

Визначено біологічну цінність складових частин хеномелесу. Досліджено основні фізико-хімічні показники хеномелесу та продуктів його переробки. Визначено фракційний склад органічних кислот, цукрів та фенольних речовин, що містяться в продуктах переробки хеномелесу. Запропоновано шляхи використання напівфабрикатів з хеномелесу в технології продуктів харчування з метою покращення їх біологічної цінності, органолептичних та структурно-механічних властивостей

Ключові слова: хеномелес, хімічний склад, хроматограми, проціанідіни, ароматичні речовини, соус, борошняні вироби

Определена биологическая ценность составляющих частей хеномелеса. Рассмотрены основные физико-химические показатели хеномелеса и продуктов его переработки. Определен фракционный состав органических кислот, сахаров и фенольных веществ, содержащихся в продуктах переработки хеномелеса. Предложены пути использования полуфабрикатов из хеномелеса в технологии продуктов питания с целью улучшения их биологической ценности, органолептических и структурно-механических свойств

Ключевые слова: хеномелес, химический состав, хроматограмы, процианидины, ароматические вещества, соус, мучные изделия

THE STUDY OF BIOLOGICALLY ACTIVE SUBSTANCES OF CHAENOMELES AND THE PRODUCTS OF ITS PROCESSING

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1. Introduction

The problem of present time is substantial deterioration of health and a decrease in life expectancy of the population, which is caused by unfavourable environmental situation, low quality food, artificial food additives and consumption of a great amount of refined products. Result of the influence of these factors is disruption of normal physiological state of a human body, increase in the number of oncological and various professional diseases. The most acute problem is the health of children, because every second child is born with certain types of allergic diseases, congenital abnormalities and other defects of normal development [1].

Over the past decades, the role of biologically active components of foods of different chemical nature has been studied in order to prevent the most dangerous and socially significant chronic non-infectious diseases.

A relevant task of today is to create food products with a directed biological effect due to the use of natural ingredients of the raw materials that possess antioxidant and adaptogenic properties.

In this regard, it is socially important to develop the technology of food products with improved consumer prop-

erties, which imply a decrease in energetic versus nutritious value and enhancing organoleptic parameters.

2. Literature review and problem statement

The leading scientists were involved in the development of scientific fundamentals of technology of processing the alternative raw material with its use in manufacturing food products [2, 3].

Fruit and vegetable and plant raw materials and products of their processing (fruit and vegetable powders, pastes, purees, concentrates and juices) are a source of natural complex of biologically active substances, which positively affect a human organism. They provide vitamins, mineral substances, phenolic compounds and pectic substances that have a wide range of biological impact (hypotensive and vessel-strengthening, radioprotective, detoxicational, etc.). They are used for improving structural, mechanical and organoleptic properties and enriching food products with nutrients.

A valuable source of biologically active substances is chaenomeles, which contains vitamins, organic acids and pectic substances and has a pleasant aroma [4]. Fruits of chaenomeles

are widely used in the Eastern medicine. The antibacterial activity of the fruit in relation to *e.coli* is confirmed by the scholars from Taiwan University [5]. The glycosides, which are contained in the fruit of chaenomeles, are actively used in the treatment of juvenile and collagen-induced arthritis [6]. The anti-inflammatory and analgetic effects of chaenomeles fruit [7], the antiviral (virus groups A and B) and anticancer effects of extracts of the chaenomeles fruit were proved [8]. The fruit of chaenomeles inhibit tissue thromboplastin [9], prevent thrombogenesis and can be used by the patients suffering from diabetes II and in medical and prophylactic diets [10].

Analysis of the literature sources revealed that chaenomeles was mainly studied for the selection of new varieties [11]. The prospect of using chaenomeles fruit for medical and prophylactic purposes was explored [12, 13]. There are no studies on using it as a biologically active additive for food products. The studies of the quality indicators of chaenomeles and of the products of its processing, and using them in food production technologies are promising.

3. The aim and the tasks of the study

The aim of the work is studying biologically active substances of chaenomeles fruit and the products of its processing and the substantiation of expediency of their use in the production of food products.

To achieve the set goal, the main tasks that had to be solved were defined:

- to explore chemical composition of chaenomeles fruit and the products of its processing;
- to carry out chromatography studies to identify the composition of phenolic substances, organic acids, sugars and volatile compounds of chaenomeles and the products of its processing;
- to explore the influence of products of chaenomeles processing on the quality of fruit sauces and flour products with their use.

4. Materials and methods of research into main physical and chemical indicators of chaenomeles and the products of its processing

4.1. Standardized methods of research into physical and chemical indicators of chaenomeles and the products of its processing

To carry out the research, the mix of chaenomeles, gathered in Ukraine, were used.

The object of research was chaenomeles, the juice and puree obtained from it, as well as fruit sauces and flour products produced with the use of products of chaenomeles processing.

To identify the main physical and chemical indicators (dry substances, acidity, vitamin C and phenolic substances), the standard methods were used [14, 15].

5. Results of the research into the content of biologically active substances in chaenomeles and the products of its processing

For the analysis of organoleptic indicators, chaenomeles at the stage of consumption ripeness, gathered in mid-

September on the territory of Ukraine, was selected. The fruits differed in color from light-yellow to yellow and had characteristic sour, slightly tart taste and pleasant saturated aroma that matches their botanical characteristics [11].

The studies to determine the components of chaenomeles fruit and their biological value are shown in Fig. 1.

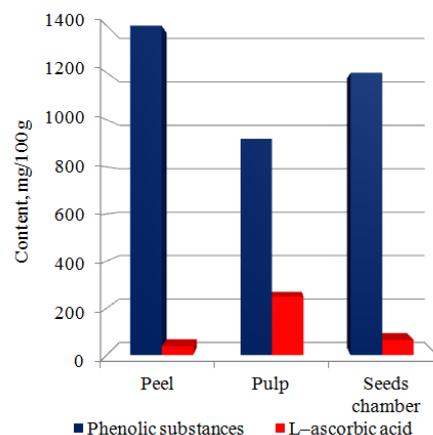


Fig. 1. Content of L-ascorbic acid and phenolic substances in the components of chaenomeles

The analysis of previously conducted research [16] and the data of Fig. 1 indicate that 60 % of the fruit is the pulp, which contains in its composition: organic acids (6,33 %), pectic substances (1,82 %), L-ascorbic acid (248 mg/100 g) and phenolic substances (920 mg/100 g), but not less valuable are the peel of the fruit (17 % of the fruit mass) and a seeds chamber (9 % of the fruit mass), which contain a significant amount of essential oils and phenolic substances (1400 mg/100 g).

A significant part of biologically active substances (BAS) of chaenomeles are in a combined state, only a part of them is in cell sap and, in the processing, it passes to a soluble part. The main carbohydrates that make up the primary cell membrane are cellulose, hemicellulose and pectin. Cellulose microfibrils are connected through hemicellulose bridges, forming a cellulose-hemicellulose network, which is surrounded by the matrix of pectin. Phenolic compounds are mainly localized in the peel and in the cell wall of the pulp of raw material and are an obstacle to transfer of useful ingredients of the fruit to soluble part. That is why it is expedient to break the integrity of these natural biopolymers by mechanical or chemical action.

The most efficient way of preliminary processing of fruit and berries is the use of enzyme preparations. Their application allows accelerating technological processes, increasing the yield of juice from the raw materials and increasing its nutritional value by enriching with phenolic compounds. This method of processing provides an opportunity not only to increase the yield of the juice and extract BAS from the peel and pulp of the fruit, but it is also the most rational method of direct extraction for enterprises in public catering [7].

The conducted experimental studies revealed that the highest yield of puree and the lowest volume of waste is achieved when blanching chaenomeles fruit in water. This method of preliminary preprocessing is the most affordable and rational under conditions of restaurant business [18].

Physical and chemical characteristics of quality were defined in chaenomeles fruits and in the products of their processing (juice and puree), the results of which are shown in Table 1.

Table 1

Physical and chemical indicators of quality of chaenomeles and theproducts of its processing (n=3, p<0,05)

Type of raw material	Indicators of quality				
	Mass fraction, %			Content, mg/100 g, dry substances, mg	
	dry substances	titrated acids	pectic substances	L-ascorbic acid	phenolic substances
Chaenomeles	18,44	6,36	1,62	248,00	885,00
Juice	11,44	5,63	0,82	144,32	410,00
Puree	13,55	4,77	1,74	98,56	560,00

The results, shown in Table 1, prove that the products of chaenomeles processing contain a significant fraction of pectic substances, phenolic compounds and L-ascorbic acid in their composition.

Pectic substances increase resistance of organism to allergies, contribute to restoration of the mucose membrane of respiratory and digestive tracts after diseases, affect the overall metabolism and are immunity strengthening means. Pectic substances are found almost in all plants. The content of pectic substances in chaenomeles fruit is 40 % higher than that of apples. Prophylactic rate of pectic consumption is 2 g per day [19].

Chaenomeles contain 6 times more of L-ascorbic acid, known for its antioxidant properties, than lemons [4]. The daily need for ascorbic acid for adults is 70–80 mg per day [20]. In the course of processing chaenomeles fruits, 42 % of L-ascorbic acid are lost while making puree and up to 60 % of it is lost while making juice, although its content remains relatively high.

To determine biological value of the products of chaenomeles processing, the study was conducted of the composition of organic acids and sugars (Table 2).

Table2

Composition of organic acids and sugars in the products of chaenomeles processing (n=3, p<0,05)

Type of raw material	Mass concentration, g/100 g						
	Organic acids				Sugars		
	citric	malic	succinic	quinic	saccharose	glucose	fructose
Juice	0,15	3,40	0,11	1,64	0,64	0,36	2,69
Puree	0,09	2,85	0,07	0,82	0,43	0,41	1,72

It can be seen from the results of the study (Table 3) that sugars, which are represented exclusively by hexoses – glucose and fructose, are the main fraction of soluble dry substances in chaenomeles. Fructose is the sugar that is easily assimilated by organism, so the products of chaenomeles processing can be used in the technology of food products for dietary purposes, including the diet of people who suffer form diabetes.

In addition to sugars, taste properties of raw material are determined by the presence of organic acids. It was found that in the products of chaenomeles processing they are mainly represented by malic and quinic acids, as well

as citric and succinic acids, which increases antioxidant properties of the fruit.

Availability of considerable amount of malic acid will allow using the products of chaenomeles processing as a natural regulator of acidity in foods.

Quinic acid is an important intermediate product of biosynthesis of aromatic compounds (flavonoids, phenolcarbonic acid and others) in higher plants and some microorganisms and has positive effect on a human organism.

Succinic acid can act as a reducing and radical-accepting agent, responsible for antioxidant protection. The main effect of succinic acid on a cell as an antioxidant is in reducing the intensity of the flow of lipid peroxidation, in increasing the content of restored glutathione, in reducing thiol-disulfide status of the cell and enhancing activity of antioxidant enzymes [21].

Phenolic compounds play a role of inhibitors in the process of oxidation of BAS. The specificity of the influence of certain phenolic compounds on reactivity of the components of crushed fruit was used to decrease the degree of oxidative transformations in them.

The research into the fractional composition of phenol substances contained in the products of chaenomeles processing (Table 3) show a significant content of procyanidins that have antioxidant activeness, which is 20 times higher than ascorbic acid and 50 times higher than vitamin E. Procyanidins contribute to the increase in macromolecular lipoproteins in blood plasma, which leads to reducing the risk of cardio-vascular diseases [22], and, as a reducing substance, is involved in preventing cancer diseases of gastro-intestinal tract and internal organs [23]. In addition, procyanidins promote weight loss and prevent development of diabetes of type 2 [24]. Catechins and chlorogenic acid also possess antioxidant properties; besides, catechins have antimicrobial properties and are used for strengthening immunity.

Rutin is an important substance in prevention and treatment of hypovitaminosis and vitamin P deficiency in the diseases that are accompanied by disruption of vascular permeability and allergic diseases.

Given that the semi-finished products from chaenomeles possess potent antioxidant properties, we can stress high biological value of food products made with their use.

The research into fractional composition of volatile substances (Table 4) in the products of chaenomeles processing prove its considerable biological value.

Table3

Composition of phenolic substances in the products of chaenomeles processing (n=3, p<0,05)

Type of sample	Groups of phenolic substances	Content, mg/100 g	% of PS content	Dominant representative	Content, mg/100 g	% of content
Juice	Procyanidins and their derivatives	276,27	69,20	Procyanidins trimmer	87,59	31,70
Puree		322,09	58,16		157,79	5,83
Juice	Flavan-3-ols and their derivatives	116,52	29,19	Epicatechins	64,08	54,99
Puree		218,59	39,47		197,94	7,31
Juice	Hydroxycinnamic acids and their derivatives	5,89	1,48	Chlorogenic acid	5,89	1,48
Puree		11,02	1,99		11,02	1,99
Juice	Flavons and their derivatives	0,54	0,14	Rutin	0,54	0,14
Puree		2,07	0,37		2,07	0,37

Table 4
Content of volatile aromatic compounds in the juice and puree from chaenomeles(n=3, p<0,05)

Groups of compounds	Type of raw material					
	Puree			Juice		
	Number of entries	Content, mg/dm ³	% of total content	Number of entries	Content, mg/dm ³	% of total content
Alcohols	9	7,49	11,77	9	4,37	18,45
Acids	12	36,24	56,93	12	7,67	32,39
Aldehydes	2	0,60	0,94	2	0,56	2,36
Ketones	4	0,98	1,54	4	1,89	7,98
Terpenes	4	3,61	5,67	4	1,04	4,39
Ethers	9	4,95	7,78	9	2,88	12,16
Unsaturated carbohydrates	8	7,45	11,70	8	2,92	12,33
Unidentified	3	2,34	3,68	3	2,35	9,92
Total content of volatile compounds	51			51		

considered “a vitamin of oxygen” and is a unique component of the skin lipids of a human. In many countries of the world, the preparation of squalene is used in the treatment of atherosclerosis, coronary heart disease, high cholesterol, liver and skin diseases, so its availability in the products of chaenomeles processing increases its biological value.

Upon analysis of the data from Table 4, it was noted that acids make up almost 60 % of the total content in puree and 30 % in juice. The group of acids is largely represented by carboxylic acids, among which the most important are caprylic and lauric acids, which have antimicrobial and antiseptic properties, immunity strengthening effect and help fight diabetes and high blood pressure. There can be found linoleic and oleic acids, known as ω-6 and ω-9 unsaturated aliphatic acids that have positive impact on a human organism and are used for prevention of diseases of different etymology [26].

The obtained data prove that the aroma of juice and puree is formed by aromatic alcohols, acids, aldehydes, ketones, ethers, carbohydrates that are present in raw materials. A significant amount of volatile aromatic substances are found in puree (Fig. 2, 3) since a whole fruit is used in its preparation, including the peels – the main source of aromatic substances.

The research results (Table 4) prove that acids, ethers and carbohydrates prevail among volatile compounds, which are represented in the products of chaenomele processing.

Alcohols are represented by unsaturated, saturated and aromatic alcohols. The combination of α-terpenil (lilac), β-terpenil (hyacinth), β-ionone (violet), α-farnesene (green apple), estragole (dragon), linalole (lily-of-the-valley), eudesmole (rose, eucalyptus), and ethylcaprylate (flower aroma) provide chaenomeles and the products of its processing with unique strong fragrance.

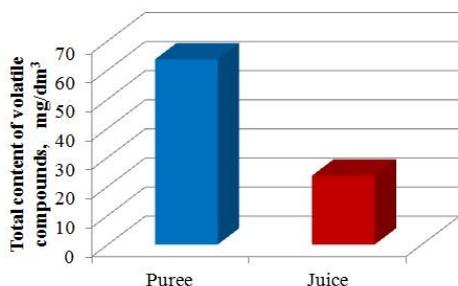


Fig. 2. Total content of volatile compounds in the products of chaenomeles processing, mg/dm³

Special attention should be paid to the presence of squalene (representative of unsaturated carbohydrates) in the amount of 2,11 mg/kg in the juice and 6,43 mg/kg in the puree; it is

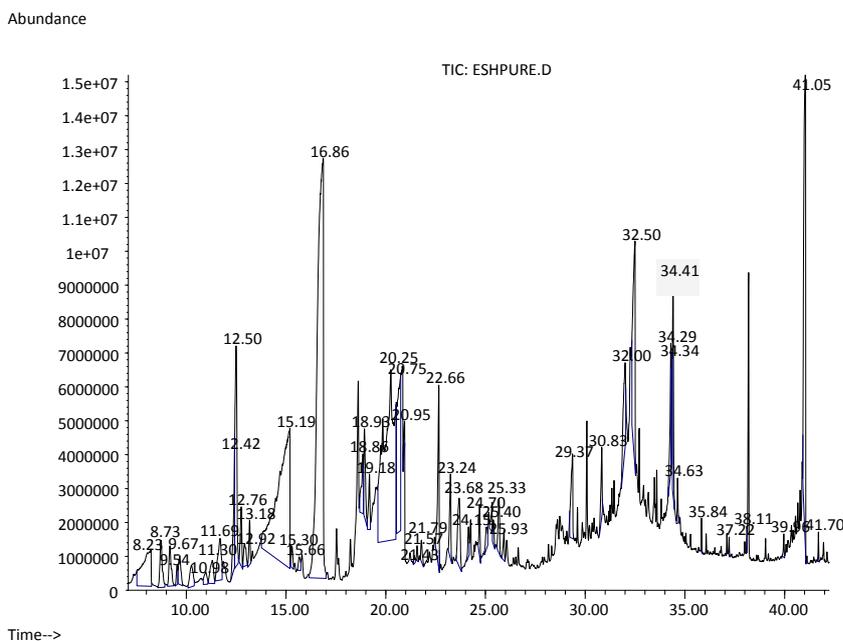


Fig. 3. Chromatogram of content of aromatic substances in puree from chaenomeles

Antimicrobial and antibacterial properties of the products of chaenomeles processing make it possible to predict a decrease in microbiological contamination of foods with the use of chaenomeles.

Given nutritional and biological value of the products of chaenomeles processing, it is rational to use them in technology of sweet sauces and pastry products, with the aim of improving organoleptic, structural and mechanical, physical and chemical indicators of the finished products.

Physical and chemical quality indicators of the finished products are presented in Tables 5, 6.

The results of the research (Table 5) prove that the use of the products of chaenomeles processing in sweet sauces enhances their biological value by increasing the content of L-ascorbic acid, pectic and phenolic substances compared with the reference sample.

Table 5
Physical and chemical indicators of sweet sauces made of the products of chaenomeles processing (n=3, p≤0,05)

Name of sauce	Mass fraction, % mass			Content, mg/100 g		pH
	dry substances	pectic substances	titrated substances	L-ascorbic acid	phenolic substances	
Apple sauce (reference)	48,00	0,42	0,13	13,45	80,00	3,70
Sauce "Nasoloda"	53,00	0,81	1,61	61,60	260,00	3,50
Sauce "TopiKhen"	55,00	1,49	1,68	61,18	262,00	3,50
Sauce chaenomeles-pumpkin	58,00	1,12	2,56	62,19	262,00	3,40

Consequently, adding products of chaenomeles processing to the formulations of flour products from yeast dough (Table 6) increases porosity of the finished products, which contributes to their better digestibility. An increase in humidity and acidity in the experimental samples, compared with the reference samples, allows increasing terms of storage of the finished products and preventing development of potato disease.

Table 6
Physical and chemical indicators of quality of finished products made of yeast dough using the products of chaenomeles processing (n=3, p≤0,05)

Indicators	Control	Tested samples	
		with juice	with puree
Specific volume, cm ³ /g	2,80	3,30	3,30
Resistance to form changing, H/D	0,60	0,70	0,70
Acidity, degree	2,50	2,60	3,00
Humidity, %	38,00	40,10	41,00
Porosity, %	68,00	75,00	75,00

6. Discussion of the results of studying the content of biologically active substances in chaenomeles and the products of its processing

The conducted studies of determining chemical composition of chaenomeles and the products of its processing prove the feasibility of their use in the production of food.

A valuable source of organic acids is chaenomeles juice, which should be used as a natural regulator of acidity and as an antioxidant. Availability of amino acids, mineral substances and monosaccharides in the juice enriches the flour medium and creates optimal conditions for the yeast vitality, shortening the process of dough formation. The set of aromatic substances contained in chaenomeles juice adds a pleasant aroma to ready products [27].

In addition, chaenomeles juice can be used as a natural inhibitor of oxidative reactions that occur in plant raw materials under the influence of polyphenoloxidase that is present in Jerusalem artichoke in large amount, which complicates its processing. Therefore, the pre-treatment of Jerusalem artichoke in chaenomeles juice is proposed

to prevent its darkening before obtaining puree that is used as a semi-finished product in the technology of sauces [18].

One of the directions of using chaenomeles juice is its use for softening the tissue of plant raw materials, which include pumpkin. It was found that the most efficient is the pre-treatment of such raw material in citric acid and in chaenomeles juice, which contains malic, quinic and tartaric acids, with subsequent blanching in water. Organic acids contained in chaenomeles juice positively affect not only the oxidation reactions that take place in pumpkin but also its organoleptic characteristics.

Since chaenomeles puree combines considerable content of pectic substances and organic acids, it can be used as a natural structuring agent in the technology of fruit sauces and pastry products. The use of chaenomeles puree in the technology of flour products from yeast dough, made of flour with weak gluten, contributes to strengthening the dough structure and the structure of gluten proteins, which can be explained by oxidation of proteins under the influence of L-ascorbic acid, organic acids and by formation of complexes with polyphenols and pectins contained in puree in sufficient quantities.

Through considerable acidity, it is not expedient to use chaenomeles puree in its pure form, that is why, in the course of developing the sauces formulations, it was blended with other pectin containing raw materials with the highest sugar-acid index: apples, pumpkin and Jerusalem artichoke. The developed sauces have high structural and mechanical properties, temperature stability and high nutritional value [18].

In addition, the use of semi-finished chaenomeles products in food technology reduces their overall microbiological contamination, prevents development of potato diseases, which is achieved due to the content of certain carbonic acids and is proved by the research.

Along with it, the use of chaenomeles products in food products provides an opportunity to enhance their biological value and antioxidant properties due to the content of phenolic substances and L-ascorbic acid.

7. Conclusions

1. The chemical composition of chaenomeles fruit, gathered on the territory of Ukraine, was determined, which revealed high content of titrated acids – 6,36 %; pectic substances – 1,62 %; L-ascorbic acid – 248 mg/100 g and phenolic substances – 885.00 mg/100 g. The products of chaenomeles processing – juice and puree – are also characterized by a significant content of biologically active substances and contain L-ascorbic acid – 144,32 mg/100 g (juice) and 98,56 mg/100 g (puree) and phenolic substances – 410,00 mg/100 g (juice) and 560,00 mg/100 g (puree).

2. According to the results of chromatographic studies, the composition of phenolic substances in the products of chaenomeles processing was identified. It was determined that the juice and puree contain procyanidins,

hydroxycinnamic acids, flavones and flavan-3-ols. The dominant representatives are procyanidin trimmer, chlorogenic acid, rutin and epicatechine. Among the organic acids, malic, quinic, citric and succinic acids were identified, malic acid being dominant among them. Sugars are represented mostly by fructose and in a less degree by glucose and saccharose. Among the volatile compounds that characterize fragrance of the products of chaenomeles processing, 51 compounds were found and 48 compounds were identified.

3. It was established that the use of products of chaenomeles processing affects quality indicators of fruit sauces and flour products with their use: in sauces, the content of L-ascorbic acid, pectic and phenolic substances increases; in flour products with yeast dough, porosity, specific volume, resistance to form changing, humidity and acidity increase.

Based on the conducted research, it was substantiated that chaenomeles is a valuable raw material and has prospects for its use in the manufacture of food products.

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