# Evaluation of the antioxidant status and design of the diet for sports nutrition

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**Abstract.** The article considers the possibility of developing a diet that provides an athlete with an adequate level of biologically active substances with an antioxidant effect. The losses of the total content of antioxidants in the composition of food products of plant origin during heat treatment in a steam convection apparatus were determined and amounted to 16.9 in heat-treated beets; 14.8% in cabbage; 34.6% in potatoes and carrots; 20.5% in onion; 22.7% in root celery; 23.5% in tomato paste; 48.5% in oatmeal; 29.9% in buckwheat. The calculation of the total antioxidant content in culinary products from vegetables and cereals showed that serving a traditional dish can provide from 1.5% to 5.7% of the recommended daily requirements (1094 mg/day) in antioxidants. The combination of vegetables with prunes and blueberries made it possible to obtain products with a functionally significant content of antioxidants. A daily diet for athletes of cyclic sports in the recovery stage of training with a calorie content of 4000 kcal was developed. The diet provides 145% of the adequate intake of antioxidants for a healthy adult. The results obtained confirm the position of many sports nutritionists that a well-balanced diet, proper selection of food products, and innovative methods of heat treatment can provide an athlete with an adequate amount of antioxidants.

## 1 Introduction

Nowadays many scientists are interested in studying antioxidants and their role in human metabolism. It should be noted that there are different opinions on this issue. This is especially true for the issue of the efficacy of natural food antioxidants compared to chemically synthesized ones. Therefore, the most important issue is to study the mechanism of interaction between antioxidants and reactive oxygen species, which is important for athletes who experience heavy loads.

The specificity of pre-competitive, competitive and recovery activities of professional athletes is associated with the need for biochemical adaptation of the body to physical and

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neuro-emotional stress, accompanied by complex metabolic processes, including an increase in the level of free radical oxidation reactions and the accumulation of toxins [1].

Professional medicine has accumulated sufficient experimental and clinical material on the effect of dietary antioxidants on the negative effects of oxidative stress accompanied by excessive formation of reactive oxygen species during intense physical and emotional exertion. In this case there is an activation of lipid peroxidation processes against the background of a decrease in antioxidant function and the appearance of symptoms of an illness state. Under these conditions, antioxidants prevent lipid peroxidation (LPO), which leads to a violation of the integrity of the membranes and, as a result, the full flow of all types of metabolism. Their utilization allows maintaining the antioxidant defense system (ADS) at the required level, blocking free radical oxidation reactions, providing a reserve of adaptive mechanisms [2, 3]. Antioxidants are important primarily for athletes involved in speed-strength sports, as well as sports that require endurance: long-distance running (skiers, marathon runners), swimming, rowing, since physical activity causes an increase in oxidative metabolism [4].

Modern science has determined the important role of some food bioregulators that are actively involved in the metabolic processes of the body [5]. Bioregulators of the balance of the antioxidant system, which coordinates various functions of the human body, include natural food antioxidants , including vitamins, steroid and protein hormones, neurotransmitters, nucleotides, prostaglandins, plant pigments, and other biologically active compounds (BAC) [6]. Foods of plant origin contain mainly non-enzymatic antioxidants: vitamins A, E, C, minerals (zinc and selenium), peptides (glutathione), phenolic acids as well as polyphenols, sulfur compounds, lignin and phytic acid [7, 8].

Advances in modern chemistry allow many biologically active compounds to be synthesized, such as water- and fat-soluble vitamins. In terms of chemistry, synthesized vitamins are identical to those contained in fruits and vegetables. To correct the diets and provide the body of athletes with an adequate level of biologically active components of the antioxidant action, it is recommended to use vitamin-mineral complexes or biologically active additives [9-11].

However, it should be noted that when some antioxidants are combined with other compounds obtained by chemical synthesis, both synergistic and inhibitory effects can be observed in food additives. Therefore, a number of studies have noted a safer and more intense protective effect on the body of natural vegetables, fruits, which by nature incorporated the optimal content and combination of biologically active substances [12, 13]. This can be exampled by the Mediterranean diet, which includes fruits, vegetables, and olive oil with high content of antioxidants [14]. Several researchers have shown that cereal products can also make a significant contribution to the daily intake of antioxidants. For example, in Norway, 11.7% of plant antioxidants come from grain products, while fruits, berries and vegetables account for 43.6%; 27.1 and 8.9%, respectively [15].

The main and most effective antioxidants of plant foods are natural water-soluble phenolic compounds: representatives of phenolic acids, flavonoids, polymeric phenolic compounds and stilbenes [16]. Fruits, vegetables, berries, honey, tea have a natural combination of bioflavonoids that are dozens of times more effective than vitamins C, E, and carotenoids. [17].

The main antioxidants in whole grains are hydroxy aromatic acids [18]. Oats contain avenanthramides, buckwheat grains contain rutins, winter varieties of rye, wheat, barley and oats contain lignans (a class of phytoestrogens) [19-21]. Polyphenol levels found in an average serving of oatmeal are comparable to those found in an equivalent amount of fruits and vegetables [22].

Fat-soluble compounds with antioxidant activity include tocopherols, carotenoids, and retinol. Fat-soluble antioxidants protect biomembranes and their lipid structures from free radicals. Sulfur-containing bioactive compounds of onion (sulfides) inhibit the growth of cancer cells, stimulate the activity of detoxifying enzymes, strengthen the body's immune system and protect it from oxidative damage [23]. The scientific literature provides data on the antioxidant effect of the beetroot betalain pigments [24]. Thus, plant foods contain hundreds of different antioxidants, and free radical removal is related to their cumulative effect. The total antioxidant content in plant products was considered in [15].

The problem of choosing a criterion for assessing the level of antioxidant activity of an athlete's diet is explained by fact that the recommended daily intake level is set for individual food and biologically active substances. Daily physiological requirements are set for vitamins C, E, beta-carotene, and selenium. For the first time, adequate levels of consumption of phenolic compounds for an adult healthy person were introduced (Table 1) [16]. For athletes involved in cyclic sports, it is planned to increase the daily intake of vitamins by 3–4 times. Therefore, the need for vitamin C is 150-350 mg, the need for vitamin A is 2.8-3.8 mg, the need for vitamin E is 28-45 mg. There are no recommendations for an adequate intake of phenolic compounds. At the same time, it is necessary to pay attention to the fact that an excessive amount of antioxidants can lead to inhibition of many fundamental metabolic processes in the body, especially those associated with the generation of bioenergy [26].

To assess the antioxidant activity of the diet in this work, the authors used the total content of substances with antioxidant action recommended for a healthy adult. It is about 1094 mg per day, of which 11% are vitamins. The total tolerable upper intake level is 2535 mg.

**Table 1.** Recommended levels of daily intake of biologically active substances with antioxidant action.

| Biologically active food components | Units | Physiological requirement Adequate Intake for a Healthy Adult* [16] | Upper Tolerable Intake Level [25] |
|---|---|---|---|
| Vitamin C | mg | 100 | 700 |
| Beta carotene | mg | 5 | 10 |
| Vitamin E | mg tocoph. equiv | 15 | 100 |
| Selenium | mkg | 70 | 150 |
| *Phenolic compounds in total:* | | *974* | *1725* |
| phenolic acids | mg | 250 | 320 |
| flavonols | mg | 30 | 100 |
| flavanones | mg | 30 | 300 |
| flavan-3-ols | mg | 200 | 100 |
| flavones | mg | 10 | 15 |
| anthocyanins | mg | 50 | 150 |
| isoflavones (isoflavones) | mg | 2 | 100 |
| tannins | mg | 400 | 600 |
| stilbene | mg | 2 | 40 |

*For vitamins and selenium the physiological requirements, and for phenolic compounds an adequate intake level are given

As part of ready meals, foods of plant origin are included in the daily diet of an athlete. They provide the body not only with macro- and micronutrients (carbohydrates, vegetable proteins and fats, vitamins and minerals), but also with minor biologically active substances with antioxidant activity. In this regard, evaluation of the total content of antioxidants in the daily food of an athlete is a prerequisite for correcting the antioxidant status of the diet.

The purpose of this study was to assess the total antioxidant activity of food products, taking into account losses during differentiated processing of raw materials and semi-finished products and the daily diet of athletes during the recovery period.

To achieve this goal, the following tasks are to be solved:

• Determination of losses of total antioxidant activity (TAA) in the composition of food products of plant origin during heat treatment in a steam convection apparatus;

• Calculation of the total content of antioxidants in culinary products and the daily diet of athletes, taking into account the physiological need for energy and nutrients.

## 2 Materials and methods

The objects of the study were chosen as high consumer demand and economically affordable plant products included in the daily diet in raw and thermally processed forms:

• Commodity batches of fresh vegetables (beetroot GOST 32285, food potatoes GOST 7176, white cabbage GOST 33494, table carrot GOST 33540, onion GOST 34306, celery root GOST 34320; tomato paste with a mass fraction of solids of at least 25% GOST 3343, oat flakes "Hercules" GOST 21149; buckwheat groats GOST R 55290),

• Thermally processed vegetables according to the following technology:

- beetroot in slices of 0.8–1.0 cm (*sample 1*);
- cabbage in squares of 1.0–1.2 cm (*sample 2*);
- potatoes in cubes of 1.2–1.5 cm (*sample 3*);
- carrots in small cubes of 0.6–0.8 cm (*sample 4*);
- onion in small cubes of 0.6–0.8 cm (*sample 5*);
- celery root in small cubes of 0.3–0.5 cm (*sample 6*);
- the tomato paste (*sample 7*) was packed using a JDZ-260/PD vacuum packer in sealed bags and subjected to heat treatment in Fagor HMM-6/11 combi oven at a temperature of 98 ºC, humidity of 90%,

• The viscous porridge made from oatmeal (*sample 8*) and the buckwheat (*sample 9*) with the addition of water (water ratio 1:3.2–3.7).

To determine the TAA in fresh and thermally processed vegetables, the coulometric method was used in accordance with the certified method (MVI.01-44538054-07) using the Expert-006 serial coulometer [27]. To determine the TAA in cereals, the amperometric method was used, based on measuring electric current flowing during the electrochemical oxidation of the test substance on the electrode surface at a certain potential. Quercetin solution was used as a standard substance [28].

The TAA losses was calculated taking into account the weight of the raw material and the finished dish or (product) after heat treatment [29].

The authors used a method for calculating nutrient content based on their original studies, reference tables and scientific publications on the chemical composition of Russian food products [27, 30].

## 3 Results and discussion

Total antioxidant activity in the plant objects before and after heat treatment is shown in Table 2.

**Table 2.** TAA in plant objects before and after heat treatment.

| Sample No. | Ingredient | TAA, mg equiv. by ascorbic acid/g | |
|---|---|---|---|
| | | before heat treatment | after heat treatment |
| 1 | Beetroot stewed in a vacuum bag | 0.42±0.04 | 0.35± 0.04 |
| 2 | White cabbage blanched in a vacuum bag | 0.27±0.02 | 0.23± 0.02 |
| 3 | Potatoes blanched in a vacuum bag | 0.26±0.02 | 0.17± 0.02 |
| 4 | Carrots sauteed in a vacuum bag | 0.16±0.01 | 0.104± 0.004 |
| 5 | Onion sauteed in a vacuum bag | 0.30±0.02 | 0.24± 0.02 |
| 6 | Root celery sauteed in a vacuum bag | 0.22±0.02 | 0.17± 0.02 |
| 7 | Tomato paste sauteed in a vacuum bag | 0.98±0.03 | 0.75± 0.03 |
| 8 | Oat flakes "Hercules" / viscous porridge | 0.57±0.04* | 0.092±0.007* |
| 9 | Buckwheat / viscous porridge | 0.76±0.06* | 0.213±0.015* |

* Data in mg equiv. for quercetin

The data in Table 2 shows that the heat treatment of vegetables packed in vacuum bags results in a decrease in TAA compared to the original fresh products. TAA losses amounted to 16.9 in heat-treated beets; 14.8% in cabbage; 34.6% in potatoes and carrots; 20.5% in onion; 22.7% in root celery; 23.5% in tomato paste. It should noted that the heat treatment of vegetable semi-finished products, pre-packed in sealed polymer bags, almost completely reduces the loss of mass fraction of solids and mass of products, due to their isolation from the environment. The loss of antioxidants in oatmeal "Hercules" after heat treatment amounted to 48.5%, and it amounted to 29.9% in buckwheat. A significant decrease in TAA in cereals is due to their thermal destruction and oxidation.

Data on the content of antioxidants in raw and thermally processed foods was used to calculate the TAA in culinary products from vegetables and cereals (cold appetizers, salads, soups, hot dishes). Information on TAA in other food products was obtained from the other sources: 90 mg in vegetable oil, 270 mg in garlic, 180 mg in walnut, 85 mg in cheese, 1400 mg in parsley, 50 mg in milk, 40 mg in butter, 350 mg in prunes per 100 g of the product [31]. The results of calculating TAA in culinary products are given in Table 3.

**Table 3.** TAA in culinary products from vegetables and cereals.

| Name of culinary products | Weight, g | TAA, mg | % of RDR* |
|---|---|---|---|
| Vinegret | 100 | 23.3 | 2.1 |
| Beet pasta | 100 | 46.0 | 4.2 |
| Carrot pasta | 100 | 27.3 | 2.5 |
| White cabbage salad with beets and carrots | 100 | 32.9 | 3.0 |
| Beet salad with prunes, nuts and garlic | 100 | 83.9 | 7.6 |
| Beet salad with cheese and garlic | 100 | 51.8 | 4.7 |
| Beetroot salad | 100 | 35.3 | 3.2 |
| Borsch | 300 | 37.5 | 3.4 |
| Carrot soup | 300 | 35.9 | 3.3 |
| Soup with buckwheat | 300 | 53.4 | 4.9 |
| Buckwheat porridge with butter | 205 | 56.4 | 5.1 |
| Oatmeal porridge "Hercules" with carrots | 250 | 43.4 | 3.9 |
| Beets stewed in sour cream | 150 | 62.4 | 5.7 |
| Carrots stewed with prunes | 150 | 122.5 | 11.1 |

| | | | |
|---|---|---|---|
| Carrot puree | 150 | 17.1 | 1.6 |
| Beet puree | 150 | 52.9 | 4.8 |
| Marmalade blueberry-beetroot** | 100 | 552.0 | 50.2 |

* Recommended Daily Requirement

** The total content of antioxidants in the finished marmalade was determined by the coulometric method

The data in Table 2 shows that one serving of dish provides from 1.5 to 5.7% of the recommended daily requirement (1094 mg/day) in antioxidants. Dishes that include blueberries and prunes are rich in antioxidants. Blueberry-beet marmalade can be considered as a functional product with the antioxidant content exceeding 50% of the daily requirement of an adult.

When compiling diets for athletes, it is necessary to consider the basic medical and biological principles: compliance with energy balance and diet; balance, consistency and adequacy of nutrition; dosing accuracy of biologically active ingredients.

For athletes involved in cyclic sports, four types of the diets are recommended depending on the stage of training. At the stages of basic, pre-competition training and during competitions, the calorie content of the diet should be 6000-7000 kcal; during the recovery period, it is recommended to reduce calories to 4000–5000 kcal. The frequency of meals should be at least five times a day. A special ratio of proteins, fats and carbohydrates as a percentage of calories is recommended, namely 13–15:24–25:58–61 [32].

During the recovery period, it is necessary to reduce the fat content in the diet and increase the amount of products containing lipotropic substances (methionine, choline, polyunsaturated fatty acids, etc.). It is recommended to include cottage cheese, milk and lactic acid products, meat, oatmeal, and buckwheat porridge into the diet; up to 25–30% of all fats in food during this period should be vegetable ones. Particular attention should be paid to the consumption of natural vegetables and fruits [33].

Taking into account the above-listed recommendations, a variant of the daily diet for athletes of cyclical types of activity during the recovery period has been developed (Table 4).

**Table 4.** The daily diet for athletes of cyclical types of activity during the recovery period

| Name of dishes | Portion weight, g | Energy value, kca | TAA, mg |
|---|---|---|---|
| BREAKFAST | | | |
| Oatmeal porridge with carrots | 250 | 351.4 | 43.4 |
| Enriched wheat loaf | 50 | 131 | 10 |
| Tea with honey | 250/25 | 82 | 50 |
| Orange | 120 | 43 | 60 |
| SECOND BREAKFAST | | | |
| Plum juice | 200 | 126 | 80 |
| Curd with sugar | 140/30 | 323 | 75 |
| Apple | 150 | 70.5 | 60 |
| LUNCH | | | |
| Fresh tomato salad with sweet pepper | 100 | 112 | 117 |
| Carrot soup | 300 | 122 | 36 |
| Meatballs | 100 | 273 | - |
| Beetroot stewed in sour cream | 200 | 249 | 83.2 |
| Enriched rye-wheat bread | 100 | 204 | 50 |
| Kissel fruit and berry | 200 | 113 | 27 |

| | | | |
|---|---|---|---|
| AFTERNOON SNACK | | | |
| Yogurt | 150 | 99 | 45 |
| Cheesecake | 150 | 384 | 30 |
| Pear | 120 | 56 | 50 |
| DINNER | | | |
| Beet pasta | 100 | 130 | 46 |
| Cod stewed in tomato souse with vegetables | 200 | 206 | 12 |
| Buckwheat porridge | 205 | 323.4 | 56.4 |
| Marmalade blueberry-beetroot | 100 | 321 | 552 |
| Enriched rye-wheat bread | 100 | 204 | 50 |
| Tea with sugar | 250 | 80 | 50 |
| TOTAL PER DAY | | 4003 | 1583 |
| Recommended daily requirement (RDR) | | 4000 | 1094 |
| % of RDR | | 100 | 144.7 |

The diet includes culinary products from vegetable raw materials with established antioxidant properties.

The calculation of the total content of antioxidants showed that the developed diet provides an adequate level of antioxidant intake for a healthy adult and does not exceed the upper allowable level. The share of blueberry-beetroot marmalade accounts for 35% of the total amount of antioxidants in the diet. The exclusion of this functional product from the diet reduces the supply of antioxidants to 94% of the daily requirement. Culinary products made from vegetables provide 26.9%, beverages and juices 19%, fresh fruit 15.5%, baked goods and cereal-based foods 12.8%, dairy products 11%, and cereal-based foods 9.1% of adequate antioxidant intake. The obtained results confirm the position of the majority of sports nutrition specialists that a well-balanced diet provides the athlete with natural biologically active substances and additional use of vitamins is not necessary [34].

## 4 Conclusions

The developed diet taking into account the physiological needs for energy, macro- and micronutrients makes it possible to provide the athlete with an adequate level of biologically active substances with antioxidant effect. Currently, preference should be given to strategies of proper food selection and innovative culinary methods preserving biologically active substances, as well as functional products, over the use of vitamin and mineral complexes.

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