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TOWARDS FOOD SECURITY THROUGH APPLICATION OF NOVEL SCIENTIFIC FINDINGS

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Abstract. This paper is devoted to novel scientific findings, which, is properly exploited, can contribute to food security both, locally and globally. Specifically, the presented paper reports on the analytical characteristics of pectic substances derived from Cucurbita cultivated in the Republic of Kazakhstan. The fractional composition of pectic substances, their analytical characteristics and degree of etherification, content of organic acids, sugars, vitamins and mineral substances are studied. The results demonstrated that these raw materials can be considered a source of pectic substances, carbohydrates, vitamin C, a niacin and carotene. Moreover, pectic substances of Cucurbita are low-etherified, a characteristic implicated in expediency of their use as detoxicator.

Keywords: food security, novel scientific findings, pectin substances, fruits of pumpkin, analytical characteristics, etherification degree, gelling and complexing ability

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1. Introduction

Application of innovations and novel scientific findings is one of the most important paths towards high value added economy, and therefore towards increase of competitiveness of novel food products, industries, and, ultimately, through food security towards economic security of the whole country (Travkina, 2015; Pauceanu, Sahli, 2016; Aleksejeva, 2016; Ciemleja, Lace, 2016).

Creation of innovations and coming to novel scientific findings is crucial constituent of and precondition of competitive outcome materialized in service or product. Recently this strand of scientific literature has been actively expanding (e.g. Ahmed et al., 2017; Kiškis et al., 2016; Rezk et al., 2016; Branten, Purju, 2015; Shatrevich, Strautmane, 2015; Oganisjana et al., 2015; Rezk et al., 2015; Petrenko et al., 2016). Commercialization of novel findings remains another important constituent in high value creation process (Laužikas et al., 2016; Tvaronavičienė, 2016; Lace et al., 2015; Njaramba et al., 2015; Laužikas et al., 2015; Dlugoborskytė et al., 2015; Prause, 2015).

Application of novel scientific findings in such specific area as food industry directly contributes to enhanced food security (Nagyová at al. 2016; Shevchuk et al. 2016). In this paper food security as an ultimate outcome

is being especially emphasized.

Pectin, a natural detoxicator and radioprotector, is an important and multifunctional substance globally (Donchenko and Firsov 2006; Il'ina, Donchenko and Zemskova 2003). Development of production technologies for different types of pectin can ensure ecological purity and safety of processes while maintaining high quality of the target product, which has attracted much attention from scientists and experts from leading companies in the industry. (Sokol, Donchenko, Hatko. 2008). Moreover, companies such as *Herbstreith und Foks* (Germany) and *CP Kelco* (USA) have pioneered expansion of pectin usage in various industries. Despite its utility and the abundance of raw material resources, pectin production and modifications remains largely impractical. Companies face difficulty in producing pectin with predictable structure, chemical composition, and properties. This difficulty can be explained by the diversity of pectin-containing raw materials which demand unique processing approaches. (Donchenko L.V., Sokol N.V., Krasnoselova E.A., 2012).

In order to develop sophisticated technologies for pectin production, it is necessary to study the analytical characteristics of the pectic substances these raw materials contain. In this regard, researches directed toward the development of an analytical basis for classification of pectin-containing raw materials and the quality and nutritional value of the product are topical and necessary. In the Republic of Kazakhstan, a Eurasian state with the world's 9th largest land area and a population of more than 17.5 million, there is an especial scientific interest in the investigation of pectin-producing raw materials and advancement of pectin production processes. To our knowledge, this study is the first to report on the analysis of pectin-producing raw materials in the context of Kazakh industry.

In addition to food safety, there is a need to investigate the efficacy of complex pectin biological products as natural detoxicators. In Kazakhstan, the Aral Sea and Semipalatinsk regions are ecological disaster zones in which destruction of natural ecological systems and degradation of flora and fauna took place. (Ecologia, 2011) As a result of this ecological situation, the health of local populations was jeopardized (Nazarbayev 2011). In the regions adjacent to the former Semipalatinsk Test Site (85 settlements with population of nearly 72 thousand of people) there is a high level of cancer diseases and mortality of the population, blood circulatory system diseases, malformations among newborns and premature aging. (Ecologia, 2011). In ecological disaster zones of the Aral Sea region (178 settlements with a total population of 186,000people), there is a high level of gastrointestinal diseases and anemia, especially among women and children, child mortality and congenital pathology. (Ecologia, 2011). For decrease in such a negative impact of the environment on a human body use of pectic substances is expedient. (Romanenko, Derevyago, 1991; Xotimchenko, Kovalev, 2000).

Furthermore, it is known that Kazakhstan has 1.6 million tons of explored reserves of uranium that brings the Republic to the second place in the world according to its volumes of explored reserves of uranium. In spite of the fact that uranium by nature is not radioactive, danger is constituted by products of uranium disintegration which are radium and radon. During uranium extraction the main radioactivity remains on the places of ore run. At the same time, during production and processing mullocks and mine refuses are formed which demand a special attention. This circumstance defines a necessity to increase the range and production of functional nutrition products with antiradiation and detoxification properties for decrease of a negative impact of ecological factors on a human body.

Functional nutrition describes integration of enriched foods that can improve and support health and also reduce the risk of disease. Enrichment by functional ingredients of food is one of the most topical directions in science of human nutrition and foodstuff in the third millennium. (Tutelyan, Spirichev et al., 2002). The most widespread diseases in Kazakhstan as well as around the world are diseases of cardiovascular system, obesity and diabetes. In this regard, development of technologies on enrichment by functional ingredients of food the population already accustomed to and with the purpose of prevention of many diseases is becoming topical and expedient. In this regard, such important properties of pectin such as complexing ability and solubility determined by such analytical characteristics as the maintenance of free carboxyl groups, level of etherification, a polyuronide component are important.

The World Health Organization (WHO) recommends pectin substances as effective functional additives, and the European Union recommends these substances for the decrease of cholesterol and glucose in blood, with recommended consumption values of 4 and 10 grams per day, respectively (Official Journal of European Union (2012).Therefore, elaboration on the functional uses of pectin (as a detoxicator or radioprotector, a structure former or gelling agent, *et cetera*) and the raw materials utilized in pectin production has not only theoretical but also important practical value. Pumpkin (*Cucurbita spp*.), a putative organism for pectin manufacture, accounts for 3,000 ha of cultivated land area across the Republic of Kazakhstan (Shepetkov, 2007). It is known that fruits of Cucurbita are rich in carotene, niacin, and vitamins C and B6. Therefore, we carried out an assessment of these nutrients in selected Cucurbita varieties. The natural tartaric acid has antioxidant properties and influences exchange and digestive processes in an organism. It is known that malic acid plays an important role in exchange processes of a human body. It promotes full digestion of iron, interacts with vitamins and decomposes in water. Previous researches showed that amber acid is an adaptogen (increases organism resilience to adverse factors of environment) that is a positive factor when developing products of a functional purpose.

The nutritional value of food is determined in part by mineral composition. Mineral substances, categorized as either micro- or macro-elements, are irreplaceable components of food. Prominent macroelements include alkaline potassium, sodium, calcium and magnesium, and acidic phosphorus, sulphur, and chlorine. Prominent microelements include iron, copper, zinc, iodine, selenium, manganese, and others. Microelements are biologically-active substances that are necessary for the human body in small amounts. In this regard, we carried out the analysis of Cucurbita fruits on the composition of such main macro elements as potassium, calcium, magnesium, phosphorus and microelements – as iron, zinc, copper.

The objective of the present study is to define the fractional structure of pectin substances derived from two major varieties of *Cucurbita spp.* and to report on their analytical characteristics, including content of polygalacturonic acid, methoxyl and acetyl components, level of etherification, gelling and complexing ability, sugar and acid composition, and nutritional value. Knowledge of analytical characteristics of pectic substances will allow to define the scopes of fruits of pumpkin in production of functional food. So the high content of a methoxy component will cause their application as the structure- and jelling agents, the high content of free carboxyl groups – as a complex agent.

2. Research Methods

Important pumpkin (Cucurbita) varieties *Karina* and *Aphrodite* from theRepublic of Kazakhstan were chosen as the subjects of the present research. The varieties of table Cucurbita chosen for this study were recommended by special government bodies on a grade testing of crops in the Republic of Kazakhstan, confirming the stability of pumpkin as a source of raw material for pectin manufacture.

Description of Varieties: *Karina* is a *Cucurbita maxima*, and a selection of the Kazakh Research Institute of potato and vegetable economy. The fruits are rounded-flattened, of average size, gray and green, rarely variegated, during its storage turn pink. Pulp of a fruit is bright orange, dense, of average thickness, very sweet. The average mass of a fruit is from 2 to 6 kg. A seed cavity is average. Seeds are of cream colour, coriaceous with a solid peel. A type is mid-season productive. Lightness and transportability are high. *Aphrodite* is a *Cucurbita moschata*, and a selection of the Kazakh Research Institute of potato and vegetable economy. The type is oblong, fruits are lengthened with the utricular end. The tail part of a fruit is 2/3 of the total lengths and has no emptiness. The colour of a fruit is orange with drawing in the form of brown not clear disrupted strips. At its full maturing drawing disappears. Pulp is orange, sweet, and dense. A fruit surface is smooth with a mealy and gray wax cover, and at a fruit stem is ribbed. The average mass of a fruit is 5-8 kg. A seed cavity is small. A type is mid-season of table consumption. Fruits are transportable and are well stored. Marketability of fruits is to 90%.

Analysis: During the experiments, standard and modern methods of physical and chemical analysis were applied. Mass fraction of moisture (refractometric), mass fraction of protein (Kjeldahl method), fractional composition of pectic substances (protopectin and *hydratopectin*) – calcium-pectic method; fractional composi-

tion of sugar (glucose, fructose, sucrose), content of vitamin C, fractional composition of organic acids, mass fraction of macroelements (capillary electrophoresis), mass fraction of water-soluble and fat-soluble vitamins (capillary electrophoresis, fluorometric, thin layer chromatography, spectrophotometric, photocolorimetry methods), mass fraction of microelements (nuclear and adsorptive). The research was conducted on 120 crop samples of 2012, 2013, 2014 with no less than 6 replicates. Samples of fruits of pumpkin were selected in a technical maturity in the industrial regions of their cultivation. For study cut out the segments consisting of bark and bark pulp without placenta and seeds from no less than 10 fruits of pumpkin. Segments crushed and selected average test weighing 100 g. Hydrolystic extraction of pectic substances from the studied objects of research was conducted with sulfuric acid at 65°C for 1 hour. The emitted pectin was besieged by technical ethanol with 96% strength. The received coagulate of pectin was dried at the temperature of 40-45°C within 2 hours to humidity of 10 – 12%.

3. Results and Discussions

The results of the general content and fractional structure analysis of pectic substances of the chosen varieties are shown in Figure 1. Researches of the general contents and fractional composition of pectic substances in the chosen objects were conducted in six replications. In the Figure 1 data of average value on indicators for each grade are presented. At an assessment of reliability of distinctions between options of experiments is used Styyudent's criterion on a significance value P = 0.05. Statistical characteristics, standard deviations, square deviations and settlement Styyudent's criterion have been for this purpose calculated. The settlement Styyudent's criterion was compared to tabular. In our experiments $T_{calc.} > T_{tabl.}$, i.e. $T_{calc.} = 4{,}3637$; $T_{tabl.} = 2{,}2281$ at significance value P = 0,05. Therefore, Aphrodite (21,8%) of muscat type has higher overall pectic content (21.8%) than Karina (15.8%).

In all studied samples, the fractional composition of pectic substances is presented by protopectin and soluble pectin (hydropectin). Thus the content of protopectin prevails over soluble fraction that is natural for vegetable raw materials. The ratio of protopectintohydropectinis larger in Karina type (3.0), causing a difference in the parameters for extraction of pectic substances. In particular, temperature and duration of the process of hydrolysis extraction of this type have to be slightly more than from Aphrodite type, in which the ratio of protopectintohydropectinis 2.46.

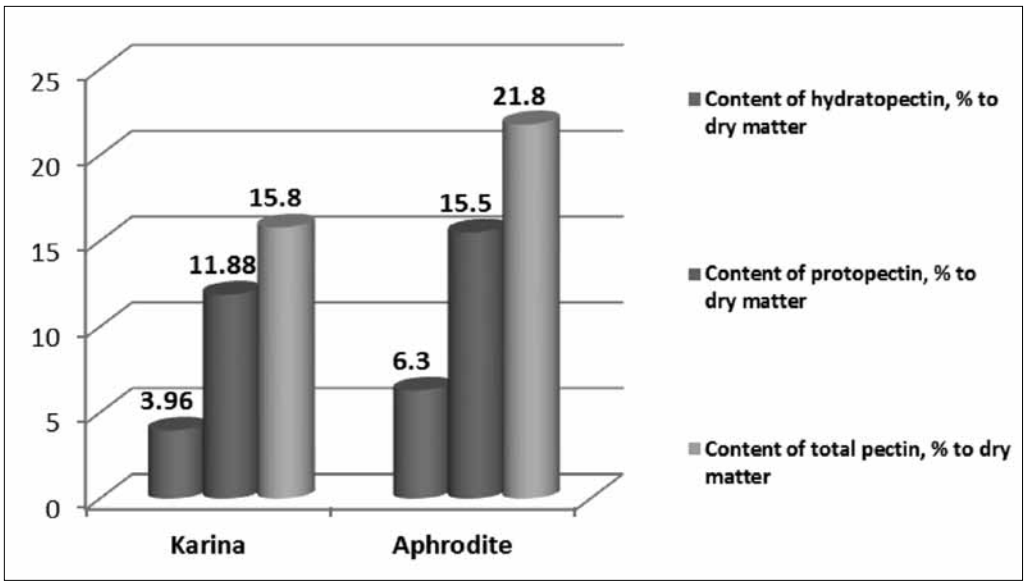

Figure 1. Fractional composition and total content of pectic substances in the chosen objects of research, % to dry matter

It is known that in the presence of strong mineral acid, pectic high etherification acid is hydrolysed at room temperature. This process is accelerated upon temperature increase, favouring pectin degradation.

Investigation of analytical characteristics of the emitted pectin indicate that the maintenance of free carboxyl groups the pectin samples allocated from fruit pulp of Cucurbita of Aphrodite and Karina types are not significantly different. At the same time, the etherification degree of Karina type is slightly less (37.94%) in comparison with Aphrodite type (43.27%). At the assessment of reliability of the values of etherification degree of the emitted pectic substances it is established that $T_{calc.} > T_{tabl.}$ At the same time $T_{calc.} = 3{,}1396$; $T_{tabl.} = 2{,}2281$ at significance value $P = 0{,}05$. Thus, the emitted pectin should be classified as low-etherified. Complexing properties of pectic substances depend on the maintenance of free carboxyl groups, i.e. level of etherification of carboxyl groups by methanol. The level of etherification determines the lineal charge density of a macromolecule, and, therefore, power and connection of cations. With reduction of the level of etherification (increase of charge of a macromolecule), the connectivity of pectic substances with cations increases. Therefore, it is possible to predict bigger complexing ability for Karina type than Aphrodite.

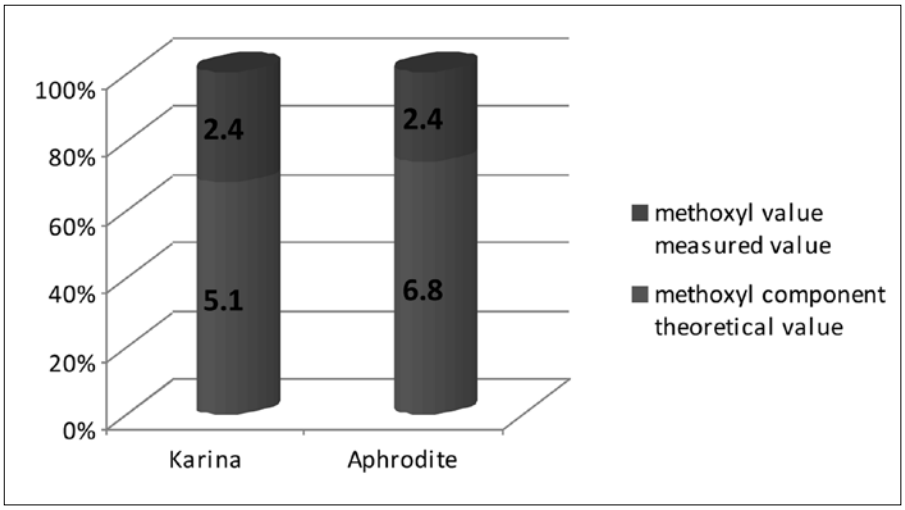

Figure 2. Comparison of methoxyl component of pectin

An important functional property of pectic substances in the food industry is gelling ability. Gelation depends on a polyuronide component, the level of etherification of its molecule and the maintenance of functional groups –methoxy and acetyl components. It was established that the composition of a polyuronide component is twice higher in the pectin emitted from Karina type (33.84%) than from Aphrodite type (15.51%). However, it is necessary to notice that the composition of polyuronide equally low that has an adverse effect on formation and durability of jelly. In order to evaluate the mechanism of gelation we defined composition of methoxyl groups (Figure 2). At methoxylation of pectin of 30 - 40% the composition of a methoxyl component made 2.4% of measured value against theoretical 5.2 - 6.8%. Pectin from Aphrodite type is capable of stronger jelly formation, based the higher etherification level, as this is related to a higher share of hydrophobic power in jellification. Thus, the part of the hydrogen binding which are formed freely and not etherified to carboxyl groups decreases. The acetyl component has an essential impact on the mechanism of jellification and strength of jelly. It was established that in both varieties the composition of the acetyl component was equally high (1.1%), considerably worsening the gelling properties of both Aphrodite and Karina types.

The content of organic acids don't differ significantly across the two Cucurbita varieties (Figure 3). However, the fractional composition of tartaric acid is three times greater in Karina type than in Aphrodite type. Citric and lactic acids in both types are absent, and according to the content of malic acid they don't differ (0.01%) and its content it very low. Rather high content of amber acid is revealed in both types (0.27-0.28%).

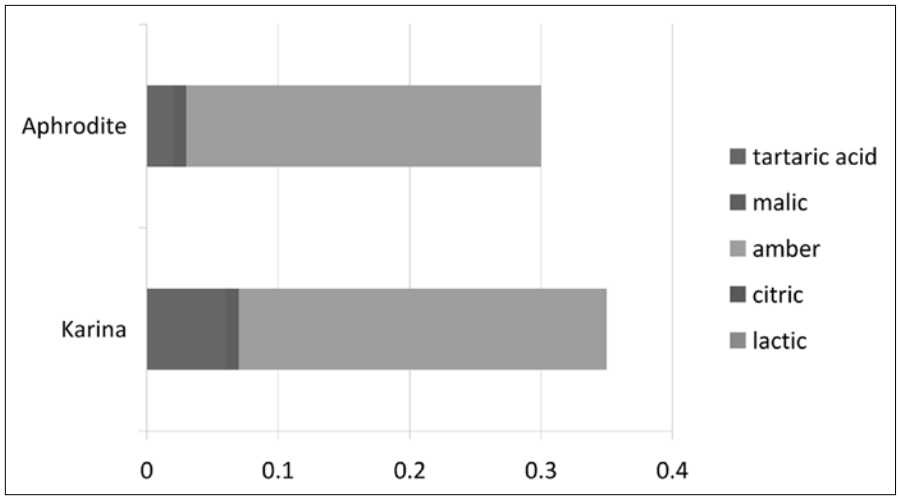

Figure 3. Fractional composition of organic acids in the studied samples of Cucurbita

The fractional composition of sugars is not less topical for definition of a functional orientation of the studied types (Figure 4). Karina type had a higher sugar content than Aphrodite, with 8.1% and 5.7% sugar composition, respectively. Fractional composition analysis revealed 5.1% sucrose in Karina and 4.2% in Aphrodite, and the glucose content of Aphrodite type is 8.6 times less (0.12%), than Karina type (1.03%). The fructose content of Aphrodite type is 31.5% less than Karina type. The results of carotene analysis showed that Karina type yielded 450 mkg/100g carotene, compared to 400 mkg/100g for Aphrodite type. The contents of water-soluble vitamin C and niacin made up 14 and 0.1 mg/100g of pulp respectively. Vitamin B6 composition was low across the two varieties, accounting for only 0.02 mg/100g of pulp. The two Cucurbita varieties did not exhibit significant differences in vitamin composition.

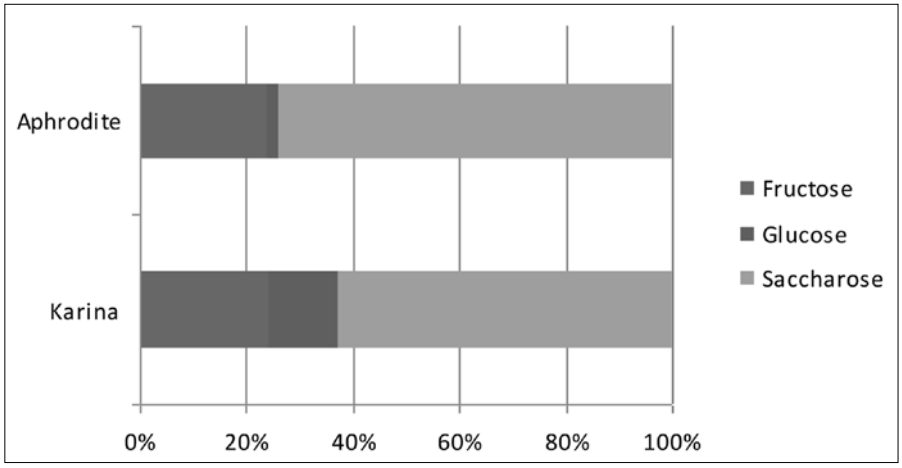

Figure 4. The fractional composition of sugars of the studied types of Cucurbita

The assessment of degree of daily provision with the main macroelements at consumption of Cucurbita fruits is given in Table 1.According to the data, the observed calcium provision of the sample material is prominent (4.4 - 4.5% of daily value) and magnum (3.3 – 4.7%). Provision of Kalium is insignificant with about 2%, and observed provision of phosphorus was also low at only 1.2%.

Table 1. Degree of daily provision of a human body by the main macroelements at consumption of Cucurbita fruits

Studied figure	Karina	% of daily provision of an organism	Aphrodite	% of daily provision of an organism	Daily consumption by a human, mg
Kalium mg/100 g	84,1	2,10	80,4	2,01	4000
Magnesium mg/100 g	10,0	3,34	14,0	4,67	300
Calcium mg/100 g	26,5	4,41	27,2	4,53	600
Phosphorus mg/100 g	14,7	1,23	15,5	1,30	1200

Table 2 shows the data on degree of daily provision with the main microelements at consumption of Cucurbita fruits. We observed that the degree of daily provision with iron, copper and zinc is low and within the range of 4.5-12% of daily value. Taking into account the requirements for functional food, the studied samples can't be considered as a source of iron, copper andzinc.

Table 2. Degree of daily provision of a human body with the main microelements at consumption of Cucurbita fruits

Studied figures	Karina	% of daily provision of an organism	Aphrodite	% of daily provision of an organism	Daily consumption by a human, mg
Iron, mg/100 g (dry matter)	0,40	0,67	0,5	0,84	15-60*
Copper, mg/100 g (dry matter)	0,02	2,23	0,04	4,45	0,9
Zinc, mg/100 g (dry matter)	0,2	1,34	0,3	2,0	10-15*

(% of provision of an organism is calculated on the maximum daily demand of a human)

Conclusions

Both Cucurbita varieties examined in the present research exhibited high efficacy in production of pectic substances. The results of our study suggest that it isn't expedient to use the pectin emitted by Karina and Aphrodite Cucurbita varieties as a gelation agent. However, the emitted pectin has good complexing ability of 290 – 400 mg of Pb^{2+}/g, which is important in developing highly-functional pectin products. Our results confirmed the necessity of further investigation of the chemical composition of the chosen varieties. Total pectin content was higher in Aphrodite type (21.8%) than in Karina. In both samples of the Cucurbita fruits, pectic substances were low-etherified, which defines their potential to use as detoxicator. It is known that etherification degree of pectic substances defines their complexing ability. At decrease in etherification degree, i.e. increase in a charge of a macromolecule because of increase in keeping of free carboxyl groups, communication of pectic substances with cations including toxic metals, increases. At the same time the stability constant of a pectate increases in the function close to logarithmic dependence. (Voragen, 1996). Besides, at decrease in etherification degree of pectic substances their radio tire-tread ability increases (Romanenko, Derevyago, 1991). It is necessary to note that daily demand of a human body for vitamin C is 50 mg. Taking it into account, it is clear that fruits of Cucurbita can be considered as a functional source of this vitamin for satisfaction of physiological requirement (extent of ensuring of daily requirement is 28%). Taking into consideration the recommended norms of consumption of the considered vitamins, level of provision at consumption of 100g of fruits of Cucurbita will make 50% of niacin and 1.0% of B6 vitamin. Thus, Cucurbita fruits are a functional source of vitamin C, niacin and carotene. Thus, we conclude that the selected varieties of Cucurbita are an example of highly-effective producers of stable pectin substances and functional foodstuffs. We have demonstrated that the pectic substances produced by these varieties have properties conducive to radioprotection and detoxification, which should be elaborated on in future investigations. Furthermore, the selected varieties contain functional quantities of carbohydrates, vitamin C, niacin, and carotene—indicating their value as a functional food.

Commercialization of those novel findings would lead to increased competitiveness of food industry, and, respectively, to enhanced food security.

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