thiamine, riboflavin, and niacin were lower. In order to reduce vitamin deficiency, it is necessary to enrich the products of the daily diet by adding functional supplements [43].

Table 5 shows that adding DRS to A95WF makes it possible to enrich the dough and bread products made from it with beta-carotene and VC. The content of beta-carotene and VC in bread samples varied within 0.086–0.239 and 16.4–49.9 mg/100 g, respectively. This is significantly more than in the control bread.

When VC is added to the dough, under the action of the enzymes ascorbate oxidase and dehydroascorbate reductase, disulfide bridges are formed in protein molecules, which increase the elasticity of gluten and reduce its extensibility [44].

In the acceptable bread sample A95WF-DRS10, the content of beta-carotene increased by an average of 0.162 mg/100 g compared to the control bread. 0.162 mg/100 g of beta-carotene equals 0.027 mg/100 g of VA. According to [3], if a person consumes 380 g of bread per day, the body is provided with an average of 0.1 mg of VA. The paper [45] cites that the US Food and Drug Administration guidelines for nutrient content claims recommend that a product can be considered a good source of VA if it contains 10 % to 19 % of the daily value per reference amount, and an excellent source if it contains 20 % or more of the daily value per reference amount. This is consistent with our research that VA in the acceptable bread option A95WF-DRS10 contains more than 10 % of the daily value, i.e. if the daily norm of VA is 0.9 mg for men and 0.7 mg for women, then the content of VA will be about 11 and 14 %, respectively.

On average, the calculated values of the beta-carotene and VC content in bread samples deviate from the actual ones by 0.62 and 0.61 %. Since the approximation error is less than 7 %, to calculate the share of change in beta-carotene (varied within 0.01–0.239 mg/100 g) and VC (varied within 0–49.9 mg/100 g) in bread samples in the technological process, you can use the equations as a regression (Table 7).

The content of thiamine, riboflavin and niacin in bread samples A95WF-DRS5, A95WF-DRS10, A95WF-DRS15 increased slightly and varied within 0.25–0.255, 0.233–0.245 and 1.167–1.187 mg/100 g, respectively. This was close to the levels of these vitamins in the control bread.

Minerals are vital components of our food. They fulfill a wide variety of functions in the optimal functioning of the immune system, building materials for our bones, influencing muscle and nerve function, and regulating the body's water balance [46].

In the bread samples A95WF-DRS5, A95WF-DRS10 and A95WF-DRS15, the content of macro- and microelements was higher than in the control bread. Among the macronutrients, the content of potassium, magnesium and phosphorus increased significantly (Table 6). Depending on the amount of DRS added, in bread samples, the proportion of change in potassium was in the range of 20.03–60.1, magnesium – 18.24–54.74 and phosphorus – 10.47–31.41 mg/100 g. In the acceptable bread sample A95WF-DRS10, the content of potassium, magnesium and phosphorus increased by an average of 40.07, 36.49 and 20.94 mg/100 g, respectively, compared to the control bread. The potassium and sodium content of DRS is significantly greater than that of A95WF and the Na/K ratio is less than 1. This is important for regulating sodium uptake, since the high potassium content promotes beneficial sodium uptake and therefore protects cardiovascular function, improves brain and muscle function, promotes the removal of excess salts from the body, which do not benefit the body. This is consistent with the findings of [39] that replacing white sugar by adding palm sugar to wheat flour results in a Na/K ratio of less than 1.

Magnesium is mainly found in bones and muscles, it is an important constituent of all cells and tissues; with ions of other elements, maintains the ionic balance of liquid mediums of the body; is included in the composition of the enzymes related to the metabolism of phosphorus and carbohydrates; activates plasma and bone phosphatase and participates in nervous-muscular irritation [19]. The daily norm of magnesium for an adult human is set at 150 mg in Azerbaijan [3]. In the preferred option A95WF-DRS10, the amount of magnesium entering the body with bread was 119.05 mg/100 g (Table 6). At the same time, the daily requirement of the human body is provided with 79.37 % magnesium. By consuming 320 g of bread with the additive A95WF-DRS10, you can provide the body with 100 % magnesium.

By adding DRS to A95WF, bakery products can be enriched with phosphorus. Phosphorus compounds play an important role in all processes occurring in the human body: phosphoric acid is involved in the construction of numerous enzymes (phosphatases) that perform chemical reactions in tissues. The human skeletal tissue is formed from salts of phosphoric acid [19]. In Azerbaijan, the daily phosphorus requirement for an adult is set at 730 mg [3]. In the preferred option A95WF-DRS10, the amount of dietary phosphorus entering the body with bread is 252.8 mg/100 g (Table 6). At the same time, the daily requirement of the human body is provided with phosphorus by 36.63 %. By consuming 289 g of bread A95WF-DRS10, the human body meets 100 % of the dietary phosphorus requirement. Eating bread A95WF-DRS10 in excess of the Azerbaijani norm or the WHO recommended norm will not lead to any adverse consequences [47].

On average, the calculated values of the potassium, magnesium and phosphorus content in bread samples deviate from the actual ones by 0.0032, 0.0025 and 0.0749 **%**. Since the approximation error is less than **7 %**, to calculate the share of change in potassium (varied within 212.46–272.56 mg/100 g), magnesium (varied within 82.56–137.3 mg/100 g) and phosphorus (varied within 231.82–263.23 mg/100 g) in bread samples in the technological process, you can use the equations as a regression (Table 7).

The content of calcium, sodium and sulfur in the bread samples with an additive increased slightly and the share of their change was in the range of 45.33–50.72 and 59.16–65.15 mg/100 g (Table 6). In the acceptable bread sample A95WF-DRS10, the content of calcium, sodium and sulfur increased on average by 5.39, 1.25 and 5.99 mg/100 g, respectively, compared to the control bread.

By adding DRS, the amount of calcium in the composition of bread can be increased. Calcium is responsible for the effectiveness of various processes, and its supply in the diet is necessary for the normal function of the human body, it is an important component of the skeleton, and also helps maintain the structure of cell organelles and regulates intracellular and extracellular fluid homeostasis [48]. According to the SSCA, the daily calcium intake is 950 mg [3]. This is consistent with the data from [48] that the majority of the world's population consumes <1000 mg calcium daily. In the preferred option II, the amount of calcium entering the body with A95WF-DRS10 bread was 48.03 mg/100 g (Table 6). Assuming an intake of 380 g of bread per day, the amount of calcium entering the body with A95WF-DRS10 bread will be about 182.51 mg (19.21 % of the norm).

By adding DRS, the amount of sodium in the composition of bread can be increased. Sodium salts have a positive effect on the cardiovascular system [49]. The normal growth and state of the body are important for the normal functioning of the neuromuscular system [3]. In this respect, it has been shown that a reduction in the salt content of bread is possible, and an alternative approach involves partial replacement with other, mainly potassium-based salts, which also counteract the effects of sodium [4]. In Azerbaijan, the daily sodium requirement for an adult is set at 575 mg [3]. By adding 10 % DRS to A95WF, you can reduce the amount of table NaCl in the bread recipe to 0.21 %. This means that assuming an intake of 380 g of A95WF-DRS10 bread per day, you can save 12 mg of NaCl (i.e. reduce Na by 4.8 mg), and accordingly reduce the amount of NaCl added to wheat flour when kneading the dough. Evidence has been found in a variety of randomized controlled experiments that a reduction in sodium consumption can decrease the risk factor of chronic diseases including cardiovascular disease, hypertension, stroke, kidney disease and other non-communicable diseases [49]. However, it is impossible to completely remove salt from the bread recipe. Because the inclusion of salt in bread formulation is crucial as it largely influences the technological processes that occur during breadmaking [50].

Sulfur is an "anti-inflammatory" mineral, contributes to the destruction of microbes and parasites, improves immunity, helps maintain the oxygen balance necessary for the normal functioning of the brain, ensures normal regeneration of body cells, which is able to resist tissue destruction by free radicals and, therefore, promotes rejuvenation processes [17]. WHO recommendations amount to 13 mg/kg per 24 h in healthy adults, which for a 70 kg person equates to 910 mg/d. When adding 10 % DRS to A95WF, the amount of sulfur in the preferred option II of bread increases slightly, i. e. by 5.99 mg and the total amount of sulfur in bread A95WF-DRS10 was 62.15 mg/100 g (Table 6). Assuming an intake of 380 g of bread per day [3], the amount of sulfur entering the body with A95WF-DRS10 bread will be about 236.17 mg (25.95 % of the norm). This is good because sulfur has a positive effect on the quality of grain protein and the processing quality of wheat, increases the volume, reduces the hardness and chewiness of bread [51].

Among trace elements, the content of iron and zinc increased significantly (Table 6). Depending on the amount of DRS added, in the bread samples, the share of changes in iron was in the range of 64.43–193.26 and zinc – 9.48–28.42 μg/100 g respectively, compared to the control bread. In the bread sample A95WF-DRS10, the content of iron and zinc increased on average by 128.86 and 18.94 μg/100 g, respectively, compared to the control bread.

Microelements are needed for the human body in very small amounts and have a visible impact on human health. Deficiencies of micronutrients like iron, zinc and other minerals can cause life threatening conditions. Zinc deficiency in the human body results in loss of appetite, skin lesions, impaired taste and smell. It also affects the utilization of VA and the metabolism of carbohydrates and protein. Through the proper selection of food, these micronutrients deficiencies can be prevented to a reasonable extent [52].

According to the SSCA, the daily iron norm for an adult human is set at 9 mg in Azerbaijan [3]. In the preferred option II, the amount of iron entering the body with A95WF-DRS10 bread was 1601.5 μg/100 g (Table 6). Assuming an intake of 380 g of bread per day, the amount of iron entering the body with A95WF-DRS10 bread will be about 6.1 mg (67.8 % of the norm).

In all regions of the world, 1.5 to 2.0 billion people suffer from one or multiple chronic mineral deficiencies [53].

According to the SSCA, the daily zinc intake is 9.4 mg [3]. In the preferred bread sample A95WF-DRS10 (option II), the amount of zinc entering the body with bread was 613.1 μg/100 g (Table 6). Assuming an intake of 380 g of bread per day, the amount of zinc entering the body with A95WF-DRS10 bread will be about 2.33 mg (24.79 % of the norm). This is consistent with research by [54] that healthy adults have an absolute need for 2–3 mg zinc per day to compensate for the relatively small loss of zinc in urine, stool, and sweat.

On average, the calculated values of the iron and zinc content in bread samples deviate from the actual ones by 0.0005 and 0.0022 %. Since the approximation error is less than 7 %, to calculate the share of change in iron (varied within 1472.64–1665.9 μg/100 g) and zinc (varied within 594.19–622.61 μg/100 g) in bread samples in the technological process, you can use the equations as a regression (Table 7).

The content of iodine and cobalt in the bread samples increased slightly and the share of their change was in the range of 0.21–0.63 and 0.31–0.92 μg/100 g, respectively (Table 6). In the acceptable bread sample A95WF-DRS10, the content of iodine and cobalt increased by an average of 0.42 and 0.62 μg/100 g, respectively, compared with the control bread.

Iodine is a component of thyroid hormones. It is involved in the regulation of energy metabolism, body temperature, the rate of biochemical reactions, the metabolism of proteins, fats, water and electrolyte metabolism, the metabolism of a number of vitamins, the processes of growth and development of the body, including neuropsychic development, increases oxygen consumption by tissues [19]. According to the SSCA, the daily iodine intake is 150 μg [3]. Studies also show that iodine intake for adults should be 150 μg per day [55]. In the preferred option bread A95WF-DRS10, the amount of iodine entering the body with bread was 3.57 μg/100 g (Table 6). Assuming an intake of 380 g of bread per day, the amount of iodine entering the body with A95WF-DRS10 bread will be about 13.57 mg (9 % of the norm). This is similar to the results of [56] that of the total 64 bread samples collected for iodine analysis, 18 were found to be non-iodized defined as bread with an iodine content below 4.5 μg/100 g while the rest were iodized (>20 μg/100 g). However, adding iodate preparations to bread is unacceptable from a chemical point of view. It is advisable to add products to bread that are rich in iodine of natural origin. This is also confirmed in the paper [19], where it is shown that one of these products can be persimmon, which contains 6.4 μg/100 g of iodine. By adding persimmon syrup (PS) to A95WF, you can increase the iodine content in bread.

Cobalt is essential for the human body. It is of great importance in the course of internal processes; it is one of the structural units of vitamin B12 involved in enzymatic reactions, hematopoiesis, regulation of the nervous system and liver [19]. In the preferred option A95WF-DRS10, the amount of iodine entering the body with bread was 3.3 μg/100 g (Table 6). Assuming an intake of 380 g of bread per day, the amount of iodine entering the body with A95WF-DRS10 bread will be about 12.54 μg. This is similar to the results of the paper [57], which showed that cobalt levels in different bread samples ranged between 3±1 to 10±3 μg/100 g. This is consistent with the results of the paper [58] that when assessing the health risk, the level of cobalt in all types of bread (n=60) was 6.91 μg/100 g. The paper [59] also shows that in Italy, the total consumption of cobalt is 19.68 μg/day.

Thus, adding DRS to A95WF can increase the nutritional value, vitamins and minerals in bread. It was found that when DRS is added to A95WF, the content of glucose, fructose, sucrose and phenolic compounds, beta-carotene, ascorbic acid, potassium, magnesium, phosphorus, iron and zinc in bread with the additive increases significantly. But the content of starch, proteins, raffinose, cellulose, pectin, thiamine, riboflavin, niacin, calcium, sulfur, iodine and cobalt increases slightly. The addition of DRS to A95WF increases the antioxidant and antimicrobial properties of bread, mainly due to ascorbic acid and phenolic compounds, and therefore increases the shelf life of bread. The resulting regression equations make it possible to predict and establish a connection between the share of changes in nutrients, vitamins and minerals in the technological process and the increase in their content in bread. Since the approximation errors are less than 7 %, this indicates the good quality of the found models. The used DRS turned out to be a good raw material for baking bread.

The results of the study proved that adding DRS to A95WF when kneading dough allows you to increase the nutritional value of bread, establish a connection between the share of changes in nutritional value, vitamins, minerals and the increase in their content in bread, expand the range, raw material base and the use of non-traditional raw materials, as well as can be recommended for use.

The results obtained will be used in the baking industry to establish the nature and determine or select the share of changes in nutritional value, vitamins and minerals, regulate their content before and after the technological process of processing raw materials and preparing bread with additives.

Further development of research is the improvement or development of appropriate technological regimes for the production of bread with additives to achieve greater preservation of useful substances. The shortcomings of the research include the lack of data on changes in essential amino acids in bread with DRS. These data are planned to be obtained by continuing research on the production technology of bread with DRS. The limitations of this study can be related to providing an insufficient supply of amino acid analyzers to bakeries. However, now this issue is being resolved, as KNP-TECHNOLOGY Research and Production Enterprise LLC is actively working on the implementation of a project for the mass production of amino acid analyzers. And this, in turn, will expand the prospects and possibilities of providing the baking industry with amino acid analyzers. The prospect of research is to develop technologies for the production of other types of bread with the combined addition of DRS and protein-rich foods, such as peas, lentils, etc., as well as establishing a connection between the share of changes in nutrients and tasting assessments of the organoleptic parameters of bread with additives.

7. Conclusions

1. It was found that when DRS is added from 5 to 15 % to A95WF, in bread samples with the additive, the content of glucose, fructose, sucrose and phenolic compounds increases significantly. Compared to the control bread, the share of change in their content in the bread samples with the additive was with a discrepancy from the preferred option II for glucose – 0.09±0.05, fructose – 0.15±0.08, sucrose – 0.02±0.01, phenolic compounds – 0.38±0.1 g/100 g. In the samples of bread with the additive, the content of starch, proteins, raffinose, cellulose and pectin substances increased slightly and the share of change in their content was almost at the same level as in the control bread: starch, proteins, raffinose – 0.01±0.01 respectively, cellulose – 0.04±0.02, pectin substances – 0.03±0.01 g/100 g. The study of the nature of changes in nutrients in the technological process of making bread makes it possible to determine the share of their content reduction (in %). Based on this, it is possible to regulate the content of nutrients before and after the technological process of processing raw materials and making bread with additives.

2. It was found that when DRS is added from 5 to 15 % to A95WF, among vitamins in bread samples with the additive, the content of beta-carotene and VC significantly increases. Compared to the control bread, the share of change in their content in the bread samples with the additive was with a discrepancy from the preferred option II for beta-carotene – 0.152±0.076, VC – 33.6±16.3 mg/100 g. However, the content of thiamine, riboflavin and niacin increases slightly and is almost at the same level as in the control bread. Compared to the control bread, the share of change in their content with a discrepancy from the preferred option II was (mg/100 g): thiamine – 0.006±0.003, riboflavin – 0.013±0.006, niacin – 0.015±0.008. The study of the nature of changes in vitamins in the technological process of making bread allows us to determine the proportion of their content reduction (in %). Based on this, it is possible to regulate the content of vitamins before and after the technological process of processing raw materials and making bread with additives.

3. It was found that when DRS is added from 5 to 15 % to A95WF, among the macroelements in bread samples with the additive, the content of potassium, magnesium and phosphorus increases significantly. Compared to the control bread, the share of change in their content in the bread samples with the additive was with a discrepancy from the preferred option II for potassium – 40.07±20.03, magnesium – 36.49±18.25, phosphorus – 20.94±10.47 mg/100 g. However, the content of calcium, sodium and sulfur slightly increases. Compared to the control bread, the share of change in their content in the bread samples with the additive was with a discrepancy from the preferred option II for calcium – 5.39±2.7, sodium – 1.25±0.62; sulfur – 5.99±2.99 mg/100 g. Among the microelements in the samples of bread with the additive, the content of iron and zinc significantly increases. Compared to the control bread, the share of change in their content in the bread samples with the additive was with a discrepancy from the preferred option II for iron – 128.86±64.43, zinc – 18.95±9.47 μg/100 g. Among the microelements in the samples of bread with the additive, the content of iodine and cobalt increases slightly. Compared to the control bread, the share of change in their content in the bread samples with the additive was with a discrepancy from the preferred option II for iodine – 0.42±0.21, cobalt – 0.62±0.31 μg/100 g. The study of the nature of changes in mineral substances in the technological process of making bread makes it possible to determine the share of changes in their content (in %). Based on this, it is possible to regulate the content of mineral substances before and after the technological process of processing raw materials and making bread with additives.

Conflict of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

Financing

The study was conducted without financial support.

Data availability

The manuscript has associated data in a data repository.

Use of artificial intelligence

The authors have used artificial intelligence technologies within acceptable limits to provide their own verified data, which is described in the research methodology section.

Acknowledgments

We express our gratitude to the Department of Food Engineering and Expertise of the Azerbaijan Technological University.

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