Production process of new generation energy gels based on brown seaweed Fucus

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Abstract. The article presents the innovative development of a fucus-based energy gel. The gel is easy to use during high physical activity and it does not cause a thirsty feeling after consumption. The polysaccharide fucoidan of fucus has antiseptic, immunomodulatory, blood thinning and many other properties. The innovative technology opens fucus cells without high temperature exploration and additional chemical agents. Thus, the entire spectrum of biopolymers, vitamins, macro- and microelements vital for the restoration and normal functioning of the human body becomes available. The latest technology developed for processing seaweeds can be used to produce energy gels for athletes.

1 Introduction

Plant-based functional nutrition is gaining increasing popularity every year. It is absolutely natural, since a healthy average person requires various substances to function and keep the immune system in good shape. At the same time, regular food often cannot satisfy all the body's needs. That is why new functional food products are currently appearing on the world market, majority of them are plant-based [1-6].

Seaweed can be used to prevent and treat a number of the so-called 'diseases of civilization', as well as to eliminate the effects of toxic substances on the human body [7-11]. Moreover, in some cases seaweed can be used as a raw material for production of certain goods. In others, seaweed derivatives are used as food additives that improve the quality of basic products by maintaining or improving their structure, taste, appearance and extending shelf life.

The significant reserves of fucus and kelps are concentrated in the coastal zones of Russia. These reserves can be renewed. In this regard, it is very relevant to develop the advanced technology for processing brown seaweeds to obtain functional food products.

Energy or sports gels are designed as food that provides energy for physical activity (running, triathlon and sports that require high energy expenditure). Replenishing carbohydrates is necessary to maintain the desired pace throughout the entire race, to avoid hitting the wall during a marathon, and even to accelerate at the finish line.

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Most runners are familiar with the signs of this exhaustion: heaviness and lethargy in the legs (glycogen stores in the muscles and liver run out), impaired concentration, irritability, and dizziness (blood glucose levels decrease, which affects the central nervous system). As a result, the heart rate increases, the pace decreases, and there is a risk of leaving the race [12]. That is why many athletes prefer energy gels, which are convenient to take over long distances. However, existing gels have a drawback: a feeling of thirst after consumption.

The research purpose is to develop the latest seaweed processing technology, which can be widely used in Russia for the production of energy gels for athletes. The relevance of the work is that a seaweed-base gel nourishes the body, and at the same time does not cause thirst after ingestion. The research is based on the advanced achievements of domestic biotechnology in the field of fucus processing, brown seaweed from the seas in the north of Russia [13-15].

The research has been on-going for five years. As a part of fucus, it was studied in detail and discovered a high biological activity of the polysaccharide fucoidan: antiseptic, immunomodulatory, blood thinning and its other properties.

Fucus is a real ‘casket’ of fucoidan (from 13% to 20%), much more than in other seaweeds, it contains a lot of macro- and microelements and iodine in optimal organic form [16].

However, there is a serious problem: fucus is almost inedible in its original form. Special equipment was developed to process seaweeds into an easily digestible gel form. The innovative technology opens fucus cells without high temperature exploration and additional chemical agents. Thus, the entire spectrum of biopolymers, vitamins, macro- and microelements vital for the restoration and normal functioning of the human body becomes available [13]. Fucus contains more than 53 useful elements in natural form. Sulfated heteropolysaccharide fucoidan has an antiviral effect; it regulates the work of the immune system. Of particular importance is the anticoagulant (anti-clotting) effect of fucoidan.

Fucoxanthin is a powerful antioxidant that protects our body from the harmful effects of ultraviolet rays, helps ‘burn’ fat, activating lipid metabolism. Alginic acid and its salts remove heavy metals and radionuclides from the body and have a regenerating and anti-inflammatory effect.

Organic iodine is involved in the synthesis of hormones, which are necessary to maintain and restore the thyroid functions.

Dietary fibres remove toxins and waste from the body and serve as a preventive measure for lipid metabolism disorders, atherosclerosis, diabetes mellitus, and gastrointestinal diseases.

Fucus contains such vitamins as B1, B2, B3, B6, B12, C, D, E, K, F, H, PP, pantothenic and folic acids and many others. For example, fucus contains 10 times more vitamin A than the same amount of carrots [17].

2 Materials and methods

The object of the study is algin hydrogels obtained from brown algae Fucus; gel-type and emulsion-type food systems based on hydrogels or mixtures thereof: alginic hydrogel – sugar – citric acid – potassium citrate. Standard and generally accepted chemical, physicochemical, organoleptic and mathematical methods were used during the experiment. Macro- and microelement composition was studied on a flame emission spectrophotometer ‘Nippon Jarrell Ash’ model AA-855 (Kovekovdova, Luchsheva, 1987), total content of nitrogenous substances – on a Kjeltec Auto Analyzer device (Tecator). The composition of the extracts and the molecular weight of alginate were analysed on a Shimadzu LS-6A liquid chromatograph (Japan) with a Shodex Asahipak GS-620 column. The strength of the gels was determined on a Valenta device at room temperature, two hours after obtaining the gels.

Statistical analysis of the results of experimental studies was carried out in three replicates using the least squares method and the Microsoft Office software package.

The determination of organoleptic, physicochemical and microbiological indicators of the quality and safety of raw materials was carried out in accordance with the state standards and regulations in food industry [18].

3 Results and discussions

The starting material (Fucus seaweed) harvested at the bottom of the sea requires a special processing to remove a layer of mucus with microorganisms and foreign impurities from the seaweed surface. Rinsing with ozonated distilled water ensures compliance with strict sanitary standards. Then the raw materials are transformed in a special rotary homogenizer under the influence of cavitation and hydraulic shock without the use of chemical reagents and high temperatures. As a result of this process, the strong cell walls are destroyed, and the components of seaweed cells become accessible. Thus, all vital for disease prevention and the human body functioning bioactive compounds of fucus become available. They are easily absorbed by the body due to the transition to their native (as in a living cell) form, therefore therapeutic and dietetic products containing such ‘living’ cells are effective in the complex therapy of some serious diseases.

A study of the kinetics of alginate extraction (Figure 1) at a temperature of 60-90ºC for 4 hours showed that the process takes place in two stages. The first stage is the actual extraction; the second one is diffusion equilibrium. It has been specified that the first stage lasts 10-15 min. at 80-90ºC and 30 min. at 60ºC. The extraction rate at the 1st stage is determined mainly by temperature. The second stage duration is determined by the onset of diffusion equilibrium, which is reached in 60 min. at 80-90ºC and in 150 min. at 60-70ºC.

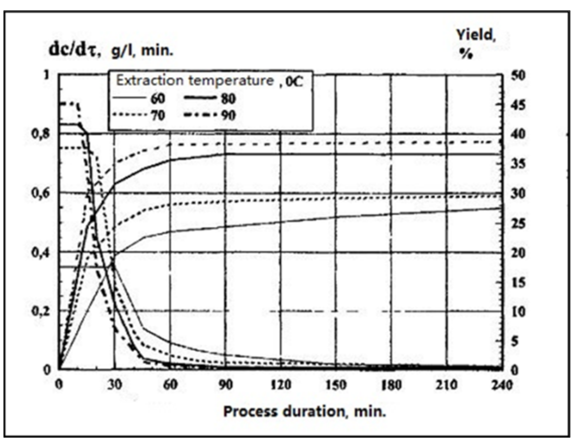

Fig. 1. Effect of temperature on extraction rate and alginate yield.

At the second stage, a significant decrease in the extraction rate is observed. On the one hand, this result relates to the internal mass transfer of the polysaccharide. On the other hand, it occurs due to a decrease in the driving force of the process – the difference of polysaccharide concentrations in seaweed and in solution. The alginate yield was 27.6% at an extraction temperature of 60^{0}C, 36.0% at 80^{0}C and 38.8% at 90^{0}C.

A chromatographic study of the extracts has shown that at 60-80^{0}C, the destruction of alginate practically does not occur. Extraction at 90^{0}C leads to thermal destruction of the polysaccharide and, as a consequence, to an increase in its polydispersity, as evidenced by two small additional peaks in the chromatogram (Figure 2, a). Determination of the molecular weight of alginate has shown that the peaks correspond to alginate fractions with a molecular weight of 2000 and 1100 kDa. In this case, the destruction of alginate begins within the first 30 min. and continues throughout the entire extraction (Figure 2, b).

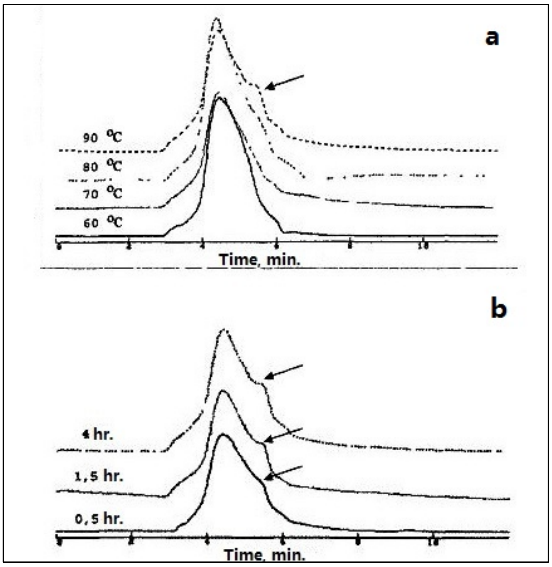

Fig. 2. Chromatograms of alginate extracts obtained at different temperatures and an extraction duration of 4 hours (a), at 90^{0}C and an extraction duration of 0.5 hours (b).

Based on the data obtained, and taking into account the maximum degree of extraction, we have determined the rational parameters for alginate release: temperature – 80^{0}C, hydromodulus – 1:40, duration – 1 hour. These conditions provide extraction of up to 95% of the content in seaweed with a molecular weight of 2000 kDa. The resulting alginate extract was conventionally called alginate hydrogel.

At the next stage, we have studied the effect of the concentration of calcium chloride in the precipitation mixture on the yield and physicochemical properties of algin hydrogels. When developing a technology for producing an algin hydrogel with maximum viscosity, we have researched the possibility of regulating the content of calcium cations in the algin hydrogel at the stage of alginic acid precipitation with a mixture of solutions of hydrochloric acid (10%) and calcium chloride. At the final production stage, the products go through soft pasteurization and then are packed and sealed. The technological process ensures the sterility and safety of products and meets the strict standards of pharmaceutical companies.

The technological scheme for the algin-based energy gel from fucus occurs in several stages, which are presented in Figure 3.

The gel production is carried out in the following sequence: weighing the necessary ingredients, removing impurities from water, raw materials homogenization, sending the resulting mixture to the reactor, adding thickeners, dyes, fragrances and preservatives, packaging process and quality control.

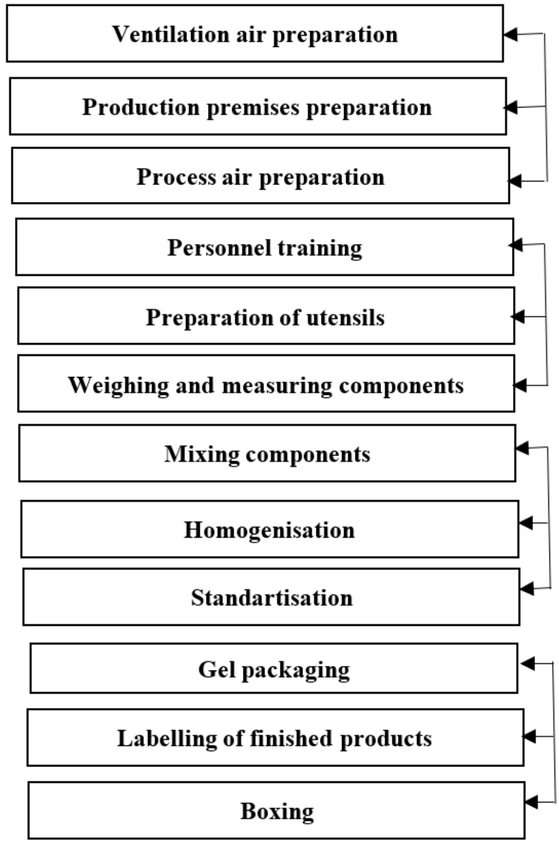

Fig. 3. Process flow diagram for the production of algin-based energy gel from fucus.

The energy gel contains the necessary amount of carbohydrates required for long-term exercise. Thus, its main potential consumers are athletes (in particular, runners), cosmonauts, and military personnel. The fucus energy gel has a large number of advantages in comparison with similar products. Comparative characteristics are presented in Table 1.

Table 1. Comparative characteristics of the fucus energy gel and other similar products.

Gel	Characteristics
Isostar	Carbohydrate gel containing caffeine. The price varies from 170 to 200 rubles. It has a thick consistency, must be washed down with water.
Nutrend	Carbohydrate gel from a Czech manufacturer contains caffeine. The price ranges from 150 to 200 rubles. The consistency is quite thick, with an unusual chemical taste; it must be washed down with water.
Mulebar	British made carbohydrate gel, the price is about 200 rubles. The manufacturer claims that gel's composition is natural, but it must be washed down with water.
Fucus gel	Carbohydrate gel, the price varies from 60 to 70 rubles. Contains a natural composition with the addition of fucus seaweed. No need to wash it down with water.

4 Conclusion

Fucus contains a lot of macro- and microelements, iodine in optimal organic form and fucoidan (significantly more than other seaweeds), but it is almost inedible in its original form. We have developed special equipment for processing brown seaweed Fucus into an easily digestible gel form. The innovative technology opens fucus cells without high temperature exploration and additional chemical agents. Thus, the entire spectrum of biopolymers, vitamins, macro- and microelements vital for the restoration and normal functioning of the human body becomes available. This technology can be widely used in Russia for the production of energy gels for athletes, cosmonauts, and military personnel. Gels have a number of useful properties; they are convenient for use during high physical activity. The fucus-based gel has a distinctive advantage: it not only nourishes the body, but also does not cause a thirsty feeling after consumption.

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