SECONDARY PRODUCTS OF TOMATO PROCESSING IN THE TECHNOLOGIES OF FOOD PRODUCTS

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Abstract. The chapter is devoted scientific substantiation by use secondary tomato resources. The theoretical and practical aspects by use tomatoes technical maturity and seeds in the justification for absract improved technology tomato raw include speciations and technological properties. Propose use recycling tomatoes for food semi-processed food, namely, the tomato seeds. The features chemical composition of tomato seeds are established. The use of secondary raw materials formed in the production of tomato products as a source of biologically active substances with their subsequent use in food technology is proposed. The results of theoretical and experimental studies of the biological value of tomato seeds. It has been found that tomato seeds have a high nutritional and biological value due to the high concentration of proteins, lipids, and carbohydrates. Accordingly, this value complies with modern recommendations on healthy diet for the population. Also, tomato seeds are rich in polyunsaturated fatty acids, phospholipids, macro- and micronutrient elements, vitamin E, and fiber. However, its nutritional value is substantially reduced by natural biologically active anti-alimentary substances, namely proteinase inhibitors. A first experimental is antinutrients tomato seeds. A number of trypsin inhibitors of tomato seeds use micronating processing, a significant reduction has been achieved. The use of hydrothermal and micronization treatment of tomato seeds to reduce the activity of trypsin inhibitors is proposed. Hydrothermal treatment for 40 min at a water temperature of 90..100°C reduced trypsin inhibitory activity by 1..3% from baseline. Thus,

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when you stand micronating processing maturity during 60 s reducing trypsin inhibitors is about 34 % and for biological maturity is 28.8%. It was found that technology tomato seeds processing allows to obtain a biologically valuable product, which is mainly represented by lipid up to 40%, as well as significant content of protein substances, carbohydrates and fibre. The purpose of this paper is the study of chemical composition and biological value of secondary tomato resources, namely tomato seeds, as well as researching the possibility of its application in food technology. It is also concerned with determination of quantitative and qualitative composition of anti-nutrients of tomato seeds and selection of ways to decrease the activity of anti-nutrients of tomato seeds.

1. Introduction

The nutrition structure of Ukrainian population today does not correspond to modern principles of rational diet and practical dietary science. Consumption of fresh fruits and vegetables in Ukraine is twice lower than the recommended dietary norm and is usually seasonal by its nature. People's diet includes a lot of bakery products and potatoes, however few main sources of complete dietary protein, fiber, micronutrients are present (Benderska, et al., 2018).

The results of studies on the actual state of nutrition of Ukrainian population in different regions indicate that the nutrition structure and nutritional status of both children and adults are characterized by serious violations. Among them is the deficiency of complete proteins; polyunsaturated fatty acids; C, E, group B vitamins, folic acid, retinol, β-carotene; macro- and microelements, namely Ca, Fe, Zn, F, Se, I and others; dietary fiber. Conversely, there is an excessive consumption of animal fats and easily digestible carbohydrates.

According to the balanced nutrition theory, fresh and processed fruits and vegetables, which are the main source of vitamins, minerals, dietary fiber, etc. make the third part of the daily diet of a healthy person. Today, the needs of Ukrainian population in vegetables and fruits are met only by 35… 45% of the recommended consumption rate (50… 53 vs. 110… 120 kg/year per person) (Mizrahi, 2010).

The analysis of existing data allows us to assert the urgency of improving existing technologies for processing fruits and vegetables and finding ways to solve the problem of insufficient consumption of fruits and vegetables by Ukrainians as the main source of bioavailable nutrients that have general strengthening and immunomodulatory functions.

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 generation. Volume of some waste is quite significant. Thus, waste in the fruit and vegetable and canning industries makes 0.5… 0.9 million tons per year (apple, berry and vegetable pomace), adding 0.1… 0.12 million tons per year (fruit kernels, nut shells).

Among the factors that actively influence the efficiency of the economy, the use of secondary raw materials is of great importance. Involvement in the economic circulation of secondary raw materials frees up scarce types of primary raw materials and products, increases material resources in the national economy. Savings are growing through the development and implementation of waste-free, low-waste and resource-saving technologies. Reuse of secondary raw materials will increase the output of products needed by the national economy. However, the pace and scale of production from raw materials are insufficient. Rapid expansion of recycling is hampered mainly by technical obstacles, lack of developed technologies and appropriate equipment, as well as by lack of information on the possibility of using secondary raw materials in various sectors of the economy, including canning.

Non-traditional types of plant raw materials, provided they are comprehensively processed, can become promising sources of biologically active lipids, proteins and trace elements. Non-traditional types of vegetable raw materials include secondary products of tomato processing, namely tomato pomace and seeds, which contain valuable substances, such as proteins, lipids, fat and water-soluble vitamins, micro- and macronutrients, however, today they are only partially used to obtain dyes and tomato oil. The remaining secondary products are disposed of or used for animal feed purposes.

By-products of interest for further research include wastes generated during the production of concentrated tomato products. These include seeds, which are separated on seed separators, and waste obtained after processing and pressing of used waste from pulping machine. This waste is up to 6.5%.

The composition of tomato waste includes (% of raw materials): pulp – up to 4.9, skin – 0.6; vascular fibers, peduncles, crushed seeds and skin – 0.4. Tomato seeds (air-dried) contain 27… 30% of fat, 25… 35% of nitrogen and 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 2.5 mg / 100 g of carotene.

Existing technologies for processing tomato raw materials are inefficient, characterized by being multistage, requiring high consumption of various types of extraction agents and, as a consequence, the loss of carotenoids and tocopherols (Goddard, 1996; Bertin, et al., 2018).

To solve the problem of complex processing of tomatoes using secondary tomato resources, it is necessary to search for new theoretically and experimentally sound ideas about the processes occurring in tomatoes processing.

While studying the mineral composition, it was found that tomato seeds are a rich source of minerals, especially potassium, calcium, magnesium, iron and phosphorus (Tomato propagation, 1990). The mineral composition has a more favorable ratio of calcium and phosphorus (1:2.3) compared to, for example, soy (1:3.1), which improves the absorption of calcium and phosphorus (Stahl, et al., 1993).

17 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 (Shutyuk, et al., 2016; Lucille et al., 2002).

According to M.D. Dacherman, the oil yield when pressing tomato seeds makes 17… 19%, during the extraction of gasoline – 26%, ether – 25%. The Ukrainian Institute of Nutrition researched tomato oil and found it suitable for eating and frying vegetables and potatoes. Digestibility of tomato oil is 97%. It contains 80% of unsaturated biologically active 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 arachin), 0.9% of phosphatides, 0.06… 0.07% of carotenoids and 0.180… 0.190% of tocopherols (Jabbari, et al., 2018).

The value of the components included in tomato seeds (protein, oil with a high content of polyunsaturated fatty acids, vitamins, minerals) allows us to consider tomato seeds as an additive for food enrichment.

It was found that the addition of up to 4% of tomato oil, which has anti-oxidant properties, gives better results than the addition of other antioxidants (James, 1998). It has also been found that tomato oil is more suitable for stabilizing ß-carotene concentrate than vitamin E concentrate used for this purpose.

When tomatoes are processed into juices and concentrated tomato products, the canning industry accumulates a significant amount of tomato waste, including seeds and skin with pulp residues (Tomato handling and processinq, 2000).

The yield of tomato pomace averages 30% by weight of tomatoes, the yield of dry seeds is 0.4% by weight of tomatoes, raw seeds – 1.2%. Dried tomato seeds are used for oil production. This accounts for about 3% of the seeds, the rest is burned, used as fertilizer, at best used for animal feed, although tomato pomace contains valuable ingredients (O'Brien, 2003; Ördög, et al., 2011).

The analysis of the enterprises work shows that an additional operation of separating the seeds from the tomato skin is provided in the process of obtaining tomato seeds (Stahl, et al., 1993). At the same time, there is evidence of a high content of biologically valuable substances in the tomato skin, such as carotenoids.

Tomato seeds are prepared and dried at many canneries according to different schemes. The most rational line is the one with preliminary selection of pulp: waste from seed separators and pulping machines is transported by horizontal belt scraper conveyors in a mechanical screw press. Here 1.5-2.5% of pulp is squeezed to the weight of raw material and 40-54% to the weight of waste, waste moisture is reduced by 14-23% (Hernandez, et al., 2007).

Separated from the pulp, the waste from the press is fed into another collection tank, where 5 times the amount of water is added. The mixture (seeds and skin) and the remains of the pulp with water are pumped for washing – separation of seeds and skin. Separation of seeds from the pomace is based on the difference between the density of seeds of the flesh and skin of the tomato fruit, i.e. the seeds sink in water, and the flesh and skin emerge. The seeds are mechanically squeezed and dried in dryers (Goddard, 1996).

When washing the moisture content of the seeds increases to 73-75%. Before drying, they are partially dehydrated in centrifuges (Bertin, et al., 2018).

At mechanical squeezing and centrifugation of tomato seeds only free moisture (surface and capillary) is removed and humidity makes to 55-64% and at centrifugation to 33-42%. Bound moisture is removed only by thermal drying.

It is known that tomato pomace contains 3.1% of pectin dry matter: cellulose 12.7%, hemicellulose 6.9%. These compounds, which belong to the group of dietary fibers, have a therapeutic and prophylactic effect, normalize metabolism and the work of the gastrointestinal tract (Benderska, et al., 2018).

In addition, 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 (James, 1998). The biological role of β-carotene as a precursor of vitamin A, its participation in the formation of chromophores of visual pigments and retina is also well known.

Tomato waste, dried to a final humidity of 8 ... 14%, is used in the production of dry feed mixtures. Although it is possible to dry mixed tomato waste, studies have shown that separate drying is more cost-effective. When drying the seeds, pure raw materials are formed for oil production, when drying skin and coarse parts of the pulp, a dry residue containing carotene, used as a component for feed mixtures, is created.

There is a tendency in the world to produce dry tomato waste. This is due to the easy transportation and storage, as well as the rich chemical composition of dry products from tomato production waste.

Tomato seeds, separated from the skin, are used in the oil and fat industry. Tomato seed oil is in great demand in the perfume and cosmetics industry.

Tomato oil is rich in tocopherol, it is added to creams and various cosmetics. The high content of unsaturated fatty acids in tomato oil, and especially linoleic, allows it to be classified as a high-value edible oil. Tomato oil is considered to be one of the best edible oils when added to salads, pastries, etc. It is 97% absorbed by the body, and its properties are close to soybean oil. It has antioxidant properties, retains good taste and physicochemical properties.

Ground tomato seeds are also used in baking. Adding them to flour increases the degree of bread freshness (Stewart, et al., 2000). The United States has developed a method of using tomato seeds for the production of dried tomatoes in powder; dry and ground tomato seeds are added to dry tomato puree. The presence of tomato seed flour keeps the finished tomato powder from clumping (Schindler, et al., 2005).

Vegetable protein is acquired from tomato seeds and oil cakes. The amino acid composition of tomato seed proteins is similar to soybean proteins. Protein is contained in the range of 28.4-31.0%, lipids are about 37.5%, lysine makes 5-6%. Tomato seed proteins are poor in methionine and cystine.

Tomato seed oil contains important nutrients. The content of linoleic acid is 53.1-55.5%, oleic – 20.8-23.5%, the ratio of unsaturated fatty acids is 3.8 (Benderska, et al., 2018; Navarro-González et al., 2018; Raffaele, 2010).

Vegetable protein is used in the diet mainly in the form of supplements that increase the nutritional value of food. It is used for the production of pâtés, soups, smoked meats, sausages, meat and vegetable mixes, various vegetable and meat and vegetable pastes, fillings and minced meat (particularly for dishes made of tomatoes, eggplant, zucchini, stuffed cabbage), as part of bakery products.

Wastes from fruit and vegetable processing can be used to obtain dyes based on carotenes, anthocyanins, chlorophyll. Production methods are based on extraction and subsequent distillation. Thus, the use of integrated approaches to the processing of fruit and vegetables is becoming widespread in the world. Secondary products of tomato processing are characterized by high nutritional and biological value, due to the presence in their composition of a significant proportion of complete dietary protein, fats, vitamins and dietary fiber. The practice of using secondary raw materials has not become widespread at Ukrainian enterprises, which causes significant losses of BAS during the manufacture of canned products. Therefore, it is proposed to study the value of secondary products of tomato processing and offer rational approaches to their processing for creating food products with high nutritional and biological value indicators.

2. Improvement of tomato seeds processing regimes

In order to effectively use raw materials and obtain a product with high quality indicators, the task is to study the physical and chemical and biochemical composition of secondary products of processing tomato raw materials, namely tomato seeds.

Tomatoes of the most cultivated varieties in the central region of Ukraine and secondary products of tomato processing, namely tomato seeds formed after receiving tomato products, were used for research. The chemical composition of tomato seeds of technical and biological maturity was studied separately and its comparative analysis was performed. The average chemical composition (2015–2017 harvest) of tomato seeds (Table 1).

Table 1

Chemical composition of tomato seeds, % dry matter

Indicator	Tomato seeds of technical ripeness	Tomato seeds of biological ripeness
proteins	38.07±0.5	36.26±0.5
lipids	36.44±0.2	38.30±0.2
carbohydrates including fiber	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

The analysis of the obtained data showed that tomato seeds have a high nutritional and biological value, which occurs due to the content of proteins, lipids, carbohydrates, and is close to modern recommendations for creating healthy diets (Mizrahi, 2010).

At the same time, seeds of technical stage of ripeness differ from biologically mature seeds by higher protein content – by 1.81% and carbohydrates – by 1.21%, which can be explained by the processes of redistribution and synthesis of organic compounds that occur during the maturation of plant raw materials. However, it should be borne in mind that in the process of achieving biological maturity of tomatoes, the content of nitrogenous substances, organic acids and reducing sugars increases (Navarro-González, et al., 2018).

2.1 Study of the protein content of tomato seeds

It is known that tomato seeds have a high content of nitrogenous substances, however, it should be noted that the literature does not provide data on their qualitative and quantitative composition.

To confirm the existing literature data on the transformation of organic compounds at different stages of ripeness, it is proposed to study the chemical composition of tomato seeds in more detail.

Changes in the fractional composition of tomato seed protein substances were studied based on their solubility (Table 2).

Table 2

Fractional composition of tomato seeds protein

Faction name	Content, % to total protein	
	Tomato seeds of technical ripeness	Tomato seeds of biological ripeness
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 experimental data shows that the main components of the protein complex of tomato seeds are albumins and globulins, which due to their physicochemical properties are highly digestible (Sasivimon, et al., 2002). Their content in tomato seeds of technical ripeness is higher by 3.59% than in seeds of biological ripeness.

The obtained data indicate a decrease in the amount of globulin fraction by 3.5% and prolamine fraction by 0.33% in the process of achieving biological ripeness of tomatoes. At the same time there is an increase in the amount of gluten by 2.76%. This redistribution of the fractional composition of proteins can be explained by the accumulation of low molecular weight fractions of nitrogenous compounds, which may occur due to the formation of amine nitrogen and is characteristic of the maturation of plant materials, which is manifested in an increase in the cleavage products by 3.16% and is confirmed by the data for the determination of amine nitrogen (Table 3).

Table 3

Content of amine nitrogen in samples of tomato seeds

	Tomato seeds of technical ripeness	Tomato seeds of biological ripeness
Amino nitrogen mg/100 g	27.8±0.1	24.5±0.1

It is established that tomato seeds of biological ripeness are characterized 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 tomato seeds of technical and biological ripeness was studied (Table 4).

Table 4

Amino acid content, % to total protein

Amino acid	Tomato seeds of technical ripeness	Tomato seeds of biological ripeness
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

Identification of the amino acid composition of tomato seeds of technical and biological ripeness showed 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 tomatoes of technical ripeness is 96.5 mg, which is 2.3% more than in tomatoes of biological ripeness. Herewith the limiting amino acid is valine, the rate of which is 55%.

2.2 Study of the composition of tomato seeds carbohydrate complex

The content of carbohydrates in raw materials significantly affects the quality of products, its nutritional and energy value. Tomato seeds contain a significant amount of carbohydrates – from 30 to 35% CF. Carbohydrates of tomato seeds are represented by starch, fiber, sugars, pectins and other substances.

To establish the appropriateness of using tomato seeds for further processing, the study of the carbohydrate composition of tomato seeds of technical and biological ripeness was conducted. Changes in tomato seed carbohydrates are due to the achievement of the final stages of ripeness, plastic processes and the formation of storage substances (Table 5).

Table 5

Carbohydrate content in tomato seeds

Carbohydrates	**Content, % dry matter**	
	Tomato seeds of technical ripeness	**Tomato seeds of biological ripeness**
Glucose	0.4± 0.2	0.5± 0.2
Fructose	0.5± 0.2	0.8± 0.2
Saccharose	2.4± 0.5	2.8± 0.5
Starch	2.0± 0.5	1.8± 0.5
Cellulose	19.6± 0.5	18.5± 0.5
Hemicellulose	7.5± 0.1	7.1± 0.1

Analysis of the obtained data showed that depending on the stage of ripeness, the process of redistribution of carbohydrates takes place, namely the content of sucrose increases by 0.4%, starch decreases by 0.2%, and fiber by 1.1%.

The increase in number of disaccharides in tomato seeds from tomatoes of biological ripeness is due to the processes of hydrolysis of low molecular weight oligosaccharides under the action of amylolytic enzymes in conditions of increasing enzymatic activity in the final stages of tomatoes ripening, which takes into account the processes of hydrolytic disorder of starch, part of which is used to build new tissues, the other remains in the form of insoluble sugars.

The obtained data allowed us to conclude that the carbohydrate composition of tomato seeds is represented by simple sugars, starch and dietary fiber. At the stage of technical ripeness, tomato seeds are dominated by fiber, hemicellulose and starch. Their content decreases when tomatoes reach biological maturity.

2.3 Study of the fatty acid composition of tomato seeds

Tomato seeds are a source of components such as carotenoids and lipids, which include polyunsaturated fatty acids.

Therefore, the content of free fatty acids of tomato seeds was studied (Table 6).

As a result of the research conducted, the presence of 72.4% of unsaturated fatty acids in the seeds of technical ripeness and 75.63% of biological one was identified, including 47.72% of polyunsaturated fatty acids for tomato seeds of technical ripeness and 50.96% of biological ripeness. In the lipophilic fraction of seeds, among the saturated acids, palmitic acid predominated, its content in relation to the amount was 21.56% for tomatoes of technical ripeness, and 20.75% for tomatoes of biological ripeness. Among the polyunsaturated acids, linoleic acid predominated. At the same time, there are no trans-isomers among fatty acids, and the ratio between unsaturated omega-3 and omega-6 acids in seeds corresponds to the latest recommendations for nutrition in accordance with the nutrition principles.

Thus, the value of the chemical composition of tomato seeds is determined by the content of essential fatty acids, which play a number of important biological functions: act as regulators of metabolic processes, participate in lipid metabolism, affect the state of the vascular wall, and affect the vascular wall. Therefore, given the established composition of fatty acids, tomato seeds can be attributed to promising types of food raw materials.

2.4 Study of the activity of anti-nutrient factors in tomato seeds

Protein substances determine the nutritional and biological value of food. The content of inhibitors in some plants leads to a significant reduction in 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-inhibitor complexes causes intensive synthesis of pancreatic enzymes. This leads to an increase in the transformation of methionine into cystine, which in turn increases the

Table 6

Content of free fatty acids in tomato seeds, % to total amount of fatty acids

Fatty acids	Tomato seeds of technical ripeness	Tomato seeds of biological ripeness
C14:0	0.37814	0.11219
C15:0	0.14795	0.06924
isoC16:0	0.16737	0.09063
C16:0	21.56107	20.75644
C16:1	0.86295	0.52893
C16:2	0.27314	0.21643
C17:0	0.27379	0.17228
C17:1	1.30101	0.62897
isoC18:0	1.32274	0.94684
C18:0	7.45303	5.92004
C18:1	23.53947	24.04448
C18:2	33,83710	39.38001
C18:3	5.98324	3.95564
C22:0	0.82807	0.64297
C20:1	0.16670	0.10474
C21:0	0.11123	0.05920
C20:4	0.30494	1.64190
C20:0	0.71594	0.35592
C22:1	0.11557	-
C22:4	0.13882	0.06337
C24:0	0.51775	0.26506
Total	100	100
ω-6/ω-3	2.55:1	4.16:1
Monounsaturated fatty acids	24.68469	24.67815
Polyunsaturated fatty acids	47.71713	50.96096
Unsaturated fatty acids	72.40182	75.63911
Saturated fatty acids	27.59818	24.36089

need for sulfur-containing amino acids, which cannot be compensated by the proteins that come with food (Bosona, et al., 2018).

It is known that the secretion of pancreatic juice is regulated by the digestive process. Digestion of food depends on the level of trypsin and chymotrypsin in the intestine. When the level of these enzymes under the action of inhibitors falls below the critical value, the pancreas begins to produce more enzymes. When trypsin binds to the inhibitor, digestion may also occur (Pomeranz et al., 2001; Smith, et al., 1980).

Inhibitors of proteolytic enzymes have been found in many plant species belonging to different systematic groups. The content of proteinase inhibitors in plants changes under the influence of growing conditions. However, species and varietal differences in their content, as well as the component composition of inhibitors persist regardless of the year of reproduction, which indicates the genetic condition of this trait (Stewart, et al., 2000).

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 sufficiently studied: they can serve as reserve proteins, regulate the activity of proteolytic processes, 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 (Wu, et al., 2018). The entry into the body of an increased amount of these antialimentary factors leads to a decrease in the process of hydrolysis of food proteins, reducing the efficiency of their digestion.

The study of the activity of trypsin inhibitor proteins in tomato seeds is conducted (Table 7).

Table 7

Activity of tomato seed trypsin inhibitors

Variety	Alexia	Lampo	Lyona
Protein content, % dry matter	34.03±0.5	35.37±0.5	32.03±0.5
Indicator on activity of inhibitors mg/g protein	0.55±0.1	0.61±0.1	0.52±0.1

Analysis of the data shows that there is a relationship between the amount of protein in tomato seeds and the presence of proteinase inhibitors. There are also data (Mizrahi, et al., 2010) on the genetic nature of anti-nutrients accumulation. Thus, for Lampo variety, which contained the highest amount of protein in its seeds, the activity of trypsin inhibitors was at the level of 0.61 mg/g protein, which is 17.3% higher than the content of anti-nutrients in Alexia variety, which was used for further research.

In order to analyze the effect of tomatoes ripeness degree on the content of anti-nutrients in tomato seeds, the content of trypsin inhibitors in samples of tomato seeds of technical ripeness of Alexia variety is established (Table 8).

Table 8

Content of trypsin inhibitors in native raw materials

Tomatoes	Inhibitor activity, mg of trypsin / mg protein
of technical ripeness	0.30±0.05
of biological ripeness	0.52±0.05

The data show that tomato seeds contain a significant proportion of anti-nutrients, which is associated with a high content of protein.

However, trypsin inhibitory activity (TIA) of tomato seeds of technical ripeness is 57% lower than TIA of seeds of biological ripeness, which can be explained by the completion of protein substances formation in the final stages of tomato ripening and the final formation of plant protective mechanisms, which also include trypsin inhibitors (Hisace, et al., 2003).

In order to reduce the activity of tomato seed proteinase inhibitors, studies were conducted to select the parameters of pre-treatment of tomato seeds and their effect on the content of biologically active substances and on trypsin-inhibiting activity of tomato seeds.

An effective way to eliminate these factors is to inactivate proteinase inhibitors caused by their destruction (Zhu, et al., 2017). It should be noted that in comparison with other antialimentary factors, trypsin inhibitors have a fairly high resistance to inactivation. In this regard, data on a significant decrease in the content of trypsin inhibitors in seed products indicate the destruction of alkaloids.

3. Development of pre-treatment modes for tomato seeds processing

In the process of heat treatment a loss of macro- and micronutrients occurs, so in order to identify the feasibility of using tomato seeds, it is necessary to conduct research on the quantitative content of essential components after the selected modes of pre-treatment.

3.1 Study of hydrothermal treatment exposure of tomato seeds

It is known that decrease in proteases activity (~ 85%) can be achieved under the action of high temperatures, especially in combination with high pressure, which in this case is due to greater efficiency of heat treatment (Wu, et al., 2018).

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 temperatures of 70; 80; 90; 100 °C for 20; 30; 40 min.

The choice of temperature is due to the protein nature of proteolytic enzymes inhibitors, and their ability to be inactivated by high temperatures (Figure 1 and 2).

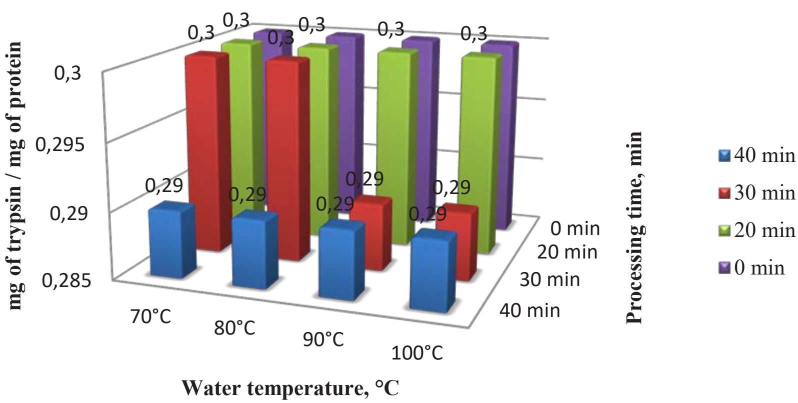

Figure 1. Activity of trypsin inhibitors in samples of tomato seeds of technical ripeness after application of hydrothermal treatment

The obtained data show that when applying hydrothermal treatment for tomato seeds of technical ripeness for 20 min at water temperature of 70-100 °C, the reduction of TIA could not be achieved. Hydrothermal treatment for 40 min at water temperature of 70-100 °C allowed to reduce the TIA by 3.3 times relatively to initial values.

The results of hydrothermal treatment of tomato seeds of biological ripeness had similar dependence: when applying treatment for 20 min at water temperature of 70-100 °C, a decrease in the TIA of tomato seeds

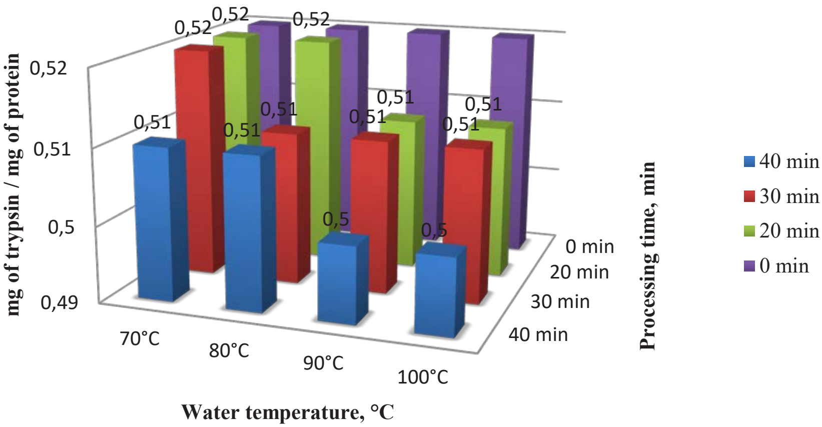

Figure 2. Activity of trypsin inhibitors in samples of tomato seeds of biological ripeness after application of hydrothermal treatment

was not observed. When treated for 20-30 min, it allowed to reduce TIA by 1.7%. Hydrothermal treatment for 40 min at water temperature of 90..100 °C reduced trypsin inhibitory activity by 3.3 times from baseline.

The obtained data indicate that the application of hydrothermal treatment of tomato seeds with the used parameters did not significantly reduce the trypsin inhibitory activity compared to the initial one. Therefore, there is need to continue the search for ways to reduce TIA of tomato seeds.

The conducted studies confirm existing literature on resistance of some types of proteinase inhibitors, which is due to their amino acid composition (Muratore, et al., 2005).

3.2 Research and grounding of tomato seed processing methods

One of the promising areas in the development of tomato seed processing technologies is use of new physical methods of heat supply to product. The use of infrared radiation intensifies the internal processes in the cell, improves quality, facilitates their control and management of technological parameters. As a result of IR treatment, the processes of biochemical transformations in seeds intensify (Schindler, et al., 2005; Stahl, et al., 2003).

The principle of micronization used for the treatment of tomato seeds is to change the structure of proteins and grain starch as a result of its intense heating by infrared rays. It is known that heating by infrared rays causes vibration of the product molecules, while releasing heat and increasing the pressure inside the seed due to the trapid evaporation of moisture. In this case the processes of protein denaturation and starch destruction take place (Wu, et al., 2018).

The heat flux density is much higher than with convective and conductive heat supply. Infrared radiation heats the seeds and penetrates into the depth of the material layer up to 4..6 mm. Thermodiffusion flow of moisture from the surface, which turns into steam, creates internal pressure and loosens each individual grain (Smith, et al., 1980).

To carry out the process of micronization of tomato seeds we used infrared heating in MS-1micronizer. When processing, the seeds, following pre-washing, enters the conveyor in the area of infrared radiation, the source of which are gas burners made of special ceramics. When heated to a dark red glow, the ceramic creates a flow in the wavelength range from 1.8 to 3.4 microns. Processing time is up to 90 seconds. The seeds are heated to 140-150 °C.

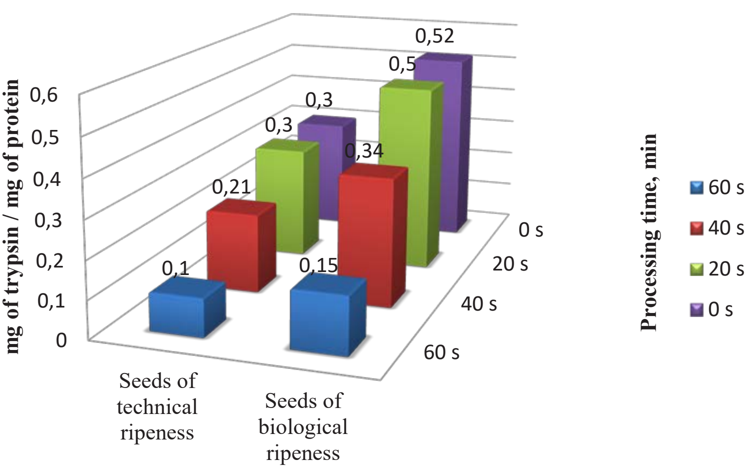

Figure 3. Activity of trypsin inhibitors in tomato seed samples after application of micronization treatment

To determine the effect of micronization treatment on trypsin inhibitory activity, tomato seeds were treated for 20, 40, 60 seconds (Figure 3).

The obtained data show that the use of micronization treatment allows to achieve significant reduction in the amount of tomato seeds anti-nutrients. Thus, when the tomato seeds of technical ripeness were kept in the micronizer for 60 s, the decrease in the content of trypsin inhibitors was about 34% and for seeds of biological ripeness – 28.8%.

Another advantage of the method is preservation of structural integrity of the seed, which increases its shelf life. A significant disadvantage of this method is the uneven heating of the inner part of the seed, as heating by infrared heat is carried out from above.

4. Development of basic-technological scheme for obtaining semi-finished product «Tomato Seed Paste»

The proposed scheme of pre-treatment of tomato seeds (Figure 4) allowed to achieve a significant reduction in the content of anti-nutrients, which confirms the assumption of the possibility of using tomato seeds to create food products based on it.

Processing of tomato seeds involved the process of their grinding. To do this, grinding was done in the laboratory, using LZM-1 laboratory mill to create the necessary pasty structure of the semi-finished product, which should provide easy dosing, uniform distribution in the mass of the product, and not cause changes in organoleptic properties. When crushed, three stages of grinding tomato seeds were used: large (particle diameter 2.6-1.8 mm) characteristic residue on a sieve having holes with a diameter of 3 mm was not more than 35%, on a sieve having 5 mm holes – not more than 5%; average (particle diameter 1.8-1.0 mm) characteristic residue on a sieve having holes with a diameter of 3 mm was not more than 12%, with holes of 5 mm it was not allowed; small (particle diameter 1.0-0.2 mm) characteristic residue on a sieve having holes of 2 mm was not more than 5%, the residue on a sieve having 5 mm holes was not allowed.

As a result of grinding, coarse suspensions were obtained, which contained a water-oil fraction with inclusions of protein, pectin substances and fiber with particle sizes of 0.5-0.8 mm after grinding.

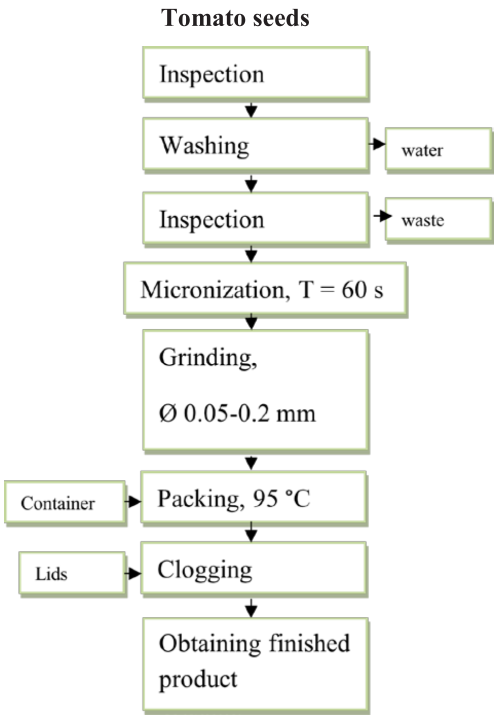

Figure 4. Schematic diagram for production of semi-finished products «Tomato Seed Paste»

4.1 Study of physicochemical parameters of tomato seed paste

To establish the possibility of using the semi-finished product «Tomato Seed Paste» for food enrichment, a necessary step is to determine the main indicators of tomato seed paste. To do this, we determined the organoleptic characteristics of tomato seed paste.

The results of the evaluation of tomato seed paste quality (Tables 9, 10).

An evaluation of the organoleptic characteristics of the new product «Tomato Seed Paste» found that the semi-finished product has a neutral taste without bitterness with an aftertaste of tomatoes and a light tomato aroma. The consistency of the product is viscous, lubricant with the presence of individual particles of larger size.

Table 9

Organoleptic characteristics of tomato seed paste

Indicator	Characteristic
Color	Orange-brown with a yellowish tinge
Taste and smell	Inherent in tomatoes with a light pepper flavor without extraneous taste and odor
Appearance and consistency	Homogeneous concentrated mass from semi-liquid to lubricating consistency. Single inclusions of crushed particles and particles of tomato skin are allowed

Table 10

Physical and chemical parameters of tomato seed paste, %

Indicator	Contents
mass fraction of moisture	14.55±0.5
lipids	39.45±0.2
proteins	18.37±0.1
carbohydrates	14.01±0.5
minerals	0.93±0.1
fiber	1.25±0.2
carotenoids	1.8±0.1

It is established that the proposed technology of tomato seed processing allows to obtain a biologically valuable product, which is mainly represented by the lipid fraction – up to 40%, as well as a significant content of protein, carbohydrates and fiber. The basis of the vitamin complex of tomato seed paste is carotenoids – 1.8-1.9% of dry matter, which are stored due to short-term pre-treatment.

Quantitative determination of the amino acid composition of tomato seed paste after micronization treatment according to the method was performed (Table 11).

Evaluation of the proteins amino acid composition at tomato seed paste showed that they contain all 10 essential amino acids, and their share is more than 50%, which confirms the high nutritional value of tomato seed paste. As a result of micronization treatment there is a partial denaturation of proteins and accumulation of free amino acids, which leads to an increase in their total amount compared to tomato seeds before processing (Table 4).

The content of mineral elements in tomato seed paste was studied (Table 12).

Table 11

Content of amino acids in semi-finished product «Tomato Seed Paste»

Amino acid	Content, % to total protein
Valine	5.652
Isoleucine	4.267
Leucine	7.887
Lysine	7.385
Methionine	1.355
Threonine	3.634
Tryptophan	1.644
Phenylalanine	4.564
Arginine	9.373
Alanine	4.284
Aspartic acid	9.258
Histidine	3.878
Glycine	5.585
Glutamic acid	14.124
Proline	4.478
Serine	4.452
Tyrosine	3.145
Cysteine	6.171

Table 12

Content of minerals in tomato seed paste

Indicator	Content of mineral elements, mg/100 g	Acceptable level, not more than mg/kg
Macronutrients, mg/100 g		
Sodium	205.8 – 210.3	not normalized
Potassium	520.7 – 530.0	not normalized
Calcium	130.5 – 135.0	not normalized
Magnesium	60.0 – 62.8	not normalized
Trace elements, mg/kg		
Iron	2.6 – 4.9	5.0
Zinc	0.98 – 1.9	5.0
Copper	0.29 – 0.44	0.5
Lead	0.06 – 0.08	0.1
Cadmium	0.002 – 0.013	0.05
Arsenic	0.01 – 0.03	0.1
Mercury	0.005 – 0.01	0.03

According to Table 12, the content of toxic elements in tomato seed paste does not exceed the acceptable level. Studies have confirmed the assumption that in terms of nutritional value, tomato seed paste can be recommended as a food supplement to enrich nutrition with protein-lipid complex and a group of antioxidants.

5. Conclusions

Analysis of the obtained data showed that tomato seeds have a high nutritional and biological value, due to the content of proteins, lipids, carbohydrates.

It is established that the seeds of technical stage of ripeness differ from biologically ripe seeds by high content of proteins, fiber and carbohydrates, which can be explained by the processes of redistribution and synthesis of organic compounds that occur during the ripening of plant raw materials.

Analysis of the chemical composition of tomato seeds showed that along with the high biological value, the nutritional value of seeds is significantly reduced by natural anti-nutrients, i.e. protease inhibitors. In order to inactivate to a safe level, a study was conducted on the effect of pre-treatment, namely the processes of micronization and hydrothermal treatment of tomato seeds. It is established that hydrothermal treatment when using temperatures in the range of 70-100 °C reduces the activity of anti-nutrients of tomato seeds by 1-2%. Micronization treatment of tomato seeds for 60 s allows to reduce the content of trypsin inhibitors by 34% without changing the properties of protein substances and amino acid composition of seeds.

It is established that the proposed technology of tomato seed processing allows to obtain a biologically valuable product, represented by the lipid fraction – up to 40%, as well as a significant content of protein, carbohydrates and fiber. The basis of the vitamin complex of tomato seed paste is carotenoids, which are saved due to short-term pre-micronization treatment.

It is established that the proteins of tomato seed paste contain all 10 essential amino acids. Their share is over 50%, which confirms the high nutritional value of tomato seed paste. As a result of micronization treatment there is a partial denaturation of proteins and accumulation of free amino acids, which leads to an increase in their total amount, compared with tomato seeds before processing.

Analysis of the kinetics of the process on enzymatic hydrolysis of tomato seed paste showed that the use of pre-micronization treatment of tomato seeds can increase the accumulation of free amino acids in tomato seed paste samples by 1.56 more intensely than in control samples.

The content of toxic elements in tomato seed paste does not exceed the acceptable level. Studies have confirmed the assumption that in terms of nutritional value, tomato seed paste can be recommended as a food supplement to enrich nutrition with protein-lipid complex and a group of antioxidants.

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