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EFFECT OF A LYCOPENE-BASED DIETARY SUPPLEMENT ON THE RHEOLOGICAL AND PHYSICOCHEMICAL PROPERTIES OF FLOUR CONFECTIONERY PRODUCTS

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The aim of the study was to evaluate the effect of a lycopene-based food additive on dough and determine the optimal level of its addition to wheat dough. Four samples of first-grade wheat flour were tested and evaluated for physicochemical quality parameters, including protein, moisture, gluten, and ash content.

Based on the results, Tsesna flour was selected for rheological studies due to its favorable combination of technological characteristics, including 18.23% protein, 40.01% gluten, and 13.96% moisture. The effect of the food additive on dough was determined at concentrations of 2%, 5%, and 10% and assessed using a Brabender farinograph. An addition of 2% had a limited effect on dough properties, while higher levels led to a gradual decrease in dough stability and quality.

Based on the rheological results, a level of 5% was selected for evaluating finished bakery products made from wheat flour. Compared to the control sample, the sample containing the food additive showed higher protein and ash content, increased water-soluble antioxidant content, and the presence of fat-soluble antioxidants and β-carotene. Vitamins A and C were also detected, and the content of vitamins B2, B3, B5, and B6 increased compared to the control sample.

The results demonstrate the technological feasibility of using a lycopene-based food additive at a level of 5% in flour confectionery products.

Keywords: lycopene, watermelon, tomato, carotenoids, rheology, flour.

ВЛИЯНИЕ ПИЩЕВОЙ ДОБАВКИ НА ОСНОВЕ ЛИКОПИНА НА РЕОЛОГИЧЕСКИЕ И ФИЗИКО-ХИМИЧЕСКИЕ СВОЙСТВА КОНДИТЕРСКИХ ИЗДЕЛИЙ ИЗ МУКИ

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Целью исследования было оценить влияние пищевой добавки на основе ликопина на тесто и определить оптимальный уровень ее добавления в пшеничное тесто. Были протестированы и оценены четыре образца пшеничной муки первого сорта по физико-химическим параметрам качества, включая содержание белка, влаги, глютена и золы.

На основании результатов для реологических исследований была выбрана мука сорта «Цесна» благодаря благоприятному сочетанию технологических характеристик, включая 18,23% белка, 40,01% глютена и 13,96% влаги. Влияние пищевой добавки на тесто определялось при концентрациях 2%, 5% и 10% и оценивалось с помощью фариографа Brabender. Добавление 2% оказывало ограниченное влияние на свойства теста, в то время как более высокие уровни приводили к постепенному снижению стабильности и качества теста.

На основании реологических результатов для оценки готовых хлебобулочных изделий из пшеничной муки был выбран уровень 5%. По сравнению с контрольным образцом, образец, содержащий пищевую добавку, показал более высокое содержание белка и золы, повышенное содержание водорастворимых антиоксидантов, а также присутствие жирорастворимых антиоксидантов и β-каротина. Были также обнаружены

витамины А и С, а содержание витаминов В2, В3, В5 и В6 увеличилось по сравнению с контрольным образцом.

Результаты демонстрируют технологическую осуществимость использования пищевой добавки на основе ликопина в количестве 5% в мучных кондитерских изделиях.

Ключевые слова: ликопин, арбуз, томат, каротиноиды, реология, мука.

ЛИКОПИН НЕГІЗІНДЕГІ ТАҒАМДЫҚ ҚОСЫМШАНЫҢ ҰННАН ЖАСАЛҒАН КОНДИТЕРЛІК ӨНІМДЕРДІҢ РЕОЛОГИЯЛЫҚ ЖӘНЕ ФИЗИКОХИМИЯЛЫҚ ҚАСИЕТТЕРІНЕ ӘСЕРІ

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Зерттеудің мақсаты ликопин негізіндегі тағамдық қоспаның қамырға әсерін бағалау және оны бидай қамырына қосудың оңтайлы деңгейін анықтау болды. Бірінші сұрыпты бидай ұнының төрт үлгісі ақуыз, ылғал, глютен және күл құрамын қоса алғанда, физика-химиялық сапа параметрлері бойынша тексеріліп, бағаланды.

Нәтижелерге сүйене отырып, Цесна ұны 18,23% ақуыз, 40,01% глютен және 13,96% ылғалдылықты қоса алғанда, технологиялық сипаттамаларының қолайлы үйлесіміне байланысты реологиялық зерттеулер үшін таңдалды. Тағамдық қоспаның қамырға әсері 2%, 5% және 10% концентрацияларда анықталды және Брабендер фариографын пайдаланып бағаланды. 2% қосу қамырдың қасиеттеріне шектеулі әсер етті, ал жоғары деңгейлер қамырдың тұрақтылығы мен сапасының біртіндеп төмендеуіне әкелді.

Реологиялық нәтижелерге сүйене отырып, бидай ұнынан жасалған дайын нан-тоқаш өнімдерін бағалау үшін 5% деңгейі таңдалды. Бақылау үлгісімен салыстырғанда, тағамдық қоспасы бар үлгіде ақуыз бен күлдің мөлшері жоғары, суда еритін антиоксиданттардың мөлшері жоғары және майда еритін антиоксиданттар мен β-каротиннің болуы байқалды. А және С дәрумендері де анықталды, ал бақылау үлгісімен салыстырғанда В2, В3, В5 және В6 дәрумендерінің мөлшері жоғарылады.

Нәтижелер ұннан жасалған кондитерлік өнімдерде ликопин негізіндегі тағамдық қоспаны 5% деңгейінде қолданудың технологиялық мүмкіндігін көрсетеді.

Түйін сөздер: ликопин, қарбыз, қызанақ, каротиноидтар, реология, ұн.

A balanced diet is the basis of human life and is considered an important factor in the prevention of most cardiovascular (atherosclerosis, myocardial infarction, stroke, hypertension, etc.), oncological, gastrointestinal, metabolic (obesity, osteochondrosis, etc.) diseases. Currently, in various regions of the country, there is a significant decrease in the population's consumption of highly biologically valuable food products, insufficient consumption of vitamins and a number of minerals. One way to solve this problem may be to include carotenoids in the diet, which have antioxidant activity and play an important physiological role in maintaining human health, strengthening the immune system and preventing chronic diseases.

Due to their biological properties, carotenoids play an important physiological role in human life, and the expansion of their scope of application requires an increase in the production of carotenoids and food products using them. Accordingly, research in the field of improving existing technologies for

obtaining carotenoids and expanding the raw material base, including the use of secondary resources at the processing plant for raw materials containing carotene, is relevant.

In horticultural crops and vegetables, carotenoids (lycopene) not only provide a beautiful color, but also have high antioxidant properties that fight peroxidation in the body, help deactivate free radicals, carcinogens, and inhibit the development of cancer and cardiovascular diseases [1].

Lycopene is a carotenoid pigment that determines the color of the fruits of some plants, such as tomatoes, guava, and watermelon. Lycopene has antioxidant activity, which is manifested, in particular, in the protection of DNA, which prevents the formation and

development of malignant tumors. It acts as a preventive measure for atherosclerosis, cataracts, and treats some inflammatory processes [2].

Lycopene is a fat-soluble carotenoid that is found in tomatoes, watermelon pulp (3.55-4.86 mg/100 g), red grapefruit, sea buckthorn, and rose hips. Lycopene is registered as a food additive E-160 and is approved for use in Russia, Belarus, the USA, Australia, New Zealand and the European Union. The recommended daily intake of lycopene is 5-10 mg [3]. The main function of lycopene in the human body is as an antioxidant. Reducing oxidative stress slows down the development of atherosclerosis, and also provides DNA protection, preventing oncogenesis. Consumption of lycopene and foods containing lycopene leads to a significant decrease in oxidative stress markers in humans. Lycopene is the most powerful carotenoid and antioxidant in human blood [4].

Scientists do not give up hope that thanks to their research they will uncover the secret of preserving youth, increasing immunity, reducing the risk of cardiovascular diseases, maintaining normal intracellular metabolism and reducing the risk of cancer. Lycopene is also one of the most powerful antioxidants among carotenoids. As one of the most potent antioxidants, its ability to neutralize singlet oxygen is twice as effective as β-carotene, ten times as effective as α-tocopherol, and one hundred and twenty-five times as effective as glutathione [5]. Lycopene, isolated from the seeds of Lycopersicum esculentum (tomato) in 1903, is named after the fruit from which it was isolated [6].

In human studies of lycopene in the treatment of cancer, lycopene has been shown to improve the outcome of localized prostate cancer [7], reduce prostate cancer-specific mortality in men at high risk of prostate cancer, and slow the progression of recurrent prostate cancer regardless of hormone sensitivity [8]. Lycopene has also been shown to improve quality of life and to relieve bone pain and control lower urinary tract symptoms [9].

Lycopene also protects the eyes from oxidative stress, which is a cause of many diseases. Lycopene has a significant effect on the chemical and inflammatory processes that lead to age-related macular degeneration, which can cause blindness in older people.

Lycopene is a water-insoluble compound that gives fruits and vegetables their yellow, orange and red colors. Our body cannot synthesize lycopene on its own, so we need to eat red vegetables and fruits or enrich our diet with dietary supplements. In the body, it works as an antioxidant, protecting cells from the harmful effects of oxidation caused by free radicals.

In addition to pigment coloring, lycopene is used in the food industry as a flavor enhancer in some products [10]. Currently, food products containing this substance have already been developed, including meat products, tomato paste, and others [11]. A monotonous diet, chosen by both adults and schoolchildren, can negatively impact metabolism in the long term. Functional nutrition has found wide application in the food industry, as it can help replenish the deficiency of essential dietary nutrients, minerals and vitamins, dietary fiber, and probiotics and prebiotics [12]. Functional ingredients can be

added to a product in quantities ranging from 10 to 50%, depending on a person's daily requirement. Compared to dietary supplements, these products eliminate the possibility of overdose, have an attractive appearance (not a medicinal form), and can be consumed regularly. One category of people who require the use of lycopene-enriched functional foods (e.g., baked goods) are residents of cities with unfavorable environmental conditions. Adding ingredients with antioxidant properties to food can reduce oxidative stress that occurs in the human body under the influence of stress factors [13].

In one experiment, UK scientists created diets containing lycopene-enriched foods. The daily diet consisted of 21-23% of the total lycopene intake from bread, 16-17% from breakfast cereals, and 7–15% from flavored soft drinks [14].

The objective of this study was to establish the maximum dose of lycopene as a functional food additive in the dough of individually consumed bakery products. The study also aimed to determine the effects of various concentrations of lycopene extract using organoleptic methods of qualitative analysis of the dough semi-finished and finished products.

Lycopene is not destroyed by heat treatment, so it is mainly found in foods and products made from tomatoes. In addition, high temperatures change the structure of the carotenoid, so it begins to be better and more fully absorbed by the body. Tomato paste contains 30 times more lycopene than fresh tomatoes. A number of studies have shown that regular consumption of foods containing the carotenoid lycopene reduces the risk of cardiovascular disease and prostate cancer.

Since local vegetables and melons are used to obtain lycopene, this leads to lower production costs. Interestingly, when products containing lycopene are

consumed raw, it is absorbed by the body in small quantities. When they are heat treated, the concentration of lycopene increases, but even in this case it may not be sufficient.

In this regard, the use of lycopene in food production is becoming a practically necessary and important element in modern life.

Materials and Methods. The main subjects of the development were oatmeal cookie samples made from oat flakes and wheat flour with the addition of a lycopene-based dietary supplement. The study subjects included oat flakes, wheat flour, the dietary supplement, sugar, butter, eggs, baking powder, salt, vanillin, and water. Experimental studies were conducted using the following modern methods, which allow for raw material characteristics to be obtained based on a set of indicators: Experimental studies were conducted using the following methods, which allow for raw material characteristics to be obtained based on a set of indicators:

GOST ISO 5530-1-2013 Wheat flour. Physical characteristics of dough;

GOST 27839-2013 Wheat Flour. Methods for Determining Gluten Quantity and Quality;

GOST 27676-88 Grain and Grain Products. Falling Number Determination Method.

GOST 5898-87 Determination of Acidity and Alkalinity.

GOST R 51478-99 (ISO 2917-74) Determination of Hydrogen Ion Concentration (pH).

GOST R ISO 22935-2-2011 Recommended Methods for Organoleptic Evaluation.

Determination of Active Acidity with a Testo 206-pH1 pH Meter.

GOST EN 12823-2-2014 Determination of Vitamin A Content by High Performance Liquid Chromatography.

GOST EN 12822-2014 Food Products. Determination of Vitamin E Content (α-, β-, γ-, and 5-Tocopherols) by High-Performance Liquid Chromatography.

GOST 34151-2017 Food Products. Determination of Vitamin C by High-Performance Liquid Chromatography.

The KazNIIPPP facility is equipped with modern instruments for determining flour quality and evaluating dough properties. The effect of a biologically active additive (BAA) on the rheological properties of wheat dough was assessed using a Brabender farinograph (Brabender GmbH & Co. KG, Duisburg, Germany). The farinograph allows one to record changes in the physical properties of dough based on its resistance to the mechanical action of mixing paddles, i.e., the behavior of the dough under

mechanical stress during the production process. The farinograph records the formation and behavior of dough under constant mechanical stress. The farinograph also determines the water absorption capacity of flour and the dough development and stabilization.

For raw material quality control, a Spektran-219 instrument (LLC Lomo Fotonika Plus, St. Petersburg, Russia) was used to determine protein mass fraction, moisture, wet gluten content, and ash content. The following first-grade domestically produced wheat flours were used: "Tsesna," "Snezhinka," "Imperator," and "Sultan."

As a result of scientific research, a technology for functional flour confectionery products using a lycopene-based biologically active additive was developed.

Results and Discussions. Determination of physicochemical quality indicators for first-grade wheat flour produced domestically: "Tsesna," "Snezhinka," "Imperator," and "Sultan." The results are presented in Table 1.

Table 1 - Physicochemical quality indicators of first grade wheat flour of different grades

Flour variety	Flour Parameters, %			
	Protein	Moisture	Gluten	Ash
Tsesna	18,23	13,96	40,01	1,08
Snezhinka	18,06	14,06	39,5	1,32
Imperator	18,08	13,50	40,21	0,75
Sultan	18,43	12,81	40,79	0,44

According to the study's quality indicators for various grades of first-grade wheat flour, the "Sultan" and "Tsesna" samples had high protein content: 18.43% and 18.23%.

A wet gluten content of 30-32% characterizes the flour as strong, possessing high gas-holding capacity, forming an elastic and resilient dough, and providing large volume and developed porosity.

Moisture content of the samples ranged from 12.81% to 14.06%, which corresponds to the GOST standard, which stipulates that the optimal flour moisture content should not exceed 14-15%, as higher values increase the risk of microbiological spoilage and reduce shelf life.

Ash content is an important indicator of flour grade and refinement. The Sultan sample's minimal ash content (0.44%) indicates a high degree of refinement and superior quality. High values were found in the Sesna and Snezhinka varieties, indicating a higher proportion of peripheral grain particles, which can impair the color and organoleptic properties of the product.

The gluten content in all samples ranged from 38.54% to 42.86% and exceeded the GOST 26574-2017 standard (at least 30%). The Pioneer sample met the ash content standard (0.57%, with a maximum permissible value of 0.75%), while the ash content in the Sesna and Snezhinka varieties significantly exceeded the standard-1.71% and 2.38%, respectively. Both samples met the moisture content standard, while the Snezhinka sample exceeded the standard by 16.06%, with a maximum permissible limit of 15%. The moisture content of all samples complied with the standard, but in the "Snezhinka" sample, it exceeded the standard by 16.06%, with a maximum permissible limit of 15%.

Based on the analysis of the physicochemical quality parameters of the wheat flour, all samples possessed high baking potential. However, for the rheological studies, "Tsesna" flour was selected as the sample with the optimal combination of technologically significant characteristics.

"Tsesna" flour was characterized by a high protein content (18.23%) and gluten (40.01%), due to the formation of a strong gluten structure. At the same time, the moisture content (13.96%) was within the standard, ensuring stable conditions for the hydration of the dough components.

Despite a slightly higher ash content (1.08%), this sample demonstrated a high gluten content, which is a determining factor in assessing baking properties. The high protein-gluten complex content ensures good gas-retention capacity and dough stability under mechanical stress.

To determine the optimal dosage of the biologically active additive, the rheological and structural-mechanical properties of dough prepared from Tsesna wheat flour with the addition of the biologically active additive at levels of 2%, 5%, and 10% were studied. Water absorption capacity, dough development time, stability, tolerance index, and farinographic quality number were determined. The results are presented in Table 2.

Table 2 - Results of rheological studies of dough using a farinograph

Samples	Water absorption, %	Development time, min	Stability, min	Tolerance index, FU	Quality number
Control	54,4	7,9	16,1	18	154
2% supplement	54,8	9,9	14,2	29	151
5% supplement	56,1	6,4	10,6	39	104
10% supplement	56,3	4,7	4,4	100	47

The study found that adding 2% of the dietary supplement did not significantly change the rheological properties. The dough remained stable and its technological stability was maintained, indicating good compatibility of the supplement with wheat flour and the absence of a significant negative impact on the gluten structure. With an increase in the dietary supplement dosage to 5%, a tendency toward a decrease in dough stability and resistance to mechanical stress is observed, indicating a partial weakening of the gluten framework.

With a further increase in the supplement content to 10%, the changes become more pronounced and are accompanied by a significant decrease in dough stability and quality, indicating a disruption of structure formation processes.

The results indicate that the effect of the developed dietary supplement on the rheological properties of dough is due to its multicomponent composition, including plant powders, lipids, and biologically active compounds.

These components likely influence protein hydration processes and gluten network formation, which is particularly evident with increasing dosage.

With increasing dosage to 5% and 10%, the effect of the composition becomes more pronounced, as evidenced by changes in stability indicators and quality scores. These changes are associated with the presence of dietary fiber, lipids, and biologically active substances in the additive, which can influence protein hydration processes and gluten network formation.

Based on the results, the developed biologically active additive exhibits technological compatibility with wheat flour at limited dosages, while its composition causes a moderate change in

the rheological properties of the dough without critical quality degradation at an addition level of up to 5%.

To assess the effect of a lycopene-based dietary supplement on the quality of flour confectionery products, a control sample and a test sample containing 5% of the dietary supplement were tested. The physicochemical and microbiological quality parameters of the finished products were assessed.

A full characterization of the nutritional and biological value of the control and test samples, including determination of the vitamin, amino acid, mineral, and fatty acid compositions, was conducted at the Research Laboratory for Food Quality and Safety Assessment at Almaty Technological University (ATU). The results of the physicochemical studies are presented in Table 3.

Table 3 - Physicochemical parameters of flour confectionery samples

Parameter, unit	Control sample	Sample with supplement
Protein, %	9.90 ± 0.11	11.01 ± 0.13
Ash, %	1.38 ± 0.02	1.61 ± 0.01
Fat-soluble antioxidants, mg/g	Not detected	0.024 ± 0.0008
Water-soluble antioxidants, mg/g	0.217 ± 0.005	0.295 ± 0.003
β-Carotene, mg/kg	Not detected	4.09 ± 0.04
Fat peroxide value, mmol/kg	15.63 ± 0.14	15.16 ± 0.17
Sucrose, g/kg	87.40	27.88

According to the data in Table 5, the addition of 5% of the lycopene-based dietary supplement improves the physicochemical parameters flour confectionery product. Protein content increased by 11.2%, and ash content by 16.7%, indicating an increased nutritional value. Fat-soluble antioxidants and β-carotene, which were absent in the control sample, were detected in the test sample. At the same time, sucrose content was reduced by more than threefold, increasing the functional value of the developed product.

Ash content in the test sample increased from 1.38±0.02% to 1.61±0.01%, indicating a higher mineral content.

According to antioxidant activity analysis, the fat-soluble antioxidant content in the test sample was 0.024±0.0008 mg/g, while none were detected in the control sample. The amount of water-soluble antioxidants increased from 0.217±0.005 to 0.295±0.003 mg/g, representing a 35.9% increase compared to the control sample. These results demonstrate the increased antioxidant activity due to the addition of a lycopene-containing supplement.

The test sample also contained β-carotene at a level of 4.09±0.04 mg/kg, while this indicator was not detected in the control sample. The presence of β-carotene is due to the presence of carotenoid compounds in the dietary supplement and further enhances the functional value of the product.

Table 4 shows that the addition of a lycopene-based dietary supplement contributes to the enrichment of flour confectionery products with vitamins. Vitamins A and C were detected in the test sample, which were absent from the control sample. The vitamin A content was 115.53 mg/kg, due to the presence of carotenoid compounds in the supplement. Furthermore, an increase in B vitamin content was noted: vitamin B2 by 39.4%,

vitamin B3 by 8.4%, vitamin B5 by 21.1%, and vitamin B6 by 63.3% compared to the control sample. These data indicate an increase in the vitamin value of the developed flour confectionery product, essential for the normal functioning of the human body.

Table 4 - Vitamin composition of the studied samples

Parameter, unit	Control sample	Sample with supplement
Vitamin A, mg/kg	Не обнаружено	115,53
Vitamin E, mg/kg	89,78±1,01	86,20±1,00
Vitamin C, mg/100 g	Не обнаружено	1,18±0,02
Vitamin B1, mg/100 g	0,114±0,020	0,120±0,024
Vitamin B2, mg/100 g	0,071±0,029	0,099±0,041
Vitamin B3, mg/100 g	2,03±0,406	2,20±0,44
Vitamin B5, mg/100 g	0,128±0,025	0,155±0,031
Vitamin B6, mg/100 g	0,030±0,006	0,049±0,009

Conclusion. The study results demonstrated that the developed lycopene-based food additive can be used to fortify flour confectionery products. Cesna wheat flour was selected for further experiments due to its favorable protein, gluten, and moisture content. Rheological studies revealed that the additive's addition affected dough properties depending on its concentration. At 2% addition, only minor changes were observed, while higher concentrations led to a gradual decrease in dough stability and quality. Therefore, 5% was chosen as the most suitable level for further product development. The flour confectionery sample containing 5% of the food additive had higher protein and ash content than the control sample. It also contained fat-soluble antioxidants and β-carotene, which were not detected in the control sample, while the content of water-soluble antioxidants increased by 35.9%. Vitamins A and C were detected in the fortified product, and an increase in several B vitamins was also observed. Therefore, the use of a 5% lycopene-based food additive represents a suitable approach for developing a functional flour confectionery product with improved nutritional and antioxidant properties.

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References

1. A. Kulawik, J. Cielecka-Piontek, P. Zalewski The Importance of Antioxidant Activity for the Health-Promoting Effect of Lycopene//Nutrients. −2023.-Vol.15(17):3821. DOI 10.3390/nu15173821.
2. Sherma J. Review of the Determination of the Antioxidant Activity of Foods, Food Ingredients, and Dietary Supplements by Thin Layer Chromatography-Direct Bioautography, Spectrometry, and the Dot-Blot Procedure//AOAC Int.-2018.-Vol.101(5). -P.1285-1294. DOI 10.5740/jaoacint.18-0116.
3. Y. Ni, F. Zhuge, M. Nagashimada, N. Nagata, L. Xu, S. et al. Lycopene Prevents the Progression of Lipotoxicity-Induced Nonalcoholic Steatohepatitis by Decreasing Oxidative Stress in Mice//Free Radical Biology and Medicine.-2020.-Vol.152.-P.571-582. DOI 10.1016/j.freeradbiomed.2019.11.036.
4. Kapała A., Szlendak M., Motacka E. The Anti-Cancer Activity of Lycopene: A Systematic Review of Human and Animal Studies // Nutrients. - 2022. - Vol.14(23):5152. DOI 10.3390/nu14235152.
5. Lado J., Zacarias J., Rodrigo M.J., Zacarías L. Visualization of Carotenoid-Storage Structures in Fruits by Transmission Electron Microscopy // Methods in Molecular Biology. - 2020. - Vol.2083. - P.235-244. DOI 10.1007/978-1-4939-9952-1_18.
6. Zhumaliyeva G., Kenenbay G., Chomanov U., Shoman A., Baizakova A. Development and Physicochemical Evaluation of a Biologically Active Additive Based on Powders of Melons and Vegetables//SciFood. - 2025. - Vol.19. - P.580-595. DOI 10.5219/scifood.72.

7. Imran M., Ghorat F., Ul-Haq I., Ur-Rehman H., et al. Lycopene as a Natural Antioxidant Used to Prevent Human Health Disorders//Antioxidants. −2020.-Vol.9(8):706. DOI 10.3390/antiox9080706.
8. Collins E.J., Bowyer C., Tsouza A., Chopra M. Tomatoes: An Extensive Review of the Associated Health Impacts of Tomatoes and Factors That Can Affect Their Cultivation//Biology. −2022.-Vol.11(2):239. DOI 10.3390/biology11020239.
9. Kristal A.R., Till C., Platz E.A., Song X., King I.B., Neuhouser M.L., Ambrosone C.B., Thompson I.M. Serum Lycopene Concentration and Prostate Cancer Risk: Results from the Prostate Cancer Prevention Trial// Cancer Epidemiology, Biomarkers & Prevention. −2011.-Vol.20(4). -P.638-646. DOI 10.1158/1055-9965. EPI-10-1221.
10. Viuda-Martos M., Sanchez-Zapata E., Sayas-Barberá E., Sendra E., Pérez-Álvarez J.A., Fernández-López J. Tomato and Tomato Byproducts. Human Health Benefits of Lycopene and Its Application to Meat Products: A Review//Critical Reviews in Food Science and Nutrition. 2014.-Vol.54(8):1032-49. DOI 10.1080/10408398.2011.623799.
11. Joshi B., Kar S.K., Yadav P.K., Yadav S., Shrestha L., Bera T.K. Therapeutic and Medicinal Uses of Lycopene: A Systematic Review//International Journal of Research in Medical Sciences. −2020. Vol.8(3):1195. DOI 10.18203/2320-6012.ijrms20200804.
12. Bramley P.M. Is Lycopene Beneficial to Human Health? // Phytochemistry. - 2000. - Vol.54(3). - P.233-236. DOI 10.1016/S0031-9422(00)00103-5.
13. Morgia G., Voce S., Palmieri F., Gentile M., Iapicca G., et al. Association between Selenium and Lycopene Supplementation and Incidence of Prostate Cancer: Results from the Post-Hoc Analysis of the Procomb Trial // Phytomedicine. - 2017. - Vol.34. - P«. D»OI 10.1016/j.phymed.2017.06.008.
14. Li J., Xian J., Zhang S., An Y., Li N., Zhou D., Sun S., Wang J. Influence of Pigment Composition on Antioxidant Capacity of Different Tomato (Solanum lycopersicum L.)//LWT. −2025.-Vol.224:117871. DOI 10.1016/j.lwt.2025.117871.

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