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UDC 577.353:577.114.5
DOI: 10.15587/1729-4061.2016.70996

THE INFLUENCE OF MECHANOLYSIS ON THE ACTIVATON OF NANOCOMPLEXES OF HETEROPOLYSACCHARIDES AND PROTEINS OF PLANT BIOSYSTEMS IN DEVELOPING OF NANOTECHNOLOGIES

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Запропоновано та розроблено нанотехнологію білкових рослинних добавок у формі нанопорошков і нанопюре із гороху, яка заснована на процесах глибокої переробки сировини. В якості інновації використовували дрібнодисперсне подрібнення термообробленої сировини, яке супроводжується неферментативним біокаталізом-механолізом нанокомплексів біополімерів (гетерополісахардів і білків) в розчинну легкозасвоювану форму

Ключові слова: нанотехнологія, дрібнодисперсне подрібнення, механоліз, нанокомплекси, біополімери, гетерополісахариди

Предложена и разработана нанотехнология белковых добавок в форме нанопорошков и нанопюре из гороха, которая основана на глубокой переработки сырья. В качестве инновации использовали мелкодисперсное измельчение термообработанного сырья, которое сопровождается неферментативным биокатализом-механолизом нанокомлексов биополимеров (гетерополисахаридов и белков) в растворимую легкоусваиваемую форму

Ключевые слова: нанотехнология, мелкодисперсное измельчение, механолиз, нанокомплексы, биополимеры, гетерополисахариды

1. Introduction

It is known that vegetable raw materials, particularly fruits, vegetables are a source of biologically active substances for human body, such as vitamins, carotenoids, anthocyanins, chlorophyll, phenolic compounds, minerals and indigestible components, i. e. prebiotics such as heteropolysaccharides, protein, cellulose, pectin substances, etc. [1–4].

They strengthen protective forces, strengthen the blood vessels of heart and brain, contribute to the prevention of cancer diseases in a human body as well as detoxify and cleanse the body from various kinds of harmful and toxic substances [5, 6]. It should be noted that despite of the useful properties of fruit and vegetable raw materials, nowadays biological potential (by the content of vitamins and other BAS (biological active substances), protein, amino acids, polysaccharides, etc.) available in plant raw materials, are used not fully but partially. Significant losses of BAS (from 20 to 80 %) occur because of traditional methods of processing and also during the consumption of fresh and finished products (from $^1/_3$ to $^1/_2$). A significant part of healthful substances are poorly absorbed by human organism. That is, considerable losses of biological potential pf valuable food plant raw materials occur both during processing and consumption, which are hundreds of billion tons within the planet Earth [1, 4, 7–9].

2. Analysis of scientific literature and the problem statement

One of the main ways to save all valuable components that the raw materials contain, and which are used in the world, is the implementation of non-waste production technology. Analysis of the literary sources found out that there are a large number of hidden (associated) BAS forms and biopolymers in plant raw materials, significant hidden biological potential, the usage of which can be compared to the increase of productivity of fruit and vegetable raw materials by several times [10–12]. The authors showed in their previous works how it was possible not only to store all the valuable in plant raw materials, but also to remove more fully BAS, biopolymers out of them that were there in hidden inactive form [6]. As a result of the long-term fundamental and applied research (over 30 years), the authors of this article for the first time in international practice revealed and found that the content of L-ascorbic acid in the plant raw materials in the inactive form is 2...4 times higher than in a free form (in the form of crystals), which is fixed by the generally accepted methods, as well as the content of pectins is 4...5 times higher (which, while removal, transform into high-methoxilated form, as evidenced by the gelling properties), the content of carotenoids is 2.5...4 times higher, the content of low molecular phenolic compounds is 1.8...2.5 times higher, etc.

Traditional methods of processing of plant raw materials lead tosignificant losses of vitamins and other BAS, biopolymers and incomplete use of the biological potential of raw materials. Thereby today, the acute problem in international practice is the development of high technologies, including nanotechnologies, which can make the process of processing of food raw materials more intense, profound, efficient with the maximum saving of BAS and nutrients, increase the removal (extraction) of target components, implement sustainable processes, non-waste technologies and less energy-consuming processes. Difficulties during the processing of fruit and vegetable raw materials with high content of hard soluble biopolymers, their nanocomplexes (including cellulose, proteins, pectins, etc.) are linked to the fact that a considerable part of the listed substances in fresh raw materials are in inactive (hidden, bound) form [8, 14].

A special place among vegetable raw materials occupy legumes, in particular peas (dried), beans, lentils, etc. It is known that the peas are a traditional source of plant high-grade proteins, essential amino acids, heteropolysaccharides (cellulose, starch, pectins, etc.), which are contained in the plant raw materials in the form of hard soluble nanoassociates and nanocomplexes that are poorly absorbed by human organism (by 30...50 % only). They belong to prebiotics, indigestible food ingredients and stimulate the development and metabolic and biological activity of one or more groups of own bacteria in human body that make up the intestinal microflora of a human, positively affect the composition of the microbiocenosis [2–6].

Today a global problem in international practice is a deficiency of protein in the diets of the population. According to statistics, the demand for proteins is not fully satisfied in Ukraine [15, 16]. Peas are an important source of valuable protein, which is not inferior to the animal one by its biological value. However, today peas have not found proper application in the food industry of Ukraine. A range of products with dried peas is limited and presented by several types of products: dry concentrate with peas for soups, pea flour, pea puree, pasty appetizers such as spreads, which are called "Humus" (Israel) and others. Literary sources carrying information about the innovative technologies of deriving additives with peas both in mashed form and in the form of powders are not revealed. Thereby, the development of new nanostructured additives with peas and health products with their use is rather actual.

It is known that today one of the progressive methods of processing of plant raw materials is a cryogenic and fine-dispersed grinding without usage of cold. As for the processing of dried peas, virtually any of these methods are not applied, the processes of mechanical destruction, mechanical activation are not studied by anyone. Today, promising ways of fine-dispersed grinding are already widely used in chemical industry, aviation, textile, construction industry [17–24]. In the food industry these processes are almost not studied.

During the development of the technology of obtaining nanopowders and nanopuree with dried peas, as an innovation it is encouraged to use fine-dispersed grinding of peas, processed by steam, and, accompanied by the processes of mechanical destruction and non-enzymatic biocatalysis. Integrated use of the mentioned technological methods allowed developing a new way of obtaining nanostructured puree and nanopowders of peas with qualitatively new characteristics compared to the original raw materials and similar products, and chemical composition, which is not possible to obtain using traditional methods.

The work is devoted to the development of nanotechnology of protein plant supplements in the form of nanopowders and nanopuree of peas, which is based on the processes of deep processing of raw materials. Fine-dispersed grinding of thermally treated raw material is used as the innovation, which is accompanied by non-enzymatic biocatalysis-mechanolysis of nanocomplexes of biopolymers (heteropolysaccharides and proteins) into the soluble instantly absorbed form (almost 2 times higher than in the original raw materials).

3. The purpose and objectives of the study

The aim of this work is the development of nanotechnologies of obtaining supplements in the form of puree and nanopowders of peas, based on the processes of deep processing of raw materials with the use of the fine-dispersed grinding of previously treated (steam and thermal) raw materials, which is accompanied by the processes of thermal mechanical destruction, mechanical activation and mechanolysis of complex poorly soluble nanoassociates and nanocomplexes of biopolymers and identifying patterns and mechanism of the mentioned processes.

To achieve the set goal, it was necessary to solve the following tasks:

– to discover patterns and the mechanism of influence of non-enzymatic biocatalysis-mechanolysis on the transformation of associated and free amino acids during obtaining nanostructured puree and nanopowders of peas;

– to explore the influence of processes of non-enzymatic biocatalysis-mechanolysis (mechanical destruction) of heteropolysaccharides (starch, cellulose, pectins);

– to design a nanotechnology of obtaining nanostructured puree and nanopowders using deep processing of peas along with steam and thermal processing and fine-dispersed grinding, which is accompanied by the processes of mechanolysis;

– to explore the features of chemical composition of nanopowders and nanopuree of dried peas (protein, irreplaceable and replaceable amino acids and their bound and free forms, amino acid score, mass particle of poor soluble heteropolysaccharides (starch, pectin, cellulose), mineral composition (K, Ca, Ma, P, Na, Si), vitamins (E, B_1, B_2, choline), monosaccharides and others.

4. Scientific substantiation of the development of nanotechnology of puree and nanopowders of peas using the processes of deep processing, in particular steam and thermal processing in combination with finely dispersed grinding

Scientific results cited in this article are a continuation of the work of the authors on the topic "Creation and implementation of advanced technologies and efficient equipment for obtaining new functional health food products", which was awarded with the State Prize of Ukraine in Science and Technology in 2006 [8].

During the development of nanotechnology of puree and nanopowders of peas using the processes of deep processing of plant raw materials, in particular steam and thermal processing in combination with finely dispersed grinding, the main thing was to increase the degree of extraction from raw materials of hidden bound forms of biopolymers in nanocomplexes to free state, to transform proteins, heteropolysaccharides (dietary fibers, including cellulose, pectin substances) into a soluble form through mechanic destruction and mechanolysis (mechanical destruction due to mechanical energy).

The research was conducted in KSUFT (Kharkiv State University of Food Technologies, Kharkiv, Ukraine) at the Department of the technologies of fruit, vegetables and milk processing, in the research laboratory "Innovative cryo- and nanotechnologies of plant supplements and health products".

In the paper we proposed and developed a technology of obtaining nanostructured puree and nanopowder of dried peas, which includes steam and thermal processing and finely dispersed grinding. The work was performed using modern equipment: steam convection oven (Italy) for steam thermal processing, the traditional machinery for steam thermal processing, activator – grinding machine – cutter (France), binocular microscope with a video camera and calibration scale in micrometer and nanometer range.

The peas, which were used as a raw material in the development of supplements had a high content of valuable protein (23,8 to 25,0 %) and contained essential amino acids, such as lysine, tryptophan, threonine, phenylalanine and tyrosine, valine, isoleucine, and leucine (Table 1).

Table 1

Features of chemical composition of dried peas, which are sold as a raw material for finely dispersed supplements in the form of puree and powders

Name of indicators	Peas samples		
	# 1	# 2	# 3
Protein %	24,5	25,0	23,8
Fat %	1,5	2,0	1,8
Starch %	46,5	45,0	44,8
Total sugar %	3,0	3,5	3,2
Pectin %	3,5	3,2	3,8
Cellulose %	10,1	8,9	9,2
Glucose %	1,0	1,2	1,4
Fructose %	1,21	1,30	1,25
Ash %	2,8	3,0	2,9
Mineral substances, mg in 100 g: K	890	910	873
Na	35	40	42
Ca	118	125	130
P	330	350	365
Mg	108	115	125
Silicon	83	95	101
Vitamins, mg in 100 g: E	9,1	10,5	11,2
Riboflavin	0,15	0,30	0,25
Thiamin	0,80	1,0	1,2
Choline	165	200	210
Moisture	14	13	14,5

Thus, the content of tryptophan in peas protein is 5 times higher than in an ideal protein (according to the value of the amino acid score in comparison with the FAO/WHO) scale (Table 2), the amino acids of lysine and phenylalanine – 3.4 times higher, threonine and valine, isoleucine, leucine – 2.3...2.6 times higher. Methionine is a limiting amino acid (its amino acid score is 74.3 %).

It is shown that peas differ in high content of poorly soluble heteropolysaccharides, i.e. starch – from 44.8 to 46.5 %, cellulose – from 8.9 to 10.1 %, pectin – 3.2...3.8 %. It was also revealed that the mass fraction of total sugar is from 3.0...3.5 %, it is represented by monosaccharides, mainly fructose (1.2...1.3 %) and glucose – 1.0...1.4 %. It is shown that the amount of ash is 2.8...3.0 %. Mineral substances of peas are presented by all range of microelements (K, Ca, P, Na, Ma), they also contain silicon. Peas vitamins are presented by vitamin E (9,1...11,2 mg in 100 g), riboflavin (0.15...0.30 mg in 100 g) and choline (200...210 mg in 100 g), thiamine (0.8...1.2 mg in 100 g).

It was found that steam thermal processing and finely dispersed grinding of dried peas in obtaining fine puree and nanopowders is accompanied by the processes of mechanical destruction and non-enzymatic biocatalysis and leads to the destruction of protein and nanocomplexes and nanoassociates of protein with other biopolymers, such as heteropolysaccharides and their partial mechanolysis by 48...55 % to separate α-amino acids (Tables 3, 4).

Table 2

Mass fraction of essential amino acids and amino acid score in comparison with the FAO/WHO scale in the protein content of the dried peas

Amino acid	Mass fraction of amino acid		
	by FAO/WHO scale, mg in 1 g of protein	in protein of dried peas, mg in 1 g	Amino acid score, %
Essential amino acids			
Tryptophan	10	50,0	500,0
Lysine	55	185,0	336,4
Threonine	40	91,0	227,5
Valine	50	121,0	242,0
Methionine	35	26,0	74,3
Isoleucine	40	105,0	262,5
Leucine	70	184,0	262,9
Phenilanine+ +tyrosine	60	118,0+74,0= =192,0	320,0

Note: protein content– 24,21 %

It was shown that in the initial raw material, in the dried peas, 10 % of protein is in a free state in the form of free amino acids and 90 % – in the associated state (1.1 g and 10.9 g, accordingly) in the form of bound amino acids (Table 4). Besides, it was shown that the amount of free amino acids in nanopowder made of pea puree increased by 3.5...7.5 times compared to the original dried peas (Table 4). This is due to the fact that a considerable part of protein was transformed to a soluble form to free α-amino acids, which are easily absorbed by living organisms. That is, the effect of mechanic destruction and destruction of proteins, which are nanoscaled, into free amino acids was discovered. It is known that the size of the molecules of α-amino acids ranges from 0.42 to 1.5 nm.

Received nanopuree is manufacturable, easily forms gels and extends the range of its application for the enrichment of different foodstuffs with essential amino acids, BAS and other nutrients.

Mechanisms of mechanical destruction and protein mechanolysis and its nanocomplexes and nanoassociates with other biopolymers that is associated with the mechanical cracking, are shown in Fig. 1.

Table 3

Influence of steam and thermal treatment and finely dispersed grinding on the contents of the bound and free amino acids of protein during obtaining of nanostructured puree of peas

Amino acid	Mass fraction of amino acids							
	bound				free			
	The original raw material (coarse ground pea puree), %	Finely dispersed ground pea puree, %	Before the original raw material, %	Decrease to raw material, times	The original raw material (coarse ground pea puree), %	Finely dispersed pea puree, %	Before the original raw material, %	Increase to the original raw material, times
Aspartic acid	1,14	0,62	54,0	1,8	0,13	0,65	515,1	5,2
Threonine	0,43	0,22	49,8	2,1	0,03	0,25	950,0	5,7
Serine	0,52	0,26	50,0	2,0	0,56	0,32	564,0	5,6
Glutamic acid	2,00	1,01	50,2	1,9	0,22	0,22	550,5	5,4
Proline	0,44	0,45	50,6	2,1	0,10	0,32	338,2	3,5
Cystine	0,33	0,16	49,2	2,0	0,03	0,19	762,1	7,6
Glycine	0,39	0,20	49,8	2,1	0,04	0,22	861,2	8,7
Alanine	0,52	0,24	47,2	2,2	0,06	0,33	592,1	5,8
Valine	0,58	0,29	50,0	2,0	0,025	0,34	1250,0	2,5
Methionine	0,12	0,06	45,9	2,2	0,01	0,08	749,0	7,5
Isoleucine	0,48	0,29	50,5	1,9	0,05	0,28	570,0	5,7
Leucine	0,86	0,45	52,6	1,9	0,06	0,47	720,0	7,2
Tyrosine	0,17	0,18	100,0	1,0	0,19	0,22	107,9	1,1
Phenilalanine	0,55	0,28	51,9	1,9	0,04	0,31	760,0	7,6
Histidine	0,30	0,15	50,0	2,0	0,07	0,42	431,3	4,3
Lysine	0,86	0,43	50,0	2,0	0,07	0,48	675,6	6,8
Arginine	1,06	0,80	75,0	1,3	0,02	0,15	600,0	6,0
Tryptophan	0,23	0,20	44,4	2,2	0,03	0,15	600,0	6,0
∑	10,90	5,88	53,9	2,0	1,1	0,32	570,0	5,9

Table 4

Influence of steam and thermal processing and finely dispersed grinding on the contents of the bound and free amino acids of protein during obtaining nanostructured powder of pea puree

Amino acid type	Mass fraction of amino acides							
	bound				free			
	The original raw material (dried peas), %	Nanopowder of pea puree, %	% before the original raw material	Decrease to the original raw material, times	The original raw material (dried peas), %	Nanopowder of pea puree, %	% before the original raw material	Increase to the original raw material, times
Aspartic acid	2,28	1,24	54,4	1,8	0,25	1,29	516,0	5,2
Threonine	0,86	0,43	50,0	2	0,05	0,48	960,0	9,6
Serine	1,02	0,51	50,0	2	0,11	0,62	563,6	5,6
Glutamic acid	3,95	1,98	50,1	1,9	0,44	2,41	547,7	5,5
Proline	0,87	0,44	50,6	1,9	0,18	0,61	339,0	3,4
Cystine	0,65	0,32	49,2	2	0,05	0,38	760,0	7,6
Glycine	0,77	0,39	50,7	1,9	0,05	0,43	860,0	8,6
Alanine	1,02	0,48	47,1	2,1	0,11	0,65	591,0	5,9
Valine	1,16	0,58	50,0	2,0	0,05	0,63	1260,0	12,6
Methionine	0,24	0,11	45,8	2,2	0,02	0,15	750,0	7,5
Isoleucine	0,95	0,48	50,5	1,9	0,10	0,57	570,0	5,7
Leucine	1,71	0,9	52,6	1,9	0,13	0,94	723,1	7,2
Tyrosine	0,34	0,35	102,9	1,1	0,38	0,41	107,9	1,1
Phenilalanine	1,1	0,57	51,9	1,9	0,08	0,61	762,5	7,6
Histidine	0,6	0,29	48,3	2,1	0,03	0,34	1133,3	11,3
Lysine	1,71	0,90	52,6	1,9	0,14	0,95	678,6	6,8
Arginine	2,13	1,60	75,1	1,3	0,16	0,69	431,3	4,3
Tryptophan	0,45	0,20	44,4	2,25	0,05	0,30	600,0	6,0
∑	21,81	11,77	54,0	1,9	2,38	12,44	574,5	5,7

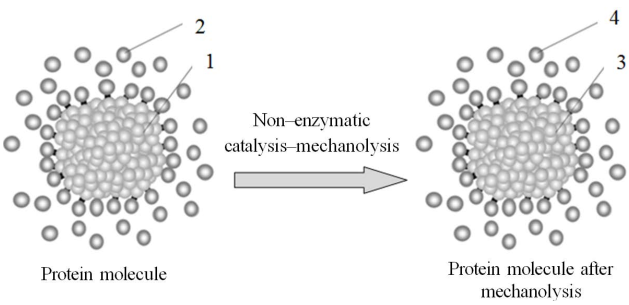

Fig. 1. Schematic representation of the mechanism of the influence of steam and thermal processing and non-enzymatic catalysis on the destruction and mechanolysis of protein molecules of peas into a water-soluble form to separate amino acids during the processing of thermally treated peas, where: 1 is the biopolymer protein; 2 are the free amino acids; 3 are the low molecular fragments of protein (dipeptides, tripeptides); 4 are the free amino acids during obtaining finely dispersed grinded supplements in nanoform

Steam and thermal processing and finely dispersed grinding of dried peas in obtaining finely dispersed puree out of it by the non-enzymatic biocatalysis-mechanolysis leads to the destruction of hard soluble biopolymers and their nanocomplexes, heteropolysaccharides, such as cellulose, starch (by 30...35 %) and protopectine by 50 % to the soluble form. In parallel, there is an increase of glucose in the nanopuree of peas (from 1.0 g in 100 g to 10.0 g in 100 g), that is by 10 times as compared to the original raw material (Table 5).

Table 5

Content of soluble and insoluble components-biopolymers of nanopowders and nanopuree of peas in comparison with analogues and original raw material

Indicator Name	Dried peas (the original material)	Finely dispersed pea puree	Nanopuree of peas	Powdered pea puree (analogue)	Pea puree (analogue)
Protein, % on CP	23,8...25,0	14,0...14,5	25,0...27,5	22,0...22,5	12,5...13,0
Bound amino acids, % on CP	21,8...22,5	5,9...6,0	10,9...12,2	19,5...20,0	11,0...11,2
Free amino acids, % on CP	2,0...2,5	6,0...7,0	11,5...13,0	3,5...4,0	1,5...1,8
Protopectin, % on CP	3,2...3,8	1,4...1,6	1,2...1,4	3,2...3,4	2,8...3,0
Soluble pectin, % on CP	0,4...0,5	1,8...2,0	3,6...4,0	0,8...0,9	0,7...0,8
Starch, % on CP	44,8...46,5	20...21	34...36	33,0...40,0	22...23
Cellulose, % on CP	8,9...10,1	3,5...4,0	5,2...7,0	8,9...9,0	6,0...6,2
Glucose, % on CP	1,0...1,4	2,5...5,0	11...15,0	2,0...2,1	1,6...1,8
Total sugar, %	3,5...3,8	7,0...7,5	24...28	6,5...6,8	3,0...3,2
Solids, %	14...14,5	45...50,0	5...8	8...9	45...50

Results of the research, obtained by chemical methods, into the influence of crio mechanical destruction on nanocomplexes and nanoassociates of biopolymers with low molecular BAS and separate biopolymers in obtaining nanosupplements made of peas were confirmed by the method of spectral analysis in the study of IR spectra (Fig. 2).

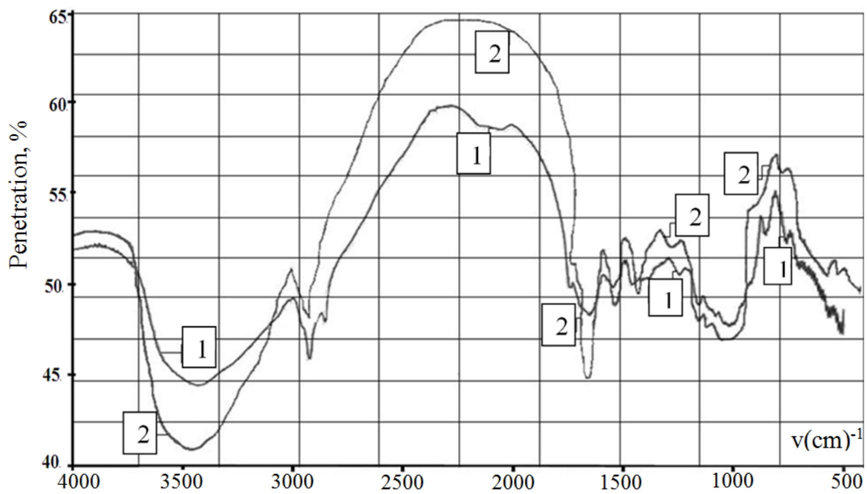

Fig. 2. Comparison of IR-spectra of thermally processed, dried and coarsely ground peas (1), finely dispersed thermally processed peas and the peas dried using the thermal dryer (2)

transformation of low molecular BAS to a free form (such as low molecular phenolic compounds and vitamins, etc.) that is confirmed by the experimental data received using chemical methods of analysis.

Based on the obtained experimental data a nanotechnology was developed of the processing of dried peas into finely dispersed puree and nanopowder, which differs from the traditional ones in that it is based on the processes of deep processing of raw materials and includes steam and thermal processing and finely dispersed grinding (Fig. 3).

New technology gives an opportunity to obtain supplements of peas as a finely dispersed puree or nanopowder with the size of particles less by tens of times than using traditional methods of grinding. Their quality exceed Ukrainian and foreign analogues by the content of soluble component biopolymers (in particular free α-amino acids, water-soluble pectins, soluble cellulose) and BAS (vitamins, unsaturated aromatic substances, phenolic compounds, etc.) that are removed from the bound to the free state.

When comparing the IR spectra of the dried peas and finely dispersed supplements derived from them (previously thermally processed) in the form of puree and nanopowders, it was found that during steam and thermal processing and finely dispersed griding a significant decrease is observed in the intensity of spectrum of the general characteristic band in the area of frequencies at V=3600...3000 cm^{-1}, which is characteristic for valent fluctuations of functional groups – OH. This testifies to the destruction of the intramolecular and intermolecular hydrogen bonds, destruction of nanocomplexes and nanoassociates of biopolymers with low molecular BAS, disaggrigation, destruction (in particular, non-enzymatic catalysis-mechanolysis, which occurs at mechanical grinding and steam and thermal processing) of biopolymers (protein, heteropolysaccharides, pectins, cellulose, starch) and their nanocomplexes and nanoassociates. In parallel, in the area of frequencies at V=2900...2000 cm^{-1} and V=1700...1100 cm^{-1} characteristic for valent fluctuations of groups $-CH_3$, $-NH_2$, $-NH_3$, CO–, as well as unsaturated double bonds, a significant increase in the intensity of the spectra is observed. It testifies to the increase of functional groups of α-amino acids after grinding that occur at breaking of proteins to separate monomers of α-amino acids as a result of non-enzymatic biocatalysis-mechanolysis, as well as the destruction of other biopolymers, such as cellulose to glucose, pectin to galacturonic acid, starch to glucose, etc., and the destruction of the nanocomplexes "biolymer – BAS" and the

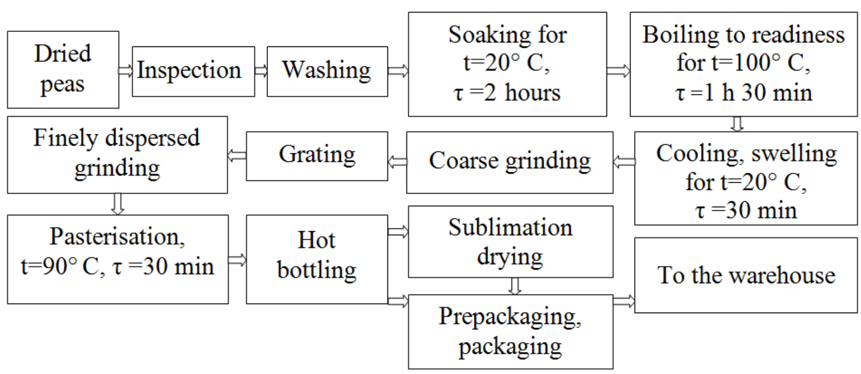

Fig. 3. Technological scheme of obtaining nanostructured puree and nanopowders with prebiotic properties of peas, using steam and thermal processing and non-enzymatic biocatalysis

During the development of new technologies, the obtained results became the basis at obtaining finely dispersed powders of peas for healthy nutrition. New technologies have undergone approbation at the production facilities in the NPP «KRIAS» (Kharkiv, Ukraine). On the basis of experimental data, normative documentation for finely dispersed puree and powder of peas was designed. New kinds of health products for mass consumption and for special purposes were developed (dry concentrates for soups, for sauces-dressings, protein pastes and snacks-spreads, etc.) on their basis.

Drawbacks and certain features of the proposed methods of pea processing include the need for adjustment of modes and specifics of its previous preparation to the steam and thermal processing and finely dispersed grinding, depending on the variety, its chemical composition, etc.

6. Conclusions

Usage of deep processing of plant raw materials (such as dried peas) is based on comprehensive effect of steam and thermal processing and finely dispersed grinding on the raw materials. The processes of mechanical destruction, mechanical chemistry occurs while obtaining nanostructured puree and nanopowder, accompanied by non-enzymatic biocatalysis – mechanolysis (destruction) of hard soluble nanocomplexes of biopolymers and the biopolymers themselves (proteins, heteropolysaccharides, such as pectins, cellulose, starch) into soluble easily absorbed form (almost 2 times higher than in the original raw material in a hidden form) to their monomers (by 35... 55 %). The reason of protein mechanical destruction and its nanocomplexes is a mechanism related to mechanical cracking.

Steam and thermal processing and finely dispersed grinding of peas in obtaining fine puree out of it leads to the destruction of polysaccharides by non-enzymatic catalysis, such as cellulose and starch by 30–35 %, protopectin by 50 % to separate monomers.

It is shown that in parallel there is an increase of glucose in the nanopuree of peas from 1.0 g in 100 g to 10.0 g in 100 g, i.e. by 10 times.

We developed a nanotechnology of finely dispersed supplements in the form of puree and nanopowder made of peas, which differs in the deep processing of raw materials and is based on the usage of comprehensive effect of steam and thermal processing of raw materials and finely dispersed grinding as well. Puree and nanopowder are in nanosized easily digestible form due to the mechanical destruction of cells, tissues, and hard soluble nanocomplexes of biopolymers and associates into separate monomers. Their quality exceeds the Ukrainian and foreign analogues.

The reason of protein destruction (to the separate monomers of α-amino acids) and hard soluble biopolymers and their nanocomplexes is probably the result of non-enzymatic biocatalysis – mechanolysis that occurs under the influence of steam and thermal processing and finely dispersed grinding.

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UDC 664.8.037.5:635.6/366.624.4
DOI: 10.15587/1729-4061.2016.69389

STUDYING THE ACCUMULATION OF NITROGENOUS SUBSTANCES IN BIOFORTIFIED PUMPKIN VEGETABLES

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Доводимо доцільність використання біофортифікованих гарбузових овочів (гарбузів, кавунів, динь), що відрізняються природно підвищеним вмістом азотистих речовин (зокрема білка) у збалансованих за вмістом тваринного і рослинного білків харчових раціонах, безглютенових дієтах, а також для харчування вегетаріанців. Біофортифікацію овочів здійснювали шляхом застосування органічного, екологічно чистого добрива «Ріверм» під час їх вирощування

Ключові слова: біофортифікація, добрива, «Ріверм», білок, азотисті речовини, амінокислоти, гарбузові овочі, мікронутрієнти

Доказываем целесообразность использования биофортифицированных тыквенных овощей (тыкв, арбузов, дынь), отличающихся естественно повышенным содержанием азотистых веществ (в частности белка), в сбалансированных по содержанию животного и растительного белков пищевых рационах, безглютеновых диетах, а также в питании вегетарианцев. Биофортификацию овощей осуществляли путем применения органического, экологически чистого удобрения «Риверм» во время их выращивания

Ключевые слова: биофортификация, удобрения, «Риверм», белок, азотистые вещества, аминокислоты, тыквенные овощи, микронутриенты

1. Introduction

Physiological value of vegetables is manifested in their pronounced influence on the digestive organs – they both stimulate appetite and secretory activity of digestive glands and improve digestion and assimilation of meat, fish, bakery products, and cereals. Low-energy value of vegetables combined with their high biological value makes them indispensable in the treatment of people with different diseases.

Nitrogen compounds include, in particular, vegetable proteins, free amino acids, nucleic acids, enzymes, nitrogenous glycosides, and nitrates. The main share of these substances is comprised of proteins and free amino acids. Biological value of vegetable protein is lower than that of animal protein: they have a scarce content of some essential amino acids, and their absorption is on average 30 % [1]. However, simultaneous use of animal protein and vegetable protein increases the value of protein nutrition since vegetable proteins (the main source of nitrogen) alongside animal ones create quite active (in biological terms) amino acid complexes that provide interstitial synthesis. Meat proteins are most beneficial if they are combined with vegetable proteins: their combination ensures the necessary "dilution" and intercomplementary amino acid composition, which results in obtaining full-value proteins of potatoes and vegetables. The total protein amount should comprise 15 % of daily calories; vegetable proteins should make up almost half of the total protein amount, and the ratio of tryptophan, methionine and lysine should be 1:3:3.

The value of vegetable protein increases when it comes to vegetarian food, especially hard one (eating only plant products). In this case, plant products remain the sole supplier of protein to the human body. One more fact should be considered: at present more people are suffering from a hereditary