

Spirulina as a protein ingredient in a sports nutrition drink

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Abstract. *The purpose of the article is to justify the possibility of using spirulina as a protein ingredient in the drink for students playing volleyball. A growing organism of students with high physical activity requires a protein of balanced composition. Materials and methods. Spirulina powder from the manufacturer was purchased in a specialized store. The amino acid content of spirulina proteins was studied using the AAA-339 amino acid analyzer. To determine the biological value of spirulina proteins, a calculation method was used. The study of the antioxidant activity (AOA) of an aqueous extract of spirulina was carried out by in vitro autooxidation of adrenaline in an alkaline medium. The accumulation of adrenaline-quinone was recorded using a UV 1700 spectrophotometer (Shimadzu) at a wavelength of 347 nm. Results. Spirulina proteins have been shown to contain all the essential amino acids. The calculated values of the amino acid scores — correlations of the essential amino acids in the studied product and the so-called "ideal" protein — allow us to make a conclusion about the high biological value of microalgae proteins. It was found that water extracts of spirulina powder exhibit antioxidant activity due to the presence of substances of a reducing nature (polyphenols, bioflavonoids, phycocyanide and chlorophyll pigments). The dosage of spirulina in the smoothie based on a comprehensive quality assessment is justified. The formulation and technology of a protein fruit and berry drink have been developed. An assessment of the nutritional value of the product for athletes has been conducted in accordance with the reference values for their physiological needs. Spirulina drinks were tested at the Department of Valeology of the Siberian Federal University among students involved in volleyball.*

Conclusion *The main results of scientific research include: the quantitative and qualitative composition of the spirulina protein, the antioxidant activity of spirulina powder, the formulation and technology of a protein fruit and berry drink with spirulina, which contains both proteins and a vitamin and mineral complex that provide increased nutritional and biological value of the drink for sports nutrition.*

Key words - spirulina, proteins, amino acid score, biological value of proteins, antioxidant activity, drink for sports nutrition.

I. INTRODUCTION

The problem of creating and producing specialized drinks for people who are actively involved in sports and fitness remains relevant and is actively discussed in scientific publications [1,2]. Specialized clinical trials motivate the creation of innovative technological developments that systematically replenish the assortment of drinks for sports nutrition. According to ISSN - the International Society for Sports Nutrition - such drinks are classified as hypotonic (restoring water balance), hypertonic (replenishing energy)

and isotonic (containing nutrients and vitamin and mineral complexes) [3].

Universal isotonic drinks may contain functional ingredients, for example, protein (for the formation and maintenance of muscle mass) or bioflavonoids (antioxidants that prevent oxidative processes) [4,5,6]. When creating protein-containing drinks and choosing a protein ingredient, which is determined primarily by nutritional value and degree of assimilation, manufacturers prefer whey protein (48%), casein (22%), whey-casein protein (18%), soy protein (8%) and egg protein (4%) [7].

An alternative protein source can be a multicellular filamentous microalgae - spirulina (Spirulina Platensis), the protein content of which in dry powder reaches 57% [8, 9]. The results of a study of the chemical and biochemical properties of microalgae made it possible to add spirulina in products with unique properties. Being a hydrobiont, spirulina turned out to be a source of protein, as well as $\omega 3$ and $\omega 6$ polyunsaturated fatty acids [10].

A number of sources indicate that the use of spirulina in nutrition leads to general health improvement, increase immunity, and reduce the risks of oncology and cardiovascular pathologies [11,12]. Clinical studies have not revealed the toxicological effect of spirulina on humans and animals, including the replacement of animal protein by 60% of the daily norm with spirulina proteins [12]. It has been shown that during exercise, the use of spirulina increases muscle endurance by 20-30% compared with the placebo group [13].

Nevertheless, despite the recognized useful chemical composition and the revealed non-toxicity, there are no data on the use of spirulina in complex sports nutrition.

The aim of the study was to justify the possibility of using spirulina as a protein ingredient in drinks for athletes.

II. MATERIALS AND METHODS

The rationale for the selection of the ingredients that make up the product for volleyball players is the physiological need of athletes for essential food substances and organoleptic characteristics of the products. Due to the fact that the diet of athletes is characterized by a lack of protein of plant origin, vitamins, and antioxidants, the authors selected spirulina, fruits, and wild berries that grow in the Krasnoyarsk Krai as sources of biologically active substances. Spirulina powder was purchased in a specialized store. The amino acid content of the spirulina protein was determined using the AAA-339 amino acid analyzer (Czech Republic) according to the

procedure [14]. To determine the biological value of spirulina proteins, a calculation method was used [15]. To study the antioxidant activity (AOA) of an aqueous extract of spirulina, an in vitro method of autooxidation of adrenaline in an alkaline medium was used [16]. The AOA assessment method is based on the ability of biologically active substances to inhibit the action of superoxide radicals during autooxidation of adrenaline. The process of autooxidation of adrenaline is a model reaction of quinoid oxidation that proceeds through a series of intermediate stages with the formation of the final adrenochrome product. The accumulation of an adrenaline autooxidation intermediate product — adrenalinequinone — was recorded using a UV 1700 spectrophotometer (Shimadzu) at a wavelength of 347 nm.

The quantitative content of spirulina in a protein fruit and berry drink was determined with comprehensive quality assessment by organoleptic indicators [17, 18]. The nutritional value of the drink for sports nutrition was estimated using the calculation method [19].

III. RESULTS AND DISCUSSION

The protein content in the dry powder of spirulina is 57.47g/100g or 77% of the daily norm (DN) of protein, which puts algae on the 6th place among protein-containing products after whey proteins, egg white, gluten and concentrated soybean powders, including isolates [7].

Using an amino acid analyzer, the presence of 23 free and bound amino acids was determined in spirulina proteins, of which eight are essential and two partially essential. The nutritional value of the studied protein was estimated by determining its amino acid score being the ratio of the content of each of the essential amino acids to the amount of this amino acid in 100 g of the "ideal protein" (ACi, %) (Table 1).

It is estimated that the biological value of spirulina proteins was 61.67%. For information, soy isolate, which ranks first in terms of protein content, has a biological value of 62.16%. For comparison: the biological value of animal proteins - boiled eggs (66%) and boiled beef (74%) - is not much higher. The utilitarian coefficient (0.89) indicates a good degree of assimilation of spirulina protein by the body.

TABLE 1. BIOLOGICAL VALUE OF SPIRULINA PROTEINS

Amino acid	Content, Spirulina g/100 g	Content, Spirulina protein g/100 g	Content, "ideal" protein g/100 g	ACi, %
(Val) Valine	3.512	6.11	5	122.2
(Ile) Isoleucine	3.209	5.58	4	139.5
(Leu) Leucine	4.947	8.61	7	123.0
(Lys) Lysine	3.025	5.26	5.5	105.2
(Met+Cys) Methionine + Cysteine	1.811	3.15	3.5	90
(Thr) Threonine	2.970	5.17	4	129.25
(Trp) Tryptophan	0.929	1.62	1	162.0
(Phe+Tyr) Phenylalanine+ Tyrosine	5.361	9.33	6	155.5

Figure 1 shows a profile, which, with few exceptions, reflects an almost identical correlation between the content of essential amino acids in the "ideal" protein and spirulina protein.

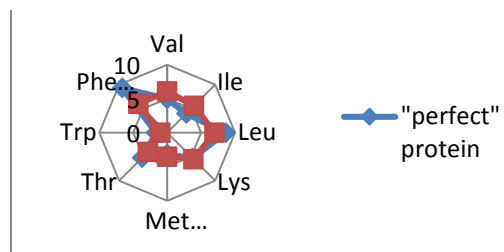


Fig. 1. The ratio of the content of essential amino acids in the "ideal" protein and spirulina protein, g/100 g

The antioxidant activity (AOA) of spirulina powder was assessed by the ability of its aqueous extract to inhibit the autooxidation of adrenaline and thereby prevent the formation of active forms of hydroxy radicals in solution (Fig. 2).

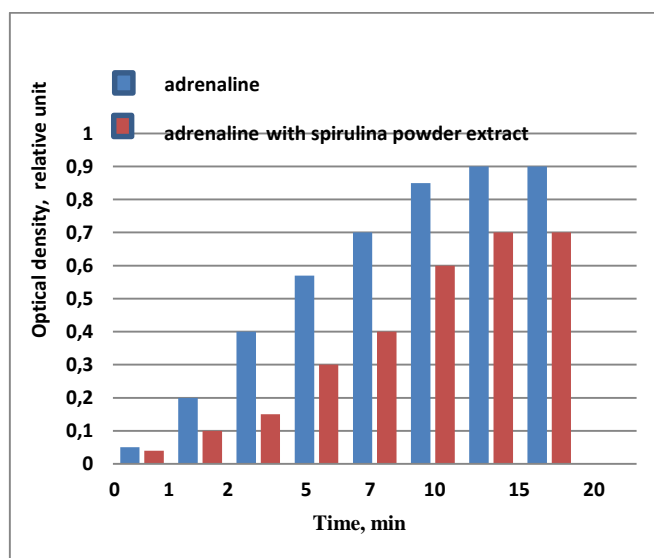


Fig. 2. Change in optical density at 347 nm of adrenaline solution in the presence of spirulina powder extract

The maximum effect of spirulina extract on autooxidation of adrenaline was detected at exposure time of 3 and 5 minutes: 73.0% and 64.2%, respectively.

With an increase in the exposure time, the antioxidant effect of the extract decreases, since multiple oxidative processes begin to occur in vitro under the influence of atmospheric oxygen.

The experimental data indicate a high AOA of an aqueous extract of spirulina. The manifestation of the antioxidant activity of spirulina is affected by the presence of polyphenolic compounds with reducing properties: blue and

green pigments phycocyanin and chlorophyll, polyphenols, bioflavonoids, ascorbic acid, tannins [20].

Data on the high biological value of spirulina proteins and its antioxidant properties were the basis for creating a protein drink for volleyball players.

When developing the formulation and technology for a protein drink, the chemical composition of biologically active substances and the consumer properties of the products were taken into account. The following products were chosen for a drink: spirulina, natural yogurt (sources of protein of plant and animal origin), fruits with pulp, berries (carbohydrates, sources of dietary fiber, bioflavonoids, chlorophyll, vitamins and minerals).

Smoothie was chosen as a drink - a thick drink based on fruit and berry, vegetable raw materials with the addition of honey, nuts, spices, etc. Nowadays, smoothies are sold both in retail and catering establishments, especially in those based on the concept of healthy eating.

For an athlete, the main properties of food products are not only organoleptic indicators, but also a balanced composition of biologically active substances in the daily diet. During training, the athlete's body consumes a large amount of energy, nutrients, so a smoothie will allow athletes to restore their proteins, micro and macro elements, vitamins, which will increase physical stamina and effectiveness in achieving sports goals.

To determine the dosage of spirulina in the composition of the smoothie, 3 samples were prepared: No 1 with 1.5 g per 100 g of drink, No 2 with 2 g per 100 g of a drink, No 3 with 2.5 g per 100 g of a drink.

TABLE 2. RECIPES OF FRUIT AND BERRY SMOOTHIE WITH SPIRULINA

Raw materials	Fraction of dry matter, %	The consumption of raw materials, g		
		Sample 1 1.5 g / 100 g	Sample 2 2.0 g / 100 g	Sample 3 2.5 g / 100 g
Banana	25.09	70.0	70.0	70.0
Lingonberry	13.0	12.0	11.0	8.75
Bog blueberry	12.3	7.25	8.0	8.0
Blueberry	14.0	7.0	7.0	7.0
Spirulina	95.32	3.75	5.00	6.25
Total	-	100	100	100
Natural yogurt	12.7	150.0	150.0	150.0
Finished product		250	250	250

As a result of a comprehensive quality assessment of the fruit and berry smoothie with spirulina, it was found that smoothie No. 1 scored an intermediate number of points between the first and second samples in terms of appearance, color and taste. Sample No 1 had a dirty brownish-green color, although the taste of the drink was quite pleasant. The least number of points in terms of organoleptic indicators had sample No 3 because of its dark violet-green color and some extraneous taste. The maximum number of points experts (volleyball players of the Siberian Federal University) gave to sample No 2 with 2 g of spirulina per 100 g of fruit and berry smoothie. The developed drink has a pleasant violet-lilac color and harmonious taste without extraneous smell and

aftertaste. Figure 3 shows the results of evaluating the organoleptic characteristics of the samples.

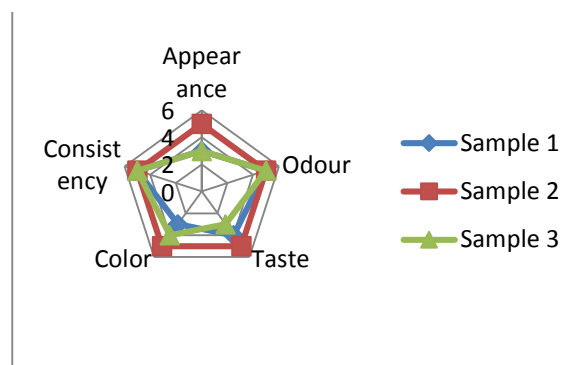


Fig. 3. Profile of organoleptic assessment of a drink for sports nutrition

Figure 4 shows the technological scheme for preparing a drink for sports nutrition.

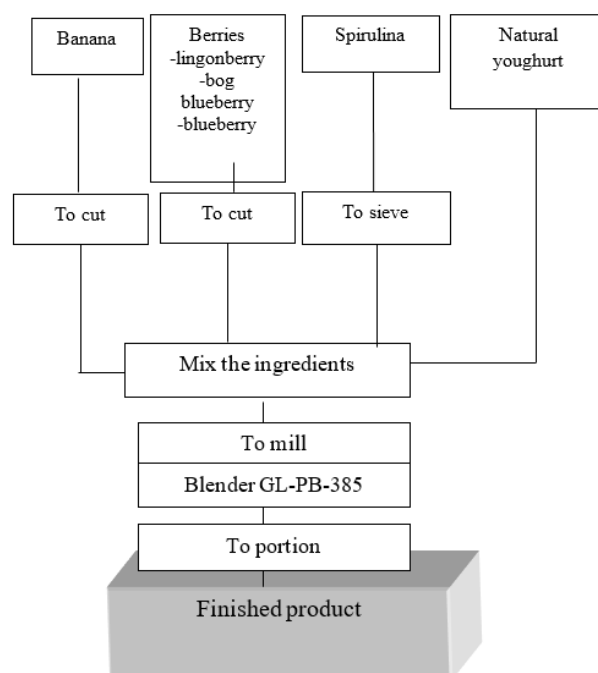


Fig. 4 Technological scheme for preparing a drink for sports nutrition

Table 3 shows the chemical composition of a fruit and berry drink with spirulina and its nutritional value.

TABLE 3. NUTRITIONAL VALUE OF FRUIT-BERRY DRINK WITH SPIRULINA

Chemical composition		Fruit and berry smoothie with spirulina	
		Content	% of daily needs
Proteins, g/100 g		11.73 ± 0.28	13.03
Lipids, g/100 g		0.80 ± 0.04	1.0
Carbohydrates, g/100 g		17.60 ± 0.88	4.9
Dietary fibers, g/100 g		1.71 ± 0.09	8.6
Vitamins	B ₁ , mg/100 g	0.98 ± 0.49	65.0
	B ₂ , mg/100 g	0.06 ± 0.01	3.3
	B ₃ , mg/100 g	0.99 ± 0.05	5.0
	B ₄ , mg/100 g	0.26 ± 0.01	13.0
	B ₅ , mg/100 g	0.03 ± 0.01	0.6
	B ₉ , ug/100 g	1.69 ± 0.08	33.8
	C, mg/100 g	10.33 ± 0.52	11.5
	A, ug/100 g	17.11 ± 0.85	1.9
	E, mg/100 g	0.52 ± 0.03	3.8
Micro- and macroelements	K, mg/100 g	266.82 ± 13.34	10.7
	Na, mg/100 g	26.46 ± 1.32	2.0
	Ca, mg/100 g	11.32 ± 0.57	1.1
	Mg, mg/100 g	31.94 ± 1.60	8.0
	Fe, mg/100 g	0.69 ± 0.03	3.83
	P, mg/100 g	21.07 ± 1.05	2.6
	Zn, mg/100 g	0.11 ± 0.01	0.9
	Cu, ug/100 g	0.02 ± 0.01	0.0
	Mn, mg/100 g	0.98 ± 0.05	49.0
	Se, ug/100 g	0.7 ± 0.04	1.0
	J, ug/100 g	0.02 ± 0.01	0.1
	F, ug/100 g	1.54 ± 0.08	0.0
	S, mg/100 g	0.03 ± 0.01	0.0

The analysis of the data in table 3 revealed that the developed drink can be considered as a source of protein, vitamins (B₁, B₉), mineral substances (Mn) and a low-fat product. The use of 250 g of a drink in the athlete's diet allows satisfying the need of protein by 32.5%, carbohydrates by 12.25%, dietary fiber by 21.5%, vitamin B₄ by 32.5%, vitamin C by 28.8 %, minerals: potassium by 26.8%, magnesium by 20%.

Thus, studies on the formulation and evaluation of the nutritional value of a fruit and berry drink with spirulina suggest that the new product can be positioned as a sports nutrition product for increased physical activity.

The next stage of the study was the testing of a drink with spirulina in the diet of students actively involved in sports at the Department of Valeology of the Siberian Federal University (SFU).

As a result of the experiment, an improvement was found in the competitive activity of athletes who regularly used a fruit and berry drink with spirulina as part of their daily diet. Male volleyball players participating in the championships in volleyball increased their competitive performance and won more matches.

This allows to recommend a fruit and berry drink with spirulina for sports nutrition. In accordance with the results of the study, we can conclude that the use of a drink with spirulina in the diet of athletes is one of the most important factors in increasing their endurance and performance.

IV. CONCLUSION

The study showed that spirulina microalgae can be used as a protein ingredient for drinks: *Spirulina Platensis* proteins

are characterized by a good degree of assimilation. Spirulina powder extracts have been shown to exhibit high antioxidant activity. The formulation and technology for a fruit and berry drink with spirulina are developed. After testing the drink among athletes of SFU, it is recommended for industrial production. It is also recommended as a means of promoting healthy nutrition and attracting young people to sports nutrition without prohibited drugs. The positive effect of the developed drink containing protein and a vitamin-mineral complex on the improvement of competitive activity was noted.

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