ISSN 2409–4951(Online)
ISSN 2310–1008 (Print)

Ukrainian Journal of Food Science

Volume 11, Issue 1
2023

Kyiv 2023

Ukrainian Journal of Food Science publishes original research articles, short communications, review papers, news and literature reviews.

Topics coverage:

Food engineering	Food nanotechnologies
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Ukrainian Journal of Food Science is Abstracted and indexated by bases:

EBSCO (2013)
Google Scholar (2013)
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Directory of Open Access scholarly Resources (ROAD) (2014)
CAS Source Index (CASSI) (2016)
FSTA (Food Science and Technology Abstracts) (2018)

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Editorial

The Ukrainian Journal of Food Science is published in challenging times to present new research in food science to the world scientific community and contribute to the solving of human nutrition issues.

Russian terrorists are destroying the chain of production and transportation of grain products in Ukraine. They are mining fruitful fields, collapsing the agricultural equipment and plundering harvests. Russian missile and drone attacks are constantly destroying grain storage facilities and port infrastructure along the Black Sea and Danube coasts. Russian military blew up the Kakhovka hydroelectric power station, and cargo transportation along the Dnipro including harvested grain now is impossible. Many food industry enterprises were damaged or totally destroyed.

In these conditions, Ukrainian scientists continue to work on research related to solving pressing problems of food production. Ukraine appreciates the support of the civilized world. We also appreciate the support of the scientific community and thanks to the support of the Editorail Board members. We gratefully accept the constructive remarks and constantly work on improving of the Journal.

We wish our respected authors, members of the editorial board and readers new creative achievements, and sincerely thank for support and attention to Ukrainian Journal of Food Science.

We all stand together!

Editor-in-Chief,
Dr. Victor Stabnikov

DOI: 10.24263/2310-1008-2023-11-1-3

Influence of rice protein concentrate on redistribution of structural groups in the production of wheat bread

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Keywords:

Bread
Dough
Wheat
Rice
Protein

Article history:

Received 16.01.2023
Received in revised form 27.05.2023
Accepted 07.07.2023

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DOI: 10.24263/2310-1008-2023-11-1-4

Abstract

Introduction. The aim of the research was to determine the effect of rice protein concentrate on conformational changes in the structural units of wheat dough and bread.

Materials and methods. Functional and technological properties of rice protein concentrate were determined by centrifugation method. Conformational transformations of structural groups in the dough after kneading and during the fermentation process and of bread were investigated by method of infrared spectroscopy in the near-infrared region.

Results and discussion. The protein content in rice protein concentrate was 6.6 times higher than that of premium wheat flour. Rice protein concentrate was coarser than wheat flour of the second grade, but finer than wholemeal wheat flour. This was evidenced by the fact that there was no residue on a sieve with holes of 670 μm, and the passage through a sieve with holes of 160 μm was greater than the standard value for wheat flour of the second grade, but less than the standard value for wholemeal flour. The moisture binding and fat binding capacity of rice protein concentrate was 4.3 and 1.7 times higher than that of wheat flour, and its moisture retaining capacity was 1.8 times higher. The infrared spectra of dough and bread showed that the difference in the chemical composition and functional and technological properties of wheat flour and rice protein concentrate affected the change of the basic structural units of dough and bread. The addition of rice protein concentrate delayed the development of the gluten network, but had a positive effect on the dough's ability to keep its shape. The addition of rice protein concentrate in amounts of 4-16% to the mass of flour had practically no effect on the digestion of bread.

Conclusions. The addition of rice protein concentrate with a higher protein content than wheat flour and with different fractional composition to the recipe of wheat bread affected the structural elements of the dough and the structural and mechanical properties of bread. In addition, it can significantly enrich bread with complete protein.

Introduction

One of the most important nutrients in food products is protein (Małecki et al., 2021). Its content in bread made from wheat flour is quite low. In addition, it is inferior in the composition of essential amino acids and is absorbed at a low level (Eleazu et al., 2014). Therefore, a promising direction is to enrich wheat bread with protein by adding raw materials with a high protein content to the recipe.

Animal sources of protein, such as casein, albumin, and whey proteins, were used in bakery production. However, animal proteins can be allergens. An alternative was plant proteins in the form of concentrates, isolates, hydrolyzates.

The use of rice protein as a hypoallergenic raw material was promising (Pantoa et al., 2020). Protein isolates obtained from various stabilized rice bran were analyzed. Bulk density was higher for isolates obtained from heat-stabilized bran, because the treatment positively affected the fat absorption capacity, while the water absorption capacity decreased due to configurational changes in the protein structure. The isolates had better foaming properties due to the flexible nature of the protein molecules with less intense disulfide bonding. The nitrogen solubility index had a curved pattern with the lowest value near the isoelectric point, which showed a tendency to increase the basic pH, and steamed protein isolates showed better gelling properties (Khan et al., 2011).

To obtain rice protein concentrate, alkaline extraction of rice bran was applied. It was established that the optimal extraction conditions were pH 11 and a duration of 45 min, which led to the extraction of 69.16% of the total protein. When adding 1-5% of the concentrate to the bread recipe, weight loss after baking was reduced compared to the control without rice protein concentrate. However, sensory evaluation showed that the addition of more than 1% protein worsened sensory parameters. An important characteristic of rice bran protein was that it contained a large amount of lysine, an essential amino acid that was limiting in wheat flour, so it was able to enrich the amino acid profile of bread (Jiamyangyuen et al., 2005).

The methods of electrophoresis and infrared spectroscopy were used to study the chemical composition, digestibility and structure of protein. It was found that during acetylation of rice protein concentrate, the protein content increased (80.90–83.10 g/100 g versus 74.20 g/100 g in the control without acetylation). It was found that during acetylation, the content of the main fractions of rice proteins (prolamin and glutelin) decreased. Using spectroscopic analysis, wave numbers corresponding to the presence of proteins or lipids, aromatic systems, and carbohydrates were observed. The use of acetic anhydride did not significantly change the digestibility of rice protein concentrate compared to the control sample. Acetylation of rice protein concentrate resulted in a significant increase in its emulsifying properties and water binding capacity, but had no effect on fat absorption capacity. An increase in protein solubility and decrease in foaming capacity were observed (Miedzianka et al., 2023).

Physicochemical and structural properties of concentrated rice bran protein and rice bran protein fractions – albumin, globulin, prolamin, glutelin, were studied by the method of multiple extraction. The amino acid composition of the concentrated protein was superior to soy protein isolates with similar solubility, emulsification and foaming characteristics. Dichroism spectra in synergy showed that the primary structures were in the form of β-helices and random helices with different denaturation temperatures (Wang et al., 2015).

Due to the influence of rice concentrates on dough and bread structure the aim of the research was to determine the effect of rice protein concentrate on conformational changes in the structural units of wheat dough and bread.

Materials and methods

Materials

Premium wheat flour and rice protein concentrate were materials for research.

Dough was prepared from wheat flour, pressed baker's yeast in the amount of 3% by weight of flour and salt in the amount of 1.5% by weight of flour (control sample). Samples were also prepared with the addition of 5% and 16% rice protein concentrate to the weight of wheat flour to provide 20 and 40% of the daily protein requirement.

Moisture

The moisture content in wheat flour and rice protein concentrate was determined using the SuperPoint moisture meter. After switching on the device there was selected the appropriate type of measuring sample or product on the LCD screen. Sample was put into the bowl of the device to fill it, the pressure cover of the pressurizes to the level until the pressure indicator is set to the level with the upper surface of the lid. It took 10 seconds to obtain the result of the measurements. Measurement is carried out with an accuracy of 0.5% with a range of moisture content measurement from 8 to 45% (Hetman et al., 2021).

Total protein content

Total protein content was measured by Kjeldahl method (burning sample with concentrated sulfuric acid) and titration of the obtained liquid. 1 g of raw material was hydrolyzed with 15 ml concentrated sulfuric acid during 2 h in a heat block at 420 °C. Two copper tablets were added as catalyst. After cooling before neutralization and titration, distilled H_2O was added to the hydrolysates. The amount of protein was calculated taking into account the nitrogen concentration in the product. Data was expressed as g proteins per 100 g of flour (Shevchenko et. al, 2022).

Fat content

Fat content in wheat flour and rice protein concentrate was by the Soxhlet method. The sample was placed in the extraction chamber. The solvent was put to the flask and when it was heated, the solvent was evaporated and moved up to the condenser. Then it was converted into a liquid and collected into the extraction chamber with the sample. When the solvent passed through the sample, it extracted fats and carried them into the flask. Extraction took 6–24 h hours. After completion of the extraction, the solvent was evaporated, and the amount of the remaining lipid was measured (López-Bascón and de Castro, 2020).

Size of the flour particles

The size of the flour particles was determined by sieving on sieves. Sieves of different sieve fabric and different hole sizes were used: N 33/36 (35) (220 μm), N 27 (260 μm), N-067 (670), N 49/52 PA (43) (132 μm), N 41/43 (38) (160 μm) (Patwa et al., 2014).

Moisture binding and retaining capacity

The centrifugation method was used for determination of moisture binding and retaining capacity. For determination moisture binding capacity, 0.5 g of raw material was placed in pre-weighed centrifuge tubes, 50 ml of distilled water was added, and tubes were centrifuged at 3500 rpm for 10 minutes. The excess water was drained, the raw materials in the test tubes were dried and weighed.

Moisture binding capacity (MBC) was calculated by the formula:

$$MBC=\frac{m_1}{m_2}\cdot 100,$$

where m_1 – weight of precipitate, g;

m_2 – weight of original flour, g.

For determination the moisture retaining capacity the same method was used. The study differed in that after adding water, the mixture was placed in a water bath for heating for 30 minutes.

Moisture retaining capacity (MRC) was calculated by the formula:

$$MRC=\frac{m_1 - m_2}{m}\cdot 100,$$

where m_1 – weight of tube with flour and water retained, g;

m_2 – weight of tube with flour, g;

m – weight of flour, g (Shevchenko and Litvynchuk, 2022).

Fat binding capacity

The centrifugation method was used for determination of fat binding capacity. The method of determination was the same as in case of the determination of moisture binding capacity, but instead of water, 15 ml of refined sunflower oil was added.

Fat binding capacity (FBC, %) was determined by the formula:

$$FBC = F_1 - F_2$$

where F_1 – fat content in the flour suspension, %;

F_2 – amount of fat released after centrifugation, % (Suriano et al., 2017):

Near-infrared reflection spectroscopy

Infrapid spectrometer (Labor-Mim, Hungary) was used to research the reflection spectra from shredded samples of dough and bread with a smooth surface in near infrared range from 1330 to 2370 nm. Firstly, the spectrometer recorded the reflectance spectrum from reference I0, secondly a reflection spectrum from the researched sample. The spectra are represented as the reflectivity of R in relative units (the ratio of the intensities I/I0 = R), depending on the wavelength in nm. The intensity of reflection was measured in wheat flour, oat bran, lecithin, in dough after kneading and after 3.5 hours of fermentation and in bread. The reflection intensity was expressed through the recalculation of relative reflection coefficient to spectral index (Yip et. al, 2012).

Statistical analysis

The data represents the mean of a minimum three replicates ± standard deviation (S.D.). Graphical presentation of experimental data was performed using standard statistical processing programs – Microsoft Excel 2010.

Results and discussion

Chemical composition of the recipe ingredients was the basis of the formation of the properties of the dough for bakery products (Table 1). The protein content of rice protein concentrate was 6.6 times higher than that of wheat flour. This indicated that such raw materials can significantly enrich products with protein.

Table 1

Chemical composition of rice protein concentrate and wheat flour of premium grade, % per 100 g of raw material

Indicator	Wheat flour of premium grade	Rice protein concentrate
Moisture, %	11.5±0.5	5.1±0.5
Protein, g	11.3±0.5	74.2±0.5
Fat, g	1.1±0.01	4.4±0.01

In addition to the chemical composition of raw materials, the properties of semi-finished products and bread were influenced by the granulometric composition and functional and technological properties of raw materials.

It was established (Table 2) that 96% of the particles of wheat flour of premium grade passed through a sieve with holes of 132 microns.

Table 2

Particle size of rice protein concentrate and wheat flour

Size indicators, No of sieve	Hole size, µm	Wheat flour, variety			Rice protein concentrate
		First	Second	Wholemeal	
The residue on sieve %, no more:					
No 33/36 (35)	220	2	-	-	18.4
No 27	260	-	2	-	4.9
No 067	670	-	-	2	-
Passage through a sieve, % no less:					
No 49/52 ПА (43)	132	80	-	-	4.08
No 41/43 (38)	160	-	65	35	56.2

Rice protein was coarser than wheat flour of the second grade, but finer than wheat wholemeal flour. This was evidenced by the fact that when examining the rice protein concentrate, there was no residue on a sieve with holes of 670 µm, and the passage through a sieve with dimensions of 160 µm was greater than the standard value for wheat flour of the second grade, but less than the for wholemeal flour.

Functional and technological properties of raw materials determined the behavior of dough during processing and characterized the ability to bind moisture and fat (Berton et al., 2002).These indicators influenced ability to form viscoelastic dough, which is important for obtaining high quality bread, and provided necessary structure and technological properties (Tsykhanovska, 2019).

It was found (Table 1) that the moisture binding and fat binding capacity of rice protein concentrate was higher. This was due to the fractional composition of the proteins of this raw material, since the proteins of the concentrate had better adsorbing properties.

Table 3

Functional and technological properties of rice protein concentrate and wheat flour

Indicator	Premium wheat flour	Rice protein concentrate
Moisture binding capacity, %	90.7±2.13	392±2.90
Moisture retaining capacity, %	148±2.89	272±2.46
Fat binding capacity, %	146±2.06	243±2.86

The increase in the moisture retaining capacity of rice protein concentrate compared to wheat flour was explained by the release of side polar groups of rice protein which had hydrophilic properties (Jayaprakash et al., 2022).

The difference in the chemical composition and functional and technological properties of wheat flour and rice protein concentrate should affect the change of the structural units of dough and bread with these components in the recipe. It was also known that the fractional composition of rice protein was significantly different from wheat protein, primarily due to the absence of gluten proteins in it. This will affect the formation of structural and mechanical properties of the dough and changes in its structural elements.

The analysis of the change and redistribution of structural groups after kneading the dough, after 3.5 hours of its fermentation and finished bread was carried out by the method of infrared spectroscopy by calculating the reflection coefficient on the spectral index (Figure 1 and Figure 2).

The values of maxima at wavelengths of 1460 nm, 1770 nm, 1930 nm, 2100 nm, 2270 nm and 2350 nm were determined, which were the same for all spectra (both control samples and with the addition of 4% rice protein concentrate). The difference in the values of the relative reflection coefficient in the spectra of the dough of the control sample after kneading and the sample with the addition of 4% rice protein concentrate can be explained by the fact that the inclusion of an additional source of protein led to changes due to the wedging of the protein substances of the additive into the gluten framework, which already began to form by flour proteins.

The extremum at a wavelength of 1460 nm corresponded to valence vibrations of the O-H group. The S-H functional group was presented at a wavelength of 1770 nm.

The wavelength range of 1700-1790 nm indicated the passage of the proteolysis process in the dough. Thus, there were functional sulfhydryl groups S-H (first overtone) and gentle extrema were presented in the spectra of all samples. The spectral index of the control sample of the dough after kneading was 0.17 at the peak, and the sample with the additive was 0.20. This was explained by the fact that supplement proteins affected the course of proteolysis (Neji et al., 2023). During the fermentation process, the spectra of the dough in this range shifted significantly upwards, especially the spectrum of the control sample, the spectral index of which was 0.30, and for the sample with the additive – 0.24. This was explained by the fact that rice protein concentrate, due to its higher moisture binding and moisture retaining capacity, contributed to less dilution of the dough during the fermentation process, which ensured its better shape retention.

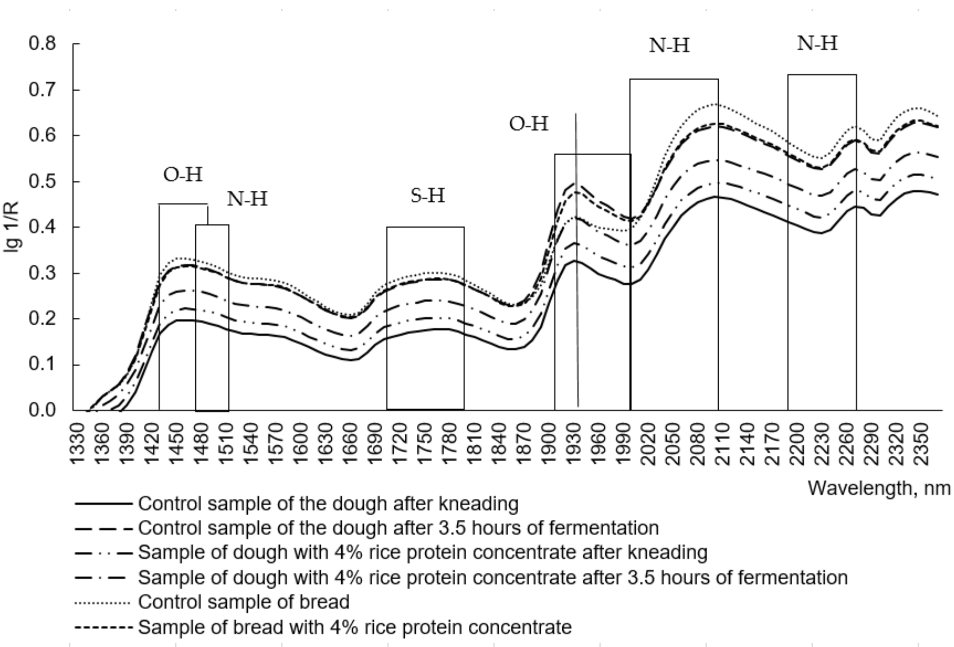

Figure 1. Changes and redistribution of structural groups in bread and dough with 4% rice protein concentrate after kneading and after 3.5 hours of fermentation

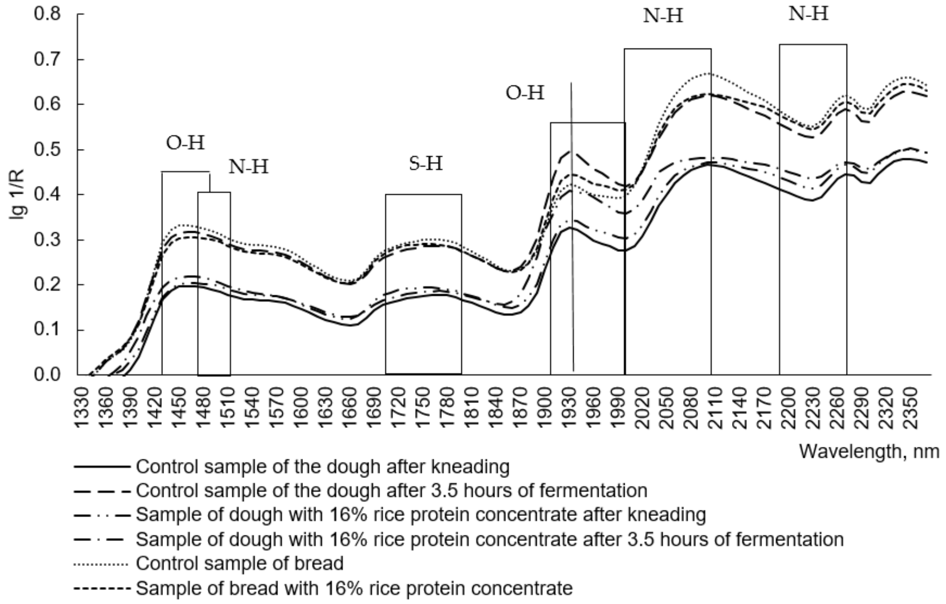

Figure 2. Changes and redistribution of structural groups in bread and dough with 16% rice protein concentrate after kneading and after 3.5 hours of fermentation

During bread baking, high temperatures caused destruction of protein structures (Zhou et al., 2021). The spectra of the bread samples, both control and with the additive, practically overlapped over the entire range of wavelengths. In the wavelength range of 1700–1790 nm, the spectral index of the peak value was 0.30, which coincided with the value of the control sample after fermentation. This was explained by the fact that the main properties of bread were determined by the characteristics of wheat flour and its properties, the share of which was predominant in the recipe.

To characterize protein structures, wavelengths of 1510 nm (N-H valence vibrations), 2060 nm, 2100 nm and 2180 nm (N-H deformation vibrations) were used. There were no peaks at wavelengths of 1510 nm, 2060 nm, and 2180 nm. At a wavelength of 2100 nm, the spectra of the dough after mixing showed that the higher the percentage of the additive was, the lower the spectral index was. So, when adding 4% of rice protein concentrate, it was 0.50, and in case of 16% – 0.47. At the same wavelength, the spectral index of the control sample was 0.46. After fermentation the spectral indices of the control sample, with 4% and 16% additives were 0.62, 0.55 and 0.48. Such values were explained by the fact that rice protein concentrate did not contain gluten proteins and did not participate in the formation of gluten (Ziobro et al., 2015). Instead, its protein substances formed complexes with flour proteins and delayed its development. Due to the properties of rice protein concentrate, the structure of the dough became looser, but the gluten was compacted.

The lignin content can be judged at a wavelength of 2270 nm (O-H valence vibrations / C-O valence combination). Since there was no lignin in rice protein concentrate, the spectrum of bread with it was a bit lower than spectrum of the control sample. This indicated practically the same digestion of bread by the body both with and without the additive (Thilagavathi et al., 2020).

Thus, the addition of rice protein concentrate with a higher protein content and different fractional composition to the recipe of wheat bread affected the structural elements of the dough as its shape-retaining ability improved.

Conclusion

- It was found that amount of protein and fat in rice protein concentrate was higher than in premium wheat flour 6.6 and 4 times.
- Granulometric composition of rice protein concentrate differed from wheat flour because 96% of the particles of wheat flour of premium grade passed through a sieve with holes of 132 microns and for rice protein concentrate this percentage was 4.08.
- Functional and technological properties of rice protein concentrate and wheat flour were characterized by moisture binding and fat binding capacity. For rice protein concentrate they were 4.3 and 1.7 times higher than for wheat flour, and imoisture retaining capacity was 1.8 times higher.
- The infrared spectra of dough and bread showed the difference in the values of the relative reflection coefficient in the spectra of the dough of the control sample and with the addition rice protein concentrate both after kneading and after fermentation. Rice protein concentrate caused delay of the development of the gluten network. At the same time there was positive effect on the dough's ability to keep its shape.

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Balanced development of the food industry in the post-war period: assessment, trends, management

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Keywords:

Food industry
Ukraine
Efficiency
Management

Article history:

Received 25.04.2023
Received in revised form 29.06.2023
Accepted 07.07.2023

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DOI: 10.24263/2310-1008-2023-11-1-5

Abstract

Introduction. The aim of the study is to develop a methodology for evaluating the effectiveness of the management of the value chain of the food industry product at the regional level, which allows using a system of balanced statistical indicators to take into account the sectoral features of the links of the value chain, including agriculture, food industry and trade.

Materials and methods. The research was conducted on the materials of the food industry of Ukraine. The research methodology included a process approach, the concept of added value, a system of balanced statistical indicators and a taxometric method.

Results and discussion. There is no clear demarcation of industry affiliation in evaluation systems. This makes it difficult to determine the development factors of individual industries, which are specific in the formation of links of the value chain at the local level. A new term "regional product value chain" (RPVC) was introduced into the terminological apparatus. To manage such a chain, three main processes are identified, which reflect the organizational and economic features of the creation of the value of the final product of the food industry (locally approximated: raw material links, production links and distribution). At the output of the process management links of the RPVC, the gross added value appears.

Depending on the goals of forming the regional value chain of the food industry product, resources can be maneuvered on a partnership basis, while increasing the gross added value of individual links of the value chain, which acts as an effective indicator of the management process at the regional level.

A method of evaluating the effectiveness of the management of the value chain of the food industry product at the regional level has been developed based on the calculation of the three-component integral indicator and its interpretation on the Harrington scale. The methodology includes five stages: the formation of a dynamic series with a developed system of balanced indicators characterizing the effectiveness and efficiency of RPVC management in terms of links (raw materials, production and distribution); calculation of integral performance and efficiency indicators; visualization of assessment results to establish trends in regional management results; management of relevant RPVC links; determination of an integral three-component indicator of effectiveness and efficiency of management of RPVC links; forming a criterion assessment using the Harrington scale and interpreting the results.

Conclusion. A process approach to the management of the regional product value chain will allow a comprehensive assessment of the results and provide a criterion-referenced assessment of the activities of the RPVC links and the food industry as a whole; determine trends in their development and apply modern management methods; assess food security in the region, the standard of living of the population employed in the RRVC food industry, and food security.

Introduction

The growing uncertainty caused by the pandemic was complicated by Russia's war against Ukraine and radically changed the business activity of enterprises. For the second year now, Ukraine has been living without agricultural products in parts of the Kherson, Zaporizhzhia, and Mykolaiv regions. According to the results of 2022, the production of grain crops decreased by 37% (is 53.9 million tons), the production of oil crops decreased to 17.5 million tons (-24%), the production of meat amounted to 3 million tons (- 11%), milk – 7.7 million tons (-12%) and eggs – 11.6 billion units (-18%) compared to the previous year 2021 (Unian.ua, 2023). The decrease in production volumes was caused by the temporary occupation of territories, weather conditions, the energy crisis, the Kakhovka tragedy, the loss of agricultural machinery (2.9 billion dollars), the destruction of production facilities, the physical death of livestock and other factors.

If we consider the situation of food industry enterprises, then the situation correlates with their location. Thus, the Western and Central regions record growth against the background of panic buying of food industry products. Devastating losses of the industrial potential of enterprises in Eastern and Southern regions of Ukraine actualized the problem of relocation of production facilities to safer regions. Among the relocated enterprises of the processing industry, 30.2% have already resumed their activities at the new location (Ministry of Economy of Ukraine, 2022). Changes in the global distribution system and the outflow of labor force affected the formation of the food industry product value chain. Despite the negative changes, food industry enterprises quickly adapted to the changes and demonstrate relative stability compared to other types of activity (Figure 1).

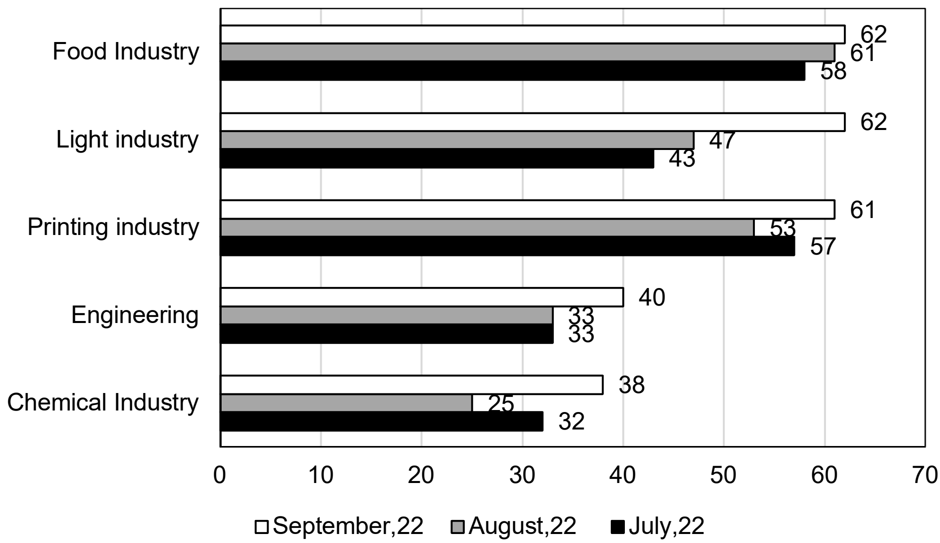

Figure 1. Share of industrial enterprises that restored their capacities and brought them to the level of the pre-war period in % of the surveyed industries (July, 2022)
(Ministry of Economy of Ukraine, 2022)

The graph clearly shows that despite the war, the food industry remains one of the most optimistic branches of the processing industry and demonstrates relative stability against the background of other types of activity, because it provides the basic needs of the population that have daily demand both in the country and abroad. However, the cost of living crisis has led to a dramatic shift in shopping baskets in favour of simple products.

The value system or industry value chain includes the suppliers that provide the firm with the necessary resources along their value chains. After a firm creates products, those products travel through the value chains of distributors (who also have their own value chains) all the way to consumers. At a time when global supply chains are being destroyed due to the pandemic and war, Ukrainian producers should build new, regional value chains for food industry products.

The analysis of the scientific literature records the lack of methodological developments regarding the evaluation of the effectiveness of the management of the value chain of the food industry product at the regional level and again actualizes the concept of the Value Chain, first mentioned in the late 1970s – early 1980s in the works of French scientists (Womack et al., 1997), and later M. Porter (1985). As for Ukrainian scientists, the evaluation of the effectiveness of management at the regional level is reduced to the management of a separate industry or a set of industries (Duginets, 2018; Kravtsova, 2016; Mostenska et al., 2018). At the same time, there is no clear demarcation of branch affiliation in the evaluation systems, and this makes it difficult to determine the development factors of individual branches, which have specificity in the formation of links of the value chain, which confirms the relevance of this study.

The aim of the study is to develop a methodology for evaluating the effectiveness of the management of the value chain of the food industry product at the regional level, which allows using a system of balanced statistical indicators to take into account the sectoral features of the links of the value chain, including agriculture, food industry and trade.

Materials and methods

In the process of preparing the article, scientific and analytical studies of statistical, financial and rating organizations of the world were used, as well as the results of the questionnaire of the Institute of Economic Research and Political Consultations, data of the Ministry of Economy of Ukraine regarding the development of the food industry during the war were processed. The research methodology included a process approach, the concept of added value, a system of balanced statistical indicators and a taxonometric method.

To choose the region, the author used such criteria as: the presence of a positive trend in the development of raw materials, production links and distribution links. According to statistical data, the Vinnytsia region, which is located in the center of Ukraine and despite the war, is showing breakthrough development.

The logic of the research is subordinated to the task of analyzing the effectiveness of managing the links of the regional value chain of the food industry product.

Results and discussion

A value chain is a series of sequential links that are added to create a finished product, from its initial design to its arrival at the customer. With ever-increasing competition for unbeatable prices, exceptional products and customer loyalty, companies must constantly re-examine the value they create to maintain their competitive edge. A value chain can help a company identify inefficient areas of its operations and then implement strategies that optimize its processes for maximum effectiveness and efficiency (Cherkas, 2018). There are many approaches to evaluating the effectiveness of managing the effectiveness of the value chain of product value creation, but there is no single method**.**

Li et al. (2021) proposed a new sustainable value creation system consisting of three possibilities: operations in the value creation chain, internal and external integration.

Grassauer et al. (2022) presented a new eco-efficiency approach using data envelopment analysis (DEA) to assess the functional value of different models of dairy farms that perform several agricultural functions, but did not consider consumers.

There is a growing awareness that basing only one's own benefits in the business model is neither effective nor sustainable. Michael E. Porter and Mark R. Kramer (2019) introduced the concept of "shared value creation" to move from individual profit-seeking to value creation along the entire value chain. A new value proposition includes many aspects – customer value, economic value, social value and environmental value (Yu et al., 2021). All this leads to the co-creation of many values by combining the interests of economic and social actors, including customers and suppliers.

Moura et al. (2021) prove that overcoming barriers in value chain processes is important for establishing its sustainability and creating dynamic flexible opportunities. The unequal power of chain partners leads to asymmetric power relations that affect relationship commitment, relationship strength, compliance, cooperation, commitment, socialization and integration processes, value creation, and productivity.

To assess the effectiveness of food industry management at the regional and local levels, it is recommended to use the following criteria: increase in the production of food products, including from raw materials of local producers; increasing the number of jobs in food industry organizations; growth of the share of products of local producers in the total volume of sales (Yaroschuk, 2020).

Taking into account the well-known performance evaluation criteria (production, labour, finance and market (Wang et al., 2020), it is necessary to follow a balanced approach that takes into account the dynamics and the structural component, in order to establish the real contribution of each link of the value chain to the creation of the gross regional product. This approach will make it possible to monitor the dynamics of the development of industries at the regional level, as well as reserves for the growth of their productivity and efficiency.

Effective management of the value chain of the value creation of the food industry product only at the level of the region directly comes from its economic development and is based on a process approach that covers (Figure 2):

1. Management of raw material links of the chain (organizations of branches of agriculture);
2. Management of production links of the food industry;
3. Management of distribution links, aimed at the development of regional wholesale and retail trade in food products, the field of hospitality (restaurants).

The selection of three main processes of PVC management reflects the organizational and economic features of the creation of the value of the final product of the food industry, which consist in the need to involve in the management processes those regional resources, with the help of which the uniqueness and value of the product will be formed. At the output of the process management of the PVC links, the gross added value appears.

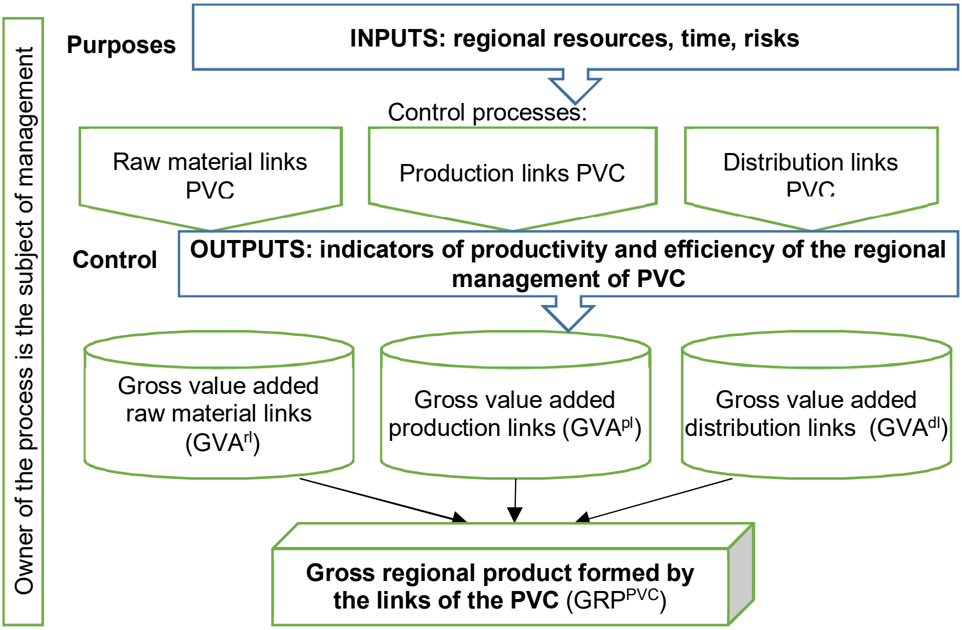

Figure 2. Characterization of the process approach to the management of the PVC at the regional level [author's model]

The massive formation of regional clusters and the local community of PVC participants determined the possibility of designing regional product value chains (regional product value chain – RPVC). Management of such value chains involves a sequence of actions to create added value by the relevant raw materials, production links and distribution links that carry out their activities in the territory of one region. Depending on the goals of forming the regional value chain of the food industry product, resources can be maneuvered on a partnership basis, while increasing the gross added value of individual links of the value chain, which acts as an effective indicator of the management process at the regional level.

The effectiveness of the management of the regional product value chain (RPVC) of the food industry can be realized by the method of calculating the integral three-component indicator (Figure 3).

The proposed method is based on a process approach, the concept of added value, a system of balanced statistical indicators in terms of determining links of the value chain.

The basis of the methodology is the taxonometric method of multidimensional comparative analysis, which allows to obtain the most accurate integral assessment of indicators that are not equal (stimulators and destimulators). It is proposed to interpret the results of the integral assessment using Harrington's scale of desirability (Trautmann and Weihs, 2006).

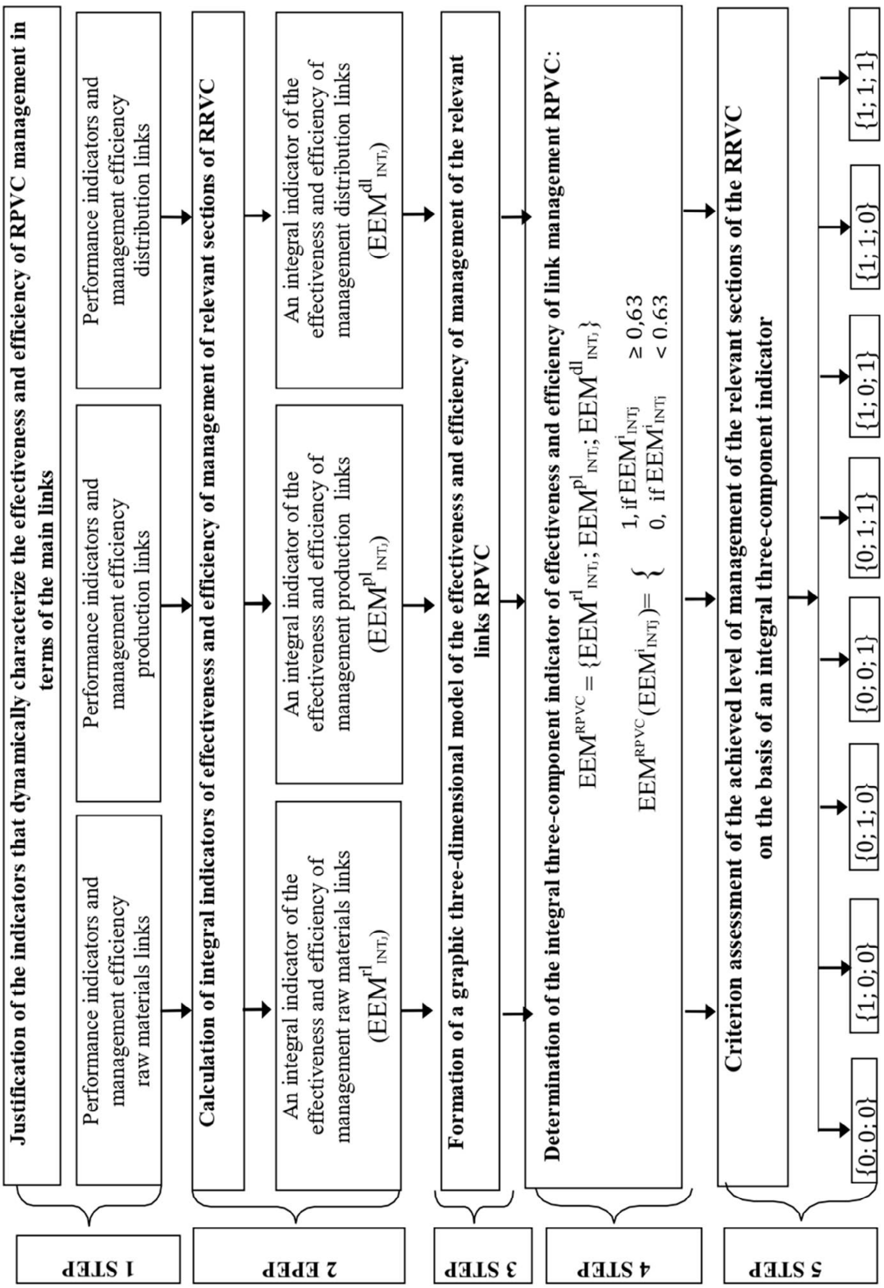

Figure 3. Methodology for evaluating the effectiveness of management RPVC of t food industry [author's model]

The methodology for evaluating the effectiveness of management of the regional product value chain (RRVC) of the food industry includes five stages. At the first stage, a dynamic series of indicators characterizing the effectiveness and efficiency of RRVC management in terms of links (raw materials, production and distribution) is formed. Indicators of effectiveness and efficiency of raw materials management, production units and distribution units of RRVC should optimally take into account the sectoral features of business entities. So, according to the indicators of the efficiency of the management of raw materials units that carry out activities in the branches of agriculture, it is possible to evaluate:

- The efficiency of regional land and labour resources use, employed in agricultural production;
- Degree of renewal of basic agricultural funds in the region;
- Profitability of investments and targeted financing of state programs invested in the development of agriculture in the region;
- The actual standard of living of the population of the region engaged in agricultural production;
- Ensuring the needs of the population and the regional market with agricultural products, including meat and dairy products;
- The level of growth (decrease) in prices for agricultural products in the region;
- The overall effectiveness of the functioning of regional raw material links through the ratio of gross added value to the gross regional product.

Indicators of the effectiveness and efficiency of the management of the RPVC production link take into account the peculiarities of the functioning of business entities in the food industry and allow to evaluate:

- The level of food security in the region due to the provision of its population with food products;
- Ensuring the needs of the regional market with food products on a national scale;
- The efficiency of the use of all types of resources in the production of food products;
- The effectiveness of the regional policy aimed at the development of small entrepreneurship in the food industry;
- Degree of innovative development of food production;
- Level of change in food prices;
- The actual standard of living of the population of the region engaged in the production of food products;
- Profitability (loss) of regional food producers;
- Profitability of investments and targeted financing of state programs aimed at the development of the food and processing industry in the region;
- The degree of renewal of the main funds of the food industry in the region;
- The overall effectiveness of the functioning of regional production units through the ratio of gross added value and gross regional product.

Indicators of effectiveness and efficiency of management of RPVC distribution links take into account the peculiarities of the functioning of economic entities in the field of public catering, wholesale and retail trade in food products and allow to evaluate:

- Development of regional trade networks that provide the population with food products;
- Ensuring the population of the region with food products through catering organizations and retail stores;

- Level of change in consumer prices for food products in the region;
- The actual standard of living of the population of the region engaged in wholesale and retail trade in food products;
- The level of average monthly purchasing power of the resident of the region;
- Effectiveness of regional foreign trade in food products and agricultural raw materials (integration of rrvc into global food supply chains);
- The efficiency of the use of labor resources in the field of food trade
- Products and public catering;
- Profitability (unprofitability) of the activities of regional organizations of trade in food products and catering;
- Profitability of investments in fixed capital aimed at the development of regional trade in food products and catering;
- The overall effectiveness of the functioning of regional distribution links through the ratio of gross added value and gross regional product.

The second stage is the calculation of integral indicators of the effectiveness and efficiency of management of the relevant links, in particular raw materials, production and distribution. Using the taxometric method of multidimensional comparative analysis, the set of actual values of indicators of the relevant links is compared. The need for such an action is due to the multidirectionality of evaluation indicators (stimulators and destimulators), the heterogeneity of their calculation methods and measurement units. The calculation of comparable values of indicators is carried out according to formula (1):

$$Z_{ij} = \frac{x_{ij} - \overline{X}i}{\sigma_i} \quad (1)$$

where Z_{ij} – is the relative value of the i-th indicator for the j-th reporting period; Xij – the actual value of the i-th indicator for the j-th reporting period; ¯Xi is the average value of the i-th indicator for the entire period; σ_i – mean square deviation (2).

$$\sigma_i = \sqrt{\frac{\sum_{j=1}^{n}(x_{ij} - \overline{X}i)^2}{n}} \quad (2)$$

n – the number of periods included in the analysis.

By comparing relative values for each evaluation indicator in the dynamics, the «reference value of the indicator» (Zi^e), is determined, for the stimulator – the maximum, for the destimulator – the minimum. The calculation of the integral indicator of effectiveness and efficiency of management of the *i-th* link of RPVC is carried out according to the formula (3):

$$EEM_{INTj}^{i} = \sum_{i=1}^{n}(Z_{ij} - Z_i^e)^2 \quad (3)$$

EEM_{INTj}^{i} – integral indicator of the effectiveness and efficiency of the regional management of the i-th link of the RPVC for the j-th period;

Z_j^e – the reference value of the i-th indicator.

At the third stage of the analysis, it is necessary to form a graphic three-dimensional model of the effectiveness and efficiency of management of the relevant sections of the RPVC for the reporting period. The continuous segment [0; 1], which requires a recalculation of the values of integral indicators in the range from zero to units, and a three-dimensional model of the effectiveness and efficiency of the management of RPVC links is built for each reporting period along three coordinate axes:

EEM_{INTj}^{rl} – integral indicator of effectiveness and efficiency of management of raw materials links of RPVC for the j-th reporting period;

EEM_{INTj}^{pl} – integral indicator of effectiveness and efficiency of management of production links of RPVC for the j-th reporting period;

EEM_{INTj}^{dl} – is an integral indicator of the effectiveness and efficiency of management of RRVC distribution links for the j-th reporting period.

The three-dimensional model of the effectiveness and efficiency of the management of RPVC links allows:

– To clearly demonstrate the level of management achieved in the region for each of the links of the value chain;
– Compare the results of the study over several reporting periods, in particular with reference values that are equal to 1;
– To establish the dynamics of evaluation indicators and the trend of changes in the results of regional management.

At the fourth stage, taking into account the average value on the Harrington scale (desirability) – 0.63, an integral three-component indicator of the effectiveness and efficiency of management (EEM) of the RRVC links is determined (formulas 4–5):

$$EEM^{RPVC}=\{EEM^{rl}int\,j\ ;\ EEM^{pl}int\,j\ ;\ EEM^{rl}int\,j\ \} \quad (4)$$

$$EEM^{RPVC}(\ EEM^{i}int\,j) = \begin{cases} 1, if\ EEM^{i}int\,j \geq 0.63 \\ 0, if\ EEM^{i}int\,j < 0.63 \end{cases} \quad (5)$$

EEM ^{RPVC} – integral three-component indicator of effectiveness and efficiency of management of RRVC links. It allows you to generalize the results of the analysis of the effectiveness and efficiency of the management of RRVC links and give them a criterion evaluation at the final stage of the study (Table 1).

The developed methodology for evaluating the effectiveness of managing the regional product value chain (RRVC) of the food industry was tested on the example of the Vinnytsia region based on statistical data for 2020–2022.

On the basis of the actual and comparative values of the indicators characterizing the effectiveness and efficiency of the management of the raw materials RPVC links of the food industry of the Vinnytsia region, integral indicators were determined, which are presented in Table 2.

Table 2 presents the actual values of the integral indicators of the effectiveness and efficiency of the management of RRVC links of the food industry of the Vinnytsia region for 2020–2022, the analysis of which revealed that a positive trend in the development of raw materials, production links and distribution links has emerged in the region. The growth of integral indicators testifies to the correctly chosen methodological toolkit of RPVC management both on the part of regional authorities and business entities.

Figure 4 presents three-dimensional models of the actually achieved level of effectiveness and efficiency of management of the relevant links of the RPVC of the food industry of the Vinnytsia region for the years 2020–2022.

Table 1

Criterion assessment of achieved level of management of the relevant links of RRVC of food industry

(R – Raw material; P – Production; D – Distribution)

Value of integral three-component indicator (EEM^{RPVC})			Result management links RPVC	Characteristics of the result
R	P	D		
0	0	0	K1- extremely low level of regional management of links	The needs and potential opportunities of RPVC links are unbalanced
1	0	0	K2 – low level of regional management of production links and distribution	RPVC raw material units provide the needs of production links and the regional market due to the effective use of all types of resources
0	1	0	K3 – low level of regional management of raw materials and distribution	Production links of RRVC cover the needs for raw materials mainly at the expense of external supplies, fully provide the regional market with food products
0	0	1	K4 – low level of regional management of raw materials and production links.	Distribution links provide the population of the region with food products mainly at the expense of external supplies from other regions and imports of food products
0	1	1	K5 – low level of regional management of raw materials	The volume of agricultural production is not able to meet the needs. Production links cover the needs of raw materials with the help of external supplies and fully supply the regional market with food products. Distribution links provide the population of the region with food products at the expense of supplies from local producers
1	0	1	K6 – low level of regional management of production links.	Food industry enterprises work inefficiently and are unable to provide the population of the region with locally produced food products. Raw material links of RRVC are able to fully meet the needs of the regional market and production links, however, due to the underdevelopment of the latter, agricultural products are sold in other regions and/or exported. Distribution links provide the population of the region with food products mainly due to external supplies from other regions and imports of food products
1	1	0	K7 – low level of regional management of distribution links	The network of retail food trade in the region is not developed.
1	1	1	K8- high level of regional management of RPVC units	The needs and potential opportunities of RPVC links are balanced

Table 2

Dynamics of integral indicators of effectiveness and efficiency of management of relevant links of the regional value chain of the food industry in Vinnytsia region during 2020-2022

Integral index								
Raw materials links			Production links			Links of distribution		
2020	2021	2022	2020	2021	2022	2020	2021	2022
0.574	0.878	0.850	0.685	0.691	0.744	0.591	0.791	0.680

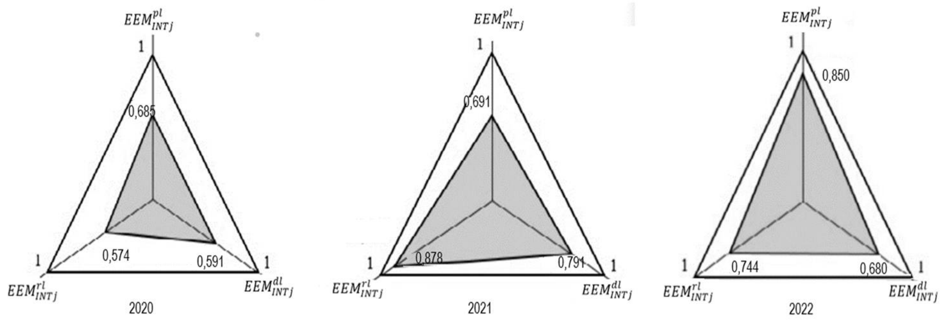

Figure 4. Three-dimensional model of the effectiveness and efficiency of the management of the links of the regional value chain of the food industry product in the Vinnytsia region during 2020-2022

Table 3

Achieved level of management of RRVC links of food industry of Vinnytsia region for 2020–2022

Date	Value of the integral three-component indicator (EEM^{RPVC})			Result of the management of RPVC links
	Raw material	Production	Distribution	
2020	0	1	0	K3 – low level of regional management of raw materials and distribution
2021	1	0	1	K6 – low level of regional management of production links.
2022	1	1	1	K8- high level of regional management of RPVC units

The area of the three-dimensional model allows you to visualize the achieved level of effectiveness and efficiency of management in terms of the main links of the regional chain of value creation of the food industry product, which, based on the example of the capacities of the Vinnytsia region, is improving annually. An isosceles triangle built on the coordinate axes displays reference values of integral indicators equal to one. The area of the isosceles triangle characterizes the maximum efficiency of management of each of the links of the regional value chain of the food industry product. Over the analyzed period, the values of the integral indicators of the effectiveness and efficiency of the management of raw materials in 2021 (0.878) and production units in 2022 (0.850) approached the reference level.

Criterion assessment of the achieved level of management of the RRVC links of the food industry of the Vinnytsia region for 2020–2022 are given in Table 3.

Conclusions

The approbation of the methodology for evaluating the effectiveness of managing the regional product value chain (RRVC) of the food industry on the example of the Vinnytsia region made it possible to determine its main differences from existing methodological tools:

- Provides a quantitative assessment of the management level of RRVC of the food industry in general and in terms of performance indicators based on the definition of an integral three-component indicator. This allows you to summarize the results of the analysis and give them a criterion evaluation;
- Evaluates food security in the region, the standard of living of the population employed in the RRVC of the food industry, and food security;
- Provides visibility of the obtained results with the help of a three-dimensional graphic model, which allows to present the level of management actually achieved in the region for each of the relevant goals of the links of the value chain;
- Provides an opportunity to determine the effectiveness and efficiency of the management of the RRVC of the food industry in dynamics with the aim of identifying the development trends of the relevant links and developing measures aimed at ensuring the growth of evaluation indicators;
- Use the indicator of added value as a result, which allows you to comprehensively evaluate the results of the activities of RRVC links of the food industry as a result of the use of resources (land, material, labor, financial) and apply modern management methods;
- Includes a system of balanced statistical multi-vector indicators (stimulators and destimulators) that reflect the sectoral features of the RRVC links of the food industry;
- Is based exclusively on calculations of relative indicators, which allow providing regional authorities with comprehensive information about the results of business entities in terms of raw materials, production links and distribution links;
- Makes it possible to identify factors (causes) that disrupt the development of RRVC of the food industry, and provides regional management bodies with information for the development of measures to influence the determining events.

The given technique is universal and can become the basis for the development of methodological tools for evaluating the effectiveness of product value chain management in other branches of the production sphere.

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Influence of the dough composition on the heat treatment of low-protein cookies

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Keywords:
Cookies
Gluten-free
Low-protein
Xanthan gum
Thermal
Maltodextrin

Article history:

Received 17.03.2023
Received in revised form 14.06.2023
Accepted 07.07.2023

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DOI:
10.24263/2310-1008-2023-11-1-6

Abstract

Introduction. The aim of research was to study the influence of dough components (xanthan gum, maltodextrin, starches) on the heating process of low-protein cookies and changes in the geometrical forms of the dough pieces during thermal treatment.

Materials and methods. Dough for low-protein cookies was made using corn and tapioca starches, maltodextrin, and xanthan gum. Traditional butter cookies with wheat flour were used as a control. Properties of low-protein dough were studied by thermal analysis (thermogravimetric analysis, differential thermal analysis and differential scanning calorimetry).

Results and discussion. Low-protein cookies had similar final height as traditional butter cookies. Low-protein cookies made with corn starch, maltodextrin and xanthan gum and traditional butter cookies made with wheat flour had a similar total weight loss 61.0 and 63.1%, respectively. At the same time, cookies made with corn starch and xanthan gum lost the lowest amount of weight, 39.5%. The temperature at which the moisture removal from the samples ends and their thermal decomposition begins was determined. Low-protein cookies made with corn starch and xanthan gum lost all moisture at 129 °C; low-protein cookies made with corn starch, maltodextrin and xanthan gum, and traditional butter cookies made with wheat flour lost all moisture at 95.4 °C and 98.7 °C, respectively. Endothermic processes (fat melting, starch gelatinization, and water evaporation) and exothermic processes (thermal decomposition) were observed by thermal analysis of dough samples. Differential scanning calorimetry curve of the low-protein cookies made with corn starch and xanthan gum had a different appearance compared to the curves of cookies with maltodextrin (low-protein cookies made with corn starch, maltodextrin, and xanthan gum; low-protein cookies made with corn and tapioca starches, maltodextrin, and xanthan gum). The largest endothermic peak began at 60 °C and reached maximum at 108 °C, while curves for low-protein cookies with maltodextrin had two peaks without overlapping events. Areas under the differential scanning calorimetry curves were calculated to estimate the amount of energy required for the heat treatment process. The lowest amount of energy was required for the heat treatment of dough for traditional butter cookies: ΔH=124.05 J/g. The heat treatment of low-protein dough required more energy: ΔH=199.46–268.33 J/g.

Conclusions. The heat treatment process of low-protein cookies was different from heat treatment of traditional cookies and required more energy (60,8–116,3% more). Replacement of 20% of corn starch with tapioca starch in a low-protein formulation leaded to decrease in energy required for heat treatment in 23.9%.

Introduction

Production of functional food for the individuals with specific diseases, and groups with different nutritional requirements is one of the main trend of food technologies in 2021-2030 (Ivanov et al., 2021). There are several diseases that require special diets. One of them is phenylketonuria (commonly known as PKU) caused by inability of the body to break down amino acid phenylalanine. Considering that there is no cure for this disease, patients must follow a diet with individually determined possible amounts of phenylalanine. In any case, this amount is much lower than in traditional diets (Rocha et al., 2021; Van Wegberg et al., 2017). To enable low-protein diets, a wide range of low-protein products should be developed, including flour confectionery such as cookies. Since low-protein products do not contain gluten, the same products can be consumed by people who follow a gluten-free diet.

Several recipe compositions of low-protein cookies are developed. This recipe compositions differ significantly from the composition of traditional butter cookies by the absence of egg products, the absence or very small amount of wheat flour, the use of different starches and hydrocolloids. All these ingredients affected the technological processes of making low-protein cookies, including the heat treatment process, which is a combined of baking and drying processes (Hrytsevich et al., 2023).

There are no studies which describe development, technological process, and heat treatment of low-protein cookies. However, there are studies which describe the development of gluten-free and conventional cookies with increased nutritional, sensory, and textural properties (Gawade et al., 2023; Itagi et al., 2023; Kaur et al., 2023). Low-protein cookies do not contain high protein raw materials, and wheat flour is used in very limited quantities. Xanthan gum, maltodextrin, and tapioca starch are used to improve structural properties. These changes in the recipe composition significantly affect the heat treatment process of low-protein cookies. During the first period of heat treatment the dough piece starts to heat up, the duration of the period is approximately 1.5 minutes. In the second, the longest period of heat treatment, the central layers are significantly heated up and heat is used for endothermic processes. In the third period, moisture evaporation reaches the central layers and moisture loss occurs at a reduced rate, moisture migrates from the central layers to the surface layers (Davidson, 2023). It should be noted that the processes are influenced by the cookie recipe and heat treatment conditions. At the same time, the addition of new recipe components and the removal of certain recipe components may require a change in the parameters (conditions) of cookies' heat treatment.

Changes in molecular structure of sugar-snap cookies during the baking process were studied. The baking process reduced the size of amylopectin molecules and amylose chain lengths and caused change of some starch granules. However, the distribution of amylopectin chains remained similar because of little change in crystallinity and gelatinization temperatures. The study revealed disruptions in starches ordered structure. These findings help understand how starch changes in cookies, impacting their quality, especially the sensory properties (Zhang et al., 2021).

Heat treatment of low glycemic index gluten-free cookies from high amylose rice flour were studied. Higher baking temperature led to increased spread ratio and hardness of cookies. Adding carboxymethyl cellulose rose resistant starch content and overall acceptability while reducing predicted glycemic index and glycemic load. The optimal conditions were determined as 185 °C baking temperature, 22 min baking time, and 0.8% carboxymethyl cellulose concentration. The resulting cookies had 4.66% dietary fiber, 7.20% resistant starch, lower predicted glycemic index, 44.60, and glycemic load, 17.51 (Naseer et al., 2021).

Maillard reaction, or browning, in cookies is intensified along with an increase of the content of sugars and proteins causing darker color of baked products (Lukinac et al., 2022). Meanwhile, due to the limited amount of proteins in low-protein dough, the formation of Maillard reaction products is minimal (Žilić et al., 2016).

Thermal analysis is a powerful tool to describe processes which occur during heat treatment. While traditional dough systems are studied quite well by different thermal analysis techniques (Rumińska et al., 2021; Xu et al., 2022), there are no studies published regarding thermal properties of low-protein dough systems. However, some studies are performed on gluten-free dough systems. Starch transitions of doughs made with different types of gluten free flour are studied by dynamic thermal mechanical analysis and differential scanning calorimetry, and it was found that starch transitions (gelatinization, amylose melting) depend on starch nature (Moreira et al., 2015). Structural support of the zein network to rice, flour gluten-free dough was studied. It was found that three different rice flours have different thermal properties mainly due to the different ratio of amylose to amylopectin (Zhang et al., 2023).

The heat treatment process of low-protein cookies is not studied yet, and the influence of different low-protein recipe components on the baking process requires additional research. The aim of research is to determine the influence of recipe components (xanthan gum, maltodextrin, corn and tapioca starches) on the heat treatment process of low-protein cookies by thermal analysis and to determine changes in the geometrical forms of the dough pieces during the process.

Materials and methods

Low-protein dough preparation. The dough for all samples were prepared in the same way: sugar was dissolved in water and then mixed with butter and eggs (if eggs are present in recipe) in mixer for 4 min. Then the mixture of other ingredients was added followed by mixing for 5 minutes.

Ingredient compositions of the samples under study were as follows:

- Sample 1: corn starch, 100%, butter, white sugar, xanthan gum, vanilla powder, soda, ammonium;
- Sample 2: corn starch, 80%, tapioca starch, 20%, maltodextrin, butter, white sugar, xanthan gum, vanilla powder, baking soda, ammonium;
- Sample 3: corn starch, 100%, maltodextrin, butter, white sugar, xanthan gum, vanilla powder, baking soda, ammonium;
- Control sample: wheat flour, eggs, butter, white sugar, vanilla powder, baking soda, ammonium.
- The follow ingredients were used in the same amounts in all recipes: butter, 27.53% of mass of all recipe ingredients; white sugar, 12%; xanthan gum, 0.1%; vanilla powder, 0.2%; soda, 0.1%, and ammonium, 0.1%.

Change in geometrical dimensions. Dough pieces were formed with diameter 50 mm, height 5 mm, and then baked for 10 min at 220 °C. The change in the geometric dimensions of the dough piece during baking and drying was determined by measuring the diameter and height of the formed dough piece and the height of the piece at each minute of heat treatment.

Thermogravimetric analysis. Thermogravimetric analysis was performed with Derivatograph Q1500 (Hungary), heating temperature 20-240 °C, sample weight in range 60-75 mg, total heat treatment time 35 minutes (Goranova et al., 2019; Ito et al., 2022).

Differential scanning calorimetry. Differential scanning calorimetry was performed with Mettler Toledo DSC 3+ (Switzerland). Calibration of the device was performed with indium. Aluminum pans with lids were used for measurement. Empty sealed pan was used as a reference. The measurement was carried out at temperature range 0-240 °C using nitrogen gas, with temperature increase 5 °C per minute (Ito et al., 2022; Zhang et al., 2021). Enthalpy change (ΔH) was calculated by integrating the area under obtained curves with STAR software.

Statistics. All measurements were performed in triplicate and average values were calculated.

Results and discussion

Change of the height and diameter of the dough after baking

Baked low-protein cookies had homogeneous surface and porosity (Figure 1).

Sample 1

Sample 2

Sample 3

Figure 1. Baked low-protein cookies:

Sample 1, low-protein cookies made with corn starch and xanthan gum;
Sample 2, low-protein cookies made with corn and tapioca starches, maltodextrin, and xanthan gum;
Sample 3, low-protein cookies made with corn starch, maltodextrin, and xanthan gum.

After the heat treatment, the height and diameter of the dough pieces increased (Table 1).

A radical change in the recipe composition in cookies can lead to an increase of their height and diameter after heat treatment compared to traditional cookies (Cappa et.al., 2020; HadiNezhad et.al., 2009).

Table 1

Change of the height and diameter of the dough pieces after baking

Low-protein cookies made with	Diameter, cm		Height, cm		Increase in diameter, %	Increase in height, %
	Before baking	After baking	Before baking	After baking		
Control sample	5.000	6.250	0.500	0.580	25.000	16.000
Sample 1: Corn starch and xanthan gum	5.000	6.150	0.500	0.595	23.000	19.000
Sample 2: Corn starch, maltodextrin, and xanthan gum	5.000	6.000	0.500	0.580	20.000	16.000
Sample 3: Corn and tapioca starches, maltodextrin, and xanthan gum	5.000	6.450	0.500	0.585	29.000	17.000

Dough expansion (increase in geometrical dimensions) was caused by the action of leavening agents and changes in the chemical state of the recipe components (HadiNezhad et.al., 2009). As a result of this increase in size, the structure of the product was formed, in particular: porosity, looseness, which largely determines the sensory perception of the product (Irondi et al., 2023). In addition, the increase in the diameter of the dough piece during baking and drying of cookies has mainly technological aspects. The cookie dough pieces are formed on the baking chamber floor at a certain distance from each other (Davidson, 2023).

During the heat treatment, the dough pieces increase in diameter and move closer to each other (Zhang et al., 2021). If the increase is not considered when forming the dough pieces, dough pieces may touch each other and stick together at the end of the heat treatment. This is a technological defect, and such products cannot be sold leading to the lost to the company's profit. Therefore, there was a need to determine the increase in the geometric dimensions of low-protein biscuit dough pieces during baking and drying (Zhang et al., 2021).

The changes in the height of the dough pieces during heat treatment at 220 °C for 10 min was shown (Figure 2).

During the heat treatment of traditional types of butter cookies, a decrease in the height of the dough piece is observed in the first period due to the melting of the fat component (Gonzalez-Ortega et al., 2023). As seen from Figure 2, low-protein cookies are also characterized by a decrease in the height of the dough piece and an increase in diameter. Expansion of dough is observed during the second period of heat treatment. This is the longest period – up to 70% of the total duration of the heat treatment process. In the low-protein samples, the height increase of the dough piece during the heat treatment is close to the height increase of the control sample. In sample made with corn and tapioca starches, maltodextrin, and xanthan gum, the height increase is slightly higher than that of the control sample. In the third period of heat treatment of traditional and low-protein cookies, a constant height of the dough piece is observed. In the last, fourth period, the height of the dough piece changes, and a decrease in its height is observed. At the same time, the decrease in the height of the dough piece of low-protein cookies is less than that of traditional cookies. It might be explained by absence of protein substances in the developed products and the presence of structure forming agents that fix the size of the dough piece (Zhang et al., 2023).

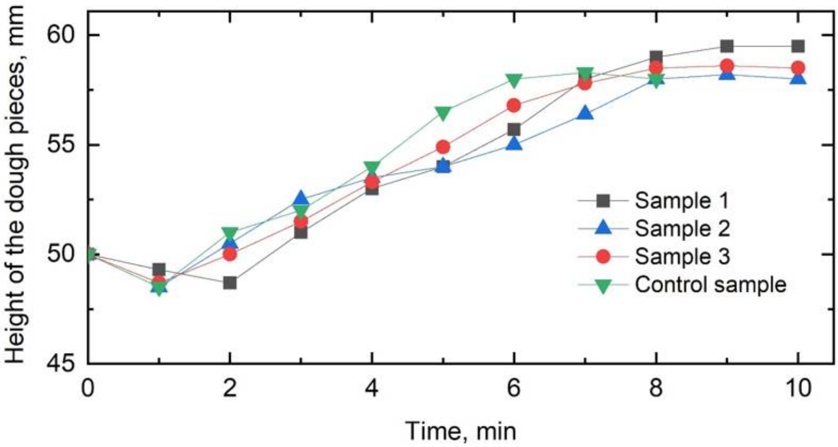

Figure 2. Change in the heigh of dough pieces during termal treatment at 220 °C:
Sample 1, low-protein cookies made with corn starch, and xanthan gum;
Sample 2, low-protein cookies made with corn and tapioca starches, maltodextrin, and xanthan gum;
Sample 3, low-protein cookies made with corn starch, maltodextrin, and xanthan gum, control sample, butter cookies made with wheat flour.

Thermogravimetric analysis

Heat treatment affects key components of food, including carbohydrates, proteins, fats, and water (Zhang et al., 2021). Temperature increase lead to alterations in both the physical aspects (melting, crystallization, evaporation, aggregation, and gelation) and chemical properties (hydrolysis, oxidation, and reduction) of food products (Ito et al., 2022).

These changes significantly impact the final product, influencing its taste, color, appearance, texture, and stability. Thermal analysis is a widely used tool in the food industry, enabling the examination of physical and chemical transformations linked to temperature fluctuations occurring during food manufacturing. Enhancing our comprehension of these processes enables precise control and optimization of production conditions, ultimately leading to improved quality (Ito et al., 2022).

The study of the behavior of raw materials and products during heat treatment is of great importance for the food industry. Since there is no literature available on thermal analyzes of low-protein processed foods and dough, we performed the most common thermal analyzes used in academic and industrial food laboratories: thermogravimetric analysis (TGA), differential thermal analysis (DTA), and differential scanning calorimetry (DSC) to characterize low-protein cookies.

Thermogravimetric and differential thermal analyses were performed using a derivatograph (Figure 3).

By observing the curve data, it is possible to determine the temperature at which the mass change of the low-protein semi-finished product begins and the final temperature.

The first derivative of TG, known as TGA, is used to assist in this identification. It is a mathematical parameter, not a thermoanalytical method that is derived from the first derivative of the mass change with time (dm/dt) versus temperature or time (Ito et al., 2022). The TGA curve improves measurement accuracy by identifying the beginning and end of thermal processes and facilitates the differentiation of superimposed events.

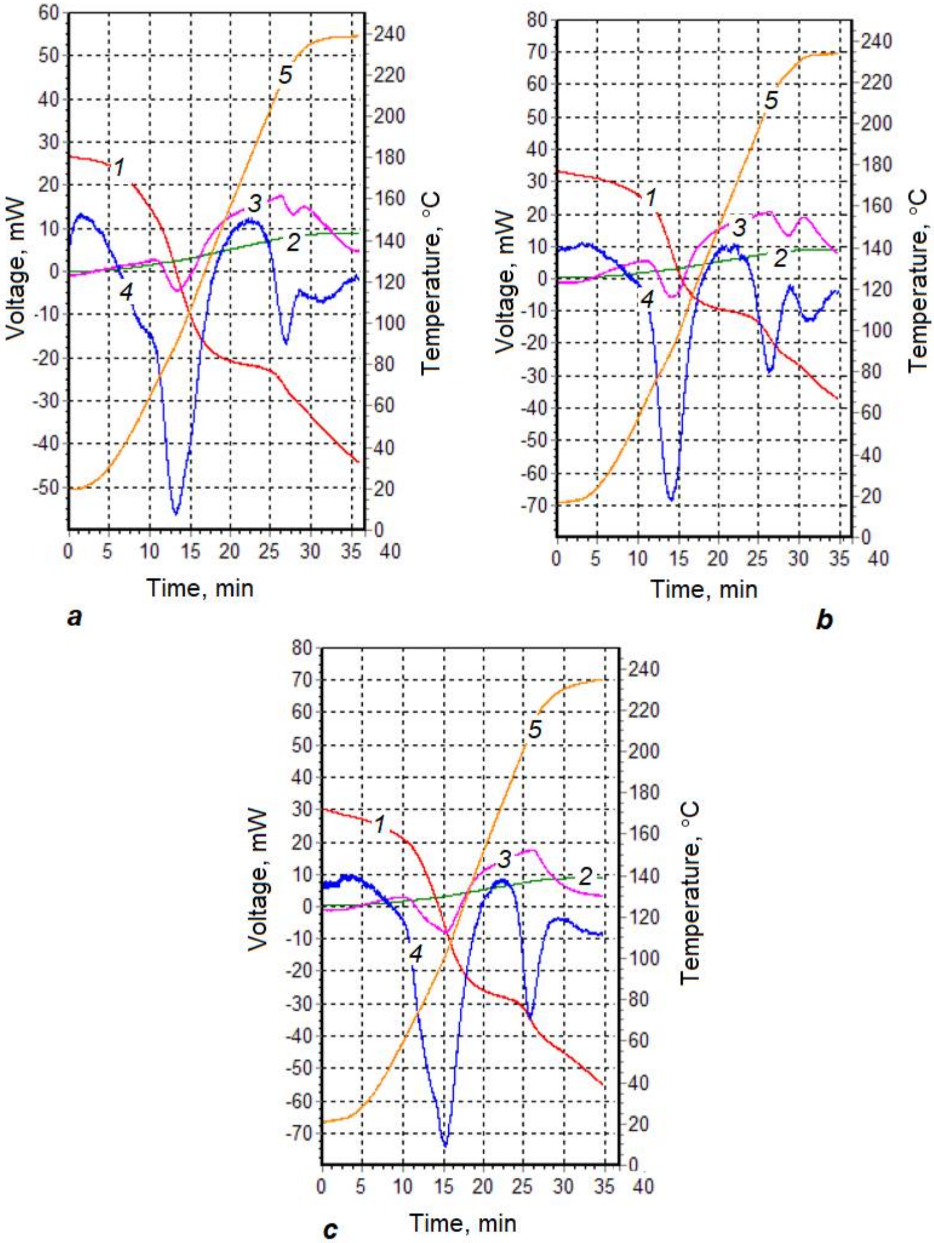

Figure 3. Thermogravimetric analysis of dough at ΔT 20-240 °C:

1, Mass; 2, Temperature (U); 3, DTA; 4, DTG; 5,Temperature (T).

Sample 1, low-protein cookies made with corn starch, and xanthan gum;
Sample 2, low-protein cookies made with corn and tapioca starches, maltodextrin, and xanthan gum;
Sample 3, low-protein cookies made with corn starch, maltodextrin, and xanthan gum, control sample, butter cookies made with wheat flour.

When the sample is stable, or with little change in mass, the TG curve is considered as a constant and therefore the derivative is zero (the DTA curve remains a straight line). A plateau may indicate the thermal stability of the material in a given temperature range (Xu et al., 2022). After reaching a temperature of 40 °C, all studied samples tested are thermally unstable during the entire test, as moisture is constantly being removed (Fig. 3).

Each time the sample changes mass, a kink is created in the TG curve, from which the first derivative is calculated, and peaks are formed that delimit areas proportional to the mass changes undergone by the sample. This results in a DTG curve from which the initial, peak, and final temperatures of the process can be determined. The peak temperature corresponds to the temperature at which the reaction rate is maximum. In addition, when sequential reactions occur, the TG curve is not sufficient to interpret the process, so it is supported by the DTG curve (Ito et al., 2022).

Decrease in weight is observed during the heating of the all sample (Table 2).

Table 2

Weight loss during heating of the dough samples with the derivatograph

Temperature, °C	**Weight of the dough samples made with**					
	Corn starch, maltodextrin, and xanthan gum		Corn starch, maltodextrin, and xanthan gum		Wheat flour (control sample)	
	mg	%	mg	%	mg	%
20	62.10	100.0	66.7	100.0	75.40	100.0
40	61.30	98.7	64.28	96.4	72.64	96.3
60	58.11	93.6	61.86	92.74	70.34	93.3
80	55.73	89.7	57.02	85.5	65.28	86.6
100	50.74	81.7	47.35	71.0	55.85	74.1
120	47.76	76.9	42.99	64.5	51.48	68.5
160	45.77	73.7	39.6	59.4	44.58	59.1
175	45.37	73.1	39.1	58.6	44.12	58.5
200	44.97	72.4	37.67	56.5	42.28	56.1
240	37.60	60.5	24.60	36.9	29.40	39.0

Based on data in Table 2, it can be concluded that the minimum weight loss is inherent in low-protein sample made with corn starch, and xanthan gum. In the formulation of this sample, xanthan gum is used as a structuring agent. In a low-protein sample made with corn starch, maltodextrin, and xanthan gum, as a structure forming agents are used xanthan gum and maltodextrin. The weight loss of this sample is close to weight loss of the control sample. In this temperature range, the decrease in the weight of the dough samples is mainly due to the release of moisture. Moisture release at the beginning of heating in all samples is virtually identical. During further heating, the moisture release in low-protein sample made with corn starch, and xanthan gum differs from a low-protein sample made with corn tapioca starch, maltodextrin, and xanthan gum and the control sample. At a temperature of 80 °C, the weight loss in low-protein sample made with corn starch, and xanthan gum is 10.3%, in low-protein sample made with corn starch, maltodextrin, and xanthan gum is 14.5%, and in the control sample is 13.4%. At a temperature of 120 °C, the difference between moisture removal increases: low-protein sample made with corn starch, and xanthan gum – 23.1%, low-protein sample made with corn starch, maltodextrin, and xanthan gum – 35.5%, control sample – 31.5%. The study is carried out up to a temperature of 240 °C. At this temperature, the weight loss in low-protein sample made with corn starch, and xanthan gum is 39.5%, in a low-protein sample made with corn starch, maltodextrin, and xanthan gum – 63.1%, in the control sample 61.0%. The mass fraction of moisture of all the tested dough masses was 23.9 %, so it is seen that in addition to the release of free and bound moisture, other processes occurred in the polymers, which were accompanied by a decrease in the weight of the samples.

It should be noted that the heat treatment to which the dough samples are subjected during the derivatograph tests differs from the heat treatment in the baking chamber during the manufacturing process. This is primarily due to the size of the dough piece. For the derivatographic study, the dough weight ranged from 62.1 to 75.4 mg (0.0621 to 0.0754 g), while the weight of the cookies dough piece usually starts at a few grams. Thus, the samples under study reach a high temperature in the inner layers of the dough piece faster (Rumińska et al., 2021). The duration of the heat treatment also differs. During the derivatographic studies, the duration of the heat treatment is 35 minutes, while the thermal treatment of a low-protein dough mass during the technological process is no more than 10 minutes.

Knowing the moisture content of the semi-finished products, we can determine the temperature at which the moisture removal from the samples ends and their thermal decomposition begins. Low-protein sample made with corn starch, and xanthan gum loses all moisture at 129 °C, low-protein sample made with corn starch, maltodextrin, and xanthan gum loses all moisture at 95.4 °C, and the control sample at 98.7 °C.

The graphs obtained from DTA analysis show the temperature change on the ordinate axis and time or temperature on the abscissa axis.

When the sample is heated, unless physical or chemical phenomena occur, a parallel line of temperature change is recorded with respect to the time axis. However, when heat is released in exothermic processes, an increase in temperature is recorded, which is reflected by a kink in the temperature-time profile. This is also true for endothermic processes, in which heat is absorbed by the sample and a temperature decrease is recorded, also represented by an inflection point, i.e. a shift from the baseline will be observed. Thus, DTA monitors the change in the physical property (temperature) of a sample by comparing it to a thermally inert material (neither absorbing nor emitting heat), called a reference (Ito et al., 2022). However, this method differs from DSC in that measurements are based on the change in temperature of the sample relative to the inert reference material, whereas in DSC, a calorimetric method, the change in energy between the sample and the reference can be estimated, which can even be used as a quantitative analysis, unlike DTA (Ito et al., 2022).

From the derivatograms (Fig. 3), it is evident that up to 80 °C, the DTA curve is linear, when the samples reach 80 °C and continue to expand, a distinct endothermic peak is observed, reaching its maximum at 120 °C. At 150-160 °C, an exothermic peak is observed, which coincides with an acceleration of mass loss on the TG scale.

Thus, the endothermic peak at 80 °C can be explained by the intensification of moisture evaporation, and the exothermic peak at 150-160 °C by the thermal decomposition of the studied marks.

Differential scanning calorimetry

For a more detailed study of the endothermic and exothermic processes occurring in low-protein dough masses during heat treatment, DSC was performed (Figure 4).

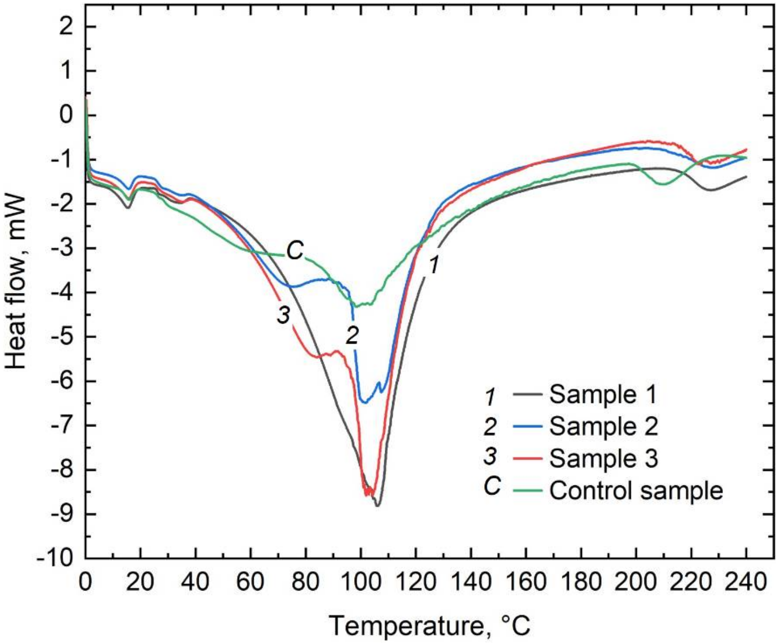

Figure 4. DSC curves of dough at ΔT 0-240 °C:
Sample 1, low-protein cookies made with corn starch, and xanthan gum;
Sample 2, low-protein cookies made with corn and tapioca starches, maltodextrin, and xanthan gum;
Sample 3, low-protein cookies made with corn starch, maltodextrin, and xanthan gum, control sample – butter cookies made with wheat flour.

Physical or chemical changes in a substance cause a change in its enthalpy. DSC determines the change in enthalpy that occurs between a sample and a reference during the heating process. This analysis is both quantitative, as the enthalpy is known from the area of the peaks recorded during the analysis, and qualitative, as it provides information such as the shape, position and number of peaks (Ito et al, 2022). The areas under the peaks are proportional to the enthalpy changes that occur in each transformation (Lucas et al., 2001). The DSC plot clearly shows that all the tested samples consume different amounts of energy during the heating process. The DSC curves are somewhat similar to the DTA curves but reflect endothermic processes. All samples were heated at temperatures ranging from 0 to 240 °C. At the beginning of the curve, it is seen that all samples behave similarly and actively absorb heat. In the temperature range from 20 to 30 °C, endothermic peak is seen associated with the melting transition of the fat phase corresponding to low melting and medium melting (Gonzalez-Ortega et al., 2023). When the temperature reaches 40 °C, the endothermic process is observed again in all the samples. This is due to a change in the aggregate state of the fat phase: the transition of butter from a solid to a liquid state associated with high melting (Gonzalez-Ortega, et al., 2023). With a further increase in temperature, the behavior of the curves of all the samples under study is slightly different.

In contrast to the low-protein dough, in the control sample, the endothermic process of changing the aggregate state of butter is immediately followed by the beginning of denaturation of wheat flour proteins and then by starch gelling. Thus, these successive endothermic processes overlap to some extent, which is why the graph does not show clear peaks for each process. At a temperature of 90 °C, the intensification of moisture removal from the sample begins. The endothermic process peaks at 102 °C. The DSC curves for low-protein samples which contain maltodextrin (samples 2 and 3) have a similar character. At a temperature of 55 °C, the endothermic process of gelling of the starches in the samples begins (Moreira et al., 2015). Compared to the low-protein sample made with corn starch, and xanthan gum, the endothermic peak begins at a lower temperature. At 78 °C, the energy absorption of the sample 2 decreases, which is explained by the partial replacement of corn starch with tapioca starch in this recipe. At a temperature of 100 °C, another rapid endothermic peak begins due to moisture removal. In sample without tapioca starch (sample 3), the intensification of the moisture removal process begins for 2 °C earlier compared to the sample with tapioca starch (sample 2).

The DSC curve of the sample made with corn starch, and xanthan gum has a different appearance compared to the samples containing maltodextrin (samples 2 and 3). The largest endothermic peak begins at 60 °C and reaches its maximum at 108 °C. This endothermic peak is the result of two main endothermic processes: starch gelling and intensive moisture removal from the dough piece.

With increasing temperature, exothermic processes are observed in all samples, which may indicate thermal decomposition of all the samples tested (Ito et al., 2022).

From the DSC curves, we can compare the amount of energy required for the heat treatment of the low-protein doughs and the control sample. The lowest amount of energy is required for the heat treatment of dough for traditional butter cookies, ΔH=124.05 J/g. The heat treatment of low-protein doughs requires more energy. This is due to the presence of xanthan gum and starches in the recipe. The largest amount of energy is required for heat treatment of dough sample made with corn starch, and xanthan gum, 268.33 J/g. Dough sample made with corn starch, maltodextrin, and xanthan gum requires less energy because the total area of the endothermic peak is smaller, 262.01 J/g. This may be due to the fact that the maltodextrin in the formulation of this sample absorbs some water, and this water is released more easily during heat treatment compared to the water absorbed by starches and xanthan gum. It could happen due to competition for water between maltodextrin and starch in the formulation of low-protein doughs (Xu et al., 2022). The heat treatment of the dough sample made with corn and tapioca starches, maltodextrin, and xanthan gum requires the least amount of energy, 199.46 J/g, among all the low-protein doughs studied. This is due to the properties of tapioca starch included in the recipe, since less energy is required for the gelling of tapioca starch.

Conclusions

1. The heat treatment process of low-protein cookies is different from the heat treatment of traditional cookies and has more similarities with heat treatment of gluten-free products due to absence of gluten network.

2. The presence of maltodextrin in a formulation of low-protein dough for butter cookies increases moisture removal during heat treatment process. Low-protein sample made with corn starch, and xanthan gum loses all moisture at 129 °C, low-protein sample made with corn starch, maltodextrin, and xanthan gum loses all moisture at 95.4 °C, and the control sample at 98.7 °C during TGA measurement.
3. The presence of maltodextrin in a formulation of low-protein cookies leads to slight decrease in energy required for baking: 268.33 J/g without maltodextrin and 262.01 J/g with maltodextrin.
4. Replacement of 20% of corn starch with tapioca starch in formulation leads to significant decrease in energy required for baking: sample with 100% corn starch has ΔH=262.01 J/g, sample with corn and tapioca starch has ΔH=199.46 J/g.
5. The lowest amount of energy is required for the heat treatment of dough for traditional butter cookies: ΔH=124.05 J/g. The heat treatment of low-protein dough requires more energy: ΔH=199.46–268.33 J/g.

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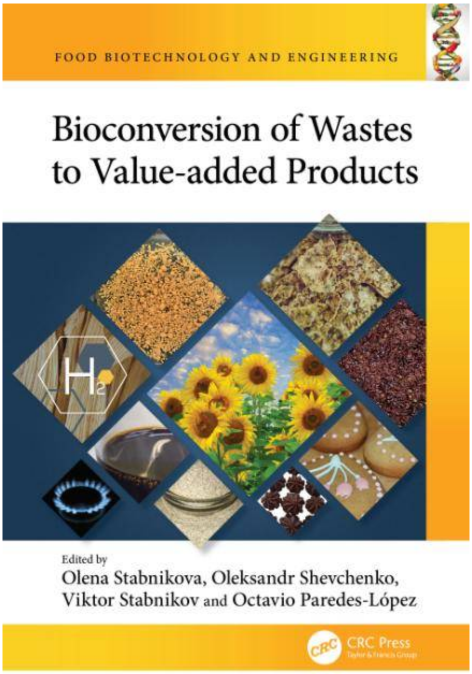
Bioconversion of Wastes to Value-added Products. International publication of Ukrainian scientists research studies

The authoritative international publishing house of scientific literature CRC Press Taylor & Francis group published the book "Bioconversion of Wastes to Value-added Products" under the leadership of the famous biochemist and nutritionist Octavio Paredes-López, which includes the studies of Ukrainian scientists.



Agricultural and food processing organic wastes contain valuable substances. Some of these organic wastes can be used as an additional source of important components to increase nutritional properties of traditional food products, others can be converted into energetic materials such as alcohol, bioethanol, hydrogen, and biogas. Application of a variety of wastes from industry, agriculture and food processing to turn them into valuable products pursues two goals at the same time, namely, the systematic and economically feasible use of the existing potential of useful products economically feasible use of the existing potential of useful products from non-recyclable wastes, as well as the creation of environmentally friendly technologies that protect the environment from potential contaminants.

This publication covers application of organic wastes as additives to enhance nutritional value of food, bioconversion of solid and liquid wastes into energy, such as biogas and hydrogen, and biotransformation of industrial and food processing wastes into biotechnological products. At the end, a chapter on design, construction and testing of biosensors for food control is described in detail.

Keys Features includes:

– Covers the use of different food wastes to enrich meat, dairy, bakery and confectionery products
– Presents new technologies for utilization of wastes from the meat, dairy and wine industries, among others
– Promotes bioconversion of agricultural wastes into energy such as hydrogen or biogas
– Proposes the use of industrial wastes to produce exopolysaccharides using bacteria or macromycetes
– Describes design, construction and testing of biosensors for food control

This book helps the students at bachelor and graduate levels, lecturers, researchers, and engineers of the food industry and environmental engineering by providing new knowledge and strategies on sustainable use of various wastes.

Detailed information about the Book: **https://doi.org/10.1201/9781003329671**

DOI: 10.24263/2310-1008-2023-11-1-7

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Abstract. The **abstract** should contain the following mandatory parts:

Introduction provides a rationale for the study (2-3 lines).

Materials and methods briefly describe the materials and methods used in the study (3-5 lines).

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Online document

Mendeley, J.A., Thomson, M., & Coyne, R.P. (2017), *How and when to reference*, Available at: https://www.howandwhentoreference.com

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Arych M. (2018), Insurance's impact on food safety and food security, *Resource and Energy Saving Technologies of Production and Packing of Food Products as the Main Fundamentals of Their Competitiveness: Proceedings of the 7th International Specialized Scientific and Practical Conference, September 13, 2018,* NUFT, Kyiv, pp. 52-57.

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Том 11, № 1 2023

Рекомендовано Вченою радою
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Протокол № 11 від 29.06.2023

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Підп. до друку 30.08.2023 р. Формат 70х100/16.
Обл.-вид. арк. 4.35. Ум. друк. арк. 4.96.
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