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Modern Tendencies and Prospects of Using Algae as an Ingredient for Bakery Products.

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ABSTRACT

The Russian Federation and other countries recognize the urgency of enriching bakery products as products of mass, daily intake. To improve the nutritional value of bakery products, a variety of functional food ingredients is used, among which sea algae make up an insignificant part. However, according to the literature, sea algae contain unique biologically active substances (BAS) of multifunctional effect, which often do not have the negative features that are inherent to substances derived from traditional sources. Typically, sea algae have wide and successfully reproducible resource base; this is important if there is a need to obtain food on an industrial scale. The article presents an analysis of the literature data on the use of sea algae as functional or physiologically active components of bread. It is shown that adding algae into flour contributes to the increase in quality of baked bread and gives it therapeutic and prophylactic properties. This work was supported by the Russian Scientific Foundation (project No. 14-50-00034).

Keywords: functional nutrition, bakery products, functional ingredient, sea algae (brown, red, green), the quality of bakery products with added algae.

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INTRODUCTION

As it is known, nutrition is one of the factors that determine human health, duration and quality of life, ability to withstand a variety of adverse environmental factors.

In this regard, the Russian Federation and other countries recognize the relevance of developing food products that promote better resistance of the human body and prevention of nutrition-related diseases.

Mass enrichment of daily intake foods (bakery and pasta products, soft drinks) is particularly relevant in this regard; these products not only contribute to the health improvement of the population of any country, but also solve the important strategic task – to ensure its food security.

Bakery products play a priority role in the range of mass consumption products in virtually all countries of the world, and the bread baking is a socially important sector of the economy. Bakery products are a part of the daily diet of the vast majority of consumers; they are one of the main sources of energy and nutrients.

However, the nutritional value of bread does not fully meet modern requirements of the "nutritional science – pharmaco-nutritiology". Analysis of the indicators that make up the nutritional value of bread shows the feasibility of balancing its chemical composition, increasing the biological value, eliminating the deficit of certain components, enriching it with proper proteins, vitamins, minerals, dietary fibre, which allows correcting the person's nutritional status quickly and effectively [1-3].

The data of scientific and technical literature have shown that for the enrichment of bakery products substances of different nature [1, 4-7] are used, which in view of modern terminology are called functional food ingredients (FFI).

Functional food ingredients suggested for the correction of the nutritional value of bakery products are represented by a wide range of substances of different origins, among which, the sea algae make up only a small part [4].

Meanwhile, according to numerous literary data on marine hydrobionts, including algae, contain unique biologically active substances (BAS) with multifunctional effect [8-11]. This is due to the conditions of their existence in the aqueous medium that is a practical solution, which includes almost all known chemical elements. The need to counter a number of factors (increased blood pressure, low oxygen content, low light, or its complete absence, unusually high or low temperatures) draws a contrast between marine organisms and their metabolites from the organisms with terrestrial biology [12-15].

As natural sources, they are not only characterized by diversity and high efficiency of biologically active substances contained in them, which often don't have negative properties of the substances obtained from conventional sources, but also have a wide and successfully reproduced raw material base [16]. The latter circumstance may become important if there is a need to obtain any specific chemical substances (proteins, polysaccharides, nucleic acids, etc.) or food products on their basis on an industrial scale.

The same opinion is shared by the scientists S.U. Kadam, P. Prabhasankar. In their monograph, they note that marine organisms, due to their phenomenal biodiversity, are the sources of many biologically active substances and food ingredients such as fish oil, fish protein, biologically active peptides and others. The functional components of marine organisms are used for the enrichment of various food products, but, according to the authors, bread and pasta, the most widely used by the population in the world, are the most suitable for the design of such food compositions [17].

Systematization of algae is based on their pigmentation, as well as biological and morphological features. Algae that are used for food purposes refer to three divisions that got their names according to the colours: brown algae *Phaeophyta*: *Laminaria* (sea cabbage), *Fucus*, *Costaria*, *Undaria*, *Macrocystis*, etc; red algae (dog whelk) *Rhodophyta*: *Rhodymenia*, *Porphyra* (red lettuce), *Ahnfeltia*, *Phyllophora*, *Furcellaria* and *Chondrus*, etc.; green algae *Chlorophyta*: *Ulva* (sea lettuce) and *Enteromorpha*, etc. [18].

Russian waters are inhabited by over 800 species of marine algae. Production is carried out in the coastal zones of the Far East seas and the White Sea. The most important are brown algae (laminaria and fucus) and red (ahnfeltia, furcellaria, phyllophora) algae.

The reserves of the renewable Laminaria algae in the seas of Russia are estimated to be from 4.5 to 8.5 million tonnes, however, only two types of Laminaria are currently used in Russia – Laminaria japonica (Far East), *Saccharina japonica* and *Laminaria saccharina* (White Sea), their consumption per capita is insignificant.

The science of algae – algology – dates back to more than two hundred years, however, its practical aspects are implemented not even close to the full potential.

Brown algae (the most abundant species of them are laminaria and fucus) were traditionally used as food products. In Japan, Laminaria has been cultivated from the 18th century; red and green algae are also cultivated for food purposes. To date, China and Japan attach particular importance to the daily intake of sea algae.

The research on the feasibility of using the brown alga *Ascophyllum nodosum* as a grain enricher was conducted in the UK. The effect of consuming bread with added algae (at a concentration of 4% per 400 g of bread) on cholesterol levels of overweight healthy men was studied. Results of the research showed a decrease in cholesterol levels among the studied population and reduction in the caloric value of their diet [19].

In Russia, the first data on the benefits of adding the Laminaria brown alga into the daily intake appeared in the early twentieth century, and soon it started to be harvested off the coast of the Sea of Japan. Laminaria, known as sea cabbage, have the main nutritional value. Laminaria have high content of iodine and bromine (170-850 and 20-40 mg per 100 g of dry matter, respectively), many other micro and macro elements, as wells as vitamins mainly of the B group [18].

Mostly, frozen and shredded algae are prepared from Laminaria; this alga is used for making canned food, culinary products (about 100 titles). Products from Laminaria, as well as sea algae, are an important source of vitamins, enterosorbents, BAS, contain a wide range of micro elements, including iodine, which is particularly important, as iodine is a vital micro element of nutrition. The ability to synthesize polysaccharides is a unique property of algae in contrast to terrestrial plants. Along with the well-known alginic acid, these algae contain polysaccharides – laminarans and fucoidans, which play the main role in the biological effect of algae.

Laminaria is also used for enriching bread, usually in a shredded form or in powder form.

Shredded sea cabbage is included in the composition for bread production that contains swollen grain, sprouted oats and sprouted soybeans, seeds of amaranth. Bread obtained by this method is recommended for dietary or health nutrition [20].

Laminaran powder that contains various biologically active agents, including iodine, alginates, polysaccharides, minerals is a part of the mix for preparing the rye-wheat bread "Murmanskiy" and "Northern" [21]. The use of laminaran powder made it possible to obtain bread of the functional purpose – with a high content of iodine, enriched with biologically active substances that contribute to the elimination of radionuclides and heavy metal ions.

Laminaran powder is used not only in the formulation of bakery products, but is also sprinkled on finished products; at the same time its amount equal to the daily need of a person can improve palatability of food, increase their preventive properties, reduce the cost of their production and increase the volume output [22].

Laminaria is also introduced into the various compositions for bread enrichment, for example, "Pectin mix with sea cabbage", which includes sea cabbage, pectin, ascorbic acid, enzymes. The addition of this mixture makes it possible to enrich bakery products with iodine, increase the output of products in the production process, improve their organoleptic properties and ensure safety during the shelf life of bread [23].

Such a combination of sea algae components with pectin, but in the form of original therapeutic and preventive additives of hydrocolloid nature for bread production was proposed by Sukhanov E.P. et al. [24]. The resulting bread was recommended in the areas of high ecological risk and iodine deficiency in order to improve the adaptation capabilities of the human body.

The complex of laminaria with dried watercress for bread recipes was formed by the FEFU scientists. The developed product met all the necessary traditional consumer requirements and had a functional purpose due to iodine-containing components such as watercress and laminaria [25].

Adding Laminaria into bread, in the form of the "Laminal" bio-gel – a food supplement created by the employees of the "TINRO-centre", contributed to the improvement of organoleptic characteristics. The use of such a product had a positive effect on the condition of the human gastrointestinal tract [26].

Algae are good sources of bioavailable iron (Fe). When studying bread with the three species of sea algae added – brown, green, red *Sargassum, Ulva, Porphyra* (respectively), it was determined that the most important source for enriching bread with polyphenols, iron, increasing the antioxidant activity is the *Sargassum* brown alga [27].

In order to develop functional bread, Korean scientists recommended adding dietary fibre extracted from sea algae of the Kombu laminaria group to wheat flour experimentally at an established optimum amount of 3% [28].

Laminaria japonica was used as part of developed bread improvers. The research results of created improvers showed that the addition of Japanese kelp, along with the other components included in their composition, improves the quality of bread made from wheat flour [29].

Similar results were obtained by the scientists Oscar Velasco-González et al. The data of their studies showed that adding the Sargassum algae powder into flour at a concentration of 2% increases gluten of the "weak" flour and can be used as a bread improving agent [30].

For dietary nutrition, scientists developed a method for producing a baked product from medium flour rye, other traditional components and thermophilic non-yeasted lactic acid sourdough; the powdered processed products from the food Laminaria and/or Fucus algae in the amount from 0.5 to 1.5% of flour mass were used in its production [31].

A study was conducted to examine the shelf life and quality of bread made with the extract of brown algae *Myagrorsis myroides*, obtained by fermenting algae with ethanol. The results showed that the total microbial count in the bread with the addition of 2% of *Myagrorsis myroides* decreased in comparison with the number of microbial count of the bread without this extract. During the sensory study of the product it was revealed that bread, containing 0.5% of *Myagrosis myroides,* was preferred over the bread without the Myagrosis myroides extract. These results showed that adding the extract of *Myagrosis myroides* brown algae at an optimal amount of 0.5% into bread ensures its good quality and increases shelf life.

The scientists have shown that it is promising to use other renewable rarer species of brown algae as FPI, so for example, *Costaria costata* (hereinafter – Costaria), which belongs to the family of *Laminariaceae*, the genus of *Costaria*, that includes only one species. It is known from the literary sources that Costaria accompanying Saccharina japonica on plantations is regarded as a weed; however, it is a valuable raw material: it contains 5-15% of protein, 70% of carbohydrate, 1-3% of lipids. Carbohydrates includes mannitol, laminitis, polyuronides – alginic acid and fumaric acid, fuksidin, laminarin (algal starch), cellulose ("alguleza"), the ratio of protein and non-protein nitrogen is 1:1; high content of iodo-amino acids in proteins is noted. Unlike other laminaria species, Costaria Costata contains a lot of calcium.

The staff of the Far Eastern Federal University – E.S. Smertin, L.N. Fedyanin et al. – explored the possibilities and feasibility of using native Costaria algae in the technology of functional purpose bakery goods. The results showed that all experimental bread samples with added algae had better organoleptic characteristics than the control sample. The taste and aroma of bread with algae compared to the control didn't change, but there were some differences in the colour of its crumb – light specks of algae were present

in the experimental samples; however, these specks did not spoil the appearance of the finished products and even made them more unique. In addition, bread made with the addition of algae had a greater shelf-life than the conventional one [33].

Quite a lot of works on the use of alginates and their various salts derived from all kinds of algae, but mostly brown, have been conducted. A positive effect of sodium alginate on the quality of flour gluten in the experiment with biscuit semi-finished products was shown. The author of the study determined that during bread baking, alginates did not lose their radioprotective properties and an increase in their concentration in the biscuit dough increased the stability of the system to mechanical stress [34].

The combination of sodium alginate with coarse particles of wheat grains, added to baked goods, cookies and extrudates allowed producing bread products with increased moldability [35].

The results of studies on the use of calcium alginate in bread production from wheat flour, as well as the mix of medium rye and wheat flour in the works of L.V. Lazareva, L.I. Puchkova, S.V. Sumatohina demonstrated that the use of calcium alginate promotes maximum manifestation of the alginic acid's sorbing properties and increases the nutritional value of bread [36].

Other than Laminaria, other fucus brown algae are also used for enriching bread. Just like Laminaria, fucus algae are most often used in the form of powder: the scientists of the State Research Institute of Baking Industry and JSC "Fazer" substantiated the use of such powder as a source of microelements and iodine for the development of the technology of production of bread from a mixture of rye and wheat flour. The bread with added edible crushed fucus differed in its organoleptic and physico-chemical properties. The authors recommended consuming bread with added fucus powder for the prevention of iodine deficiency disorders [37].

Adding biologically active additives (BAA) based on fucus brown algae appeared also quite promising for the creation of bakery goods of a functional purpose.

It was suggested to apply the BAA "Fukolam-C", consisting of alginic acids and fucoidan, derived from the *F. evanescens* brown algae as part of bakery products. Adding "Fukolam-C" helped improving the standard indicators of bread quality and gave it medical and preventive orientation, provided by the addition of dietary fibre and a minor food component – the biologically active substance – fucoidan [38].

Resources of red algae – agaro- and carrageenanophytes or dog whelk – are not as significant as the reserves of brown algae, since they do not form large bushes in nature. Red algae have a special chemical composition of the pigments complex, which differs substantially from the pigment of green and brown algae. Among dog whelk species, the most prevalent is ahnfeltia, including *Ahnfeltia tobuchiensis* (hereinafter – ahnfeltia), *Rhodomela* and others. Red algae can accumulate mineral elements to a much lesser extent than brown ones. Nevertheless, fatty acid composition of lipids of different species of red algae draws the most attention of researchers due to the high content of polyunsaturated fatty acids – arachidonic and eicosapentaenoic [39-41].

Red algae are rich in B vitamins, and by the vitamin content of this group, they exceed brown and green algae, contain significant amounts of carbohydrates with a peculiar structure and properties. The carbohydrates composition includes low molecular weight carbohydrates and polysaccharides, the total content of which in red algae amounts up to 70%.

The main polysaccharides of most red algae are sulfated galactans, unique in its monosaccharide composition, since the monosaccharide 3,6-anhydrogalactose is encountered only in their molecules.

Small red algae are edible and very useful for a person due to the specificity of their composition. Residents of the Asia-Pacific region (Japan, Philippines, Indonesia, North Korea, et.al) eat red algae most readily. In these countries, the industrial cultivation of red algae for food purposes and hydrocolloids production is developed. Edible red algae is an ingredient for salads, condiments, side dishes to meat, first dishes – soup; it is consumed more rarely in its native form; red algae are eaten mostly in a dried and candied form.

Sulfated galactans of red algae are divided into agar and carrageenan that have different structure and physico-chemical properties. These polysaccharides are obtained from different species of red algae: agar – from agarophytes, carrageenan – from carrageenophytes.

In the food industry agar is used in the preparation of jellies, sauces, icings, confections and aspics. In breadmaking agar is used as a substance that improves texture, slows down bread staling. Many canned foods, syrups, mayonnaise, toppings and coatings for confectionery products are stabilized with agar.

The main consumer of carrageenan is the food industry, where it is used as a stabilizer, emulsifier and gelling agent for the production of confectionery, dairy products, soft cheese, dough, etc. Currently, over 150 products with carrageenan are produced, mainly dairy and confectionery products. The food industry uses 70% of carrageenan produced in the world [42].

The use of carrageenan in the baked goods formulation showed that the bread with such additive corresponds to the quality category of "excellent" [43].

Red algae are also used in the baking technology. Malaysian scientists introduced the powder of the Ahnfeltiared alga *Kappaphycus alvarezii* in the amount of 2-8%, which helped reducing the stickiness of dough, increase the water absorption ability of flour and gluten strength [44].

Another type of red algae, recommended by FEFU scientists as a supplement in bakery products to improve their consumer properties, is *Ahnfeltia tobuchiensis*. It was determined that in comparison with the control, the experimental samples of hearth bread with added Ahnfeltia had better elasticity and bigger amount of wet gluten, lower elongation; porosity, shape stability and the specific volume of the experimental samples increased [45].

Assessing the overall effect of algae – *Ahnfeltia tobuchiensis* and Costaria on the quality of bread, E.S. Smertina, L.N. Fedyanina recorded improving its organoleptic and physico-chemical indicators, as well as some adjustments to the technological parameters of low-quality flour, which is a positive factor. However, scientists have noted the dependence of identified effects on the amount of introduced algae. Thus, with added *Ahnfeltia tobuchiensis* in the amount of 2.5% to the flour weight, negative effect on the taste properties of the final product was observed, namely, an unpleasant taste of algae. Scientists recommend taking into account the found fact in further work to create bread with various algae.

Bread prepared with the addition of Ahnfeltia had a greater shelf life than the traditional one; changes in the organoleptic and physico-chemical parameters in such bread during storage were less noticeable. At the same time, Ahnfeltia had more effective influence on the freshness retention of bread during storage than Costaria, probably due to the fact that in the composition of Ahnfeltia tobuchiensis, agaroids are predominate, they slow down the process of retrogradation of gelatinized starch and eventually prevent intensive staling of bread [46-47].

The effect of bread with the red Nori algae from the Porphyra genus on the glycemic response of healthy volunteers was studied. As it turned out, the consumption of bread with sea algae altered the glycemic response of healthy volunteers from 100 to 68%, which showed its beneficial properties for human health.

When comparing the effect of this bread with the red algae *Chondrus crispus* and the bread with brown algae – *Undaria pinnatifida*, it was also shown that both types of bread reduce the glycemic response of healthy volunteers, but a more pronounced effect was registered with the use of bread with red algae [48].

Green algae are organisms with green thalli as chlorophylls dominate among the pigments present in their cells. The green algae, unlike other algae, accumulate the starch carbohydrate, which is deposited in chloroplasts.

The difference between them and the majority of farmed brown and red algae is in their very short life cycle, unpretentiousness to growing conditions, a positive response to the high content of nutrients in the environment of biogenic substances. Short cyclicality of the green algae determines their advantage over the brown and red ones, because it makes it possible to produce marketable products within a shorter period [49].

However, green algae, as well as their BAS, are in the least demand as FFI.

These include *Ulothrix, Ulva, Spirogyra* etc. People eat certain species, such as sea lettuce or Ulva.

Ulva or green sea lettuce is an edible plant, some countries introduced it into the culture and cultivate on marine farms. *Ulva* is used as a garnish for fish and meat dishes as well as salads, but only a few works that demonstrate the use of green algae in bread making are known.

We studied the physical and chemical characteristics and qualitative features of the bread with the green alga of the *Enteromorpha intenstinalis* type (*Chlorophyta* of the *Ulva* genus) added. To do this, 1-4% of the *E. intenstinalis* alga powder was mixed with flour. The content of 2% the *E. intestinalis* powder in flour showed the highest values of bread quality assessment by its physico-chemical and organoleptic characteristics [50].

Thus, the relevance and usefulness of using algae as FFI to make bread for medical and preventative purposes is beyond doubt. Consumption of bread with algae is a dietary support of the human body's vital functions; it improves its resistance to all adverse environmental factors. Of course, the problem of using algae in bread making has many unresolved and controversial issues in both theoretical and applied aspects.

But, in general, the direction of such work is aimed at solving the main problems of the modern nutritiology – development of the scientific bases of the production of qualitatively new, safe food products of general and special purposes, including medical and preventative.

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УТВЕРЖДАЮ
Проректор по науке и инновациям
_____ А.В.Цхе
«01» марта 2016 г.

ЗАКЛЮЧЕНИЕ
о возможности открытого опубликования

Руководствуясь Законом РФ «О государственной тайне», Перечнем сведений, отнесенных к государственной тайне, утвержденным Указом Президента РФ от 30 ноября 1995 г. № 1203, а также Перечнем сведений, подлежащих засекречиванию, Министерства образования и науки РФ, утвержденным приказом Министра образования и науки РФ от 10 ноября 2014 г., экспертная комиссия в составе:

1. Директор Школы биомедицины Ю.С. Хотимченко
2. Начальника Отдела интеллектуальной собственности М.И. Звонарева
3. Начальника Отдела защиты государственной тайны Н.А. Телицына
4. Начальника Отдела экспортного контроля В.П. Дикарева

в период с «25» февраля 2016 г. по «01» марта 2016 г. провела экспертизу материалов статьи «Modern tendencies and prospects of using algae as an ingredient for bakery products» (Современные тенденции и перспективы применения морских водорослей в качестве ингредиентов для хлебобулочных изделий)

(вид материала, подлежащего экспертизе – статья, учебное пособие, доклад, тезисы и т. д. и его название на русском языке)

авторов Смертиной Елены Семеновны, Школы экономики и менеджмента ДВФУ, Федяниной Людмилы Николаевны, Лях Владимира Алексеевича, Школы биомедицины ДВФУ, Чадовой Татьяны Владимировны, Школы экономики и менеджмента ДВФУ, Вершининой Анны Геннадьевны, Владивостокского государственного университета экономики и сервиса

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на предмет отсутствия в них сведений, составляющих государственную тайну, и возможности их открытого опубликования.

По результатам экспертизы комиссия установила:

Сведения, содержащиеся в рассматриваемых материалах статьи «Modern tendencies and prospects of using algae as an ingredient for bakery products» (Современные тенденции и перспективы применения морских водорослей в качестве ингредиентов для хлебобулочных изделий)

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