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BIOLOGICAL VALUE OF BY-PRODUCTS OF TOMATO PROCESSING

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Abstract. The article analyses the biological value of secondary products of tomato processing, namely tomato seeds, which are seldom considered in the food industry as an object of processing. Tomato seeds, a secondary raw material formed during manufacture of tomato products, are suggested as a source of bioactive substances to be further used in food technologies. The paper presents the results of theoretical and experimental studies of the physicochemical composition of tomato seeds. It has been confirmed that tomato seeds, due to their high content of proteins, lipids, and carbohydrates, have high nutritional and biological value that conforms to modern recommendations for creating healthy diets. Tomato seeds contain 27-30% of fat, 25-35% of nitrogenous extractives, 11-18% of nitrogen-free extractives, 2.5-5.8% of minerals, and 12-25% of cellulose. They are also rich in polyunsaturated fatty acids, phospholipids, macronutrients and trace elements, vitamin E. However, their nutritional value is significantly reduced by natural bioactive antialimentary substances that inhibit proteinases. The experiments have allowed establishing the activity of trypsin inhibitors – anti-nutrients contained in tomato seeds. Their activity was 0.30mg trypsin/g protein for technically mature seeds, and 0.52mg trypsin/g protein for biologically mature seeds. To reduce the activity of trypsin inhibitors, it has been suggested to use hydrothermal treatment and micronisation of tomato seeds. Hydrothermal treatment for 40min, with the temperature of the water 90-100°C, reduced the trypsin inhibitory activity by 1-3%, as compared with the initial values. Micronisation, too, allowed significantly reducing the activity of inhibitors of tomato seed trypsin: keeping the samples for 60s in a microniser reduced the activity of trypsin inhibitors in the technically ripe tomato seeds by about 34%, and that in the biologically ripe ones by 28.8%. This research is important and topical, because it extends the range of possible applications of secondary raw materials obtained from tomato processing, namely tomato seeds, in the technology of canned products with high biological value.

Keywords: tomatoes, proteinases, seeds, inactivation, trypsin.

Introduction. Formulation of the problem

Today, the structure of Ukrainian people's nutrition is far from the modern principles of rational diet and practical dietary science [1-4]. Studies of the actual state of nutrition in different regions of Ukraine reveal serious violations of the nutrition structure and the nutritional status of both children and adults. The problems include the deficiency of complete proteins, polyunsaturated fatty acids, vitamins C, E, and those of group B, folic acid, retinol, β-carotene; macronutrients and trace elements (Ca, Fe, Zn, F, Se, I, and others), dietary fibre. Conversely, there is an excessive consumption of animal fats and easily digestible carbohydrates [5]. Fresh fruit and vegetables in Ukraine are consumed twice as little as the dietary norm prescribes, and besides, they are mostly seasonal. Today, Ukrainian people's needs of vegetables and fruit are only met by 35-45% of the recommended consumption rate (50-53 instead of 110-120kg/year per person) [1].

The current level of the food industry development requires intensification and a sharp increase in the production efficiency. One of the promising areas of intensification of the food industry is expansion of its raw material base. It includes the use of new raw materials containing vital substances, with which you can enrich foodstuffs, expand their range, improve their sensory and physicochemical parameters. The most promising additional raw materials of practical interest for the food industry include secondary resources from processing tomatoes. Valuable food raw materials are tomato seeds, which are formed as waste in the course of manufacture of tomato juice and concentrated tomato products. The existing technologies of processing tomato raw materials are inefficient: they include a number of production stages, require large amounts of various extractants, and result in the loss of carotenoids and tocopherols [6]. To solve the problem of complex processing of tomatoes using secondary resources, it is necessary to find new experimentally proved theoretical ideas about the processes taking place in tomatoes during their processing.

Analysis of recent research and publications

Food industry is one of the most developed branches of material production in Ukraine, and at the same time, it is one of the largest sources of waste. Volumes of some kinds of waste are quite significant. Thus, waste from the fruit, vegetable, and canning industries, in the form of apple, berry, and vegetable pomace, amounts to 0.5–0.9 million tonnes a year, and besides, 0.1–0.12 million tonnes a year [7] are made up by fruit kernels and nut shells.

If non-traditional plant raw materials are comprehensively processed, they can become promising sources of bioactive lipids, proteins, and trace elements. These raw materials include secondary products of tomato processing, namely tomato pomace and seeds, which contain valuable substances: proteins, lipids, fat-soluble and water-soluble vitamins, trace elements and macronutrients [8].

The composition of tomato waste includes (% of raw materials): up to 4.9 of pulp, 0.6 of skins, 0.4 of vascular fibres, peduncles, crushed seeds, and skins. Tomato seeds (air-dried) contain 27–30% of fat, 25–35% of nitrogen, 11–18% of nitrogen-free extractives, 2.5–5.8% of minerals, and 12–25% of cellulose. Tomato skin contains up to 10% of moisture, about 70% of cellulose, 5% of pectin, 5.4% of protein, 3.3% of fat, 6.5% of ash, and 2.5mg/100g of carotene [9,10]. The chemical composition is similar to that of oilseeds and indicates the high biological value of tomato seeds.

Tomato pomace is a source of biologically active lipids, namely polyunsaturated fatty acids, carotenoids, and tocopherols, which have a positive effect on fat metabolism and other important body functions. The biological value of tomato pomace is enhanced by the content of β-carotene, which has high biological activity [3,8]. There is a tendency in the world to produce dry tomato waste, because it is easy to transport and store, and dry products from tomato waste have rich chemical composition.

Tomato waste dried to the final humidity 8–14% is used in the production of dry feed mixtures [8]. Drying different types of tomato waste mixed together is possible, but studies have shown that separate drying is more cost-effective. When drying the seeds, pure raw materials are formed for oil production, and when drying skin and coarse parts of the pulp, a dry residue containing carotene is created and can be used as a component for feed mixtures. Tomato seeds, separated from the skin, are used in the oil and fat industry. Tomato seed oil is in great demand in the perfumery and cosmetics industry [11,12].

Ground tomato seeds are also used in baking. Adding them to flour increases the freshness of bread [13]. The United States has developed a method of using tomato seeds to manufacture powdered dried tomatoes; dried and ground tomato seeds are added to dry tomato puree. The presence of tomato seed flour prevents clumping in tomato powder [14].

Vegetable protein is obtained from tomato seeds and oil cakes. The amino acid composition of tomato seed proteins is similar to that of soya bean proteins. Protein is contained in the range of 28.4-31.0%, lipids canstitute about 37.5%, lysine makes up 5-6%. Tomato seed proteins are poor in methionine and cysteine [15]. Vegetable protein is used in the diet mainly in the form of supplements that increase the nutritional value of food. It is used to produce pasta, soups, smoked meat, sausages, meat and vegetable mixes, various vegetable and vegetable-meat pastes, fillings and forcemeat, and besides, can be components of bakery products [16]. Protein (35%) obtained from tomato seeds is also used for the production of plastics [17].

Studying the mineral composition has shown that tomato seeds are a rich source of minerals, especially of potassium, calcium, magnesium, iron, and phosphorus [18]. The mineral composition has a more favourable ratio of calcium and phosphorus (1:2.3) than, for example, soya has (1:3.1), which improves the absorption of calcium and phosphorus [19-21]. Seventeen amino acids have been identified in tomato seed proteins, including 33% of essential amino acids and 7.11–7.43% of lysine, which proves the high nutritional value of tomato seeds [22,23].

According to M. D. Dacherman, pressing of tomato seeds yields 17–19% of oil, solvent extraction with gasoline yields 26%, that with ether 25% [22]. The Ukrainian Institute of Nutrition researched tomato oil and found it suitable for eating and for frying vegetables and potatoes.

Digestibility of tomato oil is 97% [19]. It contains 80% of unsaturated bioactive fatty acids (34-53% of linoleic, 25-38% of oleic, up to 2.5% of linolenic), 15-18% of saturated acids (9.5-12.5% of palmitic, 4.9-6% of stearic, 1% of myristic, 0.4–1.3% of arachidonic), 0.9% of phosphatides, 0.06-0.07% of carotenoids, and 0.180-0.190% of tocopherols. Tomato oil is rich in tocopherol, which is added to creams and various cosmetics [11,12]. Tomato oil is considered to be one of the best edible oils. It is often added to salads, pastries, etc. 97% of it is absorbed by the body, and its properties are close to those of soya bean oil. It has antioxidant properties, retains its palatability and physicochemical properties.

It has been found that addition of up to 4% of tomato oil, which has anti-oxidant properties, proves more effective than addition of other antioxidants [24-26]. It has also been found that tomato oil is more suitable for stabilising ß-carotene concentrate than vitamin E concentrate used for this purpose.

The existing technologies of processing tomato raw materials include a number of production stages, require large amounts of various extraction agents, and result in loss of carotenoids and tocopherols [27].

Secondary products of tomato processing have high nutritional and biological value, because their composition includes a significant proportion of complete dietary protein, fats, vitamins, and dietary fibre. So far, using secondary raw materials is not widely practiced at Ukrainian enterprises, which causes significant losses of bioactive substances (BAS) during the manufacture of canned products [19]. Possible ways of solving this problem are considered in the article.

The purpose of the article is to study the possibilities of reducing the activity of anti-nutrients of tomato seeds for their further processing in food technologies. For this purpose, it is necessary to achieve the following **objectives:**

1. to study the physicochemical and biochemical composition of tomato seeds, which are a secondary product of processing of tomato raw materials;
2. to establish the activity of anti-nutrient components of tomato seeds;
3. to suggest ways to reduce the amount of anti-nutrients.

Research materials and methods

The research involved using tomato varieties most cultivated in the central regions of Ukraine (harvested in 2015-2017) and by-products of tomato processing, namely tomato seeds of the cultivar Alexia formed along with obtaining tomato products. Tomato seeds were washed three times with water, sieved, and used for further research. Production tests were conducted in *Ukroptbakaliya* in Chernihiv.

Technically ripe tomatoes used for the experimental studies included samples containing tomatoes: green – no more than 5%, blanche – 10–18%, brown – 25–35% pink – 50–62%. The degree of ripeness of tomatoes was determined in accordance with DSTU 2175:2017. Technically ripe tomatoes were investigated in order to reduce the amount of unused raw materials.

The experimental part of the work was performed in the laboratories of the Department of Canning Technologies and the Department of Food Chemistry, NUFT (Kyiv), in the problem research laboratory of NUFT (Kyiv), at the Palladin Institute of Biochemistry of the National Academy of Sciences of Ukraine (Kyiv), in *UkrSpetsAgroProduct* Laboratory (Kyiv), in the State Centre for Certification, Identification, and Quality of Plant Varieties (Kyiv).

The chemical compositions of technically and biologically mature tomato seeds were studied separately, and then compared and analysed. The mass fraction of moisture in tomato seeds was determined according to DSTU ISO 751:2004, the mass fraction of reducing substances was determined by Schoorl's iodometric method. The essence of the method is that when boiling the exact amount of Fehling's liquid with the test solution containing reducing sugars, the latter reduce the ions of divalent copper (Cu_2+) to copper (I) oxide. To determine the amount of divalent copper reduced by sugar, a control experiment is conducted, in which distilled water is taken instead of the test solution containing sugar. The next step is determining the amount of sodium thiosulphate equivalent to the total amount of divalent copper that participates in the experiment. To do this, the difference is determined between the volumes of sodium thiosulphate spent on titration of I_2 in the reference and test solutions. According to the value found (difference of the two volumes), expressed in cm^3 of 0.1N sodium thiosulphate solution, the equivalent amount of sugar in a certain volume of the test solution is found [30].

Determination of lipids was performed by the refractometric method, based on the removal of fat from the product by the solvent and the determination of its mass fraction by the difference between the refractive indices of the solvent and the solution of fat in the solvent.

The total content of dietary fibre in the products studied was determined by enzymatic-gravimetric method, the content of fibre (cellulose) was performed according to DSTU ISO 6865:2004 by Wende's method, the mineral content by ashing [11], pectin substances by the calcium-pectate method. To hydrolyse the pectin substances to 50ml of the test solution, an equal volume of 0.4% (1N) NaOH solution was added and left for 8–10 h at room temperature. After this, the solution was acidified with the same volume of 1N acetic acid. The resulting pectic acid was precipitated with 50 ml of a 10% solution of $CaCO_3$. The obtained precipitate of calcium pectate was filtered through a pre-dried to constant weight and weighed with a paper filter.

The protein content of the tomato seeds was determined by the modified Lowry method [30], total protein by the Kjeldahl method [30], individual amino acids were determined on an automatic amino acid analyser T-339 (Mikrotechna, Czech Republic) by ion exchange liquid column chromatography.

Anti-nutrients [32] in the tomato raw materials were determined by I. I. Behnken's modification of M.L.Kakade's caseinolytic method of determination of trypsin inhibitory activity. The method is based on spectrophotometric determination at 280nm of the optical density of the decomposition products of the protein substrate (casein) under the action of an enzyme (trypsin, chemotrypsin). The addition of trypsin-binding or chemotrypsin-binding inhibitors to inactive complexes is accompanied by a decrease in extinction.

The fatty acid composition of the tomato seed samples was determined by gas-liquid chromatography. 1g of oil paste was added to a pear-shaped flask, then 10–15cm^3 of 96% ethanol and 500 cm^3 of alkali (KOH) were added. The flask was connected to a capillary refrigerator, through which an inert gas was passed, and the mixture was saponified at 90–100°C for 2h, being constantly stirred. The contents of the flask were then cooled, diluted 1:1 with water, neutralised with H_2SO_4 fixative to pH=7, acidified to pH=2-3, and extracted with an equal volume of sulphur ether 2–3 times. The sulphur extracts were combined, washed with water 2–3 times, dried over anhydrous Na_2SO_4, then filtered through a Schott filter, and washed with Na_2SO_4 1–2 times.

The dry extracts were evaporated to give lipid residue of unsaponifiable matter, which was dissolved in benzene. 200–300cm^3 of the lipid residue was transferred to a glass ampoule, 2cm^3 of a three-molar solution of HCl in methanol was added, the ampoule was sealed and boiled at 100°C for 1 h in a water bath. The ampoule was then opened, the contents dissolved in water at the ratio 1:1 and extracted with hexane. The hexane was washed with water and dried over Na_2SO_4, then evaporated to give fatty acid methyl esters (FEM). Benzene was added to the obtained substance and applied on glass plates for cleaning. The obtained purée was injected into the injector of a Sigma chromatograph. The percentage of fatty acids was calculated according to the areas of the peaks obtained [12].

Carotenoids were determined spectrophotometrically according to the standard method [8].

To determine the effect of hydrothermal treatment on trypsin inhibitory activity of tomato seeds, studies were conducted related to their pre-treatment, which involved keeping in water with the temperatures 70, 80, 90, and 100°C for 20, 30, and 40 min, using a rotary evaporator IKA RV10 control.

To micronise the tomato seeds, we used infrared heating in a microniser MS-1. During this process, the pre-washed seeds enter the conveyor in the area of infrared radiation, the source of which is gas burners made of special ceramics. When heated to a dark red glow, the ceramics creates a flow in the wavelength range 1.8–3.4 microns. Processing time is up to 90 seconds. The seeds are heated to 80-100°C. The separated tomato seeds were treated in a microniser MS-1, crushed, and used for further studies. To determine the effect of micronisation treatment on trypsin inhibitory activity, the tomato seeds were treated for 20, 40, and 60 seconds.

Results of the research and their discussion

The average chemical composition of tomato seeds of the variety Alexia is given in Table 1.

Table 1 – Chemical composition of tomato seeds, % dry matter (n=3, p≤0.05)

Parameter	Technically ripe tomato seeds	Biologically ripe tomato seeds
proteins	38.07±0.5	36.26±0.5
lipids	36.44±0.2	38.30±0.2
carbohydrates including fibre	21.83±1 16.92±0.5	20.14±1 17.52±0.5
minerals	3.35±0.5	3.28±0.5
carotenoids	0.18±0.05	0.19±0.05

Analysis of the chemical composition of tomato seeds confirms the authors' data [9-12,23,24] on the protein content: 38.07% in the technically mature tomato seeds and 36.26 in the biologically mature ones. These values significantly exceed those of most fruit and vegetable crops and determine the biological value of tomato seeds.

At the same time, seeds of the technical stage of maturity differ from biologically mature seeds in their protein content (which is higher by 1.81%) and in the level of carbohydrates (which is higher by 1.21%). This can be explained by the processes of redistribution and synthesis of organic compounds that occur during maturation of plant raw materials. However, it should be borne in mind that while tomatoes are reaching their physiological maturity, the content of nitrogenous substances, organic acids, and reducing sugars increases [7].

It should be noted that the content of the oil component of tomato seeds is close to that of flax seeds (30–40%) and exceeds the fat content of grape seeds (20–23%) [10]. The presence of 72.4% of unsaturated fatty acids in the technically mature seeds and of 75.63% in the biologically mature ones was previously established. Of these, there was 47.72% of polyunsaturated fatty acids in the technically mature tomato seeds, and 50.96% in the biologically mature ones. In the lipophilic fraction of the seeds, among the saturated acids palmitic acid dominated: its content was 21.56% in the technically mature, and 20.75% in the biologically mature tomatoes [19].

It has been established that the seeds of the technical stage of maturity differ from the biologically mature seeds by a higher content of proteins, fibre, and carbohydrates. which can be explained by the processes of redistribution and synthesis of organic compounds that occur during the maturation of plant raw materials. The data obtained confirm that tomato seeds, due to their high content of proteins, lipids, and carbohydrates, have a high nutritional and biological value that conforms to modern recommendations for creating healthy diets.

It is known that tomato seeds are high in nitrogenous substances. However, it should be noted that the literature does not provide data on their qualitative and quantitative composition.

To confirm the data from literature on the transformation of organic compounds at different stages of ripeness, it has been suggested to study the chemical composition of tomato seeds in more detail. Changes in the fractional composition of tomato seed protein substances have been studied based on their solubility. The research results are presented in Table 2.

Table 2 – Fractional composition of tomato seeds protein (n=3, p≤0.05)

Name of the fraction	Content, % to total protein	
	Technically ripe tomato seeds	Biologically ripe tomato seeds
Albumins	20.29±0.2	19.20±0.2
Globulins	39.46±0.2	36.96±0.2
Glutelins	15.68±0.2	18.44±0.2
Prolamines	12.21±0.2	11.88±0.2
Insoluble fraction	12.36±0.2	15.52±0.2

Analysis of the experimental data shows that the main components of the protein complex of tomato seeds are albumins and globulins, which are highly digestible due to their physicochemical properties [23,24]. Their content in the technically ripe tomato seeds is higher by 3.59% than in the biologically ripe seeds.

The data obtained indicate a decrease in the amount of the globulin fraction by 3.5% and of the prolamine fraction by 0.33% in the course of achieving biological ripeness of the tomatoes. At the same time, there is a 2.76% increase in the amount of gluten. This redistribution of the fractional composition of proteins can be explained by accumulation of low molecular weight fractions of nitrogenous compounds. This can occur due to the formation of amino nitrogen and is characteristic of the maturation process in plant materials, which manifests itself by a 3.16% increase in the cleavage products and is confirmed by the data on the determination of amino nitrogen. In the samples of technically mature tomato seeds, the content of amino nitrogen was 27.8 mg/100g, which exceeded by 3.3 mg/100g the similar figure for the seeds of biologically mature tomatoes (24.5 mg/100g). These data confirm what the authors [24,29] say about reducing the amount of protein compounds in tomato fruits at the final stages of ripening. It has been established that the biologically ripe tomato seeds are characterised by some redistribution of protein substances according to their solubility and digestibility and transition to free amino acids.

Based on this, the amino acid composition of the technically and biologically ripe tomato seeds has been studied. The experimental data are given in Table 3.

Table 3 – Amino acid content in the tomato seeds, % to total protein (n=3, p≤0.05)

Amino acid	Technically ripe tomato seeds	Biologically ripe tomato seeds
Valine	3.7	4.8
Isoleucine	3.4	5.3
Leucine	7.0	7.2
Lysine	7.6	6.1
Methionine	1.5	1.4
Threonine	3.9	3.7
Tryptophan	1.4	1.8
Phenylalanine	4.1	4.5
Arginine	9.2	8.5
Alanine	4.9	6.1
Aspartic acid	10.1	10.2
Histidine	2.4	5.4
Glycine	5.5	4.2
Glutamic acid	19.6	16.5
Proline	4.4	5.2
Serine	5.5	4.8
Tyrosine	4.8	2.7
Cysteine	2.3	1.5

Establishing the amino acid composition of technically and biologically ripe tomato seeds has shown that the total number of amino acids during tomato ripening increases by 10.65%, which is due to the plastic processes that take place in tomato tissues. The content of essential amino acids in the technically ripe tomatoes is 96.5mg, which is by 2.3% more than in the biologically ripe tomatoes. The limiting amino acid is valine, the rate of which is 55%.

Protein substances determine the nutritional and biological value of food. The content of inhibitors in some plants significantly reduces the nutritional value of protein products. The presence of proteinase inhibitors in animal and human diet leads to negative physiological phenomena. It is known that the content of trypsin inhibitory complexes causes intensive synthesis of pancreatic enzymes. This leads to an increase in the transformation of methionine into cystine, which in turn increases the need for sulphur-containing amino acids that cannot be compensated by proteins that come with food [25]. Of the whole range of antialimentary factors, trypsin inhibitors are of the greatest interest due to their wide distribution and high content in the storage substance of plants, i.e. seeds. The physiological functions of these substances of protein nature are studied quite well: they can serve as reserve proteins, regulate the activity of proteolytic processes, thus preventing premature breakdown of reserve proteins, inhibit the activity of proteases of a number of harmful insects and phytopathogenic microorganisms, thereby protecting plants from damage [24-26,28]. When a lot of these antialimentary factors enter the body, this leads to a decrease in hydrolysis of food proteins, reducing the efficiency of their digestion. Analysis of the data shows that there is a dependence between the amount of protein in tomato seeds and the presence of proteinase inhibitors. There are also data [29] that accumulation of anti-nutrients is of genetic nature.

However, the trypsin inhibitory activity (TIA) of the technically ripe tomato seeds is by 57% lower than that of the biologically ripe ones. This may be because at the final stages of tomato ripening, the formation of protein substances is completed and the protective mechanisms of a plant, including trypsin inhibitors, finish forming, too [30].

To reduce the activity of proteinase inhibitors in tomato seeds, studies have been conducted to select the parameters of pre-treatment of tomato seeds and determine their effect on the content of bioactive substances and on the trypsin-inhibiting activity of tomato seeds.

An effective way to eliminate these factors is to inactivate proteinase inhibitors caused by their destruction [29]. It should be noted that in comparison with other antialimentary factors, trypsin inhibitors can resist inactivation quite well [27]. In this regard, the data on a significant decrease in the content of trypsin inhibitors in seed products indicate the destruction of alkaloids [27].

During heat treatment, macronutrients and trace elements are lost, so to check whether tomato seeds are suitable for use, it is necessary to conduct research on the quantitative content of essential components according the selected parameters of pre-treatment.

It is known that a decrease in the activity of proteases (~85%) can be achieved by the action of high temperatures, especially in combination with high pressure, which in this case is due to greater efficiency of heat treatment [26].

The choice of temperature is determined by the protein nature of proteolytic enzyme inhibitors and their ability to be inactivated by high temperatures. The results of the research are presented in Fig. 1 and 2.

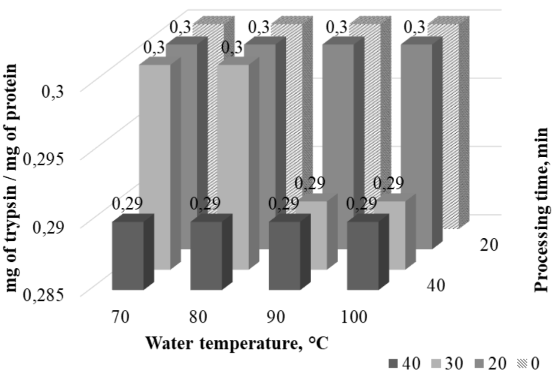

Fig. 1. Change in the activity of trypsin inhibitors in the samples of technically ripe tomato seeds after hydrothermal treatment

The data obtained show that hydrothermal treatment of technically ripe tomato seeds for 20min with the water temperature 70–100°C does not reduce the trypsin inhibitory activity. Hydrothermal treatment for 40min, with the water temperature 70–100°C, allowed reducing the trypsin inhibitory activity by 3%, as compared with the initial values. The results of hydrothermal treatment with these parameters are consistent with other scientists' data [26-29] on reduction of the trypsin inhibitory activity in seeds and legumes, and confirm the high resistance of the trypsin inhibitor. This leads to the conclusion this method of treating tomato seeds is of low efficiency.

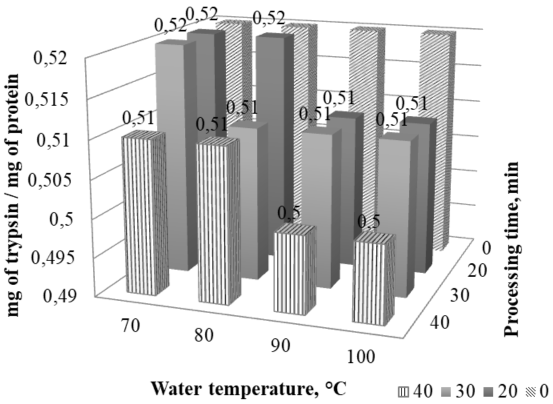

Fig. 2. Change in the activity of trypsin inhibitors in the samples of biologically ripe tomato seed after hydrothermal treatment

The results of hydrothermal treatment of biologically ripe tomato seeds demonstrate a similar dependence: after 20 min of treatment at the water temperature 70-100°C, no decrease in the trypsin inhibitory activity of the tomato seeds was observed. Treating for 20-30min allowed reducing the trypsin inhibitory activity by 1.7%. Hydrothermal treatment for 40min, with the water temperature 90-100°C, reduced the trypsin inhibitory activity by 3.3 times in comparison with its initial level.

The data obtained indicate that hydrothermal treatment of the tomato seeds using the above parameters did not significantly reduce the trypsin inhibitory activity, as compared to its initial level. So, it is necessary to continue the search for ways to reduce the trypsin inhibitory activity of tomato seeds.

The studies conducted confirm the data found in the literature on the resistance of some types of proteinase inhibitors due to their amino acid composition [26-29].

One of the promising areas in the development of tomato seed processing technologies is using new physical methods of supplying heat to a product. The use of infrared radiation intensifies internal processes in a cell, improves quality, facilitates the control of technological parameters. As a result of this treatment, the processes of biochemical transformations in seeds intensify [28].

The principle of micronisation used to treat tomato seeds consists in changing the structure of proteins and grain starch as a result of their intense heating with infrared rays. It is known that heating with infrared rays causes vibration of a product's molecules when heat is released and the pressure inside the seed increases due to rapid evaporation of moisture. In this case, the processes of protein denaturation and starch destruction take place [27].

The heat flux density is much higher than it is with convective and conductive heat supply. Infrared radiation heats the seeds and penetrates as deep as up to 4–6 mm into the layer of the material. Due to thermodiffusion, moisture flows away from the surface and turns into steam. This creates internal pressure and loosens each individual grain [31].

The research results are presented in Fig. 3.

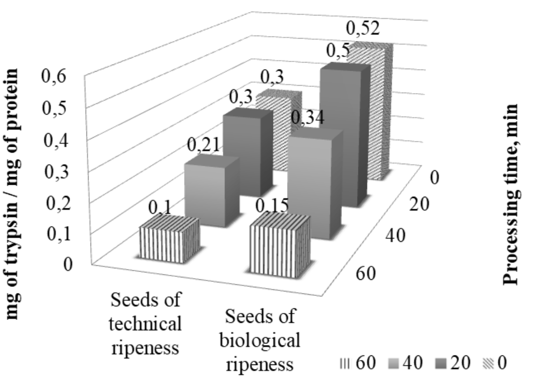

Fig. 3. Change in the activity of trypsin inhibitors in the tomato seed samples after micronisation treatment

The obtained data show that micronisation treatment allows achieving significant reduction in anti-nutrients of the tomato seeds. Thus, when the technically ripe tomato seeds were kept in the microniser for 60s, the activity of trypsin inhibitors decreased by about 34%, and for the biologically ripe seeds, this value was 28.8%. The chosen method of processing tomato seeds allows achieving a safe level of anti-nutrients and preserving the biological value of the components of tomato seeds, as it provides short-term micronisation treatment. A significant disadvantage of this method is the uneven heating of the inner part of seeds, because they are heated with infrared heat from above. Thus, micronisation of tomato seeds for 60s can be suggested as a method to pre-treat tomato seeds for further processing into semi-finished food products.

Conclusion

It has been found that tomato seeds contain 36–39% of proteins, 36–38% of lipids, and 19–22% of carbohydrates. The biological value of tomato seeds is determined by the content of all essential amino acids, which make up more than 50% of the total amino acid content, and by the presence of 72.4–75.63% of unsaturated fatty acids, which will allow its additional processing.

Analysis of the chemical composition of the tomato seeds has shown that though they are of high biological value, their nutritional value is significantly reduced by natural anti-nutrients – proteinase inhibitors. In order to inactivate them to a safe level, the effect of pre-treatment has been studied, namely the processes of micronisation and hydrothermal treatment of tomato seeds. It has been shown that the activity of trypsin inhibitors in the tomato seeds is 0.51–0.62mg/g protein. Hydrothermal treatment of the tomato seeds, with temperatures ranging 70–100°C, reduces the activity of anti-nutrients by 1–2%. It has been suggested to use micronisation processing of tomato seeds for 60s, which allows reducing the content of trypsin inhibitors by 34% without changing the properties of the protein substances and the amino acid composition of seeds.

The method of processing tomato seeds by micronisation for 60s has proved highly effective in reducing the activity of trypsin inhibitors, and allows using tomato seeds to create semi-finished food products of high biological value. The economic effect of this technology consists in reducing the amount of unused fruit and vegetable raw materials.

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БІОЛОГІЧНА ЦІННІСТЬ ПОБІЧНИХ ПРОДУКТІВ ПЕРЕРОБКИ ТОМАТІВ

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Анотація. У статті проведено аналіз біологічної цінності вторинних продуктів томатопереробки, а саме томатного насіння, що, здебільшого не розглядається в харчовій промисловості як об'єкт перероблення. Запропоновано застосування вторинної сировини, що утворюється при виробництві томатопродуктів – томатного насіння, – як джерела отримання біологічно активних речовин з подальшим їх використанням в технологіях харчових продуктів. Наведено результати теоретичних та експериментальних досліджень фізико-хімічного складу томатного насіння. Підтверджено, що насіння томатів має високу харчову та біологічну цінність, яка обумовлена підвищеним вмістом білків, ліпідів, вуглеводів та наближена до сучасних рекомендацій, щодо створення раціонів здорового харчування населення. В насінні томатів міститься 27–30% жиру, 25–35% азотистих і 11–18% безазотистих екстрактивних речовин, 2,5–5,8% мінеральних речовин і 12–25% целюлози. Також насіння томатів багате поліненасиченими жирними кислотами, фосфоліпідами, макро- і мікроелементами, вітаміном Е. Однак, його харчову цінність в значній мірі знижують природні біологічно активні антиаліментарні речовини – інгібітори протеїназ. Експериментально встановлено активність антипоживних речовин томатного насіння – інгібіторів трипсину. Активність інгібіторів трипсину становила 0,30мг трипсину/г білку для насіння технічної стиглості та 0,52мг трипсину/г білку для насіння біологічної стиглості. Для зниження активності інгібіторів трипсину запропоновано застосування гідротермічного та мікронізаційного оброблення томатного насіння. Гідротермічне оброблення впродовж 40 хв при температурі води 90–100°С дозволило знизити трипсин інгібуючу активність на 1–3% від початкових значень. При застосуванні мікронізаційного оброблення досягнуто значного зменшення активності інгібіторів трипсину томатного насіння: при витримуванні томатного насіння технічної стиглості в мікронізаторі протягом 60с зниження активності інгібіторів трипсину становило близько 34% та для насіння біологічної стиглості – 28,8%. Актуальність представлених досліджень полягає в розширенні можливості застосування вторинної томатної сировини, а саме, – томатного насіння в технологіях консервованих продуктів із підвищеною біологічною цінністю.

Ключові слова: томати, протеїнази, насіння, інактивація, трипсин.

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