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*ТЕХНОЛОГИЯ ПРОДОВОЛЬСТВЕННЫХ ПРОДУКТОВ /
TECHNOLOGY OF FOOD PRODUCTS*

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Александр Валерьевич Бурминский
[Alexander V. Burminsky][1],
Валерия Николаевна Оробинская
[Valeria N. Orobinskaya][2],
Ирина Николаевна Пушмина
[Irina N. Pushmina][3],
Татьяна Николаевна Лаврова
[Tatiana N. Lavrova][4],
Сергей Александрович Емельянов
[Sergey A. Emelyanov][5]

Применение косметологической сублимированной ламинарии в качестве пищевого обогатителя (аналитический обзор)

The use of cosmetic freeze-dried kelp as a food fortifier (analytical review)

[1, 2, 4]Северо-Кавказский федеральный университет, Пятигорский институт (филиал), г. Пятигорск, Россия / North-Caucasus Federal University, Pyatigorsk Institute (branch), Pyatigorsk, Russia
[5]Северо-Кавказский федеральный университет, г. Ставрополь, Россия / North-Caucasus Federal University, Stavropol, Russia
[3] Сибирский федеральный университет, г. Красноярск, Россия / Siberian Federal University, Krasnoyarsk, Russia
[1]https://orcid.org/0009-0008-6630-2630
[2]https://orcid.org/0000-0002-0320-0556
[3]https://orcid.org/0000-0003-3783-3535
[4]https://orcid.org/0000-0002-8968-778X
[5]https://orcid.org/0009-0001-1360-8061

Автор, ответственный за переписку: Валерия Николаевна Оробинская, orobinskaya.val@yandex.ru / Corresponding author: Valeria N. Orobinskaya, orobinskaya.val@yandex.ru

Аннотация. *Развитие системы персонализированного питания стимулирует создания инновационных продуктов питания и меняет представление об инновационном продукте и функциональном сырье. Фактическое значение обогащённых пищевых продуктов трудно переоценить во многих отраслях питания, таких как геронтология, лечебно-профилактическое питания, питание спортсменов, космонавтов и так далее. В данной статья изучена возможность применения косметологической ламинарии в качестве пищевого обогатителя для различных продуктов. Также проведены микроскопические исследования полученного витального и обработанного препарата с целью исследования витализированности и сохранности витаминного и минерального состава при сублимационной подготовке и хранении сырья.*

Ключевые слова: альганика, ламинария, функциональные продукты питания, обогатители, сублимация, восстановление, йододефицит

Для цитирования: *Бурминский А. В., Оробинская В. Н., Пушмина И. Н., Лаврова Т. Н., Емельянов С. А. Применение косметологической сублимированной ламинарии в качестве пищевого обогатителя (аналитический обзор) // Современная наука и инновации. 2023. № 3 (43). С. 72-85.* https://doi.org/10.37493/2307-910X.2023.3.7

Abstract. *The development of a personalized nutrition system encourages the creation of innovative food products and the definition of innovative and functional raw materials. The actual value of fortified foods is difficult to overestimate in many food industries, such as gerontology, therapeutic and preventive nutrition, nutrition of athletes, astronauts, and so on. This article examines the possibility of using galvanic kelp as a food fortifier for various products. Microscopic studies of the obtained vital and processed preparation were also carried out in order to study the vitalization and preservation of the vitamin and mineral composition during alganic preparation.*

Keywords: alganica, kelp, functional food products, fortifiers, sublimation, restoration, iodine deficiency

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Introduction. The full development of the human body requires balanced nutrition. Rational nutrition, in turn, provides the body not only with basic plastic substances and energy, but also meets the body's need for vitamins and minerals.

Today, 15 essential micro- and macroelements have been identified in human nutrition, which provide the basic vital functions of the human body, as well as ensure the optimal functioning of internal systems. Among these substances, iodine is very important.

Iodine in the human body is one of the most important chemical trace elements that regulate the activity of the thyroid gland, and, consequently, the entire body. However, at the moment the number of people consuming sufficient amounts of this microelement is decreasing.

A systemic decrease in iodine content in the human body leads to disruption of the functioning of the thyroid gland. This, in turn, leads to a decrease in the production of hormones T_3 and T_4, which affects not only physical, but also mental performance. According to the WHO statement, in 2022, about 20 million people have impairment of some brain functions due to iodine deficiency [4].

Materials and research methods. The problem of iodine deficiency is relevant for all regions of our country, but especially for the following regions: Transbaikalia, Kuzbass, Altai, the Republic of Tyva, the North Caucasus, Bashkortostan, the Yamalo-Nenets Autonomous Okrug, Udmurtia (Table 1.) [2].

Table 1. The number of people suffering from thyroid diseases per 100,000 of the total population (diagnosed for the first time in life) [1-12].

Indicators By years / Subjects Federation	2010	2011	2012	2013	2014	2015	2016	2017	Note
Russian Federation	324.8	344.8	354.6	339.1	346.9	358.1	354.8	346.4	[1-1 2]
Central federaldistrict	256.9	271.2	284.2	265.8	282.6	291.2	279.9	259.5	[1-1 2]
Belgorodskaya region	275.2	288	285.3	289.4	284.7	234.6	249.3	214.4	[1-1 2]
Bryansk region	767.6	759	837.3	840.3	779.6	750.4	729.3	646.6	[1-1 2]
Vladimirskaya region	378.4	439.5	506.9	445.6	428.2	441.3	365.3	386.7	[1-1 2]
Voronezh region	211.4	245	241.6	196	223	283.1	244.1	241	[1-1 2]
Ivanovskaya region	394.9	435.2	412.3	383.7	377.8	285.9	486	391.5	[1-1 2]

Kaluzhskaya region	237.9	224.4	227.7	249.4	207.3	228.8	265.1	225	[1-1 2]
Kostromskaya region	165.1	213.5	236.5	184.6	225.2	215.3	201.8	253.5	[1-1 2]
Kursk region	199.1	227.5	244.1	180.3	206.4	216.7	185.7	197.7	[1-1 2]
Lipetskaya region	235.8	243.1	258	218.2	252	198.1	188.5	146.8	[1-1 2]
Moscow region	**151**	**154.9**	**182.8**	**174**	**201.4**	**233.5**	**226.9**	**209.4**	[1-1 2]
Orlovskaya region	474.7	625.1	627.7	470	475.5	677.2	632.5	623.7	[1-1 2]
Ryazan region	301.9	307.7	401	397.1	435.8	364.8	408.8	319.9	[1-1 2]
Smolenskaya region	211.1	199.8	232.8	222.4	220.9	237.4	256.3	232.8	[1-1 2]
Tambovskaya region	291.7	243.9	211.4	205.5	202.7	145.3	190.2	170.1	[1-1 2]
Tverskaya region	173.9	207.6	228.4	257.9	262.4	317.2	252.1	277.4	[1-1 2]
Tula region	165.9	195.5	193	159.7	177.7	204.8	243.9	263.2	[1-1 2]
Yaroslavskaya region	506	444.1	441.3	406	450.8	397	359.5	368.3	[1-1 2]
City Moscow	231.6	250.6	248.1	240.6	269.1	278.7	248.3	223	[1-1 2]

Statistics from Rospotrebnadzor for 2022 prove that there is currently no positive dynamics observed. Russia is in third place among the countries in terms of iodine deficiency [2].

According to official medical statistics, over the past 5–8 years there has been a steady increase in the primary incidence of thyroid diseases of varying degrees of severity in various groups of the population [10].

Indicators vary between the recorded and actual prevalence of endemic goiter in different population groups. As shown in table. 3, the actual prevalence of goiter is 13.5 times higher than the registered one (1.6 versus 21.8%). At the same time, the calculated number of patients with undetected diffuse toxic goiter is estimated at 58,221 thousand people for the total population of the regions [1,2,3,4,5,6,7,8,9,10,11,12]. According to international statistics, more than 2 billion people suffer from iodine deficiency [3].

The prevalence of manifest primary hypothyroidism in the population is 0.2–1%, latent primary hypothyroidism: 7–10% among women and 2–3% among men [9].

As a result of the low positive dynamics, by 2023 the problem became so acute that the World Health Organization (WHO) adopted a new resolution to strengthen developments in fortifying food products with micronutrients, including iodine [5].

Various types of seaweed have been traditionally used as flavoring agents, food additives, and food products in many countries, especially in Asia [13,14, 15].

Research results and their discussion. One of the natural, well-studied iodine fortifiers used as a biologically active food additive is kelp. This is a genus of brown algae, known in the food industry as seaweed for its similarity in properties and cellular composition to Chinese cabbage. Laminaria japonica (LJ) is a popular seaweed called kombu in Japanese cuisine. Laminaria sp. is one of the most important marine medicinal foods, since its biological activity has been widely studied in in vitro and in vivo experiments as an inhibitor of triglyceride and high-density lipoprotein (HDL) absorption [13,14,15].

Laminaria is a thallus in the form of plates 20 or more meters long, brown or dark green in color. The main distribution area is the southern part of the Sea of Okhotsk and the Sea of Japan. The genus Laminaria consists of 30 individual plant species.

a) **b)**

c)

Figure 1. External view: a) Laminaria japonica; b) Laminaria saccharina, c) Laminaria digitata.

In nutrition it is represented by three species: Japanese kelp (Laminaria japonica), which are flat, light green leaves; Sugar kelp (Laminaria saccharina) is a wavy "relative" of Japanese kelp, growing in the White and Kara Seas, and Laminaria digitata has a wide distribution area (Fig. 1.).

The amount of iodine in kelp varies depending on the habitat and the content of iodine ions in the water. It has been proven that algae growing at great depths accumulate more iodine than algae growing close to the shore.

Table 2. Comparison of the content of main plastic substances, vitamins, macro and microelements of kelp with other plant fortifiers for non-fisheries [47-52]

Nutrient	**units change**	**Norm**	**Laminaria (sushi)**	**Kelp (fresh)**	**Fucus (dry)**	**Kombu (dry)**	**Nori (dry)**	**Wakame (sushi)**
Calorie content	kcal	1684	189,000	24,900	123,000	140,000	188,000	45,000
Squirrels	G	76.00	7.10	0.90	6.70	7.00	41.40	3.03
Fats	G	56.00	1.60	0.20	1.56	1.60	3.70	0.64
Carbohydrates	G	219.00	22.60	3.00	22.00	22.00	44.30	8.64
Organic acids	G	~	18.80	2.50	23.42	0.00	0.00	0.00
Alimentary fiber	G	20.00	4.80	0.60	5.00	37.00	0.00	0.50
Water	G	2273.00	2.00	88.00	0.00	0.00	0.00	79.99
Ash	G	~	30.75	4.10	3.16	0.00	0.00	7.20
Vitamins								
Vitamin A, RE	mcg	900.00	19,400	2,500	20,800	65,000	25,000	18,000
beta carotene	*mg*	5.00	1.163	0.150	1,250	0.000	0.000	0.216
Vitamin B1, thiamine	*mg*	1.50	0.240	0.040	0.330	0.070	0.690	0.060
Vitamin B2, riboflavin	*mg*	1.80	0.420	0.060	0.500	0.260	2,330	0.230
Vitamin B4, choline	*mg*	500.00	99.170	12,800	106,600	0.000	0.000	13,900
Vitamin B5, pantothenic	*mg*	5.00	4,494	0.642	5,300	0.200	1,180	0.697

Vitamin B6, pyridoxine	*mg*	2.00	0.120	0.020	0.160	0.020	0.590	0.002
Vitamin B9, folates	mcg	400.00	8,433	2,300	19,160	38,000	1900,000	196,000
Vitamin B12, cobalamin	mcg	3.00	7,917	1,000	8,000	0.100	57,600	0.000
Vitamin C, ascorbic acid	mg	90.00	6,330	2,000	16,600	20,000	210,000	3,000
Vitamin E, alpha tocopherol, TE	mg	15.00	6,743	0.870	7,200	0.000	4,600	1,000
Vitamin H, biotin	mcg	50.00	23,750	3,000	25,000	15,700	0.000	0.000
Vitamin K, phylloquinone	mcg	120.00	511,500	66,000	549,600	240,000	390,000	5,300
Vitamin RR, NE	mg	20.00	2.833	0.400	4,570	2,100	11,500	1,600
Niacin	*mg*	~	2.833	0.400	3,000	0.000	0.000	0.000
Macronutrients								
Potassium, K	mg	2500.00	7275,000	970,000	4128,000	5200,000	2400,000	50,000
Calcium, Ca	mg	1000.00	313.330	40,000	219,907	430,000	280,000	150,000
Silicon, Si	mg	30.00	382,500	51,000	424,700	0.000	0.000	0.000
Magnesium, Mg	mg	400.00	1275,000	170,000	1270,000	700,000	300,000	107,000
Sodium, Na	mg	1300.00	4073.330	520,000	4330,000	2.465	530,000	872,000
Sera, S	mg	1000.00	1060,000	134,000	1115.800	320,000	0.000	30,300
Phosphorus, P	mg	800.00	417,100	55,000	602,000	0.000	700,000	80,000
Chlorine, Cl	mg	2300.00	8271,000	1056,000	8793,000	0.000	0.000	0.000
Microelements								
Aluminium, Al	mcg	~	4350,000	580,000	4829,000	0.000	0.000	0.000
Bor, B	mcg	~	1687,000	225,000	1873,000	0.000	0.000	0.000
Vanadium, V	mcg	~	637,000	85,000	707,800	0.000	0.000	0.000
Iron, Fe	mg	18.00	117,330	16,000	54,080	3,000	11,400	2,180
Yod, I	mcg	150.00	9583,000	2500,000	24276,000	210,000	6000,000	6600,000
Cobalt, Co	mcg	10.00	110,000	15,000	125,000	0.000	0.000	0.000
Manganese, Mn	mg	2.00	1,500	0.200	6,650	0.410	3,750	1,400
Copper, Cu	mcg	1000.00	992,500	130,000	1510,000	0.190	550,000	284,000
Lithium, Li	mcg	~	0.000	7,700	0.000	0.000	0.000	0.000
Molybdenum, Mo	mcg	70.00	0.000	1,600	0.000	0.000	0.000	0.000
Nickel, Ni	mcg	~	0.000	0.200	0.000	0.000	0.000	0.000
Rubidium, Rb	mcg	~	0.000	6,000	0.000	0.000	0.000	0.000
Strontium, Sr	mcg	~	0.000	200,000	0.000	0.000	0.000	0.000
Titanium, Ti	mcg	~	0.000	54,000	0.000	0.000	0.000	0.000
Selenium, Se	mcg	55.00	4,608	0.700	3,820	2,000	0.000	0.700
Fluorine, F	mcg	4000.00	2550,000	340,000	2831,000	0.000	0.000	0.000
Chromium, Cr	mcg	50.00	3,750	0.500	4,100	0.000	0.000	0.000
Zinc, Zn	mg	12.00	9,392	1,230	5,062	0.900	3,600	0.380
Digestible carbohydrates								
Starch and dextrins	G	~	0.000	0.03 g	0.000	0.000	0.000	3,030
Mono- and disaccharides (sugars)	G	~	0.000	0.6 g	0.000	0.000	0.000	0.65 g
Polyunsaturated fatty acids								
Omega-3 fatty acids	G	up to 3.7	0.100	0.008	0.060	0.000	0.000	0.188
Omega-6 fatty acids	G	up to 16.8	0.200	0.032	0.270	0.000	0.000	0.031

Laminaria contains active substances that can reduce the level of harmful external factors on the human body.

Laminaria contains alginic acid, which belongs to the group of dietary fibers that help improve the functioning of the gastrointestinal tract and reduce the level of glucose and triglycerides in the blood.

Research by domestic and foreign scientists proves that Japanese kelp and other brown seaweeds contain a large number of different phenolic compounds (Table 1). 3., having antioxidant, anti-inflammatory and anti-carcinogenic effects [10,11].

Table 3. Total polyphenol content in kelp extracts [10,11]

Sample name	**Total polyphenol content (µg gallic acid/ml)**
Japanese kelp	2.084 ± 0.01

Note: mean ± standard error of the mean of three independent experiments.

Laminaria digitata phlorotannins are a group of tannins consisting of phloroglucinol subunits linked by carbon-carbon and ester bonds, preventing protein degradation and methanogenesis during fermentation (during storage and mechanical processing) [43].

In research by Yixiang Liu . Liu demonstrated the protective effect of fucoxanthin isolated from Laminaria japonica against visible light-induced retinal damage in in vitro and in vivo experiments [44].

In the gastrointestinal tract, fucoxanthin undergoes a process of hydrolysis at the intestinal level, forming fucoxanthinol, further metabolism occurs in the liver to amaruciaxanthin A (Fig. 2).

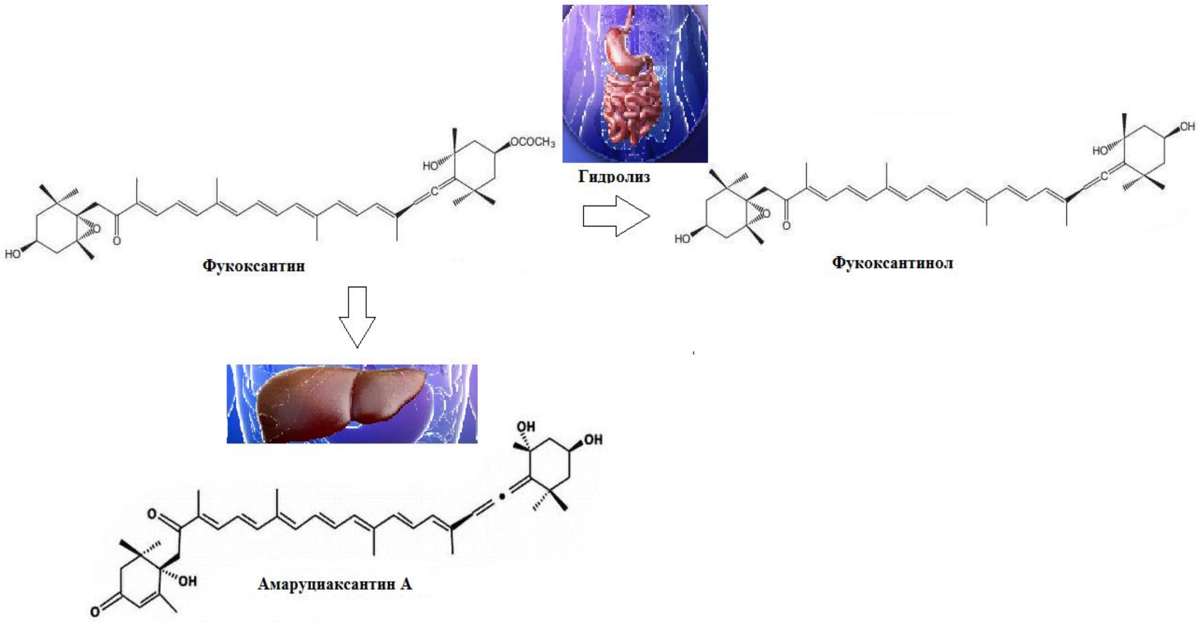

Figure 2. Structural formulas of fucoxanthin and its metabolites [47, 48,49]

Fucoxanthin, which belongs to the class of carotenoids, has a hypocholesterolemic effect by reducing the concentration of triglycerides in the blood plasma and by suppressing low-density lipoprotein (LDL) receptors. It has been proven that dietary supplements with fucoxanthin can reduce the expression of m-RNA fatty acid synthase, which catalyzes the synthesis of fatty acids; metabolites have a similar effect [47, 48, 49].

In order to improve the situation in iodine-deficient regions, we studied kelp as a potential source of iodine and biologically active compounds.

The peculiarity of this algae is that the amount of iodine in kelp varies depending on the habitat and the content of iodine ions in the water. It has been proven that algae growing at great depths accumulate more iodine than algae growing close to the shore.

One of the main reasons for high iodine losses is losses during mechanical processing and storage, due to the transition of part of the iodine into an indigestible form, which significantly reduces the quality of kelp as a fortifier. One of the main indicators of the degree of loss is the degree of cell damage during sublimation preparation. A large number of destroyed cells and a significant softening of the original restored raw material will indicate significant damage to cell walls as a consequence of destruction and loss of nutrients contained mainly in the cytoplasm of plant cells and plastids.

A widely used method of preserving the valuable properties of raw materials is the method of low-temperature freeze-drying of kelp, which is used during transportation to the processing site. This processing method allows you to preserve biologically active substances [7, 16-46].

In this regard, the purpose of our study is to study the degree of cell damage during storage and transportation of freeze-dried kelp and to determine the possibility of reducing losses during recovery.

The study was carried out using microscopic methods in transmitted light in the range: 100, 400, 1000 times magnification, dark field microscopy, as well as negative position microscopy to determine the integrity of cell walls.

When conducting research, we used the dark-field microcopying method, which allows us to contrast the surface of the cell wall, allowing us to differentiate the integrity and damage of the cell walls.

Microscopic studies (Fig. 1, 2) revealed only partial restoration of cell walls and cell turgor. When the freeze-dried kelp leaf was kept for a long time (more than 3 days), no changes were observed. A shift in the center of illumination did not reveal the destruction of cell membranes.

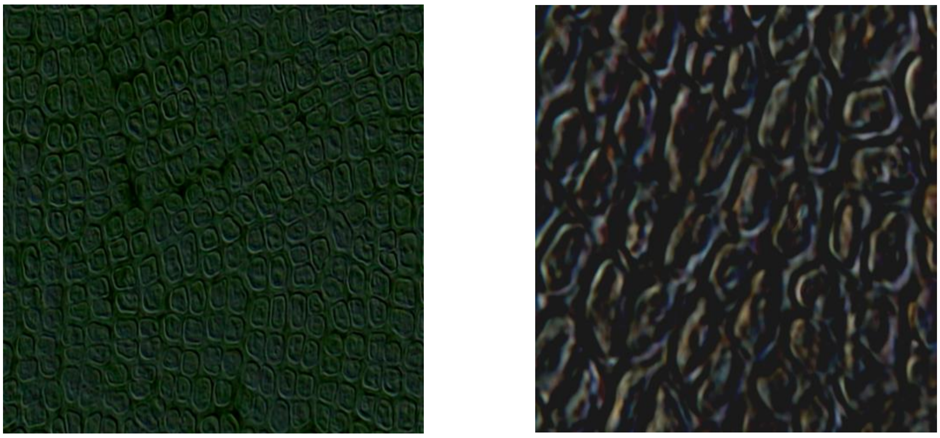

Figure 1 a and b Vitalized kelp preparation after 1 hour of recovery in distilled water (a) 800-fold magnification; 3-day vitalization exposure in distilled water (b) 2000-fold magnification using dark-field microscopy technique.

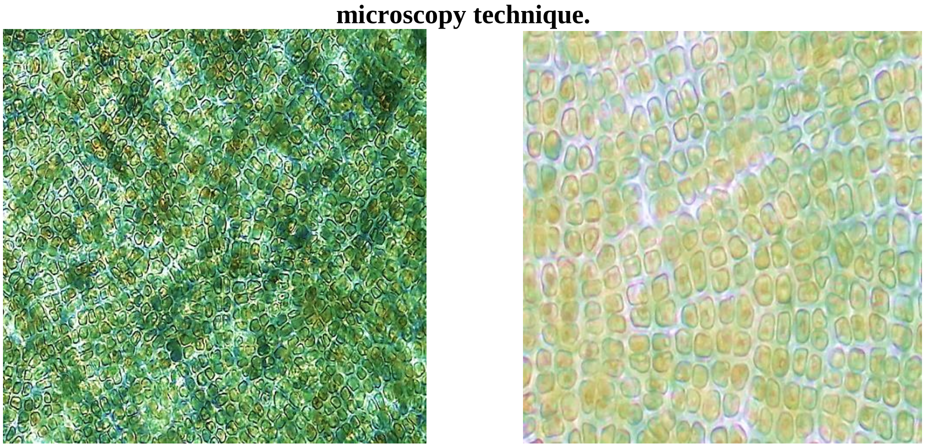

Figure 2 c and d. Vitalized kelp preparation after 1 hour of recovery in distilled water (c) 800-fold magnification; 3-day vitalization exposure in distilled water (g) 800-fold magnification with bright-field microscopy

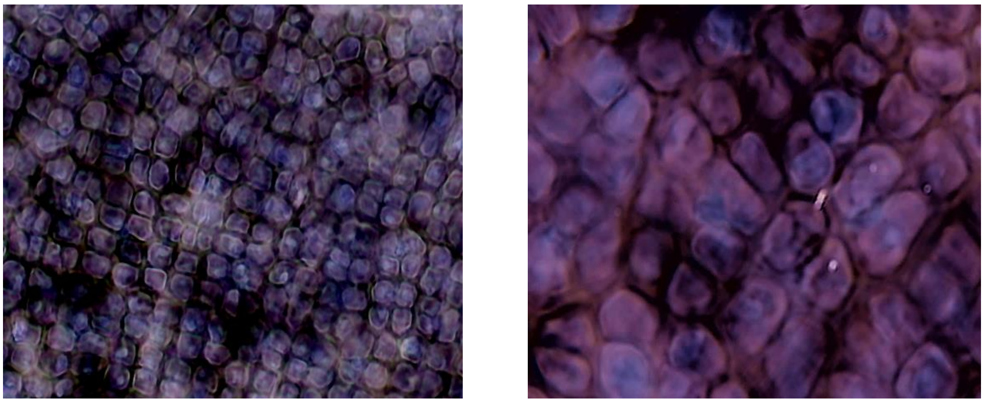

Figure 3 e and f. Vitalized kelp preparation after 1 hour of recovery in distilled water (e) 800-fold magnification; 3 - day vitalization exposure in distilled water (e) 2000-fold magnification with negative emission microscopy

The experimental studies carried out made it possible to prove that kelp cells tolerate the freeze-drying process well, preserving the tissue structure. Minor and few damage to cell walls is an indicator of the high quality of sublimation raw materials.

The use of freeze-dried kelp is more preferable than the use of various types of processing, especially when using preservative chemical compounds [16-46].

However, the high content of iodine [8] in the product determines the need for strict regulation of the amount of administration of freeze-dried kelp as a dietary supplement to avoid an overdose of biologically active substances.

The use of freeze-dried kelp in modern conditions is more promising than the use of powder and tablet forms, since the freeze-dried form allows, even during a long period of storage, to maintain the integrity of dehydrated cells, and the residual salt coating (formed as a result of freeze-drying due to the precipitation of salts with increasing concentration solutions in cells and intercellular spaces) performs an additional function of protection against the development of putrefactive and conditionally pathogenic microorganisms. Microscopic examination revealed only minor cell damage, associated largely with the sublimation preparation of cells in 2-4 mitotic stages, as a result of which dehydrogenation of the internal structures of the cell and a decrease in cell turgor affects nuclear structures (compression of the nuclear membrane, disruption of heterostructures - and euchromatins, closing nuclear pores).

Conclusion. The conducted studies have proven that the use of kelp as an iodine-containing ingredient and fortifier in the production of functional foods as a preventive product in regions of the Russian Federation that have a low iodine index in the diet will contribute to a significant reduction in the number of iodine-dependent diseases. Further research into the enrichment of kelp food products with iodine makes it possible to identify additional synergistic parameters of the interaction of iodine with micronutrients in the product and study the effect of these complexes on the human body.

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ИНФОРМАЦИЯ ОБ АВТОРАХ

Александр Валерьевич Бурминский – генеральный директор Общества с ограниченной ответственностью «МИП Вектор - В», бакалавр 4 курса кафедры технологии продукции питания и товароведенья, Пятигорский институт (филиал), Северо-Кавказский федеральный университ, г. Пятигорск, Россия, e-mail: sasha_burmins@mail.ru

Валерия Николаевна Оробинская – кандидат технический наук, ведущий научный сотрудник отдела планирования и организации научно-исследовательской работы, доцент кафедры технологии продукции питания и товароведенья, Пятигорский институт (филиал), Северо-Кавказский федеральный университ, г. Пятигорск, Россия

Ирина Николаевна Пушмина – доктор технических наук, профессор кафедры технологии и организации общественного питания, Сибирский федеральный университет, пр. Свободный, 79, г. Красноярск, 660041, Россия, root1986@mail.ru

Татьяна Николаевна Лаврова – начальник отдела планирования и организации научно-исследовательской работы, Пятигорский институт (филиал), Северо-Кавказский федеральный университ, г. Пятигорск, Россия, oponirlavrova@yandex.ru

Сергей Александрович Емельянов – кандидат биологических наук, доктор технических наук, профессор кафедры прикладной биотехнологии, Северо-Кавказский федеральный университет, г. Ставрополь, Россия, sergemelyan@mail.ru

INFORMATION ABOUT THE AUTHORS

Alexander V. Burminsky – General Director of MIP Vector - V Limited Liability Company, Bachelor of the 4th year of Departments of Food Production Technology and Commodity Science, Pyatigorsk Institute (branch), North-Caucasus Federal University, Pyatigorsk, Russia, sasha_burmins@mail.ru

Valeria N. Orobinskaya – PhD in Technical Sciences, Leading Researcher of the Department of Planning and Organization of Research work, Associate Professor of the Department of Food Technology and Commodity Science, Pyatigorsk Institute (branch), North Caucasus Federal University, Pyatigorsk, Russia

Irina N. Pushmina – Dr. Sci. (Tech.), Professor of the Department of Technology and Organization of Public Catering, Siberian Federal University, Svobodny Ave., 79, Krasnoyarsk, 660041, Russia, root1986@mail.ru

Tatiana N. Lavrova – Head of the Department of Planning and Organization of Research work, Pyatigorsk Institute (branch), North Caucasus Federal University, Pyatigorsk, Russia, oponirlavrova@yandex.ru

Sergey A. Emelyanov – Cand. Sci. (Biol.), Dr. Sci. (Tech.), Professor of the Department of Applied Biotechnology, North Caucasus Federal University**,** Stavropol, Russia, sergemelyan@mail.ru

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