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RESEARCH OF FATTY ACID COMPOSITION OF TOMATO SEEDS

Об'єктом дослідження є вторинні продукти перероблення томатів, а саме – томатне насіння технічної та біологічної стиглості. Одним з найбільш проблемних місць томатопереробної галузі є утворення значної частини (до 30 % від загальної маси томатів) відходів, що містять велику кількість білків, ліпідів, вуглеводів, мінеральних речовин та біологічно активних сполук. Вирішення проблеми перероблення вторинних томатних ресурсів стає можливим за умови встановлення їх хімічного складу та біологічної цінності і підбору технологічних параметрів подальшого перероблення.

Під час досліджень проведено аналіз хімічного складу томатного насіння та встановлено, що насіння томатів є прекрасним джерелом таких компонентів, як каротиноїди, протеїни, цукри, волокна, воски та олії. При цьому, насіння технічної стадії зрілості відрізняється від біологічно зрілого насіння підвищеним вмістом білків – на 0,81 %, клітковини – 0,4 % та цукрів – на 0,21 %. Отримані результати аналізу жирокислотного складу томатного насіння технічної та біологічної стиглості дозволили встановити, що серед жирних кислот в аналізованих зразках містилось 47,72 % поліненасичених для томатного насіння технічної зрілості та 50,96 % – біологічної зрілості. При цьому відсутні транс-ізомери, а співвідношення між ненасиченими омега-3 та омега-6 кислотами в насінні відповідає останнім рекомендаціям, щодо харчування населення згідно з принципами нутриціології.

Отримані результати аналізу хімічного складу вторинної томатної сировини показали, що важливим залишається питання вдосконалення технологій комплексного перероблення томатів, що забезпечуватиме високий економічний та соціальний ефекти. Завдяки застосуванню в технологіях харчових продуктів напівфабрикатів із томатного насіння стає можливим отримання харчових продуктів, що володіють підвищеним вмістом незамінних амінокислот, соле- та водорозчинних білків, вуглеводів та ліпідів, що представлені поліненасиченими жирними кислотами.

Ключові слова: *вторинні продукти перероблення томатів, жирокислотний склад томатного насіння, технології комплексного перероблення томатів.*

1. Introduction

To date, there is a wide range of food products that can meet the physiological and biological needs of the consumer's body. Recent studies of food rations of various strata of the population show that consumption of the most valuable biologically active food products in the last 10–15 years has decreased by almost 50 %. According to medical examinations, only 20 % of the population can be considered conditionally healthy; 40 % – as a result of food deficiencies is in a state of maladaptation; 20 % – in the final state between illness and health. Thus, more than half of the population requires a significant adjustment of nutrition due to changes in working and living conditions (lack of exercise and ecology) [1]. The ways to overcome the current situation include the use of biologically valuable raw materials to produce products that are balanced in terms of biochemical composition and nutritional value.

The soil and climatic conditions of Ukraine are quite favorable for the cultivation of many types of vegetable crops, in particular open ground tomatoes. It is interesting to note that, in accordance with the decision of the United Nations Food and Agriculture Organization (FAO), Ukraine is listed among the states as a potential exporter of these products. Now Ukraine is among 20 world leaders. China produces more than 34 million tons of tomatoes,

the United States – 13 million tons, Turkey and India – up to 11 million tons, Egypt – more than 9 million tons and Ukraine more than 1.5 million tons. [1].

In Ukraine, more than 150 varieties and hybrids of tomatoes are distinguished, differing in terms of maturation, productivity, type, form, color of the fruit, resistance to diseases, which allows to provide different types of soil and climatic zones with suitable varieties and hybrids.

The reason for increasing the capacity for growing is the multi-purpose use of tomatoes for both fresh consumption and various processing products, as well as the availability of valuable nutrients. The fruits of tomatoes contain vitamins B₁, B₂, B₃, PP, K, C, as well as carotenoids (provitamin A), minerals in accessible form Fe, K, Na, Ca, Mg, S, I. Due to the high and balanced content of biologically active substances, daily consumption of tomatoes promotes a soft regulation of metabolic processes and activity of the gastrointestinal tract, strengthening the work of other glands. The tomato fruit contains apple and citric acids, which stimulate appetite, activate digestion processes and suppress harmful intestinal microflora. In modern market conditions for consumption in fresh form and for processing it is expedient to select varieties characterized by high yield, resistance to diseases, suitability for processing and have high chemical balance [2].

Therefore, the issue of improving the technologies for complex processing of tomato raw materials, which will

include processing of tomatoes and secondary tomato resources, with the aim of obtaining food products with increased food and biological value, is topical.

2. The object of research and its technological audit

The object of research is selected tomatoes of technical and biological maturity and tomato seeds. For the research, tomatoes of the most cultivated varieties in the central region of Ukraine and secondary products of tomato processing were used, namely tomato seeds, formed after the production of tomato products. Separately, the chemical composition of tomato seeds of technical and biological maturity was studied and its comparative analysis was carried out.

Seeds are an excellent source of components such as carotenoids, proteins, sugars, fibers, waxes and oils. In Europe, for example, in 2015, 10 million tons of tomatoes were processed. Solid waste in the form of scraps from the skin and seeds (2 % of the weight of the raw materials) amounted to 200 000 tons. The main biologically active substances (BAS) contained in seeds and squeezes are lycopene, vegetable fibers, tomato oil, enzymes. Out of 100 kg of tomato production waste, 75 kg of vegetable fibers, 4 kg of oil and 3 kg of wax can be obtained. And also to withdraw about 110 mg of lycopene – a powerful antioxidant, which reduces the risk of cardiovascular disease, has an antitumor and immunostimulating effect, is used as a natural food color. An analysis of the existing data on the chemical composition of tomato seeds is given in Table 1.

Table 1

Chemical composition of tomato seeds, % to dry matter (DM)

Indicator	Value
protein	36.26–37.07
lipids, including phospholipids	37.44–38.30 1.42–1.45
minerals	3.28–3.35
carbohydrates	30.14–30.83
cellulose	17.52–17.92
carotenoids	0.018–0.019
tocopherols, incl. α – tomatine	0.072–0.073 0.028–0.030

The analysis of the obtained data shows that the seeds of tomatoes have high nutritional and biological value, which is caused by an increased content of proteins, lipids, carbohydrates, and is close to the current recommendations regarding the creation of healthy diets for the population [3].

Moreover, the seeds of the technical stage of maturity differ from the biologically mature seeds by increased protein content – by 0.81 %, fiber – 0.4 % and sugars – by 0.21 %. This can be explained by the passage of the processes of redistribution and synthesis of organic compounds that occur during the ripening of plant material. However, it must be taken into account that in the process of achieving the biological ripeness by tomatoes, the content of nitrogenous substances, organic acids and reducing sugars increases, which leads to food and organoleptic parameters of the finished product.

The received data of technological audit testify to the possibility of applying tomato seeds to create products with a high content of biologically active compounds. However,

there is a need for more detailed research and analysis of the chemical composition of tomato seeds of technical and biological ripeness.

3. The aim and objectives of research

The aim of the research is studying the possibility of using secondary raw materials in the development of an integrated technology for processing tomatoes.

To achieve this aim, it is necessary to perform the following tasks:

1. Determine the content of the main nutrients of tomato seeds.
2. Analyze the fatty acid composition of tomato seeds of technical and biological maturity.
3. Investigate the prospects of using tomato seeds in food processing technologies.

4. Research of existing solutions of the problem

In the literature [2, 4], there is sufficient information about the chemical composition of tomatoes, but the physicochemical and biochemical composition of secondary tomato resources has not been sufficiently studied.

It is established in [3, 5] that the potential of the useful properties of secondary tomato raw materials is almost not used in the food industry. Therefore, a promising issue is the improvement of technologies for processing tomato raw materials, which will include processing of tomatoes and secondary tomato resources.

The authors of [6] show that when industrial processing of tomato raw materials for the production of juices, tomato paste and sauces, a large amount of solid waste is generated in the form of scraps, seeds, substandard raw materials that contain many useful components.

The nutritional and biological value of secondary tomato resources was studied in [7, 8]. It has been established that tomato seeds contain a significant part of proteinaceous substances, which can be used as a food additive. The authors of [9] propose the preparation of an oil extract from tomato seeds and its subsequent use in food technology as an emulsifier. However, other scientists in [10, 11] recommend considering secondary tomato resources as a by-product of food production, due to the presence of anti-nutrients. But the use of the potential of biologically active compounds remains unresolved.

5. Methods of research

The chemical composition of tomato seeds was established using well-known methods:

- the mass fraction of carbohydrates by the polarimetric method, starch by the Evers method [12];
- fiber – by Kurisner and Hanek [13];
- mineral composition – by atomic emission spectrometry;
- content of organic acids – by titration [14].

To establish the fatty acid composition of tomato seeds, a lipophilic seed fraction was obtained, which was obtained by exhaustive extraction with hexane. The method for determining fatty acid composition is based on the conversion of triglycerides of fatty acids to methyl esters of fatty acids and gas chromatographic analysis of the latter. Analysis of the fatty acid composition of the lipophilic fractions

was carried out by chromatography of methyl esters of fatty acids on a gas chromatograph HRGC 5300 (Italy).

The following parameters were set on the chromatograph:

- temperature of thermostat columns – 180 °C;
- evaporator temperature – 230 °C;
- temperature of the detector – 220 °C;
- flow rate of carrier gas (nitrogen) – 30 cm³/min;
- sample volume of 2 ml³ solution of methyl esters of acids in hexane.

The identification of methyl esters of fatty acids was carried out with respect to the time of peak content compared to the standard mixture. Calculation of the composition of methyl esters was carried out by the method of internal normalization. Samples were used as standards for saturated and unsaturated fatty acid methyl esters from Sigma. Methyl esters of fatty acids were prepared by the modified Peisker method, which provides complete methylation of fatty acids. For methylation, a mixture of chloroform with methanol and sulfuric acid was used in a ratio of 100:100:1. 30–50 ml of a lipophilic extract was measured in glass ampoules, 2.5 ml of a methyl mixture was added and the ampoules were sealed. Then they were placed in a thermostat with a temperature of 105 °C for 3 hours. After the end of methylation, the ampoules were opened, the contents transferred to a tube, powdered zinc sulfate was added to the tip of the scalpel, 2 ml of distilled water and 2 ml of hexane were added to extract the methyl esters. After thorough mixing and settling, the hexane extract was filtered and used for chromatographic analysis. The results of the experimental studies were subjected to statistical processing, realized with the help of standard Microsoft Office software packages.

6. Research results

Over the past two decades, a large body of scientific data has accumulated, indicating the important role of polyunsaturated fatty acids (PUFA) in the realization of numerous physiological and biochemical processes in the body. This indicates the need to study the actual consumption of ω -3 and ω -6 fatty acids with their food, their optimal level in the diet, necessary to ensure adequate growth and development.

Previous studies have established that tomato seeds are an excellent source of components such as carotenoids and lipids, which contain polyunsaturated fatty acids.

Therefore, the content of polyunsaturated fatty acids of tomato seeds was studied. The research results are shown in Table 2. As a result of studies in tomato seeds, 21 fatty acids were found.

The analyzed samples contain 47.72 % of polyunsaturated for technical crop maturity and 50.96 % of biological maturity. In the lipophilic fraction of seeds among the saturated acids, palmitic acid prevails, its content from the sum was 21.56 % for the tomatoes of technical maturity, and 20.75 % for the tomatoes of biological ripeness. Among the polyunsaturated acids, linoleic acid predominated. The investigated samples are characterized by the percentage content of linoleic acid with linseed (15–30 %) [15], and peanut oil (12–35 %), exceeding its content in olive (3–15 %). However, corn (38–48 %), sunflower (42–70 %) and soybean (44–60 %) oils are inferior in this indicator. The content of oleic acid in tomato seed samples is close to corn oil (24–25 %) and exceeds the content of cotton oil (by 18–19 %).

The fatty acid composition of tomato seeds

Table 2

Fatty acid	Seeds of technical ripeness, % C	Seeds of biological ripeness, % C
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
MUFA	24.68469	24.67815
PUFA	47.71713	50.96096
Unsaturated FA	72.40182	75.63911
Saturated FA	27.59818	24.36089

It is known that fatty acids ω -6 and ω -3 compete for metabolism by enzyme systems and can replace each other. The ratio of ω -6/ ω -3 polyunsaturated fatty acids, recommended by the Institute of Nutrition of the Russian Academy of Medical Sciences (RAMS), in the diet of a healthy person should be 10:1, and for therapeutic nutrition – from 3:1 to 5:1. Based on clinical and experimental studies [16–18], the ratio of acids ω -6 and ω -3 is recommended to be from 4:1 to 2:1. The results of the experiments show that in the tested tomato seed samples, this ratio is 2.55:1 for technical ripeness tomatoes and 4.16:1 – biological. This allows to classify the tomato seed oil as valuable essential substances and note the high content of ω -3 in the seeds of technical ripeness, which corresponds to the latest concepts of nutritional science.

7. SWOT analysis of research results

Strengths. It has been established that the tomato seed of technical and biological maturity is a source of biologically valuable components.

The obtained data indicate that tomato seeds have high nutritional and biological value, which is caused by an increased content of proteins, lipids, carbohydrates, and is close to the modern recommendations for creating healthy diets for the population. Moreover, the seeds of the technical stage of maturity differ from the biologically mature seeds by increased protein content – by 0.81 %, fiber – 0.4 % and sugars – by 0.21 %.

Weaknesses. Inclusion of semi-finished products from tomato seeds for the enrichment of food will lead to an increase in the cost of the finished product due to the need for additional technological operations.

Opportunities. The analysis of the research results indicates the possibility of using tomato seeds in food formulas and the advisability of further research on:

- development of new tomato sauces with functional properties and increased nutritional value;
- in-depth study of the influence of semi-finished products from tomato seeds on the formation of structural and mechanical properties of the finished product;
- influence of semi-finished products from tomato seeds on the digestibility of products in *in vitro* conditions.

The introduction of products of processing tomato seeds at food industry enterprises will help expand the range of products with health-improving properties for a wide range of consumers.

Threats. Since the chemical composition of tomato seeds is not sufficiently studied, the main factors affecting the stability of tomato semi-finished products will be the determination of the parameters of the pretreatment of raw materials.

8. Conclusions

1. The conducted studies have established that tomato seeds are a source of such components as carotenoids, proteins, carbohydrates, fibers, waxes and oils. The high biological value of tomato seeds results in a significant content of protein substances – up to 37.07 % of DM and lipids – up to 38.3 % of DM, are represented by polyunsaturated fatty acids.

2. It is revealed that unsaturated acids predominate among the identified fatty acids – linoleic, oleic, linolenic. The tested samples are spicily based on the percentage content of linoleic acid with linseed (15–30 %), and peanut oil (12–35 %), exceeding its content in olive (3–15 %). The results of the experiments show that in the samples of tested tomato seeds, the ratio of ω -6 and ω -3 is 2.55:1 for technical ripeness tomatoes and 4.16:1 for biological maturity. This makes it possible to classify the oil of tomato seeds as valuable essential substances.

3. From which it is possible to conclude that the value of the chemical composition of tomato seeds is determined by the significant content of essential fatty acids, which play a number of important biological functions. And also act as regulators of metabolic processes, in particular, participate in fat metabolism, affect the state of the vascular wall, counteract the free-radical oxidation. Therefore, tomato seeds can be attributed to promising types of raw materials with subsequent use for enriching food.

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