

This paper reports the design of nanotechnology for processing chickpea into protein plant additives in the form of finely-dispersed pastes and nanopowders, based on the use of a deep processing method. A comprehensive effect exerted on the raw materials by the steam-thermal treatment and fine grinding using the modern equipment at restaurant enterprises has proven to be a real innovation. The technology involves the processes of steam- and mechanodestruction of most of the biopolymers in chickpea (proteins, starch, cellulose, pectin) to individual monomers (40...70 %), which are in the nanoscale easily-digestible form. The proposed method of deep processing makes it possible to better utilize the biological potential of raw materials.

The resulting protein supplements made from chickpea in combination with fruit and vegetable additives (from carrot, pumpkin, apple, lemon with zest, garlic, celery and ginger roots) were used as formulation components in the development of a new generation of confectionery products that promote the strengthening of immunity. We have devised waffle confectionery products, sponge cakes, dry waffle breakfasts, salted fillings for the confectionery products "PanCake", etc. Confectionery of the new generation differs from the conventional one by the absence or insignificant amount of sugar, low content of fat (to 5 %), high content of complete protein (13...20 %). In addition, 100 g of products can meet the daily need for BAS (β -carotene, phenolic compounds) and 0.5 daily need for vitamin C. The resulting food products are natural and do not contain harmful food impurities

Keywords: chickpea processing, finely-dispersed puree, protein plant supplements, cryopowders, confectionery, health products

DEVELOPMENT OF NANOTECHNOLOGY FOR PROCESSING CHICKPEAS INTO PROTEIN PLANT SUPPLEMENTS AND THEIR USE TO OBTAIN A NEW GENERATION OF CONFECTIONERY

R. Pavlyuk

Doctor of Technical Sciences, Professor, Honored figure of Science and Technology in Ukraine, State Prize Laureate of Ukraine*

E-mail: ktpom@ukr.net

V. Pogarska

Doctor of Technical Sciences, Professor, State Prize Laureate of Ukraine*

E-mail: viktorija.pogarskaya@gmail.com

T. Kotyuk

Postgraduate Student*

E-mail: micleco555@gmail.com

A. Pogarskiy

Postgraduate Student*

E-mail: valve310@gmail.com

K. Balabai

PhD*

E-mail: ekaterinabala@email.ua

*Department of Food Technologies of Products from Fruits, Vegetables and Milk and Innovations in Health Nutrition Kharkiv State University of Food Technology and Trade Klochkivska str., 333, Kharkiv, Ukraine, 61051

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1. Introduction

The unbalanced nutrition and the deficiency of protein, vitamins, minerals, other BAS have led to a decrease in the population immunity [1–3]. The situation is complicated by the general deterioration in the state of the environment, as well as the use in the manufacture of products of a wide range of food additives and synthetic components, which adversely affect health and lead to a decrease in immunity [4, 5].

A promising type of product that is popular among adults and children is the different kinds of confectionery, especially wafers, dry waffle breakfasts, sponge cakes. The conventional disadvantage of confectionery products is a high content

of sugar (from 40 to 65 %), fats (from 25 to 35 %), the lack of BAS, as well as the presence of a significant amount of food additives in the composition. Consumption of confectionery products made according to conventional technologies, combined with lack of exercise, stress, life under environmentally dangerous conditions, leads to diseases of civilization such as obesity, cardiovascular diseases, which result in heart attack and stroke. According to the WHO, more than 50 % of the world's reported deaths occur as a result of coronary heart disease and as a result of the stroke.

Designing the technology of nano-additives made from legumes, fruits and vegetables in the form of powders, pastes, purees for using them as formulation components when mak-

ing health confectionery products is a relevant task for overcoming the deficiency in the diets of protein and other BAS from plant raw materials. The use of these additives could make it possible to enrich products with natural protein, different types of BAS, prebiotic substances, and reduce the amount of sugar, fat, food supplements, which are harmful to the human body and are one of the causes of diseases of our civilization.

2. Literature review and problem statement

It is possible to improve the immunity of the human body by consuming health products high in complete protein and plant-derived biologically active substances (BAS) [4, 6, 7]. The BAS that promote immunity strengthening include the antioxidant series vitamins (C, E), β -carotene [5], chlorophyll [7], low molecular phenolic compounds and polyphenols [6, 8], as well as essential oils, prebiotic substances, etc. [4, 7, 9]. These substances are contained in large quantities in fruits and vegetables. A special place in human nutrition is occupied by proteins whose role in human life is well known [1, 10]. Proteins cannot be excluded or replaced with other components because they perform various functions [11]. Proteins are the main structural material for the construction of tissues of living organisms, they participate in energy metabolism, strengthen the body's defenses to the action of adverse environmental factors, prevent the formation of tumors, etc. [12, 13]. The main source of complete protein in the manufacture of confectionery products is milk-based concentrates: skimmed milk powder (SMP), dry whey (DMW), nuts (peanuts, walnut, hazelnuts, forest nuts, etc.), legumes (soybeans, peas, chickpeas, lentils). However, except for soybeans, other types of legumes have not yet been commonly used as a source of protein in the confectionery and food concentrate industry [14–16]. Their use is constrained by the lack of technologies for obtaining protein supplements from chickpea, which makes it possible to obtain a finely-dispersed structure due to the presence in the composition of chickpea flour of particles of hardly-soluble components that impair the quality of the products obtained.

Our analysis of the scientific literature reveals that the flour made from chickpea is used in the international practice for enriching various food products with protein [17, 18]. It is used for the manufacture of gluten-free bread and spaghetti, infant mixes [18, 19], functional health meat and vegetable pates [20]. The advantage of using chickpea flour as a source of protein compared to wheat and rice flour in food production is its low glycemic index [17]. In addition, chickpea flour possesses water- and oil-binding emulsifying and foaming properties that help improve the texture of gluten-free bread and spaghetti [21, 22]. It was found that chickpea flour is not only a source of plant-based protein with a high content of lysine, leucine, arginine, as well as tannins, and phenolic compounds. Chickpea flour demonstrates high hydrocolloid properties in the formation of the texture of various types of food products that have high moisture content [21–23]. For the manufacture of wafer confectionery, dry wafer breakfasts, sponge cakes, etc., whose mass fraction of moisture is 1.5 %, chickpea flour with a regular particle size (from 20 to 80 μm) is not used. Difficulties in using chickpea flour in the manufacture of fillings for wafer confectionery and dry waffle breakfasts are associated with a significant content of hardly-soluble components in the flour

composition – biopolymers that do not dissolve in the fat base of the filling. That is why the particles of flour are felt in the filling when consuming wafer confectionery products. Such conventional formulation components of fat fillings for wafer confectionery products as sugar, flavorings, artificial thickeners dissolve and are evenly distributed across the fat base of the filling; chickpea flour does not dissolve.

Fruit and vegetable raw materials are the source of unique BAS for the human body (vitamins, -carotene, chlorophylls a and b, phenolic compounds, tannins, minerals), as well as non-easily digestible components of food – prebiotics (cellulose, pectin, etc.) [6, 14]. In the human body, BAS maintain immunity, strengthen blood vessels of the heart and brain, promote the prevention of cancer, as well as promote detoxification and purification from the effect of various harmful and toxic substances [4, 5]. Some of them exhibit antibacterial and antiviral properties. The shortage of high-quality fruit and vegetable additives, natural BAS-enrichers, in the market hinders the development of technologies of confectionery products for health purposes.

3. The aim and objectives of the study

The aim of this work is to devise nanotechnology for processing chickpea into protein plant supplements by using the steam-thermal treatment and finely-dispersed grinding and to apply the resulting supplements together with the finely-dispersed additives made from fruit and vegetable raw materials in the development of a new generation of confectionery products for healthy nutrition.

To accomplish the aim, the following tasks have been set:

- to define a set of nutrients and biologically active substances, to determine the amino acid score of chickpeas as a raw material for devising the nanotechnology of protein plant supplements in a nanostructured form;
- to determine the comprehensive effect of steam-thermal processing and finely-dispersed grinding on the destruction of protein molecules and other biopolymers of dried chickpeas, to devise the nanotechnology of protein plant additives, to study their quality compared to analogs;
- to determine the quality and content of BAS obtained by using the nanotechnology of fruit and vegetable additives (made from carrot, pumpkin, garlic, celery and ginger roots, apple, lemon with zest) – as formulation components of a new generation of protein confectionery products to strengthen immunity;
- to develop a new generation of protein confectionery products (waffle confectionery, sponge cakes, dried waffle breakfasts, salted fillings for “PanCake”, etc.) with a high content of protein and BAS, and a low content of sugar and fat, by using the protein and fruit supplements as formulation components.

4. The study materials and methods for devising the nanotechnology for chickpea processing into protein additives, as well as for the confectionery products that contain them

4.1. The materials and equipment used in the experimental study

The selected materials for our study were the samples of dried chickpea and the protein plant supplements, derived

from them, in the form of finely-dispersed frozen pastes and powders. We also used fruit and vegetable finely-dispersed additives (from carrot, pumpkin, apple, lemon with zest, garlic, celery, and ginger roots) and the new generation of confectionery products made by using the resulting protein and fruit and vegetable supplements (Fig. 1).

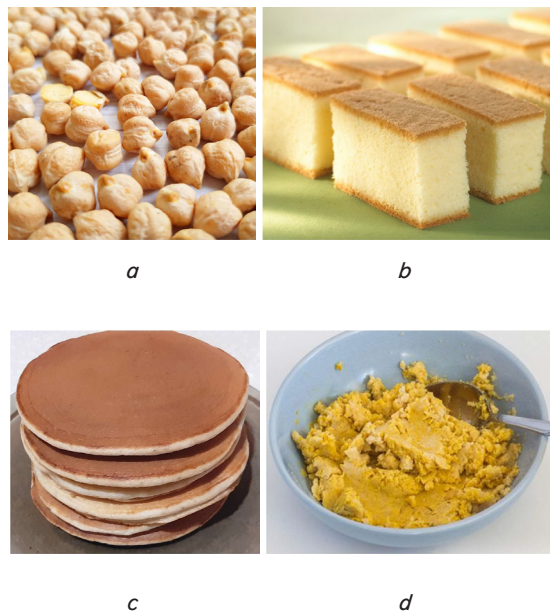


Fig. 1. The study materials: *a* – dried chickpeas; *b, c* – the new generation of confectionery products to strengthen immunity: *b* – sponge cakes, *c* – confectionery products “PanCake”; *d* – salted fillings for confectionery products

Steam-thermal processing of dried chickpeas was carried out using modern equipment made in Italy – a combi steamer “UNOX”, series XVC. For fine grinding, we used the homogenizer-shredder made in France “Robot Coupe”, as well as the innovative food processor “ThermoMix” (France) (Fig. 2) [6].



Fig. 2. Equipment involved in the experimental study: *a* – combi steamer “UNOX SPA”, series XVC (Italy), *b* – homogenizer-shredder “Robot-Coupe R2” (France), *c* – food processor “ThermoMix” (France)

The resulting vegetable protein supplements, made from chickpea, together with the additives in a nanoscale form made from fruit and vegetable raw materials were used as formulation components in the development of a new generation of confectionery products. In this case, additives from plant raw materials act as a source of protein, BAS enrichers, structure-forming agents, colorants. The following formula-

tion components were used: a protein supplement made from chickpea, a multi-carotene additive (from carrot, pumpkin), additives from spicy vegetables (garlic, celery, and ginger roots) and fruits (apple, lemon with zest). The use of additives made from plant raw materials has made it possible to prepare a new generation of confectionery products that do not contain sugar (or contain it in a small amount), are low in fat, high in vegetable protein and essential amino acids. The resulting confectionery products contain, per 100 g of product, a daily need for BAS (β -carotene, phenolic compounds) and 0.5 daily need for ascorbic acid, and do not contain harmful food impurities. In the development of health confectionery products using the protein plant additives made from chickpea and the additives from fruit and vegetable raw materials, we followed the FAO/WHO recommendations [24–26]. In addition, the modern global directions in food technology development were taken into consideration, specifically, the development of nanotechnology [27, 28] and nanofood [29, 30].

4.2. Research methods used in the development of nanotechnology and in the development of a new generation of confectionery products

We determined the content of protein, the content of amino acids, which are in a free and bound form, the content of fat, starch, dry substances, pectin, organic acids, minerals in the dried, steam-thermally-treated chickpeas, the finely dispersed paste, and the nanopowder made from it, in particular:

- protein (according to the content of total nitrogen in the samples studied) – by Kjeldahl method;
- the free and bound amino acids – by a chromatographic method and subsequent calculation of the peak area of each amino acid by the method of the external standard;
- starch – by a titrimetric method based on the dissolution of starch in a solution of calcium chloride when heated, precipitated, oxidized with potassium dichromate and subsequent titrimetric determination;
- organic acids – by a titrimetric method based on the neutralization of acids contained in the product, by NaOH solution in the presence of phenolphthalein;
- dry substances – by drying the batch to a constant mass.

In the fruit and vegetable additives in the form of cryopowders (from carrot, pumpkin, garlic, celery and ginger roots, apple, lemon with zest), we determined the quality in terms of the content of BAS and prebiotic substances, in particular:

- β -carotene – by a colorimetric method by Murray after extracting carotene from a product with an organic solvent and purifying carotene from accompanying colorants using column chromatography;
- L-ascorbic acid – by a method of the visual and potentiometric titration with a solution of Na 2,6-dichlorophenolindophenol;
- low molecular phenolic compounds (for routine and chlorogenic acid separately) – by a colorimetric method by Folin-Denis recalculated for routine and separately for chlorogenic acid;
- polyphenolic compounds – by a titrimetric method based on the properties of polyphenol compounds to oxidize in the presence of the indicator indigo carmine; the calculation of tannins was carried out in terms of tannin.

Results from the experimental study were processed using mathematical processing methods employing the Mathcad and Microsoft Excel software.

5. The development of nanotechnology for chickpea processing into protein plant supplements and for confectionery products for health nutrition

5.1. Determining a set of nutrients and biologically active substances, as well as the amino acid score of chickpeas

It was determined that chickpea dry substances are represented mainly by a starch polysaccharide (from 41.0 to 45.0 %) and proteins (from 20.1 to 25.0 %). The mass fraction of total sugar is from 4.4 to 5.5 %, which is represented in equal amounts by fructose (2.1...2.5 %) and glucose (2.0...2.4 %). The mass fraction of hardly-soluble cellulose heteropolysaccharide is between 2.8 and 4.0 %; that of total pectin – between 1.9 and 2.5 % (Table 1).

Table 1
Results of determining a set of nutrients and biologically active substances in dried chickpeas – a raw material to produce protein plant supplements

Indicator title	Dried chickpea		
	Sample 1	Sample 2	Sample 3
Protein, %	20.1...21.2	23.0...24.5	23.8...25.0
Fat, %	4.2...4.5	4.8...5.0	4.5...4.8
Starch, %	41.8...43.2	42.5...44.2	43.0...44.5
Total sugar, %	5.0...5.5	4.7...5.2	4.9...5.3
Glucose, %	2.0...2.1	2.2...2.3	2.1...2.4
Fructose, %	2.1...2.2	2.3...2.4	2.2...2.5
Cellulose, %	2.8...3.0	2.9...3.2	3.2...4.0
Total pectin, %	1.9...2.2	1.8...2.4	2.0...2.5
Protopectin, %	0.8...1.1	0.8...1.1	1.0...1.1
Soluble pectin, %	0.8...1.1	1.0...1.3	1.0...1.4
Ash content, %	2.8...3.0	3.0...3.2	2.7...3.1
Minerals, mg per 100 g			
K	1,084...1,100	890...920	1,030...1,080
Ca	190...208	192...212	204...225
Mg	125...138	118...140	129...139
P	430...450	390...420	435...444
Si	89...95	82...88	90...97
Na	50...65	66...75	65...78
Tannins (tannin)	233...250	241...265	228...270
Phenolic compounds (chlorogenic acid), mg per 100 g	205...222	218...238	200...212
Vitamins, mg per 100 g			
E	9.9...10.2	10.5...11.0	9.5...10.7
B ₁	0.82...0.90	0.85...0.95	0.90...1.00
Organic acids, %	0.10...0.11	0.12...0.13	0.14...0.15
Humidity, %	13.8...14.0	14.10...14.30	13.9...14.0

It is shown that the mass fraction of minerals in dried chickpea beans is from 2.7 to 3.2 %. The chickpea composition

includes a wide range of microelements (K, Ca, Mg, P, silicon). Chickpea vitamins are represented by vitamin E (from 9.9 to 11.0 mg per 100 g), and vitamin B₁ (thiamine) from 0.8 to 1.0 mg per 100 g.

We have determined the amino acid score for the examined samples of dried chickpeas (Table 2).

Table 2
The amino acid score of dried chickpea protein

Title of essential amino acid	Mass share of amino acid, mg per 1 g		
	in ideal protein based on the FAO/WHO scale	in dried chick-pea protein	score, %
Tryptophan	10	27	270.0
Lysine	55	130	236.4
Threonine	40	84	210.0
Valine	50	99	198.0
Methionine	35	34	97.1
Isoleucine	40	149	372.5
Leucine	70	170	242.9
Phenylalanine+tyrosine	60	130+48=178.0	296.7

Note: protein content – 21.56 %

It was found that the amino acid score of the protein of dried chickpeas in terms of the content of essential amino acids is from 198.0 to 270 % and, according to the FAO/WHO scale, exceeds the "ideal protein" by 2.0...2.7 times (Table 2). The exception is the amino acid methionine whose amount is 3 % less than that in the ideal one.

5.2. Determining the comprehensive effects of steam-thermal treatment and finely-dispersed grinding on the destruction of protein molecules and other biopolymers of dried chickpeas

It is shown that in the experimental samples of the raw material, dried chickpea, the protein content is 21.56 %. The mass fraction of amino acids found in the protein-molecule bound state is about 90 %, in the free state – respectively, about 10 % (Table 3).

It was established that the combined use of steam-thermal treatment and finely-dispersed grinding in the processing of dried chickpeas into the finely dispersed puree and powder leads to the processes of steam-thermal destruction and mechanocracking (destruction) of protein molecules. There occurs a transformation of the amino acids of the chickpea protein from a bound form into a free easily-digestible form (Tables 3, 4).

It is also shown that in parallel there is a significant mechanodestruction and transformation of the biopolymers of pectin, cellulose, and starch to individual monomers (Table 5).

Studying the quality of finely-dispersed purees and nanopowders made from chickpea has shown that the biopolymers of protein, pectin, and cellulose are, by 50...70 %, in the easily-soluble form – in the form of these biopolymer monomers (Table 5).

Table 3

Effect of steam-thermal treatment and finely-dispersed grinding on the content of bound and free amino acids of protein in the dried finely dispersed puree made from chickpeas

Amino acid title	Amino acid mass fraction						Total amount of AA per 100 g, %	Increase to the total amount of AA, time
	bound			free				
	Raw material (chickpea), %	Dried finely-dispersed puree made from chickpea, %	% to the original raw material	Raw material (chickpea), %	Dried finely-dispersed puree made from chickpea, %	% to the original raw material		
1	2	3	4	5	6	7	8	9
Essential amino acids								
Valine	0.89	0.43	48.31	0.10	0.56	560.00	0.99	1.76
Isoleucine	1.34	0.68	50.74	0.15	0.81	540.00	1.49	1.83
Leucine	1.54	0.78	50.64	0.16	0.92	575.00	1.70	1.84
Lysine	1.16	0.58	50.42	0.14	0.72	514.28	1.30	1.80
Methionine	0.30	0.14	46.66	0.04	0.20	500.00	0.34	1.70
Threonine	0.75	0.33	44.00	0.09	0.51	566.66	0.84	1.64
Tryptophan	0.24	0.11	45.83	0.03	0.16	533.33	0.27	1.68
Phenylalanine	1.16	0.59	50.80	0.14	0.71	507.14	1.30	1.83
Non-essential amino acids								
Alanine	1.07	0.47	43.92	0.12	0.72	600.00	1.19	1.65
Arginine	1.73	0.85	49.13	0.20	1.08	540.00	1.93	1.78
Asparagine acid	2.61	1.36	52.10	0.31	1.56	780.00	2.92	1.87
Histidine	0.89	0.42	47.19	0.09	0.56	622.22	0.98	1.75
Glycine	1.02	0.51	50.00	0.12	0.63	525.00	1.14	1.80
Glutamine acid	2.15	1.18	54.88	0.24	1.21	504.16	2.39	1.97
Proline	0.87	0.40	45.97	0.09	0.56	622.22	0.96	1.71
Serin	0.96	0.46	47.91	0.11	0.61	554.54	1.07	1.75
Tyrosine	0.43	0.19	44.18	0.05	0.29	580.00	0.48	1.65
Cystine	0.25	0.11	44.00	0.02	0.16	800.00	0.27	1.68
Σ	19.36	9.59		2.20	11.97		21.56	

Note: protein content – 21.56 %

Table 4

The effect of steam-thermal treatment and finely-dispersed grinding on the content of bound and free amino acids of protein when obtaining a protein supplement made from chickpea in the form of finely dispersed puree

Amino acid title	Mass share of amino acids, %						Total amount of AA per 100 g, %	Increase to the total amount of AA, time
	bound			free				
	puree from STT** chickpea			puree from STT chickpea				
	coarsely-ground (raw material)	finely-dispersed	% to the original raw material	coarsely-ground (raw material)	finely-dispersed	% to the original raw material		
1	2	3	4	5	6	7	8	9
Essential amino acids								
Valine	0.45	0.20	44.44	0.05	0.30	600.00	0.50	1.66
Isoleucine	0.63	0.31	49.20	0.08	0.40	500.00	0.71	1.77
Leucine	0.75	0.38	50.66	0.11	0.46	418.18	0.84	1.82
Lysine	0.54	0.28	51.85	0.08	0.34	425.00	0.62	1.82
Methionine	0.15	0.08	53.33	0.03	0.10	333.33	0.18	1.80
Threonine	0.39	0.20	51.28	0.05	0.24	480.00	0.44	1.3
Tryptophan	0.08	0.04	50.00	0.03	0.07	233.33	0.11	1.57
Phenylalanine	0.52	0.27	51.92	0.09	0.34	377.77	0.61	1.79
Non-essential amino acids								
Alanine	0.54	0.27	50.00	0.06	0.33	550.00	0.60	1.81
Arginine	0.83	0.42	50.60	0.12	0.53	441.66	0.95	1.79
Asparagine acid	1.23	0.60	48.78	0.21	0.84	400.00	1.44	1.71
Histidine	0.44	0.22	50.00	0.06	0.28	466.66	0.50	1.78
Glycine	0.49	0.26	53.06	0.07	0.30	428.57	0.56	1.86
Glutamine acid	1.08	0.48	44.44	0.12	0.72	600.00	1.20	1.66
Proline	0.43	0.19	44.18	0.05	0.29	580.00	0.48	1.65
Serin	0.47	0.23	48.93	0.06	0.30	500.00	0.53	1.76
Tyrosine	0.18	0.10	55.55	0.04	0.12	300.00	0.22	1.83
Cystine	0.11	0.06	54.54	0.03	0.08	266.66	0.14	1.75
Σ	9.29	4.59		1.34	6.04		10.63	

Note: protein content – 10.63%; STT* – steam-thermally treated

Table 5

The content of biopolymers in the protein plant supplement made from chickpea compared to the original raw material and an analog

Indicator title	Dried chick-peas (original raw material)	Protein plant supplement made from chickpeas in the form of a nano-powder	Chickpea powder (analog)
Protein, %	21.6...25.0	22.1...25.5	20.6...21.6
Bound amino acids, %	19.4...20.0	9.6...10.0	16.4...17.4
Free amino acids, %	2.1...2.5	12.0...12.5	3.6...4.2
Total pectin, %	2.7...3.5	2.8...3.5	2.9...3.3
Protopectin, %	1.9...2.5	0.5...0.8	0.7...0.9
Soluble pectin, %	0.8...1.0	2.3...2.7	2.2...2.4
Starch, %	41.8...43.2	25.1...26.1	35.2...36.1
Cellulose, %	2.8...3.0	1.4...1.5	8.2...9.0
Glucose, %	2.0...2.2	11.5...15.4	2.0...2.2
Total sugar, %	4.5...4.8	17.0...17.3	8.2...10.0
Dry matter, %	85.7...86.2	86.5...87.2	84.5...85.8

The results from our experimental study have become the basis for the development of the nanotechnology and manufacturing scheme of protein plant supplements made from chickpea in the form of finely-dispersed puree and nanopowder (Fig. 3).

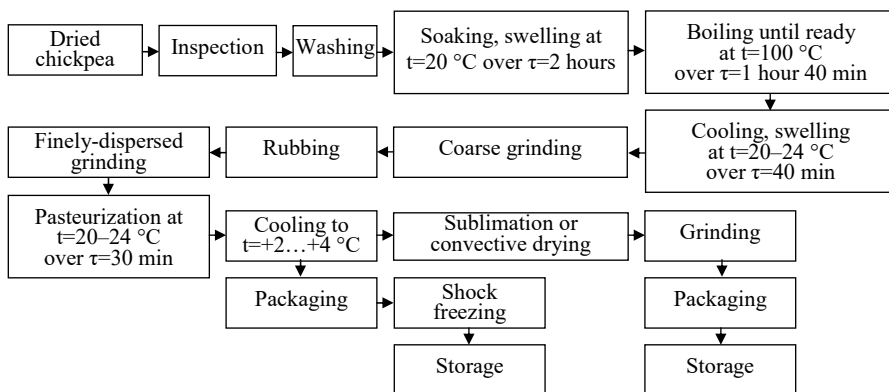


Fig. 3. Manufacturing scheme underlying the nanotechnology of chickpea processing into protein plant supplements in the form of finely-dispersed pastes and nano-powders

The devised nanotechnology of protein supplements made from chickpea differs from conventional technologies for making powders and puree by our utilization of a comprehensive effect of steam-thermal treatment and finely-dispersed grinding. This makes it possible to obtain protein supplements from the thermally-treated chickpeas in a nanoscale form with particle size ten times smaller compared to conventional purees and powders.

5. 3. Determining the quality and content of BAS from fruit and vegetable additives as formulation components for a new generation of protein confectionery products to strengthen immunity

It is shown that the fruit and vegetable additives in the form of cryopowders from carrot and pumpkin are high in β-carotene, the mass fraction of which per 100 g of product is from 120.0 to 132.4 mg (Table 6). The largest content

of vitamin C is demonstrated by supplements from lemon with zest, the mass fraction of the vitamin in which per 100 g of product is 402.6 mg.

Table 6

BAS content in the fruit and vegetable cryopowders that are the enrichment additives for a new generation of confectionery products

Cryopowder	Mass fraction, mg per 100 g				
	β-carotene	L-ascorbic acid	phenolic compounds (for chlorogenic acid)	tannins (for rutin)	soluble pectin
from carrot	120.0	250.4	1,020.6	1,420.4	7.2
from pumpkin	132.4	264.8	1,100.4	1,360.2	8.6
from lemon with zest	1.04	402.6	760.2	1,201.4	9.7
from apple	0.80	210.6	1,600.8	1,504.3	8.8
from celery root	0.50	165.6	780.6	980.6	5.4
from garlic root	0.10	174.2	820.6	1,000.6	4.4
from ginger root	0.80	204.6	1,250.6	1,230.0	5.6

Table 6 shows that all the examined samples of nanopowders contained a significant amount of natural vitamin C, phenolic compounds, tannins.

5. 4. Development of a new generation of confectionery products using plant additives

We have devised the formulations and technologies for a new generation of confectionery products (waffle confectionery products, sponge cakes, dried waffle breakfasts, fillings for confectionery products “PanCake”, etc.) to strengthen the immunity of the population implying the innovative application of vegetable protein supplements made from chickpea and the additives made

from fruit and vegetable raw materials. The use of plant supplements has made it possible to exclude the need to include food additives and a significant amount of sugar and fat in the formulation for confectionery. Thus, the protein supplements made of chickpeas act not only the carriers of complete protein in an easily-digestible form but also as substitutes for sugar and fat, and, together with fruit and vegetable additives, act as the natural structure-forming and gel-forming agents for the texture of the new types of confectionery products. Additives from fruit and vegetable raw materials were also used as enrichers with vitamin phytochemicals, such as β-carotene, vitamin C, phenolic compounds, tannins, aromatic substances, as well as natural dyes. The specified BAS from fruit and vegetable raw materials, as it is known, strengthen the defenses of the human body, demonstrate antioxidant, detoxifying properties, strengthen the blood vessels of the heart and brain, possess

anti-oncological properties. In addition, most specified BAS have bactericidal and bacteriostatic properties.

We have established the quality of a new generation of confectionery products (waffle confectionery products, sponge cakes, dried waffle breakfasts, salted fillings for confectionery products “PanCake”, etc.) in terms of the content of BAS, protein, fat, sugar (Table 7). It is shown that the new types of confectionery products have an original taste and aroma, as well as a natural pronounced color. The developed confectionery products differ from existing ones by a record content of complete protein (15...25 %) in an easily-digestible form and a record content of natural BAS. 100 g of products contain 1/3... 1/2 of a daily protein need (22.0...26.0 mg per 100 g), a daily need for β-carotene (5.0...6.0 mg), 1/2 of the daily need for L-ascorbic acid (35...40 mg in 100 g), almost two daily needs for P-active substances – the low-molecular phenolic compounds (130...180 mg per 100 g of product). In addition, they contain a significant amount of tannins.

production of protein plant supplements (Table 1). It is shown that the chickpea dry substances are represented mainly by starch polysaccharides and proteins, whose mass fraction is, respectively, 41.0...45.0 %, and 20.1...25.0 %. Chickpeas include hardly-soluble cellulose and pectin biopolymers, whose mass fraction is, respectively, 2.8...4.0 % and 1.9...2.5 %. The content of minerals is 2.7...3.2 %, which includes microelements K, Ca, Mg, P, silicon. It was found that the content of vitamins per 100 g of dried chickpeas is: vitamin E – 9.9...11.0 mg, vitamin B₁ – 0.8...1.0 mg (Table 1). When determining the amino acid score of chickpeas, it was found that in terms of the content of essential amino acids the protein of the examined samples of dried chickpea is biologically complete (Table 2).

We have established a comprehensive effect of steam-thermal treatment and finely-dispersed grinding in the processing of dried chickpeas into finely-dispersed puree and powder on the destruction of protein molecules and other biopolymers. It is shown that under the influence of the

Table 7
The chemical composition of a new generation of confectionery products using vegetable supplements

Product sample	Mass share						
	Protein, %	Sugar, %	Fat, %	Vitamin C, mg per 100 g	β-carotene, mg per 100 g	Phenolic compounds, mg per 100 g	Tannins, mg per 100 g
Waffle health-beneficial confectionary							
No. 1	15.0...20.0	3.1...5.2	5.0...6.0	35.0...37.2	5.0...5.2	144.0...175.0	166.0...175.0
No. 2	14.4...19.5	2.5...4.0	4.5...5.5	35.0...36.0	6.0...6.1	170.0...182.0	172.0...191.0
No. 3	14.0...20.0	3.5...5.0	4.0...5.0	40.0...41.0	4.5...5.0	150.0...166.0	182.0...188.2
Health-beneficial dry breakfast							
No. 1	13.2...20.2	4.5...5.0	5.1...5.4	35.0...38.0	5.5...6.0	180.0...191.0	190.0...201.0
No. 2	12.8...20.9	4.7...5.2	5.0...5.5	37.0...40.0	6.0...6.2	175.0...190.0	195.0...208.0
No. 3	14.0...18.1	5.0...5.5	5.2...5.7	35.8...39.4	6.2...6.6	164.0...175.0	175.0...186.0
Confectionary “PanCake”							
No. 1	12.3...13.4	4.0...4.5	5.0...5.6	40.2...41.0	3.5...3.8	150.6...170.0	180.0...192.2
No. 2	10.4...11.0	3.8...4.4	5.2...6.0	38.6...40.0	3.8...4.0	182.0...191.0	175.0...201.0
No. 3	12.5...13.6	4.5...5.0	5.0...5.5	37.2...39.4	4.0...5.0	186.0...195.0	195.0...205.4

Thus, it is shown that the new types of confectionery products (wafer confectionery, sponge cakes, breakfast cereals, fillings for confectionery products “PanCake”, etc.) exceed, by protein content, known analogs; in terms of the content of β-carotene, vitamin C, phenolic compounds, they have no analogs. The composition of the new confectionery products has no harmful food impurities. We have prepared confectionery products that contain, per 100 g: 35...70 mg L-ascorbic acid, 5...6 mg β-carotene, and 25 mg...100 mg of P-active phenolic compounds; according to the FAO/WHO guidelines, they can be attributed to wellness products.

The resulting confectionery products were industrially tested at the enterprises in the city of Kharkiv (Ukraine), in particular by TOV “VKG “Lisova Kazka”, TOV “KhPK”, KP “Baby Food Plant”.

6. Discussion of the study results aimed at the development of protein supplements made from chickpea and the confectionery products prepared with their use

We have defined a set of nutrients and biologically active substances in dried chickpea as a raw material for the

processes of steam-thermal destruction and mechanoc-racking there is a transformation of the amino acids of the chickpea protein from a bound form into a free easily-digestible form (Table 3). Thus, in the resulting finely-dispersed puree and nanopowder made from chickpeas, there were 30...40 % amino acids in a bound state, and 60...70 % in a free form (Tables 3, 4).

It is known that the size of amino acids ranges from 0.5 nm to 1.5 nm. That is, we have established the effect of the thermal-mechanodestruction and mechanolysis of chickpea protein molecules, by 60...70 %, to individual monomers – amino acids when making finely-dispersed puree and nanopowder (Tables 3, 4). In parallel, there is a significant mechanodestruction and transformation of pectin, cellulose, and starch biopolymers to individual monomers (Table 5). It was shown that 50...70 % of these biopolymers are in an easily-soluble form – in the form of monomers of these biopolymers (Table 5).

The nanotechnology of protein plant supplements made from chickpea has been devised, based on the joint application of processes of steam-thermal treatment and finely-dispersed grinding, which makes it possible to obtain additives made from chickpea in a nanoscale form. Compared to an analog (the chickpea powder made by conventional technology), the quality of the resulting protein plant supplements made from chickpea, in terms of the content of hardly-soluble cellulose biopolymer, the starch content, as well as the content of glucose monomers and total sugar, exceeds the quality of the analog. Thus, the mass fraction of cellulose in the resulting protein additive is 1.4...1.5 %, while the content of hardly-soluble cellulose biopolymer in the analog is 5.5...6.4 times higher, and is 8.2...9.0 %. In the resulting protein supplement, the mass fraction of glucose monomers is 5.4...7 times higher, and that of the total sugar is 1.7...2.1 times higher, than those in the analog.

We have determined the quality and content of BAS in the fruit and vegetable additives made by using nanotechnology in the form of cryopowders from carrot, pumpkin, garlic, celery, and ginger roots, apple, lemon with zest.

It is shown that the fruit and vegetable additives from pumpkin and carrot are a source of β -carotene; 100 g of them contain from 24 to 26 daily norms of the human body in β -carotene. It is determined that the cryopowders from lemon with zest are distinguished by the record content of vitamin C – up to 402.6 mg per 100 g, which is about 6 daily standards. It should be noted that all the experimental samples of the fruit and vegetable additives in the form of cryopowders contain a significant amount of natural vitamin C, phenolic compounds, tannins (Table 6). According to the content of BAS, the fruit and vegetable additives in the form of cryopowders have no analogs and were used along with the protein additives made from chickpeas as the natural enrichers with BAS when designing a new generation of confectionery products to increase immunity.

The resulting protein additives together with the finely-dispersed supplements from fruit and vegetable raw materials in the form of cryopowders were used in the development of a new generation of confectionery products to strengthen immunity (waffle confectionery products, sponge cakes, dried waffle breakfasts, salted fillings for “PanCake”, etc.). The new products differ from conventional ones by the low sugar and fat content (up to 5 %), the high content of complete protein (15...25 %), and natural vegetable BAS. Our model studies helped select the formulation amounts of protein supplements made from chickpea and the additives from fruit and vegetable raw materials, the use of which made it possible to exclude the need for the use of artificial chemical impurities in the production of confectionery products, to reduce the formulation amount of sugar and unsaturated fats that are harmful to the human body. The protein supplements and the additives from fruit and vegetable raw materials perform in the manufacture of confectionery products the role of natural structure-forming and gel-forming agents of the texture, the enrichers with vitamin phyto-components, dyes, flavors, sugar substitutes. The use of 100 g of the new types of confectionery products in diets satisfies the daily need of the human body in β -carotene and phenolic compounds. The products obtained, in accordance with the FAO/WHO recommendations, can be attributed to health-beneficial ones. They are natural and do not contain harmful food impurities.

The advantages of this work relate to that the nanotechnology has been devised for chickpea processing into protein plant supplements in the form of finely-dispersed pastes and powders. The resulting additives are in a nanoscale form due to the destruction and transformation during the processing of chickpea high molecular compounds (proteins, pectins, cellulose, etc.) into individual monomers (by 40...70 %). The innovation proposed for making protein plant additives is the deep processing of chickpeas using the processes of steam-thermal destruction and non-fermentative catalysis of the specified biopolymers. We have revealed the mechanisms of these processes, which are associated with the mechanocracking (destruction) of molecules of protein, pectin, cellulose, and their nanocomplexes. The seminal technology makes it possible to obtain protein supplements from thermally-treated chickpeas in a nanoscale form with particle size ten times smaller compared to conventional purees and powders. The resulting additives are a source of natural

plant protein, much of which is represented by amino acids, which are in an easily-digestible form. Compared to existing chickpea powders, our protein supplements are more technological because they are finely dispersed and easily combined with other components of the product, thereby forming a homogeneous structure.

When implementing the devised technology for making protein supplements, which are in a nanoscale form, one should further pay attention to the quality of the raw material – dried chickpeas. Determine how the duration and storage conditions of dried chickpeas affect the content of hardly-soluble chickpea components and the degree of microbiological damage. Define the conditions and shelf life of dried chickpeas prior to processing, which would make it possible to obtain protein supplements in a nanoscale form. The resulting chickpea additives are recommended for use as a formulation component and an enriching protein supplement in the production of a wide range of foods. Further research is required aimed at determining the effect of protein supplements on the structural and mechanical properties, physicochemical, organoleptic quality indicators, on protein preservation during the shelf life of the resulting products.

7. Conclusions

1. When studying a set of nutrients and biologically active substances in the processing of chickpeas, it is established that dry substances are represented mainly by the polysaccharide starch (from 41.0 to 45.0 %) and proteins (from 20.1 to 25.0 %). 2.5 %) and glucose (2.0...2.4 %). The mass fraction of total sugars is from 4.4 to 5.5 %, which are represented in equal amounts by fructose (2.1...2.5 %) and glucose (2.0...2.4 %). The mass fraction of hardly-soluble cellulose heteropolysaccharide is between 2.8 and 4.0 %, total pectin is between 1.9 and 2.5 %. It is shown that the protein of dried chickpeas is biologically complete and, according to the FAO/WHO scale, exceeds the “ideal protein” by 2.0...2.7 times. The exception is the amino acid methionine, whose amount is 3 % less than that in the ideal one.

2. It was established that the joint application of the processes of steam-thermal treatment and finely-dispersed grinding during the processing of dried chickpeas into finely-dispersed puree and powder leads to the mechanocracking of protein molecules and the transformation of amino acids from the bound to the free easily-digestible form. Thus, in the resulting finely-dispersed puree and nanopowder made from chickpeas, there were 30...40 % amino acids in the bound state, and 60...70 % in the free form. It is shown that in parallel there is a significant mechanodestruction and transformation of biopolymers of pectin, cellulose, and starch to individual monomers. We have devised the nanotechnology for obtaining protein plant supplements made from chickpea in the form of finely-dispersed puree and nano-powder. The technology is distinguished from conventional ones by the utilization of the comprehensive effect of steam-thermal treatment and finely-dispersed grinding, which makes it possible to receive additives from chickpea in a nanoscale form, whose particle size is ten times smaller than that in conventional purees and powders.

3. We have investigated the BAS complex in fruit and vegetable additives made from pumpkin, carrot, lemon with zest, ginger, garlic, celery roots during their processing into cryopowders, which were proposed for use as an innovation

in the manufacture of a new generation of confectionery products for healthy eating. It is shown that the carotenoid additives in the form of cryopowders from carrot and pumpkin are high in β -carotene, the mass fraction of which per 100 g of product is from 120.0 to 132.4 mg, and contain significant amounts of vitamin C, phenolic compounds, and tannins.

4. We have devised the formulations and technologies for a new generation of confectionery products (wafer confectionery, sponge cakes, dry breakfasts) to strengthen the immunity of the population using protein supplements made from chickpea in a nanoscale form. At the same time, the

resulting protein supplements act not only as the carriers of complete protein in an easily-digestible form but are also the substitutes for sugar, fat, and act as the structure-forming and gel-forming agents of the texture of the new types of confectionery products. In addition to plant protein additives, the formulations were supplemented with additives from fruit and vegetable raw materials as the enrichers with vitamin phyto-components such as β -carotene, vitamin C, phenolic compounds, tannins, aromatic substances, etc. The composition of the new confectionery products has no harmful food impurities.

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