Quality evaluation of bakery products enriched with spinach

A N Sapozhnikov, L N Rozhdestvenskaya and A V Kopylova
Department of Technology and Organization of Food Industries, Faculty of Business, Novosibirsk State Technical University, 20 Prospekt K. Marksa, Novosibirsk, 630073, Russian Federation
E-mail: a.sapozhnikov@corp.nstu.ru

Abstract. Garden spinach (Spinacia oleracea) is a well-known leaf vegetable in the world. It contains biologically active substances and thus can be used for enrichment of different kinds of food production, including bakery products. However, spinach is not yet deeply studied from this point of view. Recent studies show that spinach is advisable for introducing into the dough in state of infrared-dried powder. The paper describes the results of quality evaluation of developed bakery products enriched with spinach powder by sensory, physico-chemical characteristics and nutritional value. Three control samples (roll № 1, curd and lingonberry patties № 2 and № 3) were prepared using high-grade and second-grade wheat flour in 1:3 ratio. All experimental samples (№ 1, № 2, № 3) were enriched with infrared-dried spinach powder in the amount of 4% from flour weight. All bakery products samples were prepared according to standard technology and passed quality evaluation. The sensory characteristics of experimental samples didn’t change significantly, though some of values decreased by 0.1 points or increased by 0.1…0.3 points. The dry matter content values either decreased by 1.45…3.38% or increased by 0.36%, the acidity and ash content values increased by 0.2…0.6 deg and 0.16…0.74% accordingly. All samples were evaluated for estimated content of proteins, fats and carbohydrates and their relative approximation to ratio of 1:1:4. The ratio in control and experimental samples № 1 and № 2 are close to the recommended ratio value. In control and experimental samples № 3 the ratio value is not kept but can be improved in different ways. Thus, the results of study show, that the enrichment of bakery products with spinach can save or improve their sensory characteristics, increase organic acids and minerals content. The enrichment also doesn’t have negative effect on products’ nutritional value. The ratios of proteins, fats and carbohydrates allow to use bakery products enriched with spinach in daily diet of adults and children of preschool and school age.

1. Introduction
Bakery products are the essential part of Russian population daily diet. They are produced almost everywhere in the country at enterprises of different capacity.

One of the most important directions in Russian bread baking industry is expansion of its production range, which can be achieved by developing and introducing of functional and specialized varieties of bakery products enriched by vitamins, minerals and dietary fibers. This direction meets the purposes of the “Bread is Health” Concept, which full name is “The Concept of Ensuring the Sanitary and Epidemiological Well-Being of the Population Through the Development of Functional and Specialized Bread Baking in the Russian Federation until 2020” [1].
According to the direction, a lot of studies concerned with the development of bakery products with additives, which are obtained from local plant raw materials, have been done in Russia and other countries.

At the same time, some kinds of plant raw materials, which can be successfully applied in bakery products formulations and serve as functional ingredients, are studied insufficiently. One of these raw materials is garden spinach (Spinacia oleracea). It is known, that spinach in its fresh and processed states is a source of bioflavonoids, vitamins, minerals and antioxidants. Thus, these beneficial features allow to use it in dietary nutrition, as well as in the prevention and treatment of a wide range of diseases (anemia, diabetes, helminth infections, obesity, inflammations, nervous diseases, etc.) [2–4].

It should be noted, that spinach has specific taste and scent. Its introduction into bakery products formulations in natural state gives the products moist and fibrous texture, thereby their sensory characteristics are lowered. This indicates the feasibility of enrichment of bakery products with spinach in a powder state, preliminary reducing its moisture content through various types of drying: convective [5], freeze-drying [4], by infrared rays [6], by contact method from puree state on a roller dryer, followed by grinding in a ball mill [7]. From mentioned drying methods, infrared drying is considered as optimal, since it has simple hardware design and saves useful substances in products for a rather high degree.

To date, several studies that have shown the positive effect of spinach in natural and processed states on bakery products (including national cuisines products) quality have been conducted [5, 8, 9].

According to the information above, the objective of our study was the development of formulations of bakery products enriched with infrared-dried spinach powder. All obtained bakery product samples passed quality evaluation on their sensory, physico-chemical characteristics and nutritional value.

2. Materials and methods

2.1. Materials
The main raw materials for bakery products samples preparation were high-grade flour and second grade flour, which were obtained on “Avangard Flour Mill Plant” in Novosibirsk, Russian Federation. The other raw materials (spinach, curds, lingonberry, eggs, sugar, salt, margarine, yeast, milk, vanillin, sunflower oil) were purchased from local retail network in Novosibirsk.

2.2. Bakery products samples preparing
The control samples of bakery products were based on formulations from “The Digest of Dishes and Culinary Products Formulations for Children Nutrition in Preschool Organizations” (2005). According to our previous experimental studies, two kinds of flour were used in formulations in 1:3 ratio, i.e. 25% of high-grade flour and 75% of second-grade flour. This ratio allows to use second-grade flour with higher content of dietary fibers, B-group vitamins and other useful substances in bakery products formulations in larger amount. Therefore, high-grade flour can be used in lower amount. At the same time, it’s enough to obtain production with high sensory characteristics, such as regular shape, well-developed porosity, smooth crust surface, etc.

The dough preparing was conducted by straight method (without using leavened dough), which allows to reduce preparing time of bakery products without significant change of their sensory characteristics. The kneading process was carried out manually. The dough fermentation was held out at 38…40 °C and moisture content of 70…75% in proofing cabinet of Sveba Dahlen S200 rotary oven (Sweden). From the fermented dough the products stocks were formed and proofed during 15…20 min in the same proofing cabinet.

For the experimental samples, the infrared-dried spinach powder was introduced into the dough in the amount of 4% from flour weight. This amount was obtained by our previously carried out theoretical and practical studies and was considered by us as optimal.

The primary processed spinach was dried in the electrical infrared compact dryer (Russian patent № 2265169) at 50…60 °C during 2.5…3 h in pulse mode. After that, the dried spinach was cooled at 20…25 °C and mechanically grinded into fine powder.
Thus, the following control and experimental bakery products samples were obtained:

- wheat flour roll – control sample № 1;
- curd patty – control sample № 2;
- lingonberry patty – control sample № 3;
- wheat flour roll with spinach (4% from flour weight) – experimental sample № 1;
- curd patty with spinach (4% from flour weight) – experimental sample № 2;
- lingonberry patty with spinach (4% from flour weight) – experimental sample № 3.

All product samples were baked in Sveba Dahlen S200 rotary oven at 180…190 °C during 20…30 min. After that, they were cooled at 20…25 °C during 1…2 h and evaluated for their sensory, physico-chemical characteristics and nutritional value.

2.3. Sensory characteristics
Sensory evaluation of obtained bakery product samples was carried out according to Russian national standard GOST 31986-2012 “Public catering service. Method of sensory evaluation of catering products” for the following characteristics:

- appearance (in whole products and on the cut);
- scent;
- taste;
- color;
- consistency.

Every indicator was evaluated on the 5-point scale (5 indicates the best and 1 implies the worst) by 4 semi-trained panelists. As a result of the evaluation, the average points for each characteristic were obtained.

2.4. Physico-chemical characteristics

2.4.1. Dry matters content. This characteristic was evaluated according to GOST 21094-75 “Bread and bakery products. Method for the determination of moisture”. The drying of prepared and weighted samples to constant weight at 130±2 °C was carried out in the ShS-80-01 SPU drying cabinet (Russia). The samples before and after drying were compared by their weights and dry matters content $D (%)$ was determined using the following equation:

$$D = 100 \left(1 - \frac{m_1 - m_2}{m}\right)$$

where $m_1$ (g) is weight of cup with sample before drying, $m_2$ (g) is weight of cup with sample after drying, $m$ (g) is weight of sample before drying. In this study, $m$ is 5 g.

2.4.2. Acidity. This characteristic was evaluated according to GOST 5670-96 “Bread, rolls and buns. Methods for determination of acidity” by titration of extracts from samples with sodium hydroxide solution with a concentration of 0.1 mol/dm$^3$. Based on received data, the acidity value $X$ (deg) was determined using the following equation:

$$X = 2V \cdot K$$

where $V$ is volume (cm$^3$) of acid solution of of 0.1 mol/dm$^3$ concentration used for titration, $K$ is correction ratio of used sodium hydroxide solution adduction to solution of exact molar concentration of 0.1 mol/dm$^3$. In this study, $K$ is 1.
2.4.3. Ash content. This characteristic was evaluated according to GOST 27494-87 “Flour and bran. Methods for determination of ash content”. The sample weights were ignited in crucibles at the hotplate at 400…500 °C with following incinerating at the PM-10M 732 muffle furnace (Russia) at 350…400 °C during 1.5…2 days to constant weight. After incineration, the ash content ($A$, %) was determined using the following equation:

$$A = m_1 \cdot \frac{100}{m_0} \cdot \frac{100}{100 - H}$$  

(3)

where $m_0$ (g) is weight of sample before incineration, $m_1$ (g) is weight of sample after incineration, $H$ (%) is humidity of sample before drying. In this study, $m_1$ is 5 g. The humidity of samples was obtained from their dry matters content according to equation (1) and using following equation:

$$H = 100 - D$$  

(4)

2.5. Nutritional value

The nutritional values of bakery products samples were evaluated by calculations of proteins (g), fats (g), carbohydrates (g) and calorie (kcal) content according to reference data from “Chemical Compositions of Russian Food Products Manual” (2002).

After calculations, all samples were evaluated for relative approximation of proteins, fats and carbohydrates ratio to value of 1:1:4.

3. Results and discussion

3.1. Sensory characteristics

The results of bakery products samples evaluation for appearance, color and consistency are shown on Figure 1.

It was noted, that all samples held their shapes after baking and had uniform porosity structure on the cut. The high quality of control and experimental samples showed, that the replacement of high-grade flour with flour of second grade in amount of 75% didn’t have negative effect on technological process parameters, as well as the appearance and color of crust and crumb.

The enrichment of experimental bakery products samples with infrared-dried spinach powder showed, that there weren’t any changes of parameters in dough kneading and fermentation, stocks proofing and baking processes. The crumb of all experimental samples had nice green color, while patties stuffing (curds, lingonberry) were not colored.

The Figure 2 shows results of bakery product samples sensory evaluation for each characteristic. Since our study evaluated the effects of infrared-dried spinach powder on various types of bakery products, it was advisable to compare each experimental sample with its corresponding control sample.

According to the Figure, spinach powder increased the consistency value of wheat flour roll (control and experimental samples № 1) by 0.2 points (from 4.8 to 5.0 points), though the scent and taste were decreased by 0.1 point for each characteristic (from 4.9 to 4.8 points and 4.8 to 4.7 points accordingly), which can be explained by specific spinach flavor. The appearance and color remained at the highest value (5.0 points).
Figure 1. Results of sensory evaluation of bakery products samples.

The sensory characteristics increase was more specific for curd patties (control and experimental samples № 2). Though, the scent value of experimental sample № 2 in comparison with the corresponding control sample was decreased by 0.1 points (from 4.9 to 4.8 points) because of specific spinach flavor. The color of experimental sample increased by 0.2 points (from 4.9 to 4.7 points), which can be explained by specific combination of colored crumb and curd stuffing.

At the same time, the experimental sample № 2 in comparison with all other control and experimental samples had got high taste value (4.9 points), i.e. there were not expressed specific spinach flavor, which can be explained by fat component in formulation. It is known, that spinach contains a large amount of fat-soluble substances. Therefore, adding fat components to bakery product formulations will not only increase the digestibility of nutritional substances contained in spinach, but also can improve sensory characteristics of products [10].

The consistency and appearance values of the samples remained at the same highest values of 5.0 and 4.9 points accordingly.
Figure 2. Sensory characteristics of bakery products.
The enrichment of lingonberry patties (control and experimental samples № 3) with infrared-dried spinach powder increased the product appearance by 0.2 points (from 4.7 to 4.9 points), consistency – by 0.3 points (from 4.7 to 5.0 points), color – by 0.1 points (from 4.9 to 5.0 points). The decrease of taste value by 0.2 points (from 4.8 to 4.6 points) can be explained by bitter aftertaste flavor of lingonberry, which strengths in spinach presence. Herewith, the scent value remains at the highest point (5.0 points) without a change, because specific spinach scent is not felt in the presence of lingonberry. Therefore, using of natural flavoring additives can mask the undesirable aftertaste and improve the taste of bakery products in general.

3.2. Physico-chemical characteristics

In the Table 1 the results of physico-chemical characteristics of bakery products evaluation are shown.

| Samples                  | Dry matters content, % | Acidity, deg | Ash content, % |
|--------------------------|------------------------|--------------|----------------|
| Control sample № 1       | 20.16±1.21             | 2.1±0.14     | 0.97±0.01      |
| Experimental sample № 1  | 20.52±0.44             | 2.7±0.14     | 1.71±0.02      |
| Control sample № 2       | 38.36±2.4              | 2.4±0.07     | 0.75±0.01      |
| Experimental sample № 2  | 34.98±4.45             | 2.6±0.28     | 0.91±0.02      |
| Control sample № 3       | 31.02±0.68             | 0.9±0.14     | 0.63±0.02      |
| Experimental sample № 3  | 29.57±2.09             | 1.4±0.28     | 0.97±0.01      |

According to the obtained results, the enrichment of experimental sample № 1 with infrared-dried spinach powder practically didn’t change dry matters content in ready product, though it increased by 0.36% (from 20.16 to 20.52%). It can be explained through similar humidity content both in wheat flour and spinach powder, and through low content of spinach powder in the products. Herewith, the acidity increased by the average of 0.6 deg (from 2.1 to 2.7 deg), and ash content increased by 0.7% (from 0.97 to 1.71%). It can be explained, that infrared-dried spinach powder is a concentrated product. It contains organic acids and minerals in larger amount than spinach in its natural form. The infrared radiation also preserves most of nutritional substances in spinach. Infrared rays remove the largest portion of water from drying materials at low temperatures without destruction of other substances, so their amounts in dried products are increased [6].

The dry matters content in experimental sample № 2 decreased on average by 3.38% in relation to the corresponding control sample (from 38.36 to 34.98%). The acidity increased on average by 0.2 deg (from 2.4 to 2.6 deg), and ash content – by 0.16% (from 0.75 to 0.91%).

The dry matters content in experimental sample № 3 on average decreased by 1.45% in relation to the corresponding control sample (from 31.02 to 29.57%). The acidity increased on average by 0.5 deg (from 0.9 to 1.4 deg), and ash content – by 0.34% (from 0.63 to 0.97%).

In this case, the dry matters content decrease can be explained by the peculiarities of patty dough formulation and water absorption by the spinach powder in combination with its interaction with the fatty component [10].

The increasing of bakery products samples acidity values indicates the presence of organic acids remained in the spinach powder after infrared drying. Herewith, the acidity increase corresponds to finished products taste improvement, except control and experimental samples № 3, which can be explained by high acid content in lingonberry. The increasing of ash content in experimental samples points to the enrichment of products with minerals contained in spinach powder.

Thus, the results show that infrared-dried spinach powder can enrich bakery products with organic acids and minerals.
3.3. Nutritional value

The Table 2 shows the results of estimating and analyzing of bakery products nutritional value.

Table 2. Analysis of nutritional value of control and experimental samples of bakery products.

| Samples                  | Proteins, g | Fats, g | Carbohydrates, g | Calorie content, kcal | Protein/Fats/Carbohydrates ratio |
|--------------------------|-------------|---------|------------------|-----------------------|---------------------------------|
| Control sample № 1      | 6.0         | 6.5     | 22.3             | 144                   | 1:1:3.7                         |
| Experimental sample № 1 | 6.0         | 6.2     | 20.9             | 138                   | 1:1:3.5                         |
| Control sample № 2      | 12.1        | 9.8     | 36.8             | 262                   | 1.2:1:3.8                       |
| Experimental sample № 2 | 12.8        | 10.0    | 38.1             | 271                   | 1.3:1:3.8                       |
| Control sample № 3      | 5.9         | 9.1     | 48.7             | 285                   | 0.6:1:5.4                       |
| Experimental sample № 3 | 6.0         | 9.2     | 49.0             | 289                   | 0.7:1:5.3                       |

The figures from the Table show, that using spinach powder in bakery products formulations practically doesn’t have effect on products’ nutritional value, because it is introduced into dough in a low amount. The proteins, fats and carbohydrates ratio in control and experimental samples № 1 shows, that it is closest to the recommended ratio of 1:1:4. The ratio in control and experimental samples № 2 shows that it is also close to the same value. In control and experimental samples № 3 the ratio is not kept, because these samples have a lower proportion of proteins and a higher proportion of carbohydrates. Thus, the formulation of lingonberry patties can be recommended for the improvement. The lingonberry patties may be also consumed with products, which are both rich with proteins and have low carbohydrates content (for example, kefir and similar dairy products).

It should be noted that experimental samples № 1 and № 2 with proteins, fats and carbohydrates ratio closest to recommended value have maximum demand for the organization of intermediate food and snacks for children of preschool and school age and can be embedded in their weekly diets.

4. Conclusion

The conducted theoretical and practical studies show that infrared-dried spinach powder is a perspective ingredient for bakery products enrichment. The obtained results allow to use combination of high-grade and second-grade wheat flour in ratio 1:3 and 4% spinach powder from flour weight in bakery products formulations. These changes in classical formulations of bakery products don’t have effect on technological process parameters.

The sensory characteristics of experimental samples didn’t change significantly, though some of values decreased by 0.1 points and increased by 0.1…0.3 points. The lowest characteristic is taste of experimental sample № 3 (4.6 points), but the same sample has the highest consistency value (5.0 points). So experimental samples № 1 and № 2 have the best sensory characteristics, and sensory characteristics of experimental sample № 3 must be improved through using of natural flavoring additives, which won’t have negative effect on its nutritional value. The highest value (5.0 points) have appearance and color of control and experimental samples № 1, consistency of control and experimental samples № 2 and consistency of experimental sample № 3.

The dry matters content values in the samples either decreased by 1.45…3.38% or increased by 0.36%, the acidity and ash content values increased by 0.2…0.6 deg and 0.16…0.74% accordingly. This indicates the presence of high amount value of organic acids and minerals, which are remained in the spinach powder after infrared drying.
All samples were evaluated for estimated content of proteins, fats and carbohydrates and their relative approximation to ratio of 1:1:4. The ratio in control and experimental samples № 1 and № 2 are close to the recommended value. In control and experimental samples № 3 the ratio is not kept but can be improved by consuming with products with high protein and low carbohydrate content. Thus, the developed bakery products enriched with spinach can be recommended for children of preschool and school age, as well as for adults.

However, a more detailed study of bakery products chemical composition will make possible more accurately reveal their nutritional value, including functional properties.

References

[1] Bogomolova I P and Belimova E A 2014 Directions and mechanisms of state regulation of the production of functional bakery products Proceedings of the Voronezh State University of Engineering Technologies 2 177–83

[2] Jaime L, Vázquez E, Fornari T, Carmen López-Hazas M, et. al. 2015 Extraction of functional ingredients from spinach (Spinacia oleracea L.) using liquid solvent and supercritical CO2 extraction J. Sci. Food Agric. 95(4) 722–9

[3] Jiraungkoorskul W 2016 Review of neuro-nutrition used as anti-alzheimer plant, spinach, spinacia oleracea Pharmacognosy Review 10(20) 105–8

[4] Neascu M, Vaughan N, Raikos V, Multari S, et. al. 2015 Phytochemical profile of commercially available food plant powders: their potential role in healthier food reformulations Food Chem. 179 159–69

[5] Galla N R, Pamidighantam P R, Karakala B, Gurusiddaiah M R and Akula S 2017 Nutritional, textural and sensory quality of biscuits supplemented with spinach Intern. J. Gastron. Food Sci. 7 20–6

[6] Sarimiseli A and Yuceer M 2015 Investigation of infrared drying behavior of spinach leaves using ANN methodology and dried product quality Chem. Process Engi. 36(4) 425–36

[7] Rodionova L Ya, Sokol N V, Shubina L N and Olhovatov E A 2017 Technology and application of powdered food additives from vegetable raw materials Scient. J. Kuban State Agrarian Univ. 131(07) 1389–404

[8] Khan M A, Mahesh C, Semwal A D and Sharma G K 2015 Effect of spinach powder on physico-chemical, rheological, nutritional and sensory characteristics of chapati premixes J. Food Sci. Technol. 52(4) 2359–65

[9] López-Nicolás R, Frontela-Saseta C, González-Abellán R and Barado-Piqueras R 2014 Folate fortification of white and whole-grain bread by adding Swiss chard and spinach Acceptability by consumers LWT – Food Sci. Technol. 59(1) 263–9

[10] Xi Y, Xiaojuan L, McClements D J, Yong C and Hang X 2018 Enhancement of phytochemical bioaccessibility from plant-based foods using excipient emulsions: impact of lipid type on carotenoid solubilization from spinach Food Funct. 9(8) 4352–65