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The Beneficial Effect of Selenium-Enriched Broccoli on the Quality Characteristics of Bread

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Abstract: Broccoli is one of the most valuable representatives of the Brassicaceae family, characterized by high levels of glucosinolates and fiber, antioxidant status and tolerance to high selenium (Se) concentrations. To evaluate the efficiency of Se-enriched broccoli utilization in bread production, 4% of dry broccoli powder was added to dough using non-fortified and Se-biofortified broccoli florets. The resulting functional products were characterized by enhanced porosity, crump acidity and a specific volume exceeding those of the control bread by 109–110%, 114–121% and 107–112%, respectively, with the lower levels typical to bread with broccoli non-fortified with Se. By supplying broccoli powder to bread, the dietary fiber content of the product was enhanced by 2.1 times. Selenium-enriched broccoli powder supply improved the ascorbic acid and total phenolic content in bread by 37.5 and 2.03 times compared with the control. The effect was less pronounced in case of non-fortified broccoli supplementation due to the beneficial effect of Se on broccoli florets' antioxidant status. Selenium-enriched broccoli supply significantly decreased the intensity of bread crumb hardening during storage. High Se-biofortification level (5.6) and insignificant Se losses during bread baking (less than 4%) confirm high prospects of Se-enriched broccoli utilization in the production of new functional bread with elevated levels of antioxidants, Se and dietary fiber.

Keywords: broccoli; powder; selenium; antioxidants; bread quality

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1. Introduction

The formulation of bread with plant ingredients is often used for the production of functional food fortified with biologically active compounds [1]. In this respect, Brassicaceae representatives are of special interest due to their high-antioxidant activity and glucosinolate accumulation [2]. Among Brassicaceae plants, broccoli is considered to be one of the most valuable crops characterized by high biological activity and nutritional significance [3]. Its florets are rich in glucosinolates, vitamin C, polyphenols and fiber, containing a significant content of Fe, K and Ca. Its antioxidant, anticancer, antidiabetic, antimicrobial, immunomodulator and hepato- and cardio-protective properties provide a wide opportunity for its utilization both in medicine and nutrition [4,5]. The above facts stimulated the development of various processing technologies, such as supplementation of bread with broccoli florets [6], leaves [7–9] and sprouts [10], and intensive studies in biostimulator utilization for improving broccoli yield and antioxidant activity [11].

Furthermore, this plant is characterized by its relatively high tolerance to selenium (Se), providing the opportunity to obtain functional food products with elevated levels of this trace element [12]. Selenium is essential to humans, recording powerful antioxidant, anticancer, antiviral and cardio-protective properties and improving human fertility and

brain activity [13]. According to its position in the periodic table, Se is a chemical analog of S and freely substitutes the latter in biological objects, forming Se-containing amino acids, such as selenomethionine and selenocystein. In human organism the biosynthesis of the latter amino acid is encoded genetically, while a series of highly important enzymes contain Se in their active center (gluthatione peroxidases, thioredoxine reductases, triiodothyronine deiodinases, etc.) [14].

The uneven distribution of the elements at the Earth's surface results in widespread Se deficiency among domestic animals and humans [15]. The biofortification of plants with Se is considered to be the most efficient and economically prospective method of improving the Se status of humans and domestic animals. In Finland, the wide utilization of Se-enriched fertilizers demonstrated that such an approach provided high efficiency in the human Se status optimization resulting in a significant decrease in human mortality from cardiovascular and viral diseases and cancer [16,17]. During the COVID-19 pandemic, Se was recorded to be effective against SARS-CoV-2 [18,19].

Plants are able to convert highly toxic inorganic selenates and selenites of soil into biologically active organic forms, such as Se-containing amino acids and peptides with high biological activity. In the plant kingdom, Allium and Brassicaceae representatives record the ability to synthesize methylated forms of amino acids known to be powerful natural anticancer agents (selenomethyl selenocystein, and γ-glutamine selenomethyl selenocystein, in particular) [20]. In this respect, the biofortification of broccoli with Se provides further prospects for broccoli utilization. Furthermore, the results of previous investigations revealed the ability of broccoli and other cabbages to synthesize Se derivatives of glucosinolates, demonstrating more powerful anticancer activity than ordinary glucosinolates [21–23].

The above data indicate that broccoli fortified with Se may provide new prospects in the production of functional food with elevated levels of Se, natural antioxidants and anti-cancer compounds [17,24]. Nevertheless, to date, no attempts have been made to use broccoli florets fortified with Se in the bakery industry. Thus, the aim of the present study was to evaluate the efficiency of Se-enriched broccoli utilization in bread production and examine how it affects bread quality.

2. Materials and Methods

2.1. Characteristics of Raw Materials

The main bread ingredients in the present study were wheat flour [25], pressed bakery yeast, salt, water and dried broccoli florets, cv. Tonus. Wheat flour used in the present investigation contained 14% moisture and 28% gluten, with gluten quality equal to 60 units, demonstrating the falling number of 320 s, and whiteness—54 units.

2.2. Crop Trial

The research was carried out on broccoli (*Brassica oleracea* var italica) grown at the experimental fields of the Federal Scientific Vegetable Center, Moscow region, Russia (55°39.51′ N, 37°12.23′ E) in 2019 and 2020 on a clay loam soil, with the following characteristics: pH 6.2, 2.12% organic matter, 1.32 mg-eq 100 g^{-1} hydrolytic acidity, 18.5 mg kg^{-1} mineral nitrogen, 21.3 mg kg^{-1} ammonium nitrogen, sum of absorbed bases as much as 93.6%, 402 mg kg^{-1} mobile phosphorous, 198 mg kg^{-1} exchangeable potassium, 1 mg kg^{-1} S, 10.95 mg kg^{-1} Ca, 2.05 mg kg^{-1} Zn, 0.86 mg kg^{-1} B, 220 μg kg^{-1} d.w. Se, 7.65 mg kg^{-1} Ni, 0.22 mg kg^{-1} Cd, 1.6 mg kg^{-1} As and 12.85 mg kg^{-1} Pb.

Florets of broccoli, cv. Tonus (the selection of the Federal Scientific Vegetable Center), were used in bread production. The seeds were sown on 27–29 April in multicell containers, and the seedlings were planted at the experimental fields of the Federal Scientific Vegetable Center on 2–4 June with a plant density of 35,000 plants per ha (50 × 70 × 70 cm).

The values of mean temperature and relative humidity during the vegetation period are presented in Table 1.

Table 1. The monthly temperature and precipitation in 2019–2020.

Month	Temperature (°C)		Precipitation (mm)	
	2019	2020	2019	2020
May	16.3	16.1	57.0	71.8
June	19.6	21.0	64.1	73.0
July	17.8	23.8	69.0	74.9
August	16.3	19.0	57.0	76.9

The experimental treatments, applied to broccoli cabbage cultivar Tonus, were carried out according to the following scheme: (1) control (water) and (2) sodium selenate solution, 26.4 mM (50 mg L^{-1}). A split-plot design was used for the treatment distribution in the field with three replicates, where each experimental unit covered 10 m^2. To exclude the interference of other factors, no fertilizers were applied during the experiment.

The plants were sprayed with the appropriate solutions twice: at the stage of head formation (10 July) and 14 days later (2 August).

During the growing season, hoeing and manual weeding were carried out. The cabbage was harvested on 26–28 August.

2.3. Sample Preparation

After harvesting and removal of soil particles, broccoli florets were separated and homogenized. Fresh floret homogenates were used for the determination of the ascorbic acid. The remaining floret homogenates were dried at 70 °C to a constant weight and homogenized, and the resulting powders were used for determining the total polyphenols content (TP), and for producing the bread.

2.4. Bread Production Trial

Bread was produced in 2019 and 2020 with the use of three different processing procedures: bread obtained upon the addition of broccoli floret powder from selenium-fortified broccoli plants to dough; bread obtained upon the addition of floret powder from non-fortified broccoli plants to dough; and traditionally made bread.

A total of 200 g of wheat flour with 90 µg Se kg^{-1} d.w., 1.5 g salt and 8 g dry broccoli floret powder were placed in a Kenwood dough mixer (Model A 907 D) set at the highest speed and mixed for 1 min; control samples were not supplemented with broccoli powder. Then, a suspension of 5 g yeast in 120 mL of water was added, and the mixture was further run at high speed for 2 min. The dough was later kneaded on a kneading table, rounded into balls by hand and placed into a lightly greased fermentation bowl in a fermentation cabinet. The dough was then proofed for thirty minutes and then baking was completed at 220–225 °C for 25–27 min. Next, the baked bread was allowed to cool at room temperature before performing the analysis. Baking was completed in triplicate.

2.4.1. Specific Volume of Bread

The loaf volume was measured using the small seed displacement method described by Khalil et al. [26]. A loaf was placed in a container of a known volume and then onion seeds were added until the container was full. The volume of seeds displaced by the loaf was considered as the loaf volume, which was measured in a graduated cylinder. The weight of the loaf was determined using a sensitive weighing balance, and the specific volume of the loaf was assessed by averaging the loaf volume with the loaf weight. The specific volume was calculated according to the equation:

$$\text{Specific Volume } (cm^3\ g^{-1}) = \text{loaf volume}/\text{loaf weight}$$

2.4.2. Bread Acidity

The bread acidity was analyzed according to [27].

2.4.3. Dry Matter

The dry matter content in broccoli florets as well as in bread samples was assessed gravimetrically after the dehydration of fresh samples in an oven at 70 °C until constant weight.

2.4.4. Bread Porosity

The bread porosity was determined according to [28]. Four cylindrical grooves from fresh bread at a volume of 27 (±0.5) cm^3 each were made and weighed simultaneously. The porosity (%) was calculated using the following formula:

$$\text{porosity (\%)} = [(V - m/1.31):V] \times 100$$

2.5. Ascorbic Acid

The ascorbic acid content was determined using the visual titration of leaf and head extracts in 3% trichloracetic acid with sodium 2,6-dichlorophenol indophenolate solution (Tillman's reagent) [29]. Roots were not taken into consideration due to low ascorbic acid content.

2.6. Total Polyphenols (TPs)

Total polyphenols were determined in 70% ethanol extracts of dried samples using the Folin–Ciocalteu colorimetric method, as previously described [30]. One gram of dry homogenates was extracted with 20 mL of 70% ethanol/water at 80 °C for 1 h. The mixture was cooled down and quantitatively transferred to a volumetric flask, and the volume was adjusted to 25 mL. The mixture was filtered through filter paper, and 1 mL of the resulting solution was transferred to a 25 mL volumetric flask, to which 2.5 mL of saturated Na_2CO_3 solution and 0.25 mL of diluted (1:1) Folin–Ciocalteu reagent were added. The volume was brought to 25 mL with distilled water. One hour later, the solutions were analyzed using a spectrophotometer (Unico 2804 UV, Suite E Dayton, NJ, USA), and the concentration of polyphenols was calculated according to the absorption of the reaction mixture at 730 nm. As an external standard, 0.02% gallic acid was used. The results were expressed as mg of gallic acid equivalent per g of dry weight (mg GAE g^{-1} d.w).

2.7. Sugars

Monosaccharides were determined using the ferricyanide colorimetric method based on the reaction of monosaccharides with potassium ferricyanide [31]. Total sugars were analogically determined after acidic hydrolysis of water extracts with 20% hydrochloric acid. Fructose was used as an external standard. The results were expressed in % per dry weight.

2.8. Protein Content

The crude protein content was measured using the Kjeldahl methodology, based on a sample digestion with sulfuric acid, and quantification of ammonia after the alkalization of the reaction mixture [32].

2.9. Selenium

Selenium was analyzed using the fluorometric method previously described for tissues and biological fluids [33]. Dried homogenized samples were digested by heating with a mixture of nitric–perchloric acids, subsequent reduction of selenate (Se^{+6}) to selenite (Se^{+4}) with a solution of 6 N HCl and the formation of a complex between Se^{+4} and 2,3-diaminonaphtalene. The concentration of Se was calculated by recording the piazoselenol fluorescence value in hexane at 519 nm λ emission and 376 nm λ excitation. Each determination was performed in triplicate. The precision of the results was verified using the Mitsuba reference standard of Se-fortified stem powder in each determination with a Se concentration of 1865 μg·kg^{-1} (Federal Scientific Vegetable Center, Moscow, Russia). The results were expressed in μg kg^{-1} d.w.

2.10. Microbiological Parameters

Microbiological parameters of the powders were determined using the following methods: all visible colonies of mesophilic aerobes and facultative anaerobes were estimated by plating the powders on agarose media in Petri dishes, with their further incubation according to [34] of mesophilic aerobe and facultative anaerobe quantity. The method to detect bacteria of the *Escherichia coli* group (BGCP) was based on seeding powders into a liquid-selective media with lactose, incubating the bacterial culture, accounting for positive test tubes and further re-seeding of the culture liquid on the surface of agarose selective diagnostic media to confirm, with biochemical and cultural signs of growth of the isolated colonies, that the colonies belong to coliform bacteria. This method was performed according to [35–37].

The determination of pathogenic microorganisms was carried out at several stages, in accordance with [38,39], as follows: a 25 g suspension was introduced into buffered peptone water and then incubated at the temperature of (37 ± 1) °C for 18 h. Then, the resulting culture was inoculated in parallel with Rappaport–Vassiliadis media with soy (RVS-broth) and Muller–Kaufman tetrathionate broth (MKT-broth). After sowing, the RVS broth was incubated at the temperature of (41.5 ± 1.0) °C for 24 h, and the MKT broth was incubated at the temperature of (37 ± 1) °C for 24 h. Then, the resulting cultures were transplanted into two selective agarose media and incubated at the temperature of (37 ± 1) °C for 24 h. The count of spoilage microorganisms was carried out by seeding powders into agarose nutrient media in Petri dishes, with their further incubation in aerobic conditions at the temperature of (25 ± 1) °C for 5 days, in accordance with [40].

2.11. Heavy Metals and Radionuclides

The powders' safety indices were determined with the use of an atomic absorption spectrophotometer Varian AA240Z (Agilent, Santa Clara, CA, USA). The content of Pb [41] and Cd [42] was determined using a method based on dry mineralization of powders using nitric acid as an auxiliary and quantitative determination of cadmium with polarography in alternating current mode. Arsenic content was determined by measuring the color intensity of a solution of a complex compound of arsenic with silver diethyldithiocarbamate in chloroform according to [43]. Mercury content was determined using a method based on the destruction of the analyzed sample with a mixture of nitric and sulfuric acids and precipitation of mercury with copper iodide, according to [44], on the universal mercury-metric complex UKR-1MC (Kiev, Ukraine). Residual amounts of organochlorine pesticides were determined by extraction of pesticides with an organic solvent, purification of the extract and evaporation according to [45] on a Crystallux-4000 M chromatograph (Unichrom, Minsk, Belarus). The radiation safety of powders was assessed by the content of Sr-90 [46] and Cs-137 [47], measuring the total beta-activity of counting devices.

2.12. Statistical Analysis

The data were processed using an analysis of variance and mean separations were performed using the Duncan multiple range test, with reference to a 0.05 probability level, using SPSS software version 21. The data expressed as a percentage were subjected to angular transformation before processing.

3. Results and Discussion

3.1. Broccoli Floret Powder

Biofortification of broccoli with Se showed a beneficial effect on the yield and the quality of plants. Thus, the plant yield increased as a result of Se supplementation by 13%, while the increase in vitamin C and polyphenols reached 1.07 and 1.90 times, respectively (Table 2). On the contrary, no significant changes in the dry matter, protein, fat or carbohydrate content were registered. The content of Se in the florets increased markedly with the biofortification level reaching 22.6. The improvements in the broccoli antioxidant status recorded in the present work as a result of Se supply were in agreement with the results

of Bouranis et al. [11], confirming the close relationship between Se and other natural antioxidants. Being not essential for plants, Se at low concentrations is known to improve the antioxidant defense of crops [48].

Table 2. The yield and biochemical characteristics of Se-fortified and non-fortified broccoli.

Parameter	Non-Fortified Broccoli	Se-Fortified Broccoli
Floret weight, (g)	74 ± 5 a	83 ± 6 a
Dry matter content (%)	11.3 ± 0.1 a	11.0 ± 0.1 a
Protein (%)	12.0 ± 0.1 a	12.1 ± 0.1 a
Fat (%)	2.0 ± 0.1 a	2.0 ± 0.1 a
Carbohydrates (%) including:	72.8 ± 7.3 a	74.9 ± 7.5 a
Monosaccharides	13.5 ± 1.4 a	13.5 ± 1.4 a
Insoluble dietary fibers	41.9 ± 4.2 a	42.8 ± 4.3 a
Soluble dietary fibers	17.4 ± 1.7 a	18.6 ± 1.9 a
Vitamin C (mg 100 g^{-1})	170 ± 1.7 b	182 ± 1.8 a
Polyphenols (mg-eq GA 100 g^{-1})	126 ± 1.3 b	240 ± 2.4 a
Se (μg kg^{-1} d.w.)	93 ± 9 b	2100 ± 2 a

Values in rows with identical letters do not differ statistically according to the Duncan test at $p < 0.05$.

The phenomenon of polyphenol content increase due to the treatment of broccoli with Se indicates the nutritional significance of the resulting product. Indeed, among natural antioxidants, polyphenols are known to be the most powerful ones [49]. Agricultural crops with high polyphenol content decrease the risks of many chronic diseases connected with oxidative stress, such as cancer, inflammation, cardiovascular diseases and early aging [49]. Higher concentrations of Se are known to adversely affect polyphenol accumulation in broccoli, with the response demonstrating high varietal differences [50,51].

The analysis of the product safety indicates the presence of only trace amounts of As, Pb, Cd and Hg and an insignificant accumulation of radioactive Cs-137 and Sr-90, along with trace amounts of hexachlorocyclohexane and dichlorodiphenyl trichloromethyl methane at a concentration range significantly below MPC levels. It should be also noted that in unfavorable conditions of vegetation with anthropogenic heavy metal loading, Se biofortification is known to protect plants against the dangerous accumulation of As, Pb, Cd and Hg, which alleviates the production of vegetables of high nutritional quality [52].

The microbiological safety of the broccoli power with and without increased levels of Se was evidenced by plating mesophilic aerobes and facultative anaerobes, coliforms, *Bacillus cereus*, pathogen microorganisms including salmonella and molds. In all cases, only trace amounts of unfavorable microorganisms were detected. The data confirm the microbiological stability of the produced powders.

3.2. Bread Production

To determine the effect of broccoli powder on the quality parameters of bakery products manufactured from top-grade wheat bakery flour, bread was made with the addition of 4% of the powders relative to the wheat flour mass according to the developed dough procedure using the PFSFP. The technological process of the PFSFP consists of separating water-soluble substances—preliminarily by the onset of dough fermentation—from the powder cell structure upon hydration and distributing homogeneously the powder particles in the dough.

The ready products were characterized by organoleptic, physical and chemical quality indices. The evaluation of organoleptic quality indices showed a smooth glossy surface of bread without cracks and oven breaks. In all samples the porosity was uniform, and the crumb was elastic and not deformed under pressure. The peculiarity of bread with added broccoli powder was the crumb color—light yellow with a darkish shade. The aroma and taste of the products demonstrated pronounced broccoli aroma and flavor.

The physical and chemical quality parameters of bakery products supplied with broccoli powder are presented in Table 3 and Figure 1.

Table 3. Physical and chemical characteristics of bread produced from ordinary wheat flour and in combination with non-fortified and Se-fortified broccoli powder.

Parameter	Control	Non-Fortified Broccoli	Se-Fortified Broccoli
Crumb moisture content (%)	44.0 ± 0.4 a	44.2 ± 0.6 a	44.4 ± 0.5 a
Crumb acidity (degree)	2.80 ± 0.03 c	3.20 ± 0.02 b	3.40 ± 0.03 a
Crumb porosity (%)	68 ± 5 a	74 ± 6 a	75 ± 6 a
Specific volume (cm^3 100 g^{-1})	262 ± 3 c	281 ± 2 b	293 ± 3 a

Values in rows with identical letters do not differ statistically according to the Duncan test at $p < 0.01$.

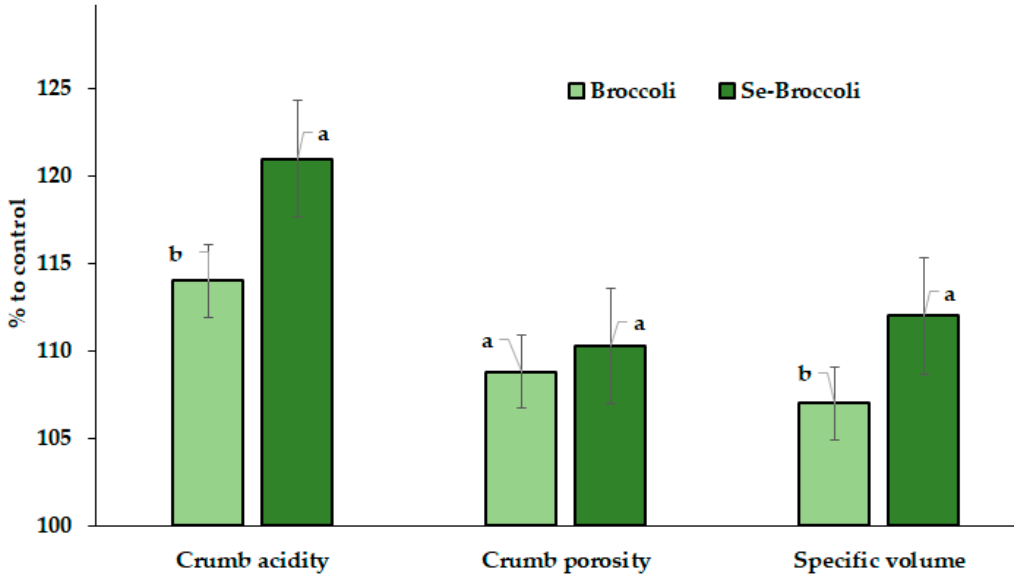

Figure 1. The intensity of changes in physical and chemical parameters of bread due to broccoli and Se-broccoli powder addition. For each parameter, the values with identical letters do not differ statistically according to the Duncan test at $p < 0.05$.

The data presented in Table 3 and Figure 1 indicate that the bakery products fortified with broccoli powder were characterized by an increase in crumb porosity by 8.8% and 10.3%; the bread-specific volume increased by 7.3% and 11.8%, respectively, relative to the control (without the addition of powder). The results were in good agreement with the previous evaluation of Se-enriched shallot leaf supplementation to bread [53].

The pore distribution in bread crumb according to their size in mm and their number in percent of the total pore number is presented in Figure 2.

During the evaluation of the broccoli powder effect on the porosity structure of the bread crumb, crumb pore sizes of 0.01 to 0.12 mm were conventionally considered as small pores, those of 0.13 to 0.18 mm were considered medium pores, and those of 0.19 to 0.34 mm were considered as large pores.

A large pore percentage in the control bread sample was 3.5%, and in that supplied with broccoli powder fortified with Se the large pore percentage was 8.1%. At the same time, the percentage of medium size pores in the bread crumb declined with the use of broccoli powder compared with the control.

It should be noted that the supplementation of Se-enriched broccoli powder had a positive effect on the porosity structure of the bread crumb—an increase in large pore percentage relative to control was recorded.

This study involved the comparative evaluation of the effect of broccoli powder on the retention of bread freshness during storage. The rate of bread hardening is characterized by the difference in indices of the product crumb loading force between the third and first days of this study. The rate of bread hardening is presented in Figure 3.

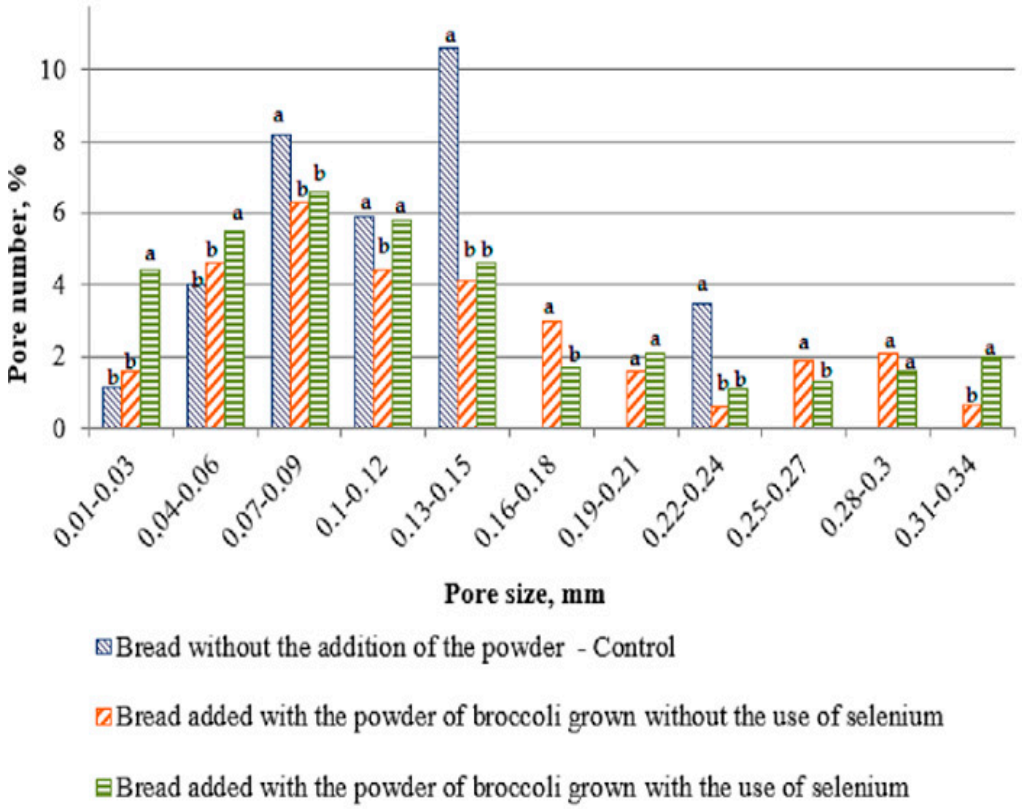

Figure 2. Histogram of pore size distribution in the bread crumb made with broccoli powder. For each pore size range, values with identical letters do not differ statistically according to the Duncan test at $p < 0.05$.

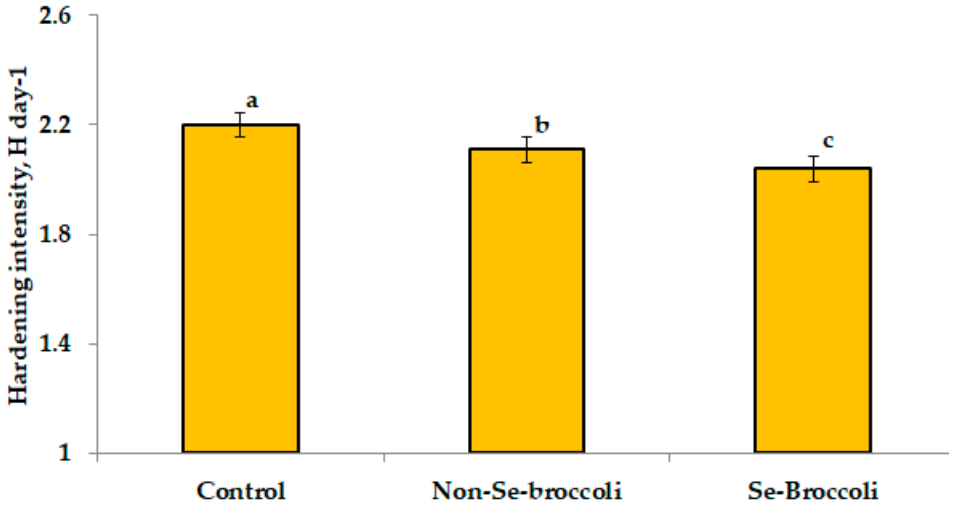

Figure 3. The effect of broccoli powder supply on the hardening intensity of the bread crumb. Values with identical letters do not differ statistically according to the Duncan test at $p < 0.05$.

According to the data presented in Figure 3, one can see that the use of broccoli powder contributed to the decrease in bread crumb hardening intensity during storage—by 4.3% (in the case of non-Se broccoli supply) and by 7.8% (in the case of Se-broccoli supply) relative to the control sample. Possibly, the use of Se-fortified broccoli preserves the cell structure of the raw material in a native state to a greater extent, which determines the reduction in the activity of starch retrogradation processes.

The use of Se-broccoli powder in bakery product technology contributed to an improvement in the crumb porosity, specific volume and hardening rate.

To determine the preservation of Se in food products containing broccoli powder, bread was produced from top-grade wheat flour according to the process presented in the Section 2. The difference between the micronutrient content in dough pieces before baking and the content in baked products was calculated. This study determined that during bread baking, Se preservation reached 96%, indicating the high thermostability of Se in broccoli.

The content of nutrients in bread was determined, and the coverage of daily physiological needs of a human organism by the consumption of 100 g of bread was calculated (Tables 4 and 5).

Table 4. Nutritional characteristics of control bread and bread supplemented with Se-fortified and non-fortified broccoli powder.

Parameter	Control	Non-Se-Fortified Broccoli	Se-Fortified Broccoli
Dietary fiber (g 100 g^{-1} f.w.)	2.2 ± 0.2 b	4.6 ± 0.5 a	4.7 ± 0.5 a
Vitamin C (mg 100 g^{-1} f.w.)	0.12 ± 0.01 b	4.2 ± 0.1 a	4.5 ± 0.1 a
Polyphenols (mg GAE 100 g^{-1} f.w.)	5.8 ± 0.1 c	9.0 ± 0.1 b	11.8 ± 0.2 a
Se (μg 100 g^{-1} f.w.)	5.04 ± 0.2 b	5.4 ± 0.2 b	13.1 ± 0.2 a

Values in rows with identical letters do not differ statistically according to Duncan test at $p < 0.01$.

Table 5. Daily consumption levels of dietary fiber, vitamin C and Se with 100 g of bread with non-fortified and Se-fortified broccoli power (% to the Dietary Reference Intake, DRI).

Parameter	DRI, mg day^{-1}	Control	Non-Se-Fortified Broccoli	Se-Fortified Broccoli
Dietary fiber	20	11 b	23 a	23.5 a
Vitamin C (adults)	100	0.12 b	4.2 a	4.5 a
Vitamin C (children)	50	0.24 c	8.4 b	9.0 a
Se (females)	0.055	9.2 b	9.8 b	23.8 a
Se (males)	0.070	7.2 b	7.7 b	18.7 a
Se (children)	0.050	10.1 b	10.8 b	26.2 a

DRI—dietary reference intake. Values in rows with identical letters do not differ statistically according to the Duncan test at $p < 0.01$.

The use of broccoli powder grown without and with Se supply resulted in an increased content of vitamin C, polyphenols and Se in bakery products.

A significant increase in vitamin C content, by 4.4 mg 100 g^{-1}, polyphenol content, by 6 mg 100 g^{-1}m and Se content, by 8 μg 100 g^{-1}, in bread was achieved due to broccoli powder supply in comparison with the products manufactured with the addition of a powder of native raw material.

The functional properties of the developed bakery products containing Se-fortified broccoli are presented in Table 5. The content of dietary fibers was 4.7 g 100 g^{-1}. The coverage of the daily need of a human organism for Se was 26% for infants, 24% for females and 19% for males as per 100 g of the product.

4. Conclusions

The results of the present investigation indicate a beneficial effect of foliar sodium selenate supply on the antioxidant status of broccoli florets and show high prospects for the utilization of the latter in the production of functional bread with increased levels of Se, polyphenols, ascorbic acid and dietary fiber. The supplementation of dough with 4% broccoli powder improved the crumb porosity and the specific volume of bread by 10.3% and 11.8%, respectively. Bread with Se-fortified broccoli may become highly valuable for improving the human Se status, as 100 g of such a product provides about 18.7–26.2% of Se DRI.

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