Development of plant-based high-protein bakery products with antioxidant activity

Lada Rozhdestvenskaya[1,2], *Igor* Lomovsky[3], and *Zhibek* Baktybekova[1]

[1]Novosibirsk State Technical University, Novosibirsk, Russia
[2]Novosibirsk Scientific Research Institute of Hygiene of the Federal Service for Supervision of Consumer Rights Protection and Human Well-Being, Novosibirsk, Russia
[3]Siberian division Russian academy of sciences, Novosibirsk, Russia

Abstract. In this paper was studied the method of development of high-protein bakery products based on vegetable raw materials, covering 20% of the daily requirement in proteins and antioxidants with 100 grams of the product. Organoleptic, physico-chemical parameters, nutritional value and amino acid composition of four samples of bakery products are estimated. The questions of preservation of antioxidant activity of tea on the basis of use of technologies of extraction followed by microencapsulation and mechanochemical processing are considered.

1 Introduction

Global problems of food security and their connection with sustainable development have been repeatedly highlighted in the modern scientific agenda. The consolidated decision of the EAT - Lancet Commission substantiated the necessity to change food stereotypes in the direction of increasing the consumption of products of plant origin in order to ensure a planetary healthy and sustainable diet [1]. Protein malnutrition also continues to be a problem in many countries of the world [2,3]. Legumes, especially when mixed with cereal proteins, nuts and seeds, and other non-traditional high-protein ingredients, can be a promising alternative source of nutritious and functional proteins and represent the basis of a healthy diet [4].

Changes in climate, diet and lifestyle are changing the nature, etiology and progression of major degenerative human diseases, including those associated with reactive oxygen species and oxidative stress. Because of this, antioxidants have become essential nutrients in the world of nutrition. They are important in terms of their ability to protect against oxidative cell damage that can lead to conditions such as Alzheimer's disease, cancer, heart disease, and chronic inflammation [5].

To be successfully introduced into food production, vegetable proteins should have a number of functional properties, as well as provide an opportunity to cover the human body's need for essential amino acids. From these positions an important source of vegetable proteins traditionally used in food are legumes (soybeans, peas, lentils, chickpeas, beans). Legumes have a fairly rich amino acid composition and contain large amounts of lysine, leucine, asparagic acid, glutamic acid and arginine [6,7]. When consumed with cereals and other foods rich in sulfur-containing amino acids and tryptophan (including nuts and seeds), legumes can provide a well-balanced profile of essential amino acids.

Pea is one of the most important legumes cultivated in 90 countries [8]. It has a high content of valine, arginine and methionine, but is poor in terms of cysteine and glutamic acid. On the other hand, peas contain high amounts of lysine, which can help to compensate for lysine deficiency in cereal-based dishes. Peas are a good source of vitamin C, E and other antioxidants; which have positive effects on the immune system, reduce inflammation and lower the risk of chronic diseases such as diabetes, heart disease and arthritis [9]. Pea protein combines all the benefits of peas as a high-protein plant product and has a digestibility of 90%.

Another actively studied high-protein oilseed legume with significant amounts of essential amino acids is sesame, which contains about 50% fat and 30 to 60% protein [10,11]. Sesame has a rich nutritional composition of antioxidants and specific bioactive compounds such as lignans (phytosterols, tocopherols, sesamin and sesamolin, etc.). Its high antioxidant activity makes it a unique and high quality functional food that can have positive effects on human health [12].

A non-traditional high-protein product is tea, which contains about 21-28% protein in terms of dry matter. Tea protein has bioactive properties such as metabolic accommodation, antioxidant activity, anticancer activity and protective effect in cardiovascular disease. The nutritional and medicinal value of tea has been highly appreciated, primarily associated with the polyphenols and catechins contained in tea possessing various physiological and pharmacological properties, antioxidant, antifungal, antibacterial and anticancer activity [13].

Bakery products and bread, as a staple food (since it is a main food) is a promising matrix to incorporate plant-based ingredients with high protein content to combine the trends of increasing demand for plant-based products on the one hand and high-protein products on the other [14]. Combining the above, we set out to obtain a bakery product combining plant products with high protein content and established antioxidant properties.

2 Materials and Methods

To eliminate the disadvantages of low bioavailability and to obtain the maximum possible amount of tea catechins, the technology of extraction followed by microencapsulation and mechanochemical treatment of tea leaves was used. During microencapsulation, the active components of green tea are encapsulated in a shell of another material, which performs a protective function and is able to offset the bitter or tart taste of the introduced ingredient.

Green tea was taken as the object of the study. The concentration of catechins in the raw material was determined by the major catechins that are most abundant, which are epigallocatechin gallate (EGCG), epigallogatechin (EGC) and epicatechin gallate (ECG) [15].

The concentration of catechins was determined by HPLC. on a Millichrome A-02 instrument in gradient mode. The stationary phase was ProntoSil 120-5-C18. Solvents: eluent A - bidistilled water; eluent B – acetonitrile.

The process of microencapsulated additive (MIA) preparation was carried out in several steps. At the initial stage, ultrasonic extraction of green tea for 40 minutes was carried out in order to obtain the extract. In this process, the surface structure is destroyed and diffusion process takes place, which facilitates the transfer of beneficial components from the tea leaf to the solvent. The resulting solution was then filtered and centrifuged. The concentration of catechins in the sample of tea US solution is presented in Table 1.

The second step involved obtaining the dry extract using lyophilic drying on Iney-4. Lyophilization is a freeze drying method, at low temperatures. Prior to lyophilic drying, the tea US solution was poured into porcelain cups and frozen for 24 hours. Lyophilic drying is the process of dehydration and preservation of the product. The result of quantitative analysis of tea US extract is presented in Table 1.

The third stage included microencapsulation of dried green tea extract obtained at the second stage by lyophilic drying. The core of the capsules was green tea extract, and the wall materials were polysaccharides - gummiarabic and maltodextrin, which performed the function of protection. To perform the microencapsulation process, the coupling of the solution containing the active ingredient with the hydrocolloid solution was carried out [15]. The optimal ratios of components for microencapsulation obtained on the basis of mathematical modeling suggests the following values:

Capsule composition: wall material:core material, in % ratio 80:20,

Gummiarabic: maltodextrin, in % ratio 40:60,

Core material: distilled water, % ratio 20:80.

The resulting mixture was again subjected to lyophilic drying for 24 h to allow uniform drying of the entire surface of the hydrocolloid mixture in Iney-4. As a result, a cream colored MIA- finished powder was obtained with quantitative analysis values shown in Table 1.

To increase the availability of catechins in green tea can, also, the method of mechanochemical processing. In this case, the complete destruction of the tea leaf structure at the cellular level leads to a significant increase in the availability of phenolic compounds [16]. The following reagents were used for mechanoactivated tea additive (MAA):

1. Green tea "Azerchay" according to TU 9191-004- 63231717-2011
2. Ascorbic acid according to GOST 4815-76

For preparation of the additive by mechanochemical technology green tea leaves were subjected to processing in energy-intensive activator AГO-2. Mechanochemical processing was carried out for 2 minutes, the mass of the processed substance was 18 grams of green tea and 2 grams of ascorbic acid. Ascorbic acid prevents catechins from oxidizing due to the formation of mechanocomposite, reducing the oxidation rate of catechins 2 times. Parameters for mechanochemical activation were selected on the basis of previously available studies. Lomovsky I.O. in his dissertation "Mechanochemical reactions of phenolic compounds of plant origin and their technological" considered the detailed course of the mechanochemical activation process [16]. The parameters for the obtained tea mechanocomposite are also summarized in Table 1.

Table 1. Results of measuring the concentration of catechins in the mechanocomposite.

№	Name of the sample	EGC, mg/g	EGCG, mg/g	ECG, mg/g	Sum of catechins, mg/g
1	Tea US solution	67,3±4,2	63,7±5,9	11,5±0,9	142,5±10,9
2	Tea US Extract	171,6±3,2	109,6±2,6	23,6±0,5	304,8±11,3
3	MIA	27,36±3,2	17,5±2,6	3,77±0,5	50 ±11,3
4	MAA	80,1±3,2	87,4±2,6	16,9±0,5	184,4±11,3

Since flour products are most often selected for target fortification [17], we have chosen a variant of such products prepared without the use of raw materials of animal origin. Preliminary assessment of the assortment of sold products in a really operating bakery, carried out on the basis of ABC analysis, allowed us to choose as the object of study, as the most demanded category among the population - simits. Further on the basis of mathematical modeling we have developed project formulations of simits enriched with different variants of tea additive and pea protein. The concentration of pea protein (CP) introduction was 5 % of flour weight, and the concentration of tea additive was determined to cover 20 % of the daily requirement in antioxidants (200 mg/g). The study compared the performance of 4 simit samples: control sample; with maiechanoactivated additive (MAA), with microencapsulated additive (MIA), with microencapsulated additive and pea protein (MIA +CP).

3 Results and Discussion

Sample No. 2 c MAA showed negative organoleptic parameters in comparison with control sample No. 1 - acidic, tart and grassy taste and odor were felt. (Table 2). Also, according to the results of physico-chemical studies, the preservation of catechins was extremely low and amounted to 9%. The graph of organoleptic evaluation of simit with MAA is presented in Figure 1.

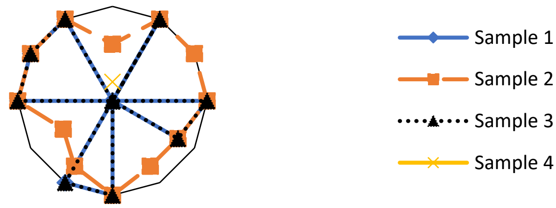

Fig. 1. Graph of organoleptic evaluation of simit. Sample 1 – CS, Sample 2 – MAA, Sample 3 – MIA, Sample 4 – MIA +CP.

The addition of MIA to sample #3 had no significant effect on sensory evaluation compared to control sample №1 (Figure 1).

The measurement of catechin concentration in the finished products revealed that catechins are labile to temperature. A series of samples were prepared with different temperature exposure and baking time, the best preservation result was found at 180 degrees for 25 minutes. The preservation of catechins in simits with MIA is 60-63%.

In sample № 4 with MIA +CP there were no changes in organoleptic parameters for the worse in contrast to the control sample № 1 and № 3.

The graph of organoleptic evaluation of simits with MIA +CP is presented in Figure 3.

Further we carried out a comparative assessment of nutritional value of the obtained samples of simites, which shows an increase in protein content in samples No. 2 and 3 compared to the control sample by 2.7%, and in sample No. 4 by 20.9% (Table 2).

Table 2. Nutritional value of simitic samples.

Product name	Protein, gr.	Far, gr.	Carbohydrate s , gr.	Calories, kcal
Sample №1 – Control sample	11,1	10,6	44,2	317,9
Sample №2 – MAA	11,4	10,8	42,5	313
Sample №3 – MIA	11,4	10,8	42,5	313
Sample №4 – MIA +CP	13,43	10,83	40,68	350

Comparative characterization on amino acid composition of samples №1 and №4 shown in Table 3 showed that in terms of amino acid composition sample №4 with MIA +CP differs from sample №1 maximally superior in isoleucine by 1.8%, lysine by 1.63% and by 1.38 for tryptophan, other amino acids more by 1.01-1.38%.

Table 3. Comparative characteristics of amino acid composition.

Amino acids	Amino acid content in ideal protein	Amino acid score in the sample №1, %	Amino acid score in the sample №4, %
Isoleucine	40	8,459302	15,9608
Valine	50	8,244186	11,40344
Leucine	70	9,634551	9,759629
lysine	55	4,471459	7,331827
Threonine	40	7,267442	9,751434

Table 3. Continued

Phenylalanine	60	13,09109	15,75526
Tyrosine			
Methionine	35	13,25581	16,27424
Cystine			
Tryptophan	10	13,13953	18,24092

4 Conclusions

In the course of the study, new plant-based bakery products were developed. Due to the introduction of MIA +CP a sample of products containing 20.9 % more protein than the control sample and covering the daily requirement for catechins by 20 % was obtained, which determines its significant antioxidant properties. In the course of the study it was found that the safety of catechins in simits with MIA (samples №3 and №4) is 60-63%, and in sample №2 with MAA only 9%, Losses may be due to the effect of oxidation, isomerization or epimerization of tea catechins at various stages of preparation. The obtained results indicate the expediency of using MIA in flour products subjected to baking in order to give them antioxidant properties, as it is less labile to temperature influence.

The conducted evaluation of organoleptic quality indicators and physicochemical studies showed that the adopted concentration of MIA is sufficient for the products to have the properties of functional purpose as antioxidant. Also, the developed products can be labeled according to the Technical Regulations of the Customs Union as "protein source" [18], because the amount of protein in it provides 15.3% of the energy value (caloric value) of 100 g of food products, and the protein content in 100 g of simit is capable of satisfying 20% of the daily requirement for average values for women of physical activity group 1 of age 18-64 years [19]. However, to achieve the label "high-protein product", especially to cover physiological norms for men, persons of other labor intensity groups or working in the Far North, the possibility of increasing the concentration of CP input should be further investigated. Also, the obtained values of amino acid scoring, although increased in the final enriched sample in comparison with the control sample, but still did not allow to achieve significant values in comparison with the ideal protein for any of the amino acids.

References

1. I. Ayesha, F. Borthwick, D. Bogueva, M. Eltholth, How the EAT–Lancet Commission on food, **7,** 1-12 (2023)
2. M. Henchion, M. Hayes, A. M. Mullen, M. Fenelon, B. Tiwari, Future Protein Supply and Demand, **6**, 7 (2017)
3. P. J. Moughan, Population protein intakes and food sustainability indices: The metrics matter, **29**, 929-932 (2021)
4. L. Hooper, A. Abdelhamid, D. Bunn, T. Brown, Healthy diet, **8**, 9 (2015)
5. P. Rajendran, N. Nandakumar, T. Rengarajan, Antioxidants and human diseases, **36**, 332-347 (2014)
6. J. Boye, F. Zare, A. Pletch, Pulse proteins: Processing, characterization, functional properties and applications in food and feed, **2**, 43 (2010)
7. S. D. Arntfield, H. D. Maskus, 9 - Peas and other legume proteins, **2**, 233-266 (2010)
8. C. Ducoli, M. Clementi, Food and Agriculture Organization of the United Nations **13**, 96 (2018)

9. S. Nisha, J. Priyanka, U. Megha, Langyan Sapna Escalate protein plates from legumes for sustainable human nutrition Frontiers in Nutrition, **9**, 16 (2022).
10. P. Kanu, Z. Kerui, Z. Ming, Sesame protein 11: Functional properties of sesame (Sesamum indicum L.) protein isolate as influenced by pH, temperature, time and ratio of flour to water during its production **2**, 289–301 (2018)
11. A. Idowu, A. Alashi, M. Nwachukwu, Functional properties of sesame (Sesamum indicum Linn) seed protein fractions. Food Prod Process and Nutr., **3**, 4 (2021)
12. O. Edwige, D. Zoénabo, C. Diarra, Physicochemical, potential nutritional, antioxidant and health properties of sesame seed oil: a review, Frontiers, **40**, 618 (2023)
13. D. Nijdam, G. Rood, H. Westhoek, Food Policy, **37**, 760–770 (2012)
14. A. Hoehnel, C. Axel, J. Bez, Comparative analysis of plant-based high-protein ingredients and their impact on quality of high-protein bread, **25**, 180–189 (2019)
15. L. Mayurnikova, E. Bychkova, I. Lomovsky, D. Belyakova, A. Bychkov, Methodology for the development of food products with increased antioxidant activity. Polzunovsky Bulletin, **4**, 90-96 (2021)
16. I. O. Lomovsky, Mechanochemical reactions of phenolic compounds of plant origin and their technological application: abstract of thesis, **97**, 557-563 (2018)
17. L. N. Rozhdestvenskyaya, Formation of the healthy food market in Russia, **5**, 83-89 (2018)
18. TR CU 022/2011 Food products regarding their labeling (2011)
19. Methodological recommendations MR 2.3.1.0253-21 “Norms of physiological needs for energy and nutrients for various groups of the population of the Russian Federation” (2021)