

## Quality and safety problems of sports nutrition products

E. Volf<sup>1</sup>, I. Simakova<sup>1,\*</sup>, Yu. Eliseev<sup>3</sup>, R. Perkel<sup>2</sup>, E. Malyshev<sup>1</sup> and A. Zinin<sup>1</sup>

<sup>1</sup>Federal State Budgetary Educational Institution of Higher Education Saratov State Vavilov Agrarian University, Teatralnaya sq. 1, RU410012 Saratov, Russia

<sup>2</sup>St. Petersburg Polytechnic University Peter the Great, Graduate School of Biotechnology and Food Technology, Novorossiyskaya street 50, RU194021 St. Petersburg, Russia

<sup>3</sup>Razumovsky Saratov State Medical University, B. Kazachya street 112, 410012 Saratov, Russia

\*Correspondence: [simakovaiv@yandex.ru](mailto:simakovaiv@yandex.ru)

**Abstract.** The purpose of this work was to study the quality and safety of some sports nutrition products. The objects of study were sports nutrition products: protein bars of ‘ProteinBar’ (Russia) and ‘Bombbar’ (Russia); capsule forms of dietary supplements  $\omega$ -3,  $\omega$ -6,  $\omega$ -9 firms ‘Sportline’ (Russia), ‘Multipower’ (Germany) and ‘Maxler’ (USA). According to the research results, the normalized safety indicators of the fat component of the studied products for sports nutrition (acid number and peroxide) are within acceptable values. The standardized safety indicators of the fat component do not fully reflect the safety requirements for the fat component of sports nutrition products, since there are no standards for the most important indicators of fat safety – the content of secondary oxidation products – copolymers insoluble in petroleum ether and epoxides. The results obtained in the course of the work showed that in almost all of the studied samples are content of epoxides (7.5–47.6 g<sup>-1</sup>) and secondary oxidation products – 1% or more.

**Key words:** carcinogenic effect, epoxides, fat component, oxidation products, safety, sports nutrition, quality.

### INTRODUCTION

Throughout the world, the development of evidence-based food technology and its production is given particular importance. A lot of research is being done in this perspective (Bazarnova et al., 2019; Laukaleja & Kruma, 2019). Separately, the production of the sports nutrition product line is singled out. Sports nutrition is a constantly developing area in which hundreds of scientific papers on various topics related to the studies of effectiveness of minor components of food are published annually (Kerksick et al., 2018; McGinnis et al., 2019); studying the influence of the main nutrients on optimizing the athlete’s functional status, increasing its performance, accelerating post-load recovery, increasing the ‘buffer’ capacity of the body when performing extreme loads (Stendig-Lindberg et al., 1987; Nieman et al., 2002; Bilsborough & Crowe, 2003; Tambovtseva & Soshnikov, 2018; Tiller et al., 2019). A lot of papers are dedicated to the development of methods and rules for rehydrating the body in the training process and recovery phase (Cox & Clarke, 2014; De Oliveira et al., 2014; Leckey et al., 2017; O'Malley et al., 2017). There is a wide range of studies of polyunsaturated fatty acids

(Sinitskaya et al., 2018), their particular importance in sports nutrition has been stated in connection with their participation in the synthesis of eicosanoids, which are the precursors of prostaglandins and leukotrienes which inhibit the development of atherosclerosis, regulate inflammatory processes in the body, reduce cholesterol, have cardioprotective and antiarrhythmic and oncoprotective properties (Benito et al., 2006; Apte et al., 2013). However, there are practically no papers dedicated to the study of their safety. Nevertheless, they can be a potential source of danger to the body, due to the fact that during the oxidation process, oxidation products, such as glycidol esters (Irwin et al., 1996; Appe et al., 2013; Aasa et al., 2019), epoxides (Li et al., 2015; Wang et al., 2017), secondary oxidation products insoluble in petroleum ether are formed, they are teratogenic, mutagenic and carcinogenic effects (Rogozin et al., 2018). Some scientific papers (Maughan et al., 2018; Baltazar-Martins et al., 2019) have shown that athletes do not have a clear idea of the effects and risks of food, do not know the platforms for testing their safety and quality, and rely on trainers, family and teammates when choosing products, rather than objective scientific data. In this regard, the safety aspect of sports nutrition products remains open. Thus, the study of the quality and safety of products for sports nutrition throughout the “product lifecycle” is of high importance.

The aim of this paper was to study the most significant safety indicators of polyunsaturated fatty acids and the fat component of some sports nutrition products.

## MATERIALS AND METHODS

**The objects of study** were sports nutrition products.

Protein bars of the firms ‘ProteinBar’ (Russia) and ‘Bombbar’ (Russia). Technology which involves the preparation of used dry raw materials, its dosing, mixing with sugar invert syrup, fat component, vitamin premix, rolling, calibration, molding, molding and packaging. Capsule forms of dietary supplements  $\omega$ -3,  $\omega$ -6,  $\omega$ -9 by ‘Sportline’ (Russia), ‘Multipower’ (Germany) and ‘Maxler’ (USA). There are a variety of technologies for the production of encapsulated materials: spray drying to obtain capsules, spray freezing, inclusion in matrix, co-extrusion, encapsulation in a gel, encapsulation in a fluidized bed. Vegetable oils for encapsulations are pre-cleaned. The manufacturer as follows indicates the storage conditions of the test products: ‘Keep away from direct sunlight, in a dry, cool place, inaccessible to children’. The sell-by-date of the control sample is 12 months. Studies of the fat component were carried out on the 3<sup>rd</sup> month of product storage. The research took place at a given shelf life for the purpose of modeling assessment of real safety when consuming sports nutrition products. Subsequently, research results in the dynamics of storage of this product line will be reflected.

### Research methods

Generally accepted regulated methods that normalize the safety and quality of fats were used. Fat was extracted from the finished product by the extraction-weight method according to GOST R 54053-2010 ‘Methods for determining the mass fraction of fat’. The following indicators were studied:

– concentration of epoxides by reaction with concentrated phosphoric acid (Stopskij et al., 1986);

- acid number was determined by standardized methods to GOST R 52110-2003. Vegetable oils. Methods for determination of acid value;
- the peroxide number of the fat component of the product was determined by the iodometric method;
- content of oxidation products (copolymers) insoluble in petroleum ether (CIPE) according to the method described in the manual of the All-Russian Research Institute of Fats with the following additions.

A mixture of oxidation products insoluble in petroleum ether was dissolved in hot ethyl alcohol, concentrated to a small volume in a water bath, transferred quantitatively to a 50 cm<sup>3</sup> volumetric flask, made up to the mark with ethyl alcohol and mixed well. The resulting solution containing CIPE from 5 g of the fat fraction was divided into 2 equal parts. One part was dried to constant weight, and then calcined to determine the ash, as described in the main method. According to the data obtained, the content of CIPE in oxidized fat was calculated in % of the fat mass, given that the treated solution contains CIPE of 2.5 g of fat. In the second part of the solution, the fatty acid content was determined by titration with a 0.1 mol dm<sup>-3</sup> alkali solution. According to the obtained results, the content of CIPE in oxidized fat in mmol kg<sup>-1</sup> of fat was calculated (Rzhehina & Sergeeva, 1967).

Statistical processing was carried out in accordance with GOST R (national standard) R ISO 5725-2-2002. The arithmetic average of the results of two parallel determinations made under the conditions of repeatability (convergence) is taken as the measurement result. The mathematical processing of the results included the determination of the arithmetic mean  $\bar{X}$ , the standard deviation of the individual result (standard deviation)  $S$  and the standard deviation of the arithmetic mean (standard error)  $S\bar{X}$ . The measurement results  $x_i$ , the absolute deviation of which from the arithmetic mean  $\bar{x}$  exceeded  $3S$ , were discarded as unreliable. Accuracy of the measurements (absolute error  $\Delta x$ ) was determined with reliability  $\alpha = 0.95$ . The correlation dependence was calculated using the Microsoft Excel program.

## RESULTS AND DISCUSSION

### Results

Table 1 presents the nutritional data of the test samples indicated on the package. The content of the fat component in capsules is 25% of the daily intake for 'Sportline', 20.8% of the daily intake for 'Maxler' and 21.8% of the daily intake for 'Multipower'. The remaining PUFAs come with the main diet of athletes. The content of protein components in the bars is 32.1% of the daily intake for 'ProteinBar', 27.7% of the daily intake for 'Bombbar'.

The qualitative composition of sports nutrition products indicated on the label is shown in Table 2. Based on the labeling data, the analyzed 'ProteinBar' bars contain flavors, soya lecithin, soy protein isolate, glycerin. These components can have a negative effect on the human body, causing allergic reactions, exacerbation of the course of chronic diseases of the gastrointestinal tract. In addition, soy proteins are characterized by an unbalanced amino acid composition, they are imperfect.

In 'Bombbar' bars, the content of whey protein isolate and milk protein concentrate shows that the product contains complete protein and the product containing it does not cause any concern, except for milk protein intolerance.

The origin of fatty acids in capsules, such as eicosapentaenoic acid, docosahexanoic acid, alpha-linolenic acid, oleic acid, is not indicated.

**Table 1.** Nutritional value of control samples of bars and capsules

Product	Proteins, g	% of the daily intake	Fats, g	% of the daily intake	Carbohydrates, g	Energy value, kcal
'ProteinBar' (per 100 g)	35.0	32.1	20.0		39.0	476.0
'Bombbar' (per 100 g)	30.2	27.7	13.1		8.0	262.0
'Multipower' Capsules (in 3 capsules / daily rate)	0		3.1	21.8	2.0	15.0
'Sportline' (in 3 capsules / daily rate)	0		3.6	25.0	3.0	39.0
'Maxler' (in 3 capsules / daily rate)	0		3.0	20.8	0.6	10.0

**Table 2.** The qualitative composition of sports nutrition products indicated on the label

Protein bars		Encapsulated Fats		
'ProteinBar'	'Bombbar'	'Sportline'	'Maxler'	'Multipower'
isolate, whole-grain cereals that do not need cooking, cocoa butter, fructose, caramel starch syrup, banana, emulsifier, chocolate icing, cocoa powder, soy lecithin, cream flavor.	protein complex (whey protein isolate, milk protein concentrate), sweetener maltitol, inulin, almond flour, cocoa butter substitute, milk fat, water-retaining agent, glycerin, milk powder, dried pear, yogurt powder, cinnamon, pear flavoring, soya lecithin, lemon acid, contains sugars of natural origin.	$\omega$ -3 – 340 mg, $\omega$ -6 – 42 mg, $\omega$ -9 – 271 mg, fish oil, unrefined linseed oil, unrefined olive oil, eicosapentaenoic acid, docosahexanoic acid, alpha-linolenic acid, oleic acid.	$\omega$ -3 – 540 mg, $\omega$ -6 – 150 mg, $\omega$ -9 – 210 mg, organic linseed oil, alpha-linolenic acid, oleic acid, linolenic acid, gelatin, glycerin, locust bean gum, purified water.	$\omega$ -3 – 340 mg, $\omega$ -6 – 42 mg, $\omega$ -9 – 271 mg, fish oil, unrefined linseed oil, unrefined olive oil, eicosapentaenoic acid, docosahexanoic acid, alpha-linolenic acid, oleic acid.

The results of the study of the fat component of protein bars for sports nutrition and  $\omega$ -3,  $\omega$ -6,  $\omega$ -9 capsules are shown in Table 3.

In the study of the fat component, the content of free fatty acids was determined. This indicator in the Russian Federation is controlled by technical regulations in fat products. The content of free fatty acids value, mmol kg<sup>-1</sup> of oil: the permissible level is 10.7–71.3 (according to the regulatory documentation of the Russian Federation).

**Table 3.** The results of the study of the fat component of protein bars for sports nutrition and  $\omega$ -3,  $\omega$  6,  $\omega$ -9 capsules

Sample name	Acid number, mEq0 kg <sup>-1</sup>	Peroxide value, Mmol 0.5O kg <sup>-1</sup>	Mass fraction of oxidation products insoluble in petroleum ether, %	The content of epoxides, mmol kg <sup>-1</sup>
'ProteinBar'	33.9	0.9	0.4	47.6
'Bombbar'	30.03	2.0	0.3	13.6
Capsules	7.1	4.1	1.1	8.5
$\omega$ -3, $\omega$ -6, $\omega$ -9 'Sportline' Capsules	30.3	4.0	1.0	9.6
$\omega$ -3, $\omega$ -6, $\omega$ -9 'Maxler' 'Multipower' Capsules	33.9	4.8	0.7	9.8

The peroxide value in the fat component in the product indicates the presence of peroxides, the primary oxidation products. Peroxides are toxic to the body and therefore are standardized by TR TS 021/2011 and TR TS 024/2011 on safety. Peroxides, when ingested in large quantities, cause necrosis of the cells of the gastrointestinal tract, the development of cancer cells. The peroxide value, mEq0 kg<sup>-1</sup>: permissible level – no more than 10.0.

The content of copolymers insoluble in petroleum ether (CIPE, %): acceptable level is not more than 1.0 (Onishchenko, 2001). This indicator does not exceed the norm, but these values correspond to frying fats subjected to repeated thermal effects; for native fats, this indicator is not standardized.

The content of epoxides, mmol kg<sup>-1</sup>: the permissible level is not more than 60–65 mmol kg<sup>-1</sup> (Rogozin et al., 2018). The amount of epoxides of the Bombbar bar is 13.6 mmol kg<sup>-1</sup>, which corresponds to the acceptable level of food safety. The amount of epoxides of the 'ProteinBar' bar is 47.6 mmol kg<sup>-1</sup>, which is approximately twice the permissible level.

Specified parameters for the fat component of  $\omega$ -3,  $\omega$ -6,  $\omega$ -9 capsules for sports nutrition have indicators that do not exceed the regulated norm.

The mass fraction of oxidation products in 'Maxler' products reached the maximum permissible value, while 'Sportline' products exceeded the indicators by 0.1%. In 'Multipower' capsules, all the studied parameters, excluding mass fraction of oxidation products, are normal. Thus, despite the encapsulated form, the fat component is susceptible to oxidation. Given the fact that athletes of many sports (Ronald, 2013; Kashapov & Kashapov, 2019) consume sports nutrition products daily, there is a need for further refinement studies of the safety of the lipid fraction.

### Discussion

In scientific periodicals, there are no works describing the study of the safety of the fat component in the composition of products for sports nutrition, but there is a significant number of works concerning the safety of fats in general.

Hydroperoxides and free radicals are highly reactive compounds and undergo various complex transformations with the formation of other free radicals (reflects the value of the acid number) and secondary oxidation products – including peroxide radicals, epoxy compounds, as well as polymerization and polycondensation products.

In the study of the fat component, we determined the content of free fatty acids, which, although they do not affect the safety of the product, indicate a certain degree of oxidation – if their content is too high, then saponification of fats occurs, respectively, a change in the organoleptic characteristics of the product takes place. This information correlates with the data obtained by scientists of various countries conducting studies of the fat component of meat, fish products (Martinez-Yusta et al., 2014), drinks (Ajmal et al., 2019); vegetable oils from various raw materials (Shahidi, 2005). These are not stable components, they react with each other or with other oxidation products, and their content varies. In food compositions, free radicals cause impulsive oxidation and produce undesirable biochemical compounds that are associated with the development of a number of diseases in biological systems (Bienkiewicz et al., 2019). Excessive intake and limited elimination of free radicals, as a rule, lead to oxidative stress, triggers a chain reaction that violates the integrity of cells, leads to their damage or death, initiates oncological processes (Chesnokova et al., 2006; Dong et al., 2019), the development of arthritis and neurodegenerative diseases (Spagnuolo et al., 2015).

The amount of 'ProteinBar' bar epoxides is  $47.6 \text{ mmol kg}^{-1}$ . The number of epoxides is not standardized in any of the normative and technical documents, but scientific studies have proved that these products are toxic.

Researchers from different countries have confirmed the toxic effect of epoxides on various body systems. For many of them, toxicological studies have shown cyto- and genotoxicity, carcinogenicity and mutagenicity, this may become a precursor of leukotoxins, which can cause leukocyte degeneration and necrosis, disrupt the endocrine system, block the estrous cycle in rats, and stimulate the proliferation of human breast cancer cells (Greene et al., 2000; Gulyaeva et al., 2000). Epoxidation serves as the activation of many known chemical carcinogens; chemical carcinogenesis is a multi-stage process, which includes initiation, promotion and progression (Makarenko et al., 2018). Epoxides trigger initiation – the first critical and irreversible step in carcinogenesis, requiring covalent binding of the carcinogen to DNA. They are inserted into the nucleotide and change the body's genome, that is, they are mutagenic products (Gulyaeva et al., 2000).

One of the secondary products formed during the oxidation of oils and fats is polyoxyacids. The quantitative content of these compounds is defined as the total content of oxidation products insoluble in petroleum ether. According to literature data, a close correlation between the content of fat breakdown products insoluble in petroleum ether and the effect of oxidized fats on the body is known (Simakova et al., 2015). Negative effects on blood and biochemical parameters of fat metabolism were recorded in experiments on animals (Simakova et al., 2014). Oxidation products insoluble in petroleum ether have a proven toxic effect and have a carcinogenic and carcinogenic effect (Goicoechea & Guillen, 2010). Our experimental data obtained in the study of some indicators of the safety of the fat component of the selected sports nutrition products are highly correlated with the experimental data on the study of fat safety described in the literature.

## CONCLUSION

Global guidelines for food producers are the Codex Alimentarius Standards, which are developed on the basis of the latest scientific research with the assistance of independent international organizations and specialized consulting risk assessment



centers established by WHO and WTO. This code regulates the following indicators in edible oils: acid value (refined fats and oils 0.6 mg KOH g<sup>-1</sup> which is equivalent 10.7 mmol kg<sup>-1</sup>; natural fats and oils and cold-pressed fats and oils 4.0 mg KOH g<sup>-1</sup> is equivalent 10.7 mmol kg<sup>-1</sup>), peroxide values (natural oil and cold pressed fats and oils up to 15 milliequivalents of active oxygen kg<sup>-1</sup> of oil; other fats and oils up to 10 milliequivalents of active oxygen kg<sup>-1</sup> of oil); determination of volatile substances at 105 °C (0.2% m m<sup>-1</sup>), insoluble impurities (0.05% m m<sup>-1</sup>), soap content (0.005% m m<sup>-1</sup>), iron (refined fats and oils 2.5 mg kg<sup>-1</sup>; natural fats and oils, and cold-pressed fats and oils 5.0 mg kg<sup>-1</sup>) and copper (refined fats and oils 0.1 mg kg<sup>-1</sup>; natural fats and oils, and cold-pressed fats and oils 0.4 mg kg<sup>-1</sup>). The main documents of the Russian Federation that regulate the safety of sports products are the Technical Regulations of the Customs Union (TR/TS 021/2012 and 027/2011), which give standards for microbiological indicators, the content of toxic substances and radionuclides. The safety indicators of the fat component regulated by the technical regulations of the Customs Union do not fully reflect the safety requirements for the fat component of sports nutrition products, as there are no standards for the most important indicators of fat safety – the content of secondary oxidation products – CIPE and epoxides. In our opinion, the studies have shown the need for further study of the safety indicators of the fat component in sports nutrition products during storage. The data obtained indicate the need for a critical assessment of production technology, products for sports nutrition, as well as the feasibility of amending the regulatory documentation in order to further control the safety of the fat component.

## REFERENCES

- Aasa, J., Granath, F. & Törnqvist, M. 2019. Cancer risk estimation of glycidol based on rodent carcinogenicity studies, a multiplicative risk model and in vivo dosimetry. *Food and Chemical Toxicology* **128**, 54–60.
- Ajmal, M., Nadeem, M., Imran, M., Mushtaq, Z., Ahmad, M., Tayyab, M., Khan, M. & Gulzar, N. 2019. Changes in fatty acids composition, antioxidant potential and induction period of UHT-treated tea whitener, milk and dairy drink. *Lipids Health Dis.* **18** <https://doi.org/10.1186/s12944-019-1161-x>
- Appel, K., Abraham, K., Berger-Preiss, E., Hansen, T., Apel, E., Schuchardt, S., Vogt, C., Bakhiya, N., Creutzenberg, O. & Lampen, A. 2013. Relative oral bioavailability of glycidol from glycidyl fatty acid esters in rats. *Arch. Toxicol.* **87**, 1649–1659.
- Apte, M., Wilson, J., Lugea, A. & Pandol, S. 2013. A starring role for stellate cells in the pancreatic cancer microenvironment. *Gastroenterology* **144**, 1210–1219.
- Baltazar-Martins, G., Brito de Souza, D. & Aguilar-Navarro, M. 2019. Prevalence and patterns of dietary supplement use in elite Spanish athletes. *Int Soc Sports Nutr.* **16**(30). <https://doi.org/10.1186/s12970-019-0296-5>
- Benito, P., Caballero, J., Moreno, J., Gutierrez-Alcántara, C., Muñoz, C., Rojo, G., Garcia, S. & Soriguer, F. 2006. Effects of milk enriched with ω-3 fatty acid, oleic acid and folic acid in patients with metabolic syndrome. *Clin. Nutr.* **25**, 581–587.
- Bazarnova, J., Kuznetsova, T., Aronova, E. & Toumi, A. 2019. Use of lipids of Chlorella microalgae in poultry meat marinades and sauces recipes *Agronomy Research* **17**(S2), 1287–1298.
- Bienkiewicz, G., Tokarczyk, G., Czerniejewska-Surma, B. & Suryn, J. 2019. Changes in the EPA and DHA content and lipids quality parameters of rainbow trout (*Oncorhynchus mykiss*, Walbaum) and carp (*Cyprinus carpio*, L.) at individual stages of hot smoking, *Heliyon* **5**. <https://doi.org/10.1016/j.heliyon.2019.e02964>

- Bilsborough, S. & Crowe, T. 2003. Low-carbohydrate diets: what are the potential short- and long-term health implications? *Asia Pac J Clin Nutr.* **12**(4), 396–404.
- Chesnokova, N.P., Ponukalina, E.V. & Bizenkova, M.N. 2006. Molecular-cellular mechanisms of inactivation of free radicals in biological systems. *Usp. lie. Natural Sciences* **7**, 29–36 (in Russian).
- Cox, P. & Clarke, K. 2014. Acute nutritional ketosis: implications for exercise performance and metabolism. *Extrem. Physiol. Med.* **3**. <https://doi.org/10.1186/2046-7648-3-17>
- De Oliveira, E., Burini, R. & Jeukendrup, A. 2014. Gastrointestinal complaints during exercise: prevalence, etiology, and nutritional recommendations. *Sports Med.* **44**(1), 79–85.
- Dong, J., Feng, X., Zhang, J., Zhang, Y., Xia, F., Liu, L., Jin, Z., Lu, C., Xia, Y., Papadimos, T. & Xu, X. 2019.  $\omega$ -3 fish oil fat emulsion preconditioning mitigates myocardial oxidative damage in rats through aldehydes stress. *Biomedicine & Pharmacotherapy* **118**. <https://doi.org/10.1016/j.biopha.2019.109198>
- Goicoechea, E. & Guillen, M. 2010. Analysis of hydroperoxydes, aldehydes and epoxydes by <sup>1</sup>H nuclear magnetic resonance in sunflower oil oxidized at 70 and 100 °C. *Agric. Food Chem.* **58**, 6234–6245.
- Greene, J., Newman, J., Williamson, K. & Hammock, B. 2000. Toxicity of epoxy acids and related compounds to cells expressing human soluble epoxide hydrolase. *Chem. Res. Toxicol.* **13**(4), 217–226.
- Gulyaeva, L., Vavilin, V. & Lyakhovich, V. 2000. *Enzymes of biotransformation of xenobiotics in chemical carcinogenesis*, Novosibirsk, / GPNTBSO RAN, 84 pp. (in Russian).
- Irwin, R., Eustis, S., Stefanski, S. & Haseman, J. 1996. Carcinogenicity of glycidol in F344 rats and B6C3F1 mice. *Appl. Toxicol.* **16**, 201–209.
- Kashapov, R. & Kashapov, R. 2019. Features of nutrition of athletes–styers in cyclic sports. *Vopr. nutrition* **88**(6), 12–21 (in Russian).
- Kerksick, C., Wilborn, C., Roberts, M. Smith–Ryan, Kleiner, S., Jäger, R., Collins, R., Cooke, M., Davis, J., Galvan, E., Greenwood, M., Lowery, L., Wildman, R., Antonio, J. & Kreider, R. 2018. ISSN exercise & sports nutrition review update: research & recommendations. *Int. Soc. Sports Nutr.* **15**(38).
- Laukaleja, I. & Kruma, Z. 2019. Phenolic and volatile compound composition influence to specialty coffee cup quality. *Agronomy Research* **17**(S2), 1367–1379.
- Leckey, J., Ross, M., Quod, M., Hawley, J. & Burke, L. 2017. Ketone Diester ingestion impairs time-trial performance in professional cyclists. *Front Physiol.* **8**. doi: 10.3389/fphys.2017.00806
- Li, P., Oh, D., Bandyopadhyay, G., Lagakos, W., Talukdar, S., Osborn, O., Johnson, A., Chung, H., Mari.s M. & Ofrecio, J. 2015. LTB4 promotes insulin resistance in obese mice by acting on macrophages, hepatocytes and myocytes. *Nat. Med.* **21**, 239–247.
- McGinnis, G., Stout, J., Smith, J., Arent, S., Campbell, B. & Bannock, L. 2019. International Society of Sports Nutrition Position Stand: nutritional considerations for single-stage ultra-marathon training and racing. *Int. Soc. Sports Nutr.* **16**(50).
- Makarenko, M., Malinkin, A., Bessonov, V., Sarkisyan, V. & Kochetkova, A. 2018. Secondary lipid oxidation products. Human health risks evaluation (Article 1). *Problems of Nutrition;* **87**(6), 125–38 (in Russian).
- Martinez–Yusta, A., Goicoechea, E. & Guillen, M. 2014. A review of thermo-oxidative degradation of food lipids studied by <sup>1</sup>H NMR spectroscopy: influence of degradative conditions and food lipid nature. *Compr. Rev. Food Sci. Food Saf.* **13**, 838–859.
- Maughan, R., Burke, L., Dvorak, J., Larson–Meyer, D., Peeling, P., Phillips, S., Rawson, E., Walsh, N., Garthe, I., Geyde, H., Meeusen, R., Van Loon, L., Shirreffs, S., Spriet, L., Stuart, M., Vernec, A., Currell, K., Ali, V., Budgett, R., Ljungqvist, A., Mountjoy, M., Pitsiladis, Y., Soligard, T., Erdener, U. & Engebretsen, L. 2018. Ioc consensus statement: dietary supplements and the high-performance athlete. *Sports Med.* **52**(7), 439–55.



- Nieman, D., Henson, D., McAnulty, S., McAnulty, L., Swick, N., Utter, A., Vinci, D., Opiela, S. & Morrow, J. 2002. Influence of vitamin C supplementation on oxidative and immune changes after an ultramarathon. *J. Appl. Physiol.* **92**(5). doi: 10.1152/jappphysiol.00961.2001
- O'Malley, T., Myette-Cote, E., Durrer, C. & Little, J. 2017. Nutritional ketone salts increase fat oxidation but impair high-intensity exercise performance in healthy adult males. *Appl. Physiol. Nutr. Metab.* **42**(10). doi: 10.1139/apnm-2016-0641
- Onishchenko, G. 2001, *Sanitary and epidemiological requirements for the organization of public catering, the manufacture and turnover of food products and food raw materials in them. S.P. 2.3.6.1079-01*. Moscow, FSUE "InterSEN", 22 pp. (in Russian).
- Rogozin, I., Perkel', R. & Simakova, I. 2018 Kinetics of changes in life safety indicators when deep-fried dough semi-finished products. *Actual biotechnology* **3**(26), 466–470 (in Russian).
- Ronald, J. 2013. Maughan, Quality Assurance Issues in the Use of Dietary Supplements, with Special Reference to Protein Supplements. *Nutrition* **143**(11), 1843–1847.
- Rzhehina, V. & Sergeeva, A.G. 1967. *Determination of the total content of oxidation products insoluble in the petroleum estate: a guide to methodological research, technological control and accounting of production in the oil and fat industry*, VNIIZh, Leningrad, 1007 pp. (in Russian).
- Shahidi, F. 2005. *Lipid oxidation: Theoretical aspects Bailey's industrial oil and fat products*, Vol. 1, John Wiley & Sons, Inc., Hoboken, 3616 pp.
- Simakova, I., Perkel, R., Kutkina, M. & Volovei, A. 2015. Problems of ensuring the safety of deep-fried fast food products. *Voprosy pitaniya* **84**(5), 112–120 (in Russian).
- Simakova, I., Volovey, A., Kutkina, M., Perkel, R., & Mathison, V. 2014. Safety assessment of deep fat fats in an animal experiment. *Proceedings of the III International Forum "Innovative Technologies for Quality and Food Safety. Problems and Prospects", V International Scientific and Practical. Conference "Food Safety and Quality. Science and Education"*. M.: Publishing house-polygr. Moscow, MSUPP Center, pp. 55–58 (in Russian).
- Sinitskaya, E., Kokoricheva, L. & Manyk, F. 2018. Role of eicosanoids in human life. *Young scientist* **50**, 97–99 (in Russian).
- Spagnuolo, M., Mollica, M., Maresca, B., Cavaliere, G., Cefaliello, C., Trinchese, G., Scudiero, R. & Crispino, M. 2015. High fat diet and inflammation-modulation of haptoglobin level in rat brain. *Front Cell Neurosci.* **9**. doi:10.3389/fncel.2015.00479
- Stendig-Lindberg, G., Shapiro, Y., Epstein, Y., Galun, E., Schonberger, E., Graff, E. & Wacker, W. 1987. Changes in serum magnesium concentration after strenuous exercise. *Am. Coll. Nutr.* **1**, 35–40.
- Stopskij, V., Melamud, N., Kulichenko, G. & Jestrina, F. 1986. Scientific Production Association 'Maslozircon'. 19. SP 2.3.6.1079; USSR author's certificate No. 1040914, MPK7G 01 N 33/02, G 01N 31/02. Method for the quantitative determination of epoxy groups in fat.
- Tambovtseva, R. & Soshnikov, N. 2018. Monitoring and adjusting the nutrition of athletes of skiers of 14–15 years old using the software "Athlete's diary-calculator". *Almanac "New Studies"* **1**(54), 66–72 (in Russian).
- Tiller, N., Roberts, J., Beasley, L., Chapman, S., Pinto, J., Smith, L., Wiffin, M., Russell, M., Sparks, S., Duckworth, L., O'Hara, J., Sutton, L., Antonio, J., Willoughby, D., Tarpey, M., Smith-Ryan, A., Ormsbee, M., Astorino, T. & Kreider, R. 2019. International Society of Sports Nutrition Position Stand: nutritional considerations for single-stage ultra-marathon training and racing. *Int. Soc. Sports Nutr.* **16**(50). doi: 10.1186/s12970-019-0312-9
- Wang, W., Yang, J., Qi, W., Yang, H., Wang, C., Tan, B. & Zhang, G. 2017. Lipidomic profiling of high-fat diet-induced obesity in mice: Importance of cytochrome P450-derived fatty acid epoxides. *Obesity (Silver Spring)* **25**, 132–140.