PAPER

ANTIOXIDANT ACTIVITY AS WELL AS VITAMIN C AND POLYPHENOL CONTENT IN THE DIET FOR ATHLETES

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ABSTRACT

The aim of the study was to analytically evaluate the total content of vitamin C and polyphenols as well as the antioxidant potential of daily food rations planned for athletes. Chemical analyses showed that an average food ration for women (2,120.1 kcal, 90.8 g protein, 53.1 g fat and 354.0 g carbohydrates) contained 5.5±2.6 mg vitamin C and 20.1±4.1 mg polyphenols in 100 g fresh mass. An average food ration for men (2,648.8 kcal, 112.5 g protein, 63.1 g fat and 447.4 g carbohydrates) contained 5.6±1.4 mg vitamin C and 22.9±8.1 mg polyphenols in 100 g fresh mass. The antioxidant potential of an average ration for women expressed as reducing power (FRAP index) in 100 g fresh mass was 8.2±0.7 mmol Fe^{+2}, and for men, 8.9 ±0.9 mmol Fe^{+2}. The antioxidant potential of an average ration prepared for women and men expressed as antiradical activity against DPPH in 100 g fresh mass was respectively: 2.7±02 mmol and 2.7±0.4 mmol Trolox equivalent. Balanced food rations rich in products with high nutrient density can ensure the appropriate intake of vitamin C and polyphenols and high antioxidant potential of the diet.

Keywords: vitamin C, polyphenols, antioxidant potential, diet, athletes, chemical analyses

1. INTRODUCTION

The situation of intensive physical exercise leads to the disruption of body homeostasis, also in terms of prooxidant-antioxidant equilibrium (oxidative stress) as a result of intense metabolic processes and the influence of psychological and environmental factors. Intensive physical exercise induces the overproduction of reactive oxygen species, which cause oxidative damage to tissues as a result of peroxidation of lipids, proteins and DNA. By reducing the skeletal muscle contraction strength, speeding up fatigue and lowering immunity, they reduce athletes' performance (SUNG *et al*., 2016; YAVARI *et al*., 2015).
High oxidative stress occurring in athletes generates increased demand for antioxidant vitamins and polyphenols (HEATON *et al*., 2017; MORILLAS-RUIZ *et al*., 2006; ORLANDO *et al*., 2018; SCHNEIDER *et al*., 2018; YAVARI *et al*., 2015). A rich source of dietary antioxidants is fruit and vegetables with high contents of bioactive substances, including vitamin C, carotenoids and polyphenols (phenolic acids and flavonoids with anthocyans) (NADERI *et al*., 2018; SIKORA *et al*., 2008). The Swiss food pyramid for athletes recommends daily consumption of 5 portions of fruit and vegetables in all colors, ensuring a wide range of bioactive substances (WALTER *et al*., 2007). In this context, planning balanced food rations, rich in products with high nutrient density, such as fruit and vegetables and other products with high nutrient density, is of special importance in athletes' diet (YAVARI *et al*., 2015).
Literature review shows that many works present the nutritional value, including the content of antioxidant substances and antioxidant activity of selected products and dishes, such as e.g., honey (CIANCIOSI *et al*., 2018), fruit (AIRES *et al*., 2017; NADERI *et al*., 2018; SHIN *et al*., 2018; ZENTENO-RRAMÍREZ *et al*., 2018), vegetables (JAISWAL *et al*., 2012; SOTIROUDIS *et al*., 2010), legumes (DURAZZO *et al*., 2013), whole grains (DURAZZO *et al*. 2015), several varieties of wheat and black barley (SIEBENHANDL *et al*., 2007), different cereal grain species (VAN HUNG, 2016), sour cherry juice (FERRETTI *et al*., 2010; MCCORMICK *et al*., 2015), sprouts (HOTNOG *et al*., 2017), as well as grilled chicken salad and spaghetti with tomatoes and parmesan cheese (FRĄCZEK and GĄCEK, 2013; GĄCEK *et al*. 2012). Fewer works describe the nutritional value and antioxidant properties of daily food rations (ALIAKBARLU *et al*., 2014; BEDOGNI *et al*., 1999; KORÉISSI-DEMBÉLÉ *et al*., 2017; MARCONI *et al*., 2018; ZLOCH *et al*., 2018). Evaluation of antioxidant potential of different products and dishes is one aspect of the innovative approach to research on food (DURAZZO, 2017).
Therefore, this study focused on vitamin C and polyphenol content as well as antioxidant properties of complete daily food rations planned for athletes with consideration of products and dishes they prefer, in accordance with qualitative and quantitative recommendations. The study aimed to answer the question whether it is possible to prepare food rations that meet the qualitative and quantitative recommendations for athletes (balanced in terms of energy and macroelements intake) and at the same time are rich in dietary antioxidants and have high antioxidant properties. The innovative approach to the issue is the verification through chemical analyses of the nutritional value of food rations based on theoretical databases. In this context, the aim of the study was to analytically evaluate the total content of vitamin C and polyphenols as well as the antioxidant properties of daily food rations planned for athletes (women and men) of disciplines that require them to maintain low body mass.

2. MATERIALS AND METHODS

2.1. Material

Daily food rations were prepared on the basis of dietary databases for Polish athletes (women and men) professionally doing disciplines that require them to maintain low body mass, with consideration of their dietary preferences. The criterion for the open selection of participants was doing the sport professionally for at least 3 years. The explored group of athletes for whom the menus were prepared included people aged 18-30 (22±3.8), representing the following disciplines: long-distance running, middle-distance running, triple jump, race walking, ballet, artistic gymnastics, rhythmic gymnastics, ski jumping, Nordic combined, synchronised swimming and dancing.
The age and somatic indices of the participating athletes are presented in Table 1. Body composition (total fat mass TBF and total body water TBW) was measured using bio-impedance testing method (Body Comp MF from Akern).

Table 1. Statistical characteristics of anthropometric indices of the study subjects.

Group	Statistics	Age (years)	Body weight (kg)	Body height (cm)	TBF (%)	TBW (%)	BMI (kg/ m^2)
Overall	Mean	22.0	58.4	171.5	11.7	64.6	19.8
	SD	3.8	6.9	7.1	4.6	3.4	1.6
Men	Mean	21.3	62.6	175.3	9.1	66.5	20.0
	SD	3.7	5.3	6.4	3.3	2.4	1.5
Women	Mean	22.9	53.2	166.8	15.1	62.2	19.1
	SD	3.8	4.9	4.7	3.8	2.9	1.4

The athletes' dietary preferences were determined for 185 products and dishes using a 5-point hedonic scale (5 – like very much, 4 – like, 3 – neither like nor dislike, 2 – dislike, 1 – dislike very much). The proposed menus included products and dishes for which a high level of preference was obtained (mean values in the 4.64-4.00 range for 41 products, such as vegetables, fruit, cereal products, flour products, poultry, eggs and egg dishes). Products that were disliked were excluded from the diet (mean preference indices in the 2.50-2.99 range, such as pumpernickel, soy products, margarines, fish in cream sauce and in oil). Based on the analysis of dietary preferences, two weekly menus were prepared – 14 daily food rations (7 for women: W1-W7 and 7 for men: M1-M7).
The menus were prepared in accordance with qualitative (WALTER *et al*., 2007) and quantitative recommendations for athletes (KREIDER *et al*., 2010; POTGIETER, 2013) on the basis of data concerning products' and dishes' nutritional value in Polish "Tables of food ingredients and nutritional value" (KUNACHOWICZ *et al*., 2005). The quantitative assumptions for the planned food rations are presented in Table 2. The nutritional value of dishes was calculated on the basis of the adopted recipes, taking into consideration raw products (and values for edible parts).

Table 2. Detailed assumptions for intended diet plans for women and men (CRP – daily food serving).

Energy/nutrient	Women	Men
Energy (kcal)	2162.0	2779.0
Protein (g/kg b.w.)	1.7	1.7
Protein (g)	90.4	106.4
Protein (% of energy)	16.7	15.3
Fat (g/kg b.w.)	1.0	1.0
Fat (g)	53.2	62.6
Fat (% of energy)	22.1	20.3
Carbohydrates (g/kg b.w.)	6.5	7.4
Total carbohydrates (g)	350.4	470
Indigestible carbohydrates (g)	315.4	430
Carbohydrates (% of energy)	61.2	64.4
Dietary fiber (g)	25-40	25-40

The planned daily food rations were prepared in a food laboratory and then sent for chemical analyses to the Malopolska Centre of Food Monitoring at the University of Agriculture in Krakow. Each food ration was prepared and analyzed twice in 2 samples (each ration was evaluated in 4 iterations). Tables 3 and 4 present the basic list of products and dishes in the weekly menus for athletes (women and men).

Table 3. Weekly menu prepared for women (the list of products/dishes).

	Breakfast	Lunch	Dinner	Supper
W1	Strawberry porridge	Chocolate pudding and a nectarine	Tomato soup with pasta, grilled chicken breast with rice and grilled vegetables	Rye bread with fish spread and vegetable salad
W2	Rye bread with honey, white cheese and vegetables	Banana shake (with buttermilk)	Tomato cream soup, beef chops with barley groats, raw salad (carrot, apple)	Vegetable salad with toasts
W3	Muesli with natural yoghurt, rye bread with white cheese and vegetables	Fruit salad with natural yoghurt	Cucumber soup with rice, tagliatelle with shrimp	Layer salad (vegetables, boiled eggs) with yoghurt sauce and white rye bread
W4	Scrambled eggs with rye bread, an orange	Steamed dumplings with shake (buttermilk, strawberries)	Vegetable soup with potatoes, spaghetti Bolognese	Rye bread with, white cheese and vegetables, fruit yoghurt
W5	Porridge with natural yoghurt, rye bread with chicken ham and vegetables	Yoghurt ice-cream	Zucchini cream soup, cod fillet with rice and boiled vegetables	Pancakes with strawberry jam, rye bread with cheese and tomato
W6	Rye bread with egg spread, natural yoghurt, lettuce, a nectarine	Pancakes with roasted apple	Beetroot soup with potatoes, farfalle with chicken and broccoli	Rye bread with white cheese spread and tomatoes
W7	Rye bread with strawberry jam and mozarella, tomato, natural yoghurt	White rice with strawberry mousse	Tomato cream cheese, beef steak with pearl barley and lettuce	Lecsó with white rye bread

Table 4. Weekly menu prepared for men (the list of products/dishes).

	Breakfast	Lunch	Dinner	Supper
M1	Scrambled eggs with rye bread, an orange	Steamed dumplings with strawberry shake (with buttermilk)	Vegetable soup, spaghetti Bolognese	Rye bread with, white cheese and vegetables, fruit yoghurt
M2	Porridge with natural yoghurt, rye bread with chicken ham and vegetables	Yoghurt ice-cream, sponge cake	Zucchini cream soup, roasted cod fillet with potatoes and vegetables	Pancakes with strawberry jam, rye bread with cheese and tomato
M3	Rye bread with egg spread and lettuce, a nectarine	Pancakes with roasted apple	Beetroot soup with potatoes, farfalle with chicken and broccoli	Rye bread with white cheese spread and tomato, cherry yoghurt with muesli
M4	Porridge with raspberry, a roll with strawberry jam	Banana shake (with buttermilk)	Tomato soup with pasta, chicken breast with rice and cabbage salad	Nice-style salad with rye bread
M5	Muesli with natural yoghurt, rye bread with Gouda cheese and vegetables, a banana	Strawberry dumplings	Tomato cream soup with toasts, risotto with vegetables	Rye bread with fish spread and vegetable salad
M6	Muesli with natural yoghurt, rye bread with white cheese, vegetables and strawberry jam, an apple	Yoghurt ice-cream, sponge cake	Leek cream soup with a baguette, beef steak with rice and rocket and tomato salad	Rye bread with chicken ham, egg and vegetables
M7	Muesli with natural yoghurt, rye bread with mozarella cheese and tomato	Fruit salad with fruit yoghurt	Cucumber soup with rice, chicken pizza	Rye bread with white cheese spread and smoked salmon with vegetables

The mean mass of complete food rations for women was: 2,108.5 g (W1), 2,046.5 g (W2), 2,266.5 g (W3), 2,073.0 g (W4), 2,034.0 g (W5), 2,014.0 g (W6) and 2,085.5 g (W7), and for men: 2,359.5 g (M1), 2,572.5 g (M2), 2,454.5 g (M3), 2,824.0 g (M4), 2,566.5 g (M5), 2,507.0 g (M6) and 2,349.5 g (M7). The mean mass of an average food ration prepared for women (W1-W7) was: 2,090.42±92.29 g, and for men (M1-M7): 2,519.07±161.56 g.

2.2. Preparation of materials

The rations were homogenized and air-frozen using a freezing chamber (Feutron-type 3626-51, Germany) within 90 minutes in order to reach a temperature of -30°C in the thermal centre. The frozen material was then dried. Drying parameters: initial product temperature: -30°C, condenser temperature: -52°C, shelf temperature: 20°C; drying: 6 hours of total drying time at shelf temperature of 30°C. Drying was carried out for 24 hours.

2.3. Chemical analyses

Homogenates were used to determine dry mass content, and lyophilized samples were used to test the other indices. Dry mass content was determined in accordance with the AOAC procedure (2005, no. 930.04) with the weighing method, by drying up to solid mass at a temperature of 105 °C. Total nitrogen was determined in accordance with the AOAC

procedure (2005, no 978.04) with the Kjeldahl method using Distillation Unit B-324 (Büchi, Switzerland). Protein content was determined using the 6.25 rate of conversion, and fat content in accordance with the AOAC procedure (2005, no. 920.39) with the Soxhlet method using diethyl ether-based extraction. Total ash content was determined in accordance with the AOAC procedure (2005, no. 920.05) by incinetaring the material at 485°C, and dietary fiber content in accordance with the AOAC procedure (2005, no. 991.43) enzymatic fermentation and drying the remnants at 105 °C. Total carbohydrates content and the energy value of the rations were determined in accordance with the guidelines of FAO (2003).

The vitamin C content in food rations was tested via the HPLC method according to EN 14130 (2003). The analysis was performed on a Thermo Scientific DIONEX ULTIMATE 3000 UPLC chromatograph with a DAD detector. The extract was injected onto an Onyx Monolithic C 18 column (100 x 4.6 mm). Elution was carried out using 0.1 M metaphoric acid at a flow rate of 1 ml/min. Absorbance measurement was carried out at a wavelength of λ = 254 nm. The sum of L-ascorbic acid and dehydroascorbic acid was determined after reduction with L-cysteine according to EN 14130 (2003). To determine antioxidant properties, 80% methanol extracts were made from lyophilized food rations using sonification.

The total polyphenol content was determined using the method described by SINGLETON *et al*. (1999). The appropriate amount of extracts from lyophilized food rations was collected and a reaction was carried out with the Folin-Ciocalteu reagent in the presence of Na_2CO_3. After 60 minutes, absorbance was read on a Hitachi UV-VIS spectrometer, type U-2900 (Hitachi, Japan) compared to the blind sample at λ = 675 nm. The results were read on the basis of a standard curve prepared for gallic acid.

Antioxidant activity against DPPH radical (1,1-diphenyl-2-pictyhydrazole) was determined using the method described by PEKKARINEN *et al*. (1999). Extracts from lyophilized food rations were mixed with a DPPH radical solution, and after 10 minutes of reaction, the absorbance was measured on a Hitachi UV-VIS U-2900 (Hitachi, Japan) UV-VIS spectrophotometer at a wavelength of λ = 516 nm. The percentage of radical scavenging level (% RSA) was determined by referring the absorbance of extracts from lyophilized food rations to the absorbance of the blind sample. The value of antioxidant activity against DPPH radical is expressed in Trolox millimoles (water-soluble α-tocopherol analogue – 2-carboxyl-6-hydroxyl-2,5,7,8-tetramethylchromate).

Antioxidant activity using the FRAP method was determined according to the procedure described by BENZIE and STRAIN (1996). Extracts from lyophilized food rations were mixed with a TPTZ solution (2,4,6-Tripyridyl-S-triazine) and $FeCl_3$ in an acetate buffer. After 10 minutes of incubation at 37°C, absorbance was measured on a Hitachi UV-VIS U-2900 (Hitachi, Japan) UV-VIS spectrophotometer at a wavelength of λ = 595 nm against a blind sample. The value of antioxidant activity determined by the FRAP method was expressed in millimoles of Fe^{2+} ions.

3. RESULTS

The analyses showed that an average food ration prepared for women contained: 2,120.1 kcal, 90.8 g protein, 53.1 g fat and 354.0 g carbohydrates, and for men: 2,648.8 kcal, 112.5 g protein, 63.1 g fat and 447.4 g carbohydrates (Tables 5 and 6).

Table 5. Nutritional value of food rations planned for women (M±SD).

	W1	W2	W3	W4	W5	W6	W7	W1-W7
Energy value (kcal)	2066.0	2228.8	1969.8	2121.2	2135.0	2117.2	2203.0	2120.1±86.1
Protein (g)	86.8	88.5	84.7	93.3	92.0	95.3	94.9	90.8±4.1
Fat (g)	51.1	58.4	44.4	52.9	52.9	54.0	58.0	53.1±4.7
SFAs (g)	12.1	18.0	12.6	13.5	14.6	13.5	19.2	14.8±2.7
MUFAs (g)	27.5	29.1	22.6	27.6	28.1	28.9	27.2	27.3±2.2
PUFAs (g)	11.4	11.3	9.1	11.8	10.1	11.7	11.6	11±1.0
Carbohydrates (g)	346.6	380.9	336.7	349.3	351.4	349.2	363.8	354±14.3
Dietary fiber (g)	31.9	43.7	28.8	31.3	28.6	36.8	38.5	34.2±5.6

Table 6. Nutritional value of food rations planned for men (M±SD).

	M1	M2	M3	M4	M5	M6	M7	M1-M7
Energy value (kcal)	2585.7	2754.9	2578.9	2683.6	2714.8	2667.2	2556.2	2648.8±76.0
Protein (g)	116.7	114.4	114.5	100.4	110.7	112.5	118.7	112.5±6.0
Fat (g)	65.5	68.7	62.0	60.7	63.7	61.4	59.7	63.1±3.1
SFAs (g)	15.2	18.4	15.6	15.1	21.0	19.4	21.2	18±2.7
MUFAs (g)	34.9	38.2	32.7	32.9	28.0	29.5	30.1	32.3±3.5
PUFAs (g)	15.4	12.1	13.7	12.7	14.6	12.5	8.3	12.8±2.3
Carbohydrates (g)	420.7	460.0	426.9	484.3	466.5	452.9	420.4	447.4±25.1
Dietary fiber (g)	38.3	40.2	36.2	50.4	41.7	36.9	34.4	39.7±5.3

W1/M1 - first daily food serving, W2/M2 - second daily food serving, W3/M3 - third daily food serving, W4/M4 - fourth daily food serving, W5/M5 - fifth daily food serving, W6/M6 - sixth daily food serving, W7/M7 - seventh daily food serving

The chemical analyses showed that 100 g fresh mass of an average food ration prepared for women contained: 5.5±2.6 mg vitamin C and 20.1±4.1 mg polyphenols, and for men, respectively: 5.6±1.4 mg and 22.9±8.1 mg. The antioxidant properties of an average ration for women expressed as reducing power (FRAP index) in 100 g fresh mass was found to be 8.2±0.7 mmol Fe^{+2}, and for men 8.9±0.9 mmol Fe^{+2}. The antioxidant properties of an average ration developed for women and men expressed as antiradical activity against DPPH in 100 g fresh mass was respectively: 2.7±02 mmol and 2.7±0.4 mmol Trolox equivalent. The respective values for dry mass were higher (Tables 7 and 8).

Table 7. Vitamin C and polyphenol content as well as antioxidant potential of food rations planned for women (per 100 g fresh and dry mass) (M±SD).

Evaluated indices		W1	W2	W3	W4	W5	W6	W7	W1-W7
100g fm	Vitamin C (mg)	5.0±0.3	3.5±0.2	5.3±0.2	3.6±0.2	5.0±0.2	11.1±0.4	5.0±0.2	5.5±2.6
	Polyphenols as gallic acid (mg)	16.4±5.4	23.1±3.4	23.2±2.0	21.2±5.6	12.60.9	21.6±1.2	22.9±0.8	20.1±4.1
	Reducing activity (the FRAP method) (mmol Fe^{+2})	7.5±0.4	9.2±0.4	7.6±0.4	7.9±0.2	7.9±0.8	7.9±0.4	9.1±0.8	8.2±0.7
	Antioxidant activity against DPPH (mmol Te – Trolox equivalent)	2.3±0.6	2.8±0.2	2.8±0.1	3.0±0.4	2.7±0.2	2.8±0.2	2.8±0.3	2.7±0.2
100g dm	Vitamin C (mg)	21.0±1.0	13.2±0.6	24.3±1.2	14.3±0.7	19.8±0.9	43.3±2.1	19.6±0.9	22.2±10.1
	Polyphenols (mg) as gallic acid	68.3±21.5	86.1±13.9	106.8±9.3	84.0±21.9	49.6±4.2	83.9±6.5	88.9±2.8	81.1±17.9
	Reducing activity (the FRAP method) (mmol Fe^{+2})	31.3±1.1	34.4±1.4	35.1±2.1	31.6±0.6	31.1±3.8	31.0±1.8	35.5±3.7	32.9±2.0
	Antioxidant activity against DPPH (mmol Te – Trolox equivalent)	9.4±2.3	10.5±0.6	12.9±0.4	12.0±1.5	10.5±0.8	10.9±0.8	10.9±1.1	11.0±1.1
	Antioxidant activity against DPPH (%RSA for extract: 20 mg lyophilized food ration/g)	13.1±3.1	14.4±0.9	17.8±0.5	16.6±2.0	14.5±1.2	15.0±1.1	15.1±1.5	15.2±1.6

Table 8. Vitamin C and polyphenol content as well as antioxidant potential of food rations planned for men (per 100 g fresh and dry mass) (M±SD).

Evaluated indices		M1	M2	M3	M4	M5	M6	M7	M1-M7
100g fm	Vitamin C (mg)	4.9±0.3	5.9±0.3	4.2±0.3	4.8±0.3	5.1±0.3	8.6±0.5	5.8±0.3	5.6±1.4
	Polyphenols (mg) as gallic acid	26.2±1.0	19.4±0.8	20.1±0.2	18.7±1.3	16.9±2.8	19.4±1.7	40.2±6.2	22.9±8.1
	Reducing activity (the FRAP method) (mmol Fe^{+2})	9.1±0.1	7.4±0.2	8.5±0.4	8.2±0.4	9.0±0.5	9.6±0.7	10.4±0.2	8.9±0.9
	Antioxidant activity against DPPH (mmol Te – Trolox equivalent)	2.8±0.1	2.4±0.2	2.5±0.2	2.6±0.1	2.8±0.9	2.3±1.2	3.6±0.3	2.7±0.4

100g dm	Vitamin C (mg)	18.4±1.2	22.8±1.4	16.4±1.0	20.2±1.3	19.8±1.2	33.1±2.1	21.8±1.4	21.8±5.4
	Polyphenols (mg) as gallic acid	97.7±3.4	74.8±3.5	78.8±1.9	78.8±5.7	65.2±11.1	75.1±8.2	151.4±25.2	88.8±29.2
	Reducing activity (the FRAP method) (mmol Fe^{+2})	33.8±0.3	28.4±0.7	33.3±1.2	34.8±1.8	34.7±2.1	37.2±2.8	39.1±1.1	34.5±3.4
	Antioxidant activity against DPPH (mmol Te – Trolox equivalent)	10.3±0.1	9.4±0.8	9.7±0.9	11.0±0.5	10.8±3.8	8.9±4.7	13.6±1.5	10.5±1.6
	Antioxidant activity against DPPH (%RSA for extract: 20 mg lyophilized food ration/g)	14.2±0.2	13.0±1.0	13.4±1.3	15.2±0.6	15.0±5.2	12.3±6.4	18.8±2.1	14.6±2.1

4. DISCUSSION

Different groups of sports disciplines have different dietary requirements, connected with the kind of exercise and the dominant energy pathways, development of specific motor properties and the rigor of maintaining body mass and composition. One of special groups is athletes who train disciplines that require maintaining low body mass and low fat content, which is connected with planning a balanced diet with relatively lower energy intake but high nutrient density (rich in i.a., vegetables, fruit, wholegrain cereal products, legumes, fish and nuts) (THOMAS *et al*., 2016).

The presented original study showed that food rations prepared for athletes (women and men) of disciplines that require maintaining low body mass, in accordance with qualitative and quantitative recommendations, balanced in terms of energy and basic nutrients intake, rich in fruit and vegetables and other products with high nutrient value and with high content of dietary antioxidants, including vitamin C and polyphenols, ensuring high antioxidant properties (with the energy intake of 2,120 kcal in female and 2,649 kcal in male athletes). High vitamin C and polyphenol content results from including in the prepared food rations an appropriate number of portions of products being natural sources of dietary antioxidants (i.a., fruit and/or vegetables in each meal).

The mean content of vitamin C found in the prepared food rations, i.e., 5.5 mg/100 g fresh mass (women) and 5.6 mg/100 g fresh mass (men), with the assumption of their average weight of 2,090.42 g for women and 2,519.07 g for men, corresponds to vitamin C content of 114.97 mg (women) and 141.07 mg (men). Comparing the content of vitamin C in an average (within a week) food ration to the norms of physiological demand for vitamin C (RDA: 75 mg/day for women and 90 mg/day for men) (KREIDER *et al*., 2010), additionally increased in athletes (POTGIETER, 2013), shows that this diet can ensure its normative intake and the demand can be covered, also in the conditions of physical exercise. The described mean content of vitamin C in an average food ration corresponds to satisfying the RDA demand of 153.29% (in women) and 156.74% (in men). High vitamin C content in the prepared food rations results from high vitamin C content in products and dishes included in them, such as raw fruit and vegetables (KUNACHOWICZ *et al*., 2005). Extremely high content of vitamin C occurs in red peppers, but it is also high in tomatoes and lettuce (KUNACHOWICZ *et al*., 2005), which are the ingredients of many salads and (cream) soups planned in the analyzed food rations for athletes.

The total content of polyphenols in the analyzed food rations is also the product of their high content in the ingredients. The mean content of polyphenols found in the prepared food rations, i.e., 20.1 mg/100 g fresh mass (women) and 22.9 mg/100 g fresh mass (men), with the assumption of their average weight of 2,090.42 g for women and 2,519.07 g for men, corresponds to polyphenol content of 420.17 mg (women) and 576.87 mg (men). The recommended intake of polyphenols, promoting good functioning of the body, is estimated at 250-500 mg/day (SIKORA *et al*., 2008). An average food ration, supplying this amount of polyphenols, covers the recommended intake. A study aimed to estimate the intake of phenolic compounds with the diet showed that a statistical Pole consumes approx. 440 mg polyphenols/day, and important sources of these antioxidants are vegetables (31%) and fruit (23%) (SIKORA *et al*., 2008). It is estimated that Western societies consume on average 50-800 mg, and Eastern up to 2 g flavonoids/day. An average Mediterranean diet provides 100-1000 mg flavonoids/day (SIKORA *et al*., 2008). In the Czech population the average intake of plant polyphenols was 426.6 mg/day (less than in other European as well as non-European, countries, including Spain, France, Ireland, Brazil etc.) (ZLOCH *et al*., 2018). A population of elderly Japanese (mostly men) consumed 1492 mg/day of polyphenols on average, and coffee and green tea were the largest sources of polyphenols in their daily life (TAGUCHI *et al*., 2015). Total polyphenol content in fruit and vegetables varies. In vegetables the content is the highest in: broccoli (290 mg/100 g), carrots (156 mg/100 g) and onions (150 mg/100 g) (CIEŚLIK *et al*., 2006). In apples, peaches and mandarines the content of extracted polyphenols was between 18.8 and 28.0 mg/100 g fresh fruit (ARRANZ *et al*., 2009). Out of the vegetables used to prepare the dishes in the analyzed food rations, the richest in polyphenols are red peppers (68.50 mg/100 g), onions (45.81 mg/100 g) and garlic (36.10 mg/100 g) (CIEŚLIK *et al*., 2006).

Foods' antioxidant properties are correlated with the content of substances with antioxidant properties, including vitamin C and polyphenols. The antioxidant potential of an average food ration determined in this study, expressed as reducing power (FRAP index) was: 8.2 mmol Fe^{+2}/100 g ration fresh mass (for women) and 8.9 mmol Fe^{+2}/100 g ration (for men), and expressed as antiradical activity against DPPH was: 2.7 mmol/100 g ration fresh mass (for women and men). Antioxidant properties of food rations prepared for athletes is the product of content of bioactive substances with antioxidant properties and antioxidant potential of individual products/dishes and results from including the recommended number of portions of fruit and vegetables with high antioxidant activity, including honey and wholegrain cereal products. It is worth pointing out that antioxidant capacity of vegetables is usually lower than that of fruit, especially berries, and higher than that of cereal products. Antioxidant activity of fruit varies from 1.02 (pears) to 3.91 mmol/100 g (strawberries), and of vegetables, mushrooms and legumes from 0.27 (cucumbers) to 6.91 mmol/100 g (beans). High potential (>2 mmol/100 g) also occurs in peas, dill, dock, red cabbage and beetroot. Especially high antioxidant potential expressed as DPPH scavenging activity has been described for Brussels sprouts and red peppers (EC50 7.8 mg and 11.9 mg, respectively) (CIEŚLIK *et al*., 2006; SIKORA *et al*., 2008). Significant antioxidant properties of fruit and vegetable snacks have also been reported (GRAMZA-MICHAŁOWSKA and CZŁAPKA-MATYASIK, 2011). With reference to antioxidant properties of wholegrain cereal products, studies have shown that the antioxidant potential of boiled wholegrain pasta (expressed as FRAP index) is from 3.26±0.08 to 19.52±1.28 μmol/g dry mass (DURAZZO *et al*., 2014). Another study concerning dishes preferred by athletes showed high antioxidant properties of chicken salad (0.29 mmol/100 g) and tomato spaghetti (0.35 mmol/100 g) (GĄCEK *et al*., 2012).

Antioxidant activity of the prepared and analyzed food rations, being the product of content of antioxidant substances, including vitamin C and polyphenols, proves they are useful in a rational diet, also for people engaging in intensive physical exercise, who need more antioxidants. Exogenous antioxidants have an impact on the total antioxidant capacity and physical fitness in athletes (MORILLAS-RUIZ *et al*., 2006; SCHNEIDER *et al*., 2018), so an important aspect of a rational diet is the appropriate intake of vegetable bioactive substances. Research has confirmed the importance of diet with high antioxidant properties for the restoration of athletes' antioxidant status. In this respect, it has been shown that antioxidant-rich diet improved the redox status of triathlon athletes (Schneider *et al*., 2018), and high consumption of flavones from cocoa improved the total antioxidant capacity during workout and regeneration in professional cyclists (DECROIX *et al*., 2017). It has been confirmed beyond doubt that satisfying higher nutritional demand, also in terms of vitamin C and other antioxidants, promotes the implementation of dietary strategies connected with muscle regeneration, glycogen replenishment, preventing fatigue, the improvement of immunity and preparation for further training and contests (HEATON *et al*., 2017; MYBURGH, 2014). It is recommended to apply dietary strategies that improve diet antioxidant potential (so-called antioxidant food ration) (YAVARI *et al*., 2015). When discussing the importance of antioxidants in the diet of physically active people, we may refer to a study that showed a positive influence of 6-week Nordic walking training on the improvement of blood antioxidant protection system in women over age 55 (CEBULA *et al*., 2017).

Due to some cases of nutritional deficiencies and because of the importance of antioxidants for increasing antioxidant activity and protecting skeletal muscles from oxidation damage caused by physical exercise, researchers attempt to study the supplementation of athletes' diet with antioxidant substances, including melatonin (LEONARDO-MENDONCA *et al*., 2017), coenzyme Q (ORLANDO *et al*., 2018), vitamin C (YAVARI *et al*., 2015), and L-carnitine (SUNG *et al*., 2016) and whey protein (XU *et al*., 2011). Some studies have also shown the risk of negative impact of supplementing high doses of vitamin C (1g/day) and E (≥260 IU/day) on disorders in skeletal muscles adjusted to long training sessions (MASON *et al*., 2016). Functional drinks based on almonds and olive oil enriched with α-tocopherol and docosahexaenoic acid (DHA) can also be used to modulate oxidative stress and improve effort tolerance of athletes. They also help improve blood polyphenol concentration in older athletes and increase the expression of antioxidant enzyme genes in peripheral blood cells after exercise in young athletes (CAPO *et al*., 2016). Supplementation with purple grape juice displayed ergogenic activity (by delaying exhaustion) and led to increasing antioxidant activity and decreasing the concentration of inflammation markers in recreational runners (TOSCANO *et al*., 2015). Literature also includes other examples of supplementing athletes' diet with antioxidant substances (YAVARI *et al*., 2015).

The presented results can be useful in planning diet and dietary strategies improving the antioxidant properties of the diet of people with high physical activity and increased nutritional needs. Regular consumption of fresh fruit and vegetables, whole grains, legumes and beans, sprouts and seeds is an effective and safe way to cover the antioxidant needs of physically active people.

5. CONCLUSIONS

Balanced food rations prepared for athletes (with the mean energy value of approx. 2,120 kcal for women and approx. 2,649 kcal for men included the normative amount of vitamin C (114.97 mg – women and 141.07 mg – men) and polyphenols (420.17 mg – women and 576.87 mg – men). Balanced food rations for athletes, including fruit and/or vegetables in each meal and the normative amount of vitamin C and polyphenols, have high antioxidant properties. Preparing balanced food rations for athletes, providing not only appropriate amounts of energy and macroelements but also bioactive substances (vitamin C and polyphenols) as well as high antioxidant properties is possible, though not easy. Chemical analyses confirmed the nutritional value of food rations planned on the basis of tables of products' and dishes' nutritional value.

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