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CHANGES IN STRUCTURAL UNITS IN DOUGH AND BREAD FROM WHEAT FLOUR WITH THE ADDITION OF PUMPKIN CELLULOSE IN COMBINATION WITH PHOSPHOLIPIDS

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Abstract

Unfavorable ecological and food security situation in the world causes frequent spread of diseases of the gastrointestinal tract. In particular, the number of cases of irritable bowel syndrome is increasing, especially among the young working population. Diet therapy, which includes increasing the amount of dietary fiber in combination with phospholipids, is effective for the prevention of these diseases. A perspective raw material with a high content of dietary fibers is pumpkin cellulose, which can be added to the recipe of bakery products instead of part of wheat flour. The aim of the work was to find the effect of pumpkin cellulose in combination with sunflower lecithin on the conformational changes of the structure of dough and bread from wheat flour and the completeness of assimilation of products with this raw material by the organism. It was established that the infrared spectra of wheat flour, pumpkin cellulose and sunflower lecithin differ in reflection intensity and character. In the process of dough fermentation, the conformational transformations deepened with an increase in the amount of replacement of wheat flour with pumpkin cellulose, and the reflection coefficient increased. For bread samples, the reflectance coefficient was lower compared to dough, but there were almost no differences in the location of the spectra. In general, the biological value of samples of bread with additives was lower than the control sample, however, the high content of dietary fibers in pumpkin cellulose makes it a promising raw material for enriching bakery products with a valuable nutrient and giving bread health properties. The rational amount of replacing wheat flour with pumpkin cellulose is no more than 7 %, taking into account the decrease in the biological value of bread with this raw material.

Keywords: bread, pumpkin cellulose, lecithin, infrared spectroscopy, dough, biological value, irritable bowel syndrome, fiber, wheat flour, protein.

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1. Introduction

Unfavorable ecological and food security situation in the world causes frequent spread of diseases of the gastrointestinal tract. In particular, the amount of cases of irritable bowel syndrome (IBS) is increasing, especially among the young working population [1].

It is manifested by peristalsis disorders, abdominal pain while the known organic pathology is absent and is not conditioned by organic or biochemical changes [2]. The prevalence of IBS ranges from 14 to 48 patients per 100000 population (about 11 % of the global population). This problem is global, because according to statistical data, even in highly developed countries, such diseases take the 2nd place as a cause of disability. IBS is associated with lower socioeconomic status, because lower income is associated with poorer health care, lower overall quality of life and increased life stress factors [3].

The recommended method of prevention and reduction of morbidity is diet therapy [4]. The FODMAP diet is based on the minimization or reduction products with a high carbohydrate content and their replacement in the diet. The acronym FODMAP means a group of fermentable (F) carbohydrates – oligo-(O), di-(D) and monosaccharaides (M), and (A) polyols (P). Absorbed carbohydrates are actively fermented by bacteria of the large and small intestine with the formation of gases – hydrogen and methane. Some of them are characterized by high osmotic activity, which mostly leads to the movement of liquid into the intestinal space [5].

Products with a high FODMAP content are replaced by alternative foods, particularly rich in fiber [6]. One of these products is pumpkin and its processed products.

Such raw materials can be used in various branches of the food industry, in particular in the bakery industry. Bakery industry provides part of the human diet with useful nutrients. But due to the changes in nutrition priorities the production of bread requires significant revision and improvement and adding pumpkin by-products is perspective direction.

A comprehensive analysis of the nutritional value, mineral and vitamin complexes of raw materials and bread with the addition of pumpkin puree was carried out, which is necessary for further substantiation of the development of technology for the manufacturing of new types of bakery products, expansion of the product range and satisfaction of various consumer needs. It was established that the addition of pumpkin puree practically does not affect the amount of washed gluten. However, when dosing pumpkin puree from 5 to 25 %, the gluten deformation index increased from 68.5 to 94.7 units. Based on this, it is possible to regulate the content of nutrients, minerals, vitamins during the technological process of alteration raw materials and preparing bread with additives [7].

The use of pumpkin seed milk in the amount from 0 to 40 ml for the production of wheat flour bread was studied. The content of crude protein, crude fiber, ash, carbohydrates, and energy value of the bread gradually increased with the increase in the proportion of pumpkin seed milk, with 40 ml having the highest values: 12.50 % protein, 6.40 % fat, 2.20 % crude fiber, 2.65 % ash, 63.25 % carbohydrates and 360.60 kcal, respectively, while the lowest values were recorded for the unsupplemented control sample. It was established that there were no noticeable differences in the specific volume, porosity, and dimensional stability of bread with different dosages of milk from pumpkin seeds. There were significant differences between control and enriched bread in all sensory attributes. Thus, bread with pumpkin seed milk had the highest hedonic mean scores for all tested sensory parameters [8].

The effects of pumpkin powder (12 %) and basil seed gum (0.00 %, 0.50 %, 1.00 % and 1.50 %) on the physicochemical, rheological, textural properties and sensory parameters of bread were evaluated. Fresh pumpkin slices (thickness was 5 mm) were dried (hot air, 65 °C), and the samples were ground into powder. The dough showed pseudoplastic and thixotropic behavior. Dough viscosity increased from 10.95 to 21.53 as the percentage of basil seed gum increased from 0.00 % to 1.50 %. The density of baked bread decreased from 880.10 to 692.45 kg/m^3. The volume of bread increased, and during baking it decreased. Bread with pumpkin powder and 1.5 % basil seed gum had the best porosity and appearance, while bread with 1 % was the most satisfactory in terms of textural properties [9].

High in protein pumpkin seeds can be used to improve wheat bread protein profile and modify bread properties. A study was conducted on the inclusion of pumpkin seed flour in whole grain bread. Physical and sensory properties showed that replacing 5 %, 10 % and 15 % of whole wheat flour with pumpkin seed flour improved bread properties. The study showed high values of bread volume (485 ml), specific volume (1.9 ml/g) and lower baking losses (7.42 %) when adding 15 % pumpkin flour. Bread with a 15 % additive had a high crude protein content (12.22 %). However, whole grain bread made with 10 % pumpkin seed flour had higher acceptability compared to the control and other bread recipes [10].

There is little information in in literary sources about the inclusion of pumpkin cellulose in wheat bread recipes, so this direction is relevant, especially considering that this raw material is rich in dietary fibers and is considered to be food waste. Its use will contribute to compliance with the concept of sustainable production development.

The use of phospholipids is also important in the diet, because they participate in the formation of the layer of intestinal mucin, which plays protective role [11].

The aim of the work was to find the effect of pumpkin cellulose in combination with sunflower lecithin on the conformational changes of the structure of dough and bread from wheat flour and the completeness of assimilation of products with this raw material by the organism.

2. Materials and Methods

2. 1. Object of research

Research was conducted with raw materials, semi-finished products and baked bread. The analyzed raw materials were wheat flour of the highest grade, pumpkin cellulose and sunflower lecithin. The dough was prepared from wheat flour, pressed baker's yeast and salt. Sunflower lecithin was included in the amount of 3 %, based on the recommendations of the daily rate for lecithin for people who suffer from diseases of the gastrointestinal tract [12]. Replacement of wheat flour with pumpkin cellulose was carried out in the amount of 5 %, 7 %, 10 % and 15 %. A sample without pumpkin cellulose and sunflower lecithin was the control sample.

2. 2. Protein content

Kjeldahl method was used for evaluation of protein content. This method involves the digestion of food with a strong sulfuric acid, after this process nitrogen is released, which is then determined quantitatively using a titration technique. This is considered to be the standard method for protein measurement. 1 g of raw material was hydrolyzed with 15 mL of acid for 2 h in a heat block at 420 °C. Copper tablets were used as process catalyst. After this hydrolysate was cooled and distilled H_2O was added before neutralization and titration. Protein quantity is then calculated from the nitrogen concentration of the food using a conversion factor (usually 6.25 which is equivalent to 0.16 g nitrogen per gram of protein) and was expressed as g proteins per 100 g of flour [13].

2. 3. Fiber

Method of extended enzymatic digestion was used to determine the total dietary fiber. Digestion was conducted at 37 °C to simulate intestinal digestion followed by gravimetric isolation and determination amount of total dietary fiber [14]. Content of total dietary fiber was calculated as the mass of the residue minus the weight of ash and protein [15].

2. 4. Biological value of bread

Biological value of bread includes several indicators: utilitarian coefficient, redundancy coefficient, DCAS and biological value in general.

Utilitarian coefficient is the conformity of essential amino acids (EAA) in proteins to physiological norm:

$$U = \frac{C_{\min} \cdot \sum_{j=1}^{8} A_{ej}}{\sum_{j=1}^{8} A_j}, \tag{1}$$

where $C_{\min}$ is score of the first limited acid; A_j is the content of the j-th of EAA in the product, mg/g protein; A_{ej} is the content of the j-th of EAA in the protein model, mg/g protein (FAO/WHO scale).

Redundancy coefficient means the completeness of use protein:

$$\sigma_{red} = \frac{\sum_{j=1}^{k} \left(A_j - C_{\min} \cdot A_{ej} \right)}{C_{\min}}. \tag{2}$$

DCAS is coefficient of difference of amino acid score. It was calculated by the formula:

$$DCAS = \frac{\sum \Delta DAS}{n}, \quad (3)$$

where *DAS* is the difference in amino acid score for each *EAA* compared to the amino acid score of a limiting amino acid, %; *n* – the number of amino acids.

Biological value was calculated by the formula:

$$BV = 100 - DCAS, \quad (4)$$

where *BV* is the biological value of the protein expresses as % [16].

2. 5. Near-infrared reflection spectroscopy

The basic principle of reflectance spectroscopy in the near-infrared region of the spectrum is to evaluate the diffuse reflection that occurs during the penetration of optical radiation through the surface layer of the sample, the excitation of the vibrational modes of the analyzed molecules, and the scattering of optical radiation in all directions. The reflectance spectra of ground samples with a smooth surface were studied on an Infrapid spectrometer (Labor-Mim, Hungary) in the wavelength range from 1330 to 2370 nm. The spectrometer recorded the reflection spectrum from the standard and from the sample under study. The spectra are expressed in relative units and presented as reflectance R, depending on the wavelength [17, 18]. The intensity of reflection was measured in raw materials, dough after kneading and after 3.5 hours of fermentation, and in bread. The reflection intensity was expressed by recalculating the relative reflection coefficient to the spectral index [19].

2. 6. Statistical analysis

The obtained results were presented as average data after repeating the experiments 3 times± ±standard deviation. Graphical presentation of experimental data was made in Microsoft Excel 2010.

3. Results and Discussion

Key role in the technological process of producing bakery products belongs to the dough, which is a complex system with different characteristics, depending on the used raw materials. Raw materials play a decisive role in forming structure, properties of the dough system and accordingly the quality of bread. Chemical composition of wheat flour and pumpkin cellulose is significantly different. Fiber has an increased content of protein – 42.1 % and dietary fiber – 32.2 % compared to wheat flour – 11.3 % and 3.5 %, respectively. The composition of sunflower lecithin mainly includes lipids, the most part of which is phosphatidylcholine. Changes in the composition of recipe components lead to changes in the properties of the dough, in particular the gluten framework, during the fermentation process.

To identify and analyze the main nutrients in raw materials and their influence on processes in dough and bread, it is advisable to provide research using the reflection spectrum in the near-infrared region [20]. The infrared reflection spectra of wheat flour, pumpkin cellulose and sunflower lecithin are showed in **Fig. 1.**

Obtained results showed, that the spectrum of wheat flour had a higher reflection intensity than the spectrum of pumpkin cellulose, and the spectrum of sunflower lecithin was located between them. At the same time, the spectra of wheat flour and pumpkin cellulose had a more similar character than that of sunflower lecithin, but each of them was special. Mostly, the spectra of wheat flour and pumpkin cellulose were characterized by extremes located at the same wavelengths, but there were also significant differences that indicate the different chemical composition of the studied types of raw materials.

In the analyzed wavelength range of 1330–2370 nm, the first minimum of reflection intensity for sunflower lecithin was at 1450 nm, for wheat flour – at 1460 nm, and for pumpkin cellulose this extremum shifted to 1500 nm. The next common minimum for sunflower lecithin and pumpkin cellulose was at wavelength of 1720 nm, which did not appear at all in the spectrum of wheat flour. This length is related to lipid components and indicates the absorption of carbonyl esters of fats.

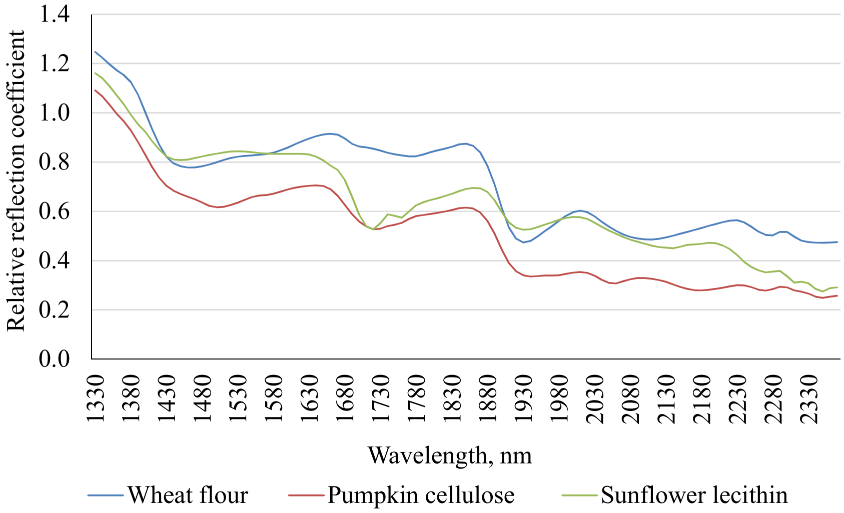

Fig. 1. Reflectance spectra of wheat flour, pumpkin cellulose and sunflower lecithin in the near infrared region

At a wavelength of 1740 nm, the spectrum of sunflower lecithin had a maximum reflection intensity, the spectrum of wheat flour had a barely noticeable distortion at this wavelength, which was not observed in the spectrum of pumpkin cellulose. This is explained by the presence of choline in lecithin in large quantities, a slightly lower content in wheat flour, and it is absent in pumpkin cellulose.

The minimum reflectance characteristic for moisture lies at a wavelength of 1930 nm, and indicates the lowest moisture content in lecithin, slightly higher in wheat flour and higher in pumpkin cellulose.

At a wavelength of 2100 nm, the spectrum of pumpkin cellulose showed, although insignificant, but a maximum of reflection intensity, wheat flour – a minimum, and the spectrum of sunflower lecithin continued to decrease slowly, which indicates the absence of protein in it, which is present in samples of flour and pumpkin cellulose [21].

The wavelength of 2180 nm was the reflection minimum for pumpkin cellulose, which was not characteristic of the other two spectra – wheat flour and sunflower lecithin, which grew slowly. At this wavelength, the protein content is characterized, avoiding the influence of starch. That is, due to the absence of protein in lecithin and the presence of starch in wheat flour, it is impossible to detect protein groups at this wavelength.

The minima of reflection intensity, which are present only in the spectrum of lecithin, appeared at wavelengths of 2310 and 2350 nm and characterize lipid groups due to its lipid nature.

The obtained results indicate a different chemical composition of the wheat flour compared to lecithin and pumpkin cellulose, and therefore it is possible to predict an effect of pumpkin cellulose and lecithin on the redistribution of the main structural units of bread and dough with these components in the recipe. The dough system has springy-elastic and visco-plastic properties, therefore it is advisable to determine the influence of the studied raw materials on their change. The obtained reflection spectra of dough were compared immediately after mixing (**Fig. 2**).

According to the location of the curves, the reflection spectra of all dough samples practically overlap one another. However, there is a direct legitimacy in the location of the spectra of dough samples with pumpkin cellulose of different concentrations to replace wheat flour: the lowest spectrum is of the control sample of dough, above it is spectrum with 5, 7, 10 and 15 % replacement, however this regularity is hardly noticeable. The absence of significant visible changes can be explained by the absence of transformations in the test system. After all, it takes more time to start the interaction of biopolymers of raw materials. At the wavelength of 1930 nm, that characterizes the presence of moisture in the dough, there is a minimum extremum for all dough samples, at which the difference in reflectance is most noticeable. This is because pumpkin cellulose has a higher water absorption ability than flour, due to which, in case of the same dosage of water in dough, its absorption and binding will be much higher. That is, at the stage of mixing, the samples have no significant differences from a technological point of view. The wavelengths of 1720, 1760 nm, 2310 nm and 2350 nm, characterize the lipid groups and the extrema of the lecithin sample present at them. There were no extrema detected in the spectra of the dough. It is explained by the fact that the amount of lecithin in the dough is too small to show its influence on the conformations in the system, and the main properties of the dough are determined by the properties of the main component of it – flour.

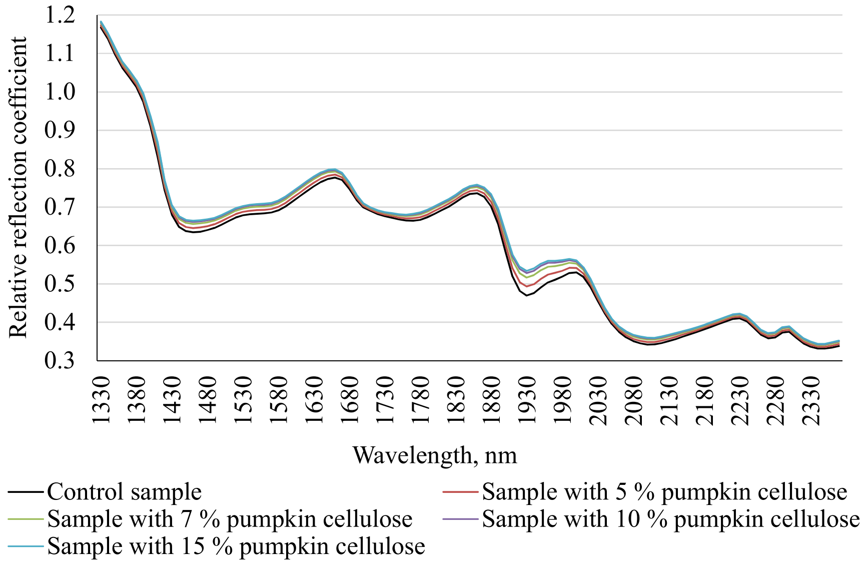

Fig. 2. Infrared spectra of dough samples with pumpkin cellulose (5, 7, 10 and 15 % replacement) after kneading

In the process of the dough fermentation during 3.5 hours, the components of the recipe get into stronger bonds, providing its structure and stimulating physico-chemical and colloidal processes. They will be affected by added pumpkin cellulose and lecithin (**Fig. 3**).

As opposed to the reflection spectra of dough obtained immediately after kneading, after fermentation there were noticeable changes in all analyzed spectra: their intensity differed depending on the percentage of replacement of wheat flour with pumpkin cellulose, although the spectra preserved their legitimacy of location. This indicates that the influence of different amounts on the processes in the dough during fermentation is constant, regardless of their amount. But, quantitatively, the difference was significant. Thus, the greater the replacement of wheat flour with pumpkin cellulose, the more the reflection coefficient increased. Accordingly, this spectrum was located higher than the spectrum of the control sample of the dough. The wavelength of 2100 nm characterizes protein structural groups. A minimum extremum for all samples appeared on it, the value of the relative reflection coefficient of the control sample was 0.24, of samples with 5, 7, 10, and 15 % substitution – 0.28, 0.32, 0.34, and 0.35, respectively. Such a position of minimums is explained by the fact that pumpkin cellulose has no gluten proteins and does not take part in the formation of gluten. Instead, its fiber is embedded in the gluten framework formed by the gliadins and glutenins of wheat flour and delays its development. Due to the large content of dietary fiber in pumpkin cellulose, it can be predicted weakening of the protein matrix of the dough.

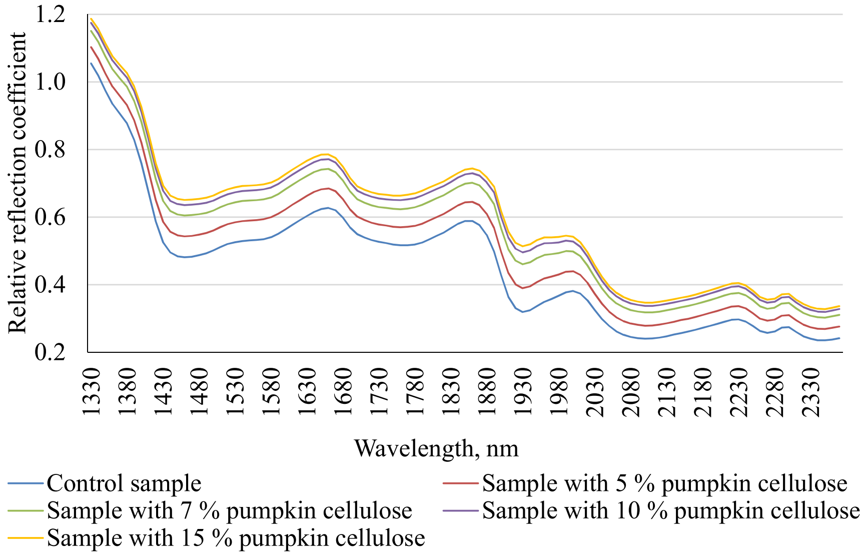

Fig. 3. Infrared spectra of dough samples with pumpkin cellulose (5, 7, 10 and 15 % replacement) after 3.5 hours of fermentation

Since changes in the dough were established during fermentation, they should be expected in the process of bread baking. All the reflectance spectra of the bread samples (both control and with 5, 7, 10 and 15 % pumpkin cellulose replacement) after baking had the same character and in the studied region of wavelengths almost overlapped each other (**Fig. 4**).

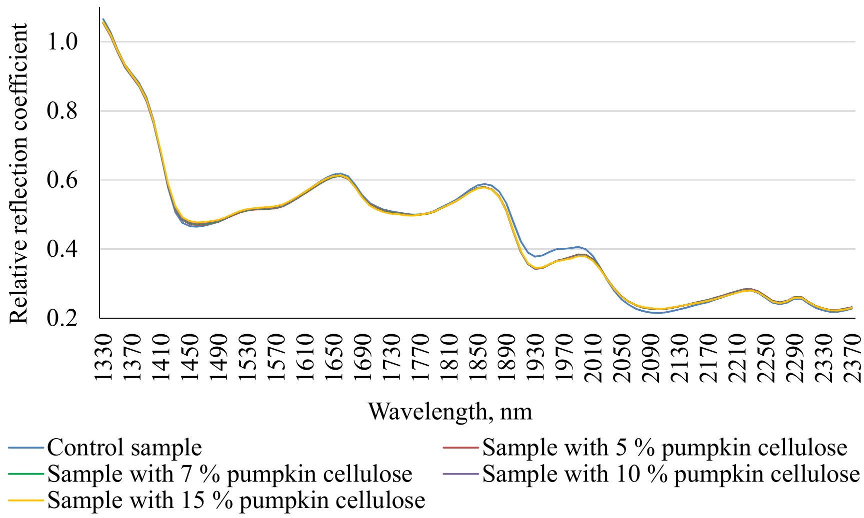

Fig. 4. Infrared spectra bread with pumpkin cellulose (5, 7, 10 and 15 % replacement)

The parameters of the baking process as the final stage in the production of bread significantly affect the structure of the dough and its properties. In contrast to the spectra of the dough samples after fermentation, where a significant difference between the intensity of reflection was observed, there were almost no differences in the reflection index for the bread samples. This is explained by the influence of high temperatures during baking on the state of biopolymers of raw materials in the dough system, in particular, gelatinization and decomposition of starch, destruction of protein macromolecules [22].

In quantitative terms, the reflection coefficient of bread spectra was lower than the reflection coefficient of dough samples both after kneading and during fermentation. At a wavelength of 2100 nm, the reflectance coefficient was 0.21–0.23 for bread, while for dough samples after fermentation it was higher than 0.25, and after kneading it was higher than 0.35.

The data on the conformational transformations of the structural elements of the dough with pumpkin cellulose and sunflower lecithin allow to predict the difference in the assimilation of bakery products with these raw materials in the recipe. To do this, the utilitarian coefficient, the redundancy coefficient, DCAS and biological value were calculated (**Table 1**).

Table 1

Utilitarian coefficient, redundancy coefficient, DCAS and biological value products when replacing part of the wheat flour by pumpkin cellulose

Indicators	Control sample	Sample with lecithin	Pumpkin cellulose to replace wheat flour, %			
			5	7	10	15
Utilitarian coefficient	0.49±0.01	0.49±0.01	0.38±0.01	0.36±0.01	0.33±0.01	0.30±0.01
Redundancy coefficient	37.25±1.11	37.25±1.11	57.51±1.27	63.84±1.32	71.98±2.01	82.84±2.09
DCAS	0.47±0.01	0.47±0.01	0.89±0.01	1.03±0.01	1.22±0.01	1.49±0.01
Biological value (%)	99.53±2.49	99.53±2.49	99.11±2.42	98.97±2.38	98.78±2.30	98.51±2.26

Note: results given as: M±SD (mean±standard deviation) of triplicate trials.

It was established that the balance of essential amino acids in relation to the physiologically necessary norm was the highest in the control sample, with the increase in replacement it significantly decreased – by 22.5–38.7 %. The protein of bread in the control is more fully used by the body for anabolic needs, as evidenced by the coefficient of redundancy of the samples. As the replacement percentage increased, the DCAS indicator increased too. This indicates that the amino acids contained in the control are more fully used by the body than when the supplement is applied. In general, the biological value of the control sample was slightly higher than of bread with pumpkin cellulose, but this increase was insignificant.

In view of the obtained results, the rational amount of replacing wheat flour with pumpkin cellulose is no more than 7 %, taking into account the decrease in the biological value of bread with this raw material.

The obtained results allow to follow changes during the bread-making technological process for obtaining bread with dietary properties. They can be used for the development of recipes of products for special purpose with pumpkin cellulose as raw material rich in fiber. The direction of providing future studies is to carry out research on rheological characteristics in dough systems with pumpkin cellulose and bread quality indicators.

Restrictions when conducting research concerned martial law conditions in Ukraine due to the impossibility of conducting research during an air raid, which delayed the timing of their conduct and processing of results.

4. Conclusions

The expedience of replacing part of the wheat flour by pumpkin cellulose in the recipe of bakery products, as well as its introduction in combination with lecithin, was found in order to expand the range of bread for patients with irritable bowel syndrome and in view of the need to increase the fiber content in their diet, because the content of dietary fibers in pumpkin cellulose is 9.3 times higher.

It was established that the infrared spectra of wheat flour, pumpkin cellulose and sunflower lecithin differ in reflection intensity and character. In the process of dough fermentation, the conformational transformations deepened with an increase in the amount of replacement of wheat flour with pumpkin cellulose, and the reflection coefficient increased. For bread samples, the reflectance coefficient was lower compared to dough, but there were almost no differences in the location of the spectra. It was established that the proteins of bread with pumpkin cellulose will be absorbed worse, since the degree of balance of essential amino acids decreased with an increase in its dosage. In general, the biological value of the control sample was higher than the samples of bread with additives, however, the high content of dietary fibers in pumpkin cellulose makes it a promising raw material for enriching bakery products with a valuable nutrient and giving bread health properties.

The rational amount of replacing wheat flour with pumpkin cellulose is no more than 7 %, taking into account the decrease in the biological value of bread with this raw material.

Conflict of Interest

The authors declare that there is no conflict of interest in relation to this paper, as well as the published research results, including the financial aspects of conducting the research, obtaining and using its results, as well as any non-financial personal relationships.

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The study was performed without financial support.

Data availability

Manuscript has no associated data.

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