

# The safety study of the fat component in adapted infant formula

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**Abstract.** The growth and harmonious development of an infant depends on nutrition provided by natural or artificial feeding. Accordingly the adaptation of the composition of adapted infant formula to the composition of human milk is carried out with all major nutrients. The fat component is one of the key components of an infant's diet and its' important aspects are biological effectiveness and safety which changes during processing, storage, transportation and subsequent storage after opening the package. Data on pathological changes in the body with consumption of oxidized fats are known. The aim of the paper is to study some indicators of safety and quality of the fat component of adapted infant formula provided by various manufacturers. As the objects of study we selected one of the most popular adapted infant formula in Russia (in various price categories) under the code names: "IS" (Denmark), "IM", "IN", "IL" (Russian Federation), "IX" (Germany). It was found that the quality composition of the fat component of dry infant formula corresponds to the one indicated on the package. However, no one of the test samples according to the averaged composition of the prevailing fatty acids, is fully identical to human milk. The normative documentation of the Customs Union (TR TS 021/2011, TP TS 024/2011, TP TS 033/2013) only regulates organoleptic analysis of the quality indicators of adapted infant formula and from the safety parameters, only finding the peroxide value, which characterizes the accumulation of primary fat oxidation products. It was found that the peroxide numbers of the studied infant formula do not exceed the regulated values. At the same time almost all milk nutrition made from dry infant formula has unsatisfactory organoleptic characteristics. Defects of taste and aroma can be associated with the accumulation of a significant amount of secondary products of fat oxidation, aldehydes particularly in the adapted infant formula. These conclusions are confirmed by the results of determination of the anisidine number in the adapted infant formula, as well as by the accumulation of 0.3-1.0% of highly polar compounds insoluble in petroleum ether (CIPE) and 25-3 mmol/kg of epoxides which lead to decrease of white blood cells and a change in blood formula at a biological animal test. The data obtained indicate the need for assessment of the technology for the production, packaging and storage of adapted infant formula as well as the feasibility of amending the regulatory documents of the Russian Federation and in the future, the regulatory documents of the Customs Union with the aim of further monitoring the safety of the fat component of adapted infant formula.

## 1 Introduction

The best food for the baby in the first months of life is his mother's milk, which corresponds to the features of its digestive system and metabolism, which ensures the adequate development of the baby's body with the rational nutrition of a lactating woman. Lactotrophic nutrition (breastfeeding) is the postnatal equivalent of fetal haemotrophic nutrition. It has a unique biological and emotional effect on the health of both mother and child. All nutrients of human milk are easily absorbed, because their composition and ratio correspond to the functional capabilities of the gastrointestinal tract of a baby / infant. After giving birth, the mother-placenta-fetus system transforms into its postnatal analogue,

mother-breast-milk-native milk-baby, with the preservation of the genetic connection that formed during the period of fetal development. Thus, breastfeeding is an important factor in the formation of health, has a multilateral impact on the physical and mental development of infants / children, the formation of their behavior, intellectual development [1-2].

However, a significant proportion of women, for various reasons, cannot provide their babies with natural feeding. In these cases, optimal artificial (formula) feeding is important, as, with the proper approach, it can ensure the correct growth and development of a child [3] although it can't replace breast milk. The current trend in artificial feeding is the use of specialized baby food products of industrial production, modern substitutes for

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breast milk, the so-called baby "formulas" - adapted formulas. The main principle of creating substitutes is their maximum approximation (adaptation) to the composition and properties of human milk and compliance with the characteristics of digestion and metabolism of an infant. Adaptation of the composition of infant formula to the composition of human milk is carried out for all the main components - protein, carbohydrate, vitamin, mineral and fat [4]. The need for fats for an infant is maximum and amounts to 44–49% of the energy value of the diet [3]. A number of controlled studies have shown that approximating the composition of the fat component of infant formula to the breast milk one improves neuropsychological development of infants, in particular, increases the mental development index (MDI) by 7 points [5], improves the psychomotor development of babies aged 4 months [6], improves cognitive development at the age of 3 and 10 months [7,8], and also has a long-term effect on intellectual development. Therefore, it is imperative that an infant continues to receive the fat component of the optimal fatty acid composition either with breast milk or as part of infant formula [9].

One of the expected results of the implementation of world strategies in the field of healthy nutrition is the reduction of alimentary-dependent diseases among children / infants, providing them with full nutrition from the first days of life. Increased hygiene requirements for the safety and quality of industrially produced baby foods for infants and young children are determined by the immaturity of their protective mechanisms, physiological and metabolic characteristics [10].

However the safety requirements for the fat component of adapted infant formula, in our opinion, are still not sufficiently regulated by the regulatory documents of the Russian Federation and the Customs Union.

The aim of this paper is to study some indicators of safety and quality of the fat component of adapted infant formula by various manufacturers.

## 2 Methods

Among a wide range of infant formulas available on the market, one of the most popular in Russia in different social segments adapted Russian adapted infant formula "IS" (Denmark), "IM", "IN", "IL" (Russian Federation), IX" (Germany) were selected as objects of study.

Fat for the analysis was isolated from infant formula by the extraction-weight method [11].

In the extracted fat, the fatty acid composition was determined by gas-liquid chromatography of methyl esters of fatty acids [12]. Fatty acid methyl esters were prepared according to [13] and the correspondence of the averaged fatty acid composition of the studied infant formula to the composition of human milk was compared.

The normative documentation of the Customs Union (TR TS 021/2011 (Technical regulation of the Customs Union "On the safety of food products), TR TS 024/2011

(Technical regulation of the Customs Union on oil and fat products), TR TS 033/2013 (Technical regulation of the Customs Union" On the safety of milk and dairy products) only regulates organoleptic analysis of the quality indicators of adapted infant formula, and, from the safety parameters, only finding the peroxide value, which characterizes the accumulation of primary fat oxidation products. The peroxide value of the fat component of the infant formula was found by the iodometric method [14].

Infant milk nutrition for organoleptic analysis was prepared according to the recommendations indicated on the package, with a one-to-three hydraulic module. Organoleptic analysis was performed according to [15].

Preliminary studies of ready for use infant formula showed that almost all samples had an unsatisfactory taste and smell, which is typical for relatively oxidized fat mixtures. Therefore, for a more complete assessment of the degree of hydrolysis and oxidation of the fat component of the infant formula, we determined the acid value of the released fat by the titrimetric method [16], the anisidine value from [17], the content of secondary oxidation products insoluble in petroleum ether (CIPE) from [18], and the content of epoxides from reactions with concentrated phosphoric acid [19]. All studies were carried out immediately after opening cans with infant formula.

Determination of acid value is important for determining the degree of hydrolysis of fat. This indicator is of particular importance in the analysis of infant formula containing coconut and palm oil, because when there is a noticeable amount of free lauric acid in a mixture, a soapy taste arises. In addition, with the intensive hydrolysis of fats, di- and monoglycerides accumulate, which, according to modern data, can be the precursors of the dangerous toxicant 3-chloropropanediol (3-MCPD), which is detected in infant formula in concentrations up to 1.0 mg / kg of fat, isolated from the product [20].

The anisidine value correlates in a certain way with the accumulation of free aldehydes (hexenal, nonenal, 2,4-decadienal), which give the product off-flavors of fish, beans, etc.

The accumulation of mixtures of thermostable secondary oxidation products in the fat component is characteristic of the oxidation of fats during their heat treatment. The formation of highly polar compounds insoluble in petroleum ether (CIPE) and epoxides was discovered during the study of deep-fried dough products, as well as in the storage of confectionery products with a high fat content, e.g. Kurabye cookies, shortbread cookies, Chak-Chak confectionery product, Creamy cake and others. In the previous biological animal test, as was shown in our previous papers, the fats containing more than 1% of CIPE, when systematically consumed, have a negative effect on the organs of the gastrointestinal tract, sharply reduce the level of red blood cells and white blood cells, as well as cause the accumulation of cholesterol and bilirubin [21]. The risk of formation of such compounds in baby food is of serious concern.

The study was performed on the basis of Saratov State Vavilov Agrarian University.

### 3 Results

Edible fats are an essential component of a baby's diet. Reproduction of the fatty acid composition of breast milk when creating infant formula is a complex scientific, technological and medical problem.

According to the requirements of Article 4 of TR TS 021/2011, adapted infant formula should be as close to human milk as possible in order to satisfy the physiological needs of infants in substances and energy in their first year of life. The fatty acid composition of breast milk is characterized by a relatively high content of polyunsaturated fatty acids (PUFAs), the concentration of which in mature breast milk is 12–15 times higher than in cow's milk (0.4–0.5 g / 100 ml versus 0.009 g / 100 ml). In the baby's body, PUFAs are either synthesized to a limited extent (monounsaturated) or not synthesized at all (polyunsaturated), and these compounds perform the most important plastic and metabolic functions. For infants and young children, representatives of the  $\omega$ -3 and  $\omega$ -6 fatty acid families are of the greatest importance, of which  $\alpha$ -linolenic and linoleic acids are the most significant. In breast milk, the ratio of PUFAs of  $\omega$ -6 and  $\omega$ -3 classes is optimal and ranges from 10: 1 to 7: 1. Under the influence of the delta-6 desaturase enzyme, these compounds turn into long-chain polyunsaturated fatty acids which play a leading role in the development of the central nervous system of infants, the visual analyzer and the immune system, regulation of metabolic processes and inflammatory reactions [22]. Comparative characteristics of the averaged composition of the predominant fatty acids of adapted infant formula and breast milk are presented in table 1.

**Table 1.** Comparative characteristics of the averaged fatty acid composition of human milk [23] and adapted infant formula.

| Trivial name of fatty acid, the number of carbon atoms in the chain and the | Mass fraction of fatty acid in samples,% |      |      |      |      |      |
|---|--|------|------|------|------|------|
|   | Human milk                               | IS   | IN   | IM   | IL   | IX   |
| Caprylic acid C8: 0   | 0.17                                     | 3.2  | 2.2  | 2.2  | 2.0  | 0.9  |
| Capric acid C10: 0  | 1.66                                     | 2.5  | 1.8  | 1.7  | 1.6  | 0.8  |
| Lauric acid C12: 0  | 5.8                                      | 17.9 | 13.0 | 12.7 | 11.9 | 9.3  |
| Myristic acid C14: 0  | 8.6                                      | 6.6  | 5.4  | 5.3  | 5.2  | 3.6  |
| Palmitic acid C16: 0  | 21.0                                     | 8.4  | 18.9 | 18.6 | 19.2 | 24.4 |
| Palmitoleic acid C16: 1   | 3.4                                      | 0.1  | 0.2  | 0.2  | 0.2  | 0.2  |
| Stearic acid C18: 0   | 8.0                                      | 2.8  | 3.1  | 3.3  | 3.4  | 3.3  |
| Oleic acid C18: 1   | 36.5                                     | 39.3 | 38.0 | 38.3 | 38.7 | 38.1 |
| Linoleic acid C18: 2  | 10.8                                     | 16.9 | 14.1 | 14.1 | 14.2 | 16.2 |
| Linolenic acid C18: 3   | 1.0                                      | 1.5  | 2.4  | 2.7  | 2.6  | 2.2  |
| Arachic acid C20: 0   | 0.21                                     | 0.2  | 0.3  | 0.3  | 0.3  | 0.3  |
| Gadoleic acid C20: 1  | 0.20                                     | 0.2  | 0.4  | 0.4  | 0.4  | 0.4  |
| Behenic acid C22: 0   | 0.10                                     | 0.4  | 0.2  | 0.2  | 0.3  | 0.2  |
| Mass fraction of  | 4.4                                      | 3.46 | 3.4  | 3.3  | 3.3  | 3.6  |

The data presented in table 1 indicates the presence of gadoleic acid C20: 1 and a sufficiently high amount of linolenic acid C18: 3 in the infant formula "IN", "IM", "IL", which suggests the content of erucic-free rapeseed oil in them. According to the analysis of the fatty acid composition, infant formula of "IN", "IM", "IL" may have an almost identical formula.

From the above data it is seen that the infant formula were selected, first of all, according to the content of oleic and palmitic acids. Sample IX contains 15-20% of coconut oil, sample IS contains 35%, the rest contain 30% of coconut oil. On the contrary, the composition of the "IS" powder contains about 20% of palm oil, the "IX" sample contains 40-45% of palm oil, the rest contain 35-40% of palm oil.

The highest content of polyunsaturated acids (linoleic and linolenic) is in the "IS" and "IX" infant formula, while the most favorable ratio  $\omega$ 6/ $\omega$ 3=11:1, corresponding to the characteristics of human milk, was found in the "IS" powder.

The mass fraction of the fat component is from 24.1% ("IM") to 27.7% ("IX").

Based on the research results, the fatty acid composition of a adapted infant formula of various

manufacturers corresponds to the information indicated on the labels of the products being studied.

From Table 1, it is seen that the proposed infant formula contain an excessive amount of lauric acid and linoleic acid, with a relatively lower mass fraction of stearic acid. None of the samples studied according to the averaged composition of fatty acids fully correspond to human milk.

Infant formula were prepared for organoleptic analysis according to the recommendations indicated on the package, with a 1:3 hydraulic module. The dispersion of dry infant formula in water occurred with the same intensity. The results are presented in Table 2.

**Table 2.** The results of organoleptic analysis of ready-prepared for use infant formula.

| Sample name | Flavor                                  | Odor         | Consistency                         | Color                   |
|-------------|---|--------------|-------------------------------------|-------------------------|
| IS          | fishy aftertaste                        | mild fishy   | homogeneous, light, watery          | baked milk              |
| IN          | sweet and salty with a fishy aftertaste | mild fishy   | homogeneous, light, non-watery      | white with a cream tint |
| IM          | slightly sweet, creamy                  | slight fishy | homogeneous, light, non-watery      | white with a cream tint |
| IL          | sweet-salty, with a metallic finish     | slight fishy | homogeneous, light, slightly watery | white with a cream tint |
| IX          | bean, with a cold synthetic flavor      | herbal       | homogeneous, light, non-watery      | light cream             |

Baby foods made from "IS", "IN", "IM" and "IL" infant formula had a fishy smell of varying degree; the "IX" sample was more herbal, beany. Sweet taste was most explicit in "IN" sample, and it was least explicit of all in "IM" sample. The consistency of ready-prepared food systems did not differ significantly, the color ranged from white to cream.

In general, an unsatisfactory organoleptic assessment of the varying degrees of strength in food compositions from all infant formula should be noted. The worst performance is "IX". Thus, a negative organoleptic assessment of the prepared infant formulas may indicate an unacceptable level of oxidation of the fat component of the dry adapted infant formula

In accordance with the requirements of Annex 9 Technical regulation of the Customs Union "On the safety of milk and dairy products" (TR TS 033/2013), the standardization of oxidative damage of dry adapted infant formula is determined by the peroxide value (not more than 4 meq/kg). It is known that fat oxidation products are toxic, they have a carcinogenic effect, the

ability to cause diseases of the gastrointestinal tract and liver, growth retardation, irritation of the skin and mucous membranes, the development of malignant tumors [24-30], in addition and it can initiate cell damage and contribute to the development of oxidative stress [31-36]. In this regard, a more detailed study of the safety of the fat component in the adapted infant formula was carried out. The data are presented in table 3.

**Table 3.** Safety indicators of adapted infant formula.

| Sample Name | Acid number, mg KOH / g | Peroxide value, meq / kg | Anisidine index, c.u. | Mass fraction of oxidation products insoluble in petroleum ether, % | The content of epoxides, mmol / kg |
|-------------|-------------------------|--------------------------|-----------------------|---|------------------------------------|
| IS          | 0.5                     | 0.4                      | 1.9                   | 0.3   | 25.6                               |
| IN          | 0.2                     | 0.9                      | 2.2                   | 0.8   | 27.1                               |
| IM          | 0.6                     | 1.4                      | 3.6                   | 1.0   | 31.1                               |
| IL          | 0.7                     | 0.8                      | 2.6                   | 0.7   | 27.9                               |
| IX          | 0.4                     | 1.1                      | 2.9                   | 0.6   | 26.3                               |

Analyzing the data of table 3, we can conclude that the safety indicator, i.e. peroxide value is within the normal range for all samples, standardized according to TR TS 033/2013 "On the safety of milk and dairy products".

The limit value of the acid number (value) for adapted infant formula is not determined by the regulatory documentation of the Customs Union. According to TR TS 024/2011 "On fat and oil products" for refined oils and their fractions, mixtures of refined oils, the acid value is normalized to not more than 0.6 mg KOH / g. For most dry infant formula, the acid number does not exceed this indicator, only in the "IL" sample the content of free fatty acids in the fat component is 0.7 mg KOH / g

The permissible value of the anisidine index, showing the concentration of secondary oxidation products, i.e. aldehydes, is also not determined by the normative documentation for adapted infant formula. GOST (National State Standard) 1129-2013 Sunflower oil. Technical conditions (as amended) this indicator is not more than 3 c.u. for Premium oil and high-grade oils. In the "IM" sample, the anisidine index is 3.6 c.u.

## 4 Discussion

The mass fraction of compounds insoluble in petroleum ether is regulated for spent deep frying fats according to SP 2.3.6.1079-01 is not more than 1%. This indicator has not yet been reflected in ensuring the safety of the fat component of other food products, although there are a number of papers, showing the need for its regulation [37; 38]. In the "IM" sample, the mass fraction of CIPE is 1%.

In biological studies on animals (white rats) [39], it was noted that with the systematic consumption of fats containing more than 0.88% of CIPE, progressive negative pathological changes in the body are observed (granular dystrophy and hyperaemia of the liver, desquamation processes in the intestinal wall, oedema submucosal layer of the intestine, a change in the blood formula). Such changes indicate an increase in the number of eosinophils and compounds that are leukotoxins, which in general leads to disorders in the work of antioxidant defense systems of the body.

A number of studies [40-44] have shown that it is the isomers of epoxyoleic acid that have the properties of leukotoxins. Determining the concentration of epoxides can be suggested as an operational method for monitoring the safety of the fat component of dry infant formula and other food products. In the studied adapted infant formula, the content of epoxides was 25-31 mmol / kg.

Weakened antioxidant defence and uncontrolled intensification of lipid peroxidation processes have been proven to be one of the important links in the pathogenesis of autonomic dysfunction, atopic dermatitis, dental pathology, diabetes mellitus, arthropathy, diseases of the gastrointestinal tract, urinary tract, etc. [45-48].

It should be noted that all the studied indicators of hydrolysis and oxidation of fats are at the lowest level in the "IS" sample.

The data obtained indicate that there is a need for additional safety monitoring of the fat component of adapted infant formula, which is advisable to reflect in the regulatory documentation.

As a result of the safety study of the fat component in adapted infant formula named "IM", "IS", "IN", "IL", "IX", it was found that the qualitative composition of the fat fraction corresponds to that stated on the package. None of the studied samples according to the averaged composition of the predominant fatty acids fully corresponds to the composition of human milk. According to an important indicator, i.e. the ratio of polyunsaturated fatty acids  $\omega 6 / \omega 3$ , the optimal value (11: 1) is the "IS" sample.

According to organoleptic indicators, food systems made from "IS", "IN", "IM" and "IL" dry infant formula had a fishy smell of varying intensity; "IX" sample is more herbal. Sweet taste was most pronounced in the "IN" sample, and was least pronounced in the "IM" sample. The consistency was slightly different, the color ranged from white to cream. A negative organoleptic assessment, in general, may indicate an unacceptable level of oxidation of the fat component of dry infant formula.

The safety indicators of the fat component regulated by TP TS 021/2011, TP TS 024/2011, TP TS 033/2013 do not fully reflect the safety requirements for the fat component of adapted dry infant formula, since there are no standards for the most important indicators of fat safety, i.e. the content of secondary oxidation products CIPE and epoxides. In our opinion, the research shows the need for further study of safety indicators of the fat

component of adapted dry infant formula during storage after opening the package by the consumer.

The obtained data determine the necessity for an assessment of the production technology, packaging and storage of adapted infant formula, as well as the feasibility of amending the regulatory documents of the Russian Federation, and in the future, the regulatory documents of the Customs Union with the aim of further monitoring the fat component safety of adapted infant formula.

## References

- [1] A. Mecke, I. Lee, J.R. Baker, M.M. Banaszak Holl, B.G. Orr, *Eur. Phys. J.*, **E 14**, 7 (2004).
- [2] M.V. Gmoshinskaja, Podderzhka grudnogo vskarmlivanija: sistemnyj podhod, *Breastfeeding support: a systematic approach, Voprosy detskoj dietologii, Child nutrition issues*, **10**, 5, 57-63 (2012).
- [3] L.V. Abol'jan, P.M. Evloeva, E.I. Barteneva, *Sovremennye podhody k ocenke pokazatelej grudnogo vskarmlivanija na primere Chechenskoj Respubliki i Respubliki Ingushetija, Modern approaches to the assessment of breastfeeding indicators on the example of the Chechen Republic and the Republic of Ingushetia, Voprosy sovremennoj pediatrii, Issues of modern pediatrics*, **12**, 4, 58-63 (2013).
- [4] V.A. Tutel'jan, I.Ja. Kon', *Detskoe pitanie, Rukovodstvo dlja vrachej, Baby food, A guide for doctors*, Moscow: MIA, 744 (2013).
- [5] A.V. Petrenko, *Sovremennye podhody k iskusstvennomu vskarmlivaniju detej, Modern approaches to artificial feeding of children, Novaja nauka: opyt, tradicii, innovacii: Mezhdunarodnoe nauchnoe periodicheskoe izdanie po itogam Mezhdunarodnoj nauchnoprakticheskoj konferencii, 12 avgusta 2016 g, Omsk, New science: experience, traditions, innovations: International scientific periodical on the results of the International Scientific and Practical Conference, 12 August 2016, Omsk, Part. 2, Sterlitamak: AMI*, 13-17 (2016).
- [6] E.E. Birch, S. Garfield, D.R. Hoffman, et al., A randomised controlled trial of early dietary supply of long-chain polyunsaturated fatty acids and mental development in term infants, *Dev. Ved. Child Neurol.*, **42**, 174-181 (2000).
- [7] C. Agostoni, S. Trojan, R. Bellu, et al., Neurodevelopmental quotient of healthy term infants at 4 months and feeding practice: The role of long-chain polyunsaturated fatty acids, *Pediatr. Res.*, **38**, 262-266 (1995).
- [8] P. Willatts, J.S. Forsyth, V.R. Dimodugno, et al., The effects of longchain polyunsaturated fatty acids on infant attention and cognitive behavior,

- In: David T. J. (ed), Major controversies in infant nutrition: International congress and symposium, London: Royal Society of Medicine, **215**, 57-70 (1996).
- [9] P. Willatts, J.S. Forsyth, M.K. Dimodugno, et al., Effect of longchain polyunsaturated fatty acids infant formula on problem solving at 10 months of age, *Lancet*, **352**, 688-691 (1998).
- [10] N.M. Shilina, Jekspertnyj vzgljad na rol' zhirov v detskom pitanii, Expert view on the role of fats in baby food, *Pediatricheskaja farmakologija, Pediatric Pharmacology*, **11**, 1, 38-42 (2014).
- [11] V.A. Tutel'jan, I.Ja. Kon', *Detskoe pitanie, Rukovodstvo dlja vrachej*, Baby food, A guide for doctors, Moscow: MIA, 941 (2009).
- [12] GOST ISO 1736-2014, Moloko suhoe i suhie molochnye produkty, Opredelenie sodержaniya zhira, Gravimetricheskij metod (kontrol'nyj metod), State Standard ISO 1736-2014, Methods for determining the mass fraction of fat, Dried milk and dry dairy products, Determination of fat content, Gravimetric method (control method), Moscow, Standartinform Publ., 16 (2016).
- [13] GOST R 51483-99, Masla rastitel'nye i zhiry zhitovnye, Opredelenie metodom gazovoj hromatografii massovoj doli metilovyh jefirov individual'nyh zhirnyh kislot k ih summe, State Standard 51483-99, Vegetable oils and animal fats, Determination by gas chromatography of the mass fraction of methyl esters of individual fatty acids to their sum, Moscow, Standartinform Publ., 11 (2008).
- [14] GOST R 51486-99, Masla rastitel'nye i zhiry zhitovnye. Poluchenie metilovyh jefirov zhirnyh kislot, State Standard 51486-99, Vegetable oils and animal fats. Preparation of fatty acid methyl esters, Moscow, Standartinform Publ., 10 (2008).
- [15] GOST R 51487-99, Masla rastitel'nye i zhiry zhitovnye, Metod opredelenija perekisnogo chisla, State Standard 51487-99, Vegetable oils and animal fats, Method for determination of peroxide value, Moscow, Standartinform Publ., 8 (2008).
- [16] GOST ISO 6658-2016, Organolepticheskij analiz, Obshhee rukovodstvo, State Standard ISO 6658-2016, Organoleptic analysis, General leadership, Moscow, Standartinform Publ., 26 (2016).
- [17] GOST R 52110-2003, Masla rastitel'nye, Metody opredelenija kislotnogo chisla, State Standard 52110-2003, Vegetable oils, Methods for determining the acid number, Moscow, Standartinform Publ., 11 (2008).
- [18] GOST 31756-2012, ISO 6885:2006, Masla rastitel'nye i zhiry zhitovnye, Metod opredelenija anizidinovogo chisla, State Standard 31756-2012, ISO 6885:2006, Vegetable oils and animal fats, Method for the determination of anisidine number, Moscow, Standartinform Publ., 11 (2014).
- [19] V.P. Rzhedin, A.G. Sergeev, Opredelenie summarnogo sodержaniya produktov okslenija, nerastvorimyh v petrolejnom jefire, Rukovodstvo po metodam issledovanija, tehnohimicheskomu kontrolju i uchetu proizvodstva v maslozhirovoj promyshlennosti, Determination of the total content of oxidation products insoluble in petroleum ether, Guide to research methods, techno-chemical control and accounting of production in the oil and fat industry, Leningrad: All-Russian Research Institute of Fats Publ., 1007 (1967).
- [20] V.S. Stopskij, N.L. Melamud, G.E. Kulichenko, F.B. Jestrina, Sposob kolichestvennogo opredelenija jepoksigrupp v zhirah, The method of quantitative determination of epoxy groups in fats, Author's certificate USSR, no. 1040914, IP C7G 01 N 33/02, G 01N 31/02.
- [21] R. Jedrkiewicz, M. Kupska, A. Glowacz, J. Gromadzka, J. Namiesnik, 3-MCPD: A worldwide problem of food chemistry, *Crit. Rev. Food Sci. Nutr.*, **56**, 14, 2268-2277 (2016).
- [22] I.V. Simakova, Issledovanie pal'movogo masla v tehnologii proizvodstva friturnoj produkcii, Avtoref. diss. kand. tekhn. nauk, Research palm oil in the technology of frying products, Sankt-Peterburg, 138 (2004).
- [23] Ju.A. Zaharova, I.N. Dmitrieva, E.A. Gordeeva, Membrana zhirovyh globul moloka: innovacionnye otkrytija uzhe segodnja, Milk fat globule membrane: innovative discoveries today, *Rossijskij vestnik perinatologii i pediatrii, Russian Bulletin of Perinatology and Pediatrics*, **6**, 15-21 (2015).
- [24] R. Yuhas, K. Pramuk, E.L. Lien, Human milk fatty acid composition from nine countries varies most in DHA, *Lipids*, **41**, 851-858 (2006).
- [25] H.P. Al-Shaikh, J. Mancini-Filho, L.M. Smith, Improving quality of used deep-frying fats, *J. Amer. Oil Chem. Soc.*, **62**, 4, 228-235 (1985).
- [26] M.M. Dubeneckaja, Vlijanie oksilivshegosja podsolnechnogo masla na organizm jeksperimental'nyh zhitovnyh, The effect of oxidized sunflower oil on the body of experimental animals, *Gigiena i sanitarija, Hygiene and Sanitation*, **12**, 33-36 (1971).
- [27] V.G. Parteshko, A.A. Lesjuis, G.V. Belous, O snizhenii urovnja lipidnyh bioantioksidantov v pecheni zhitovnyh pod dejstviem vysokonenasyshennyh jekzogenykh lipidov, On the reduction of lipid bioantioxidants in the liver of animals under the action of highly unsaturated exogenous lipids, *Biofizika, Biophysics*, **16**, 1, 160-162 (1971).
- [28] K. Fukuzumi, Studies on the Reaction of Fats and Oils – Hydrolysis, Autoxidation, Hydrogenation,

- ets. Mem. Fac. Eng. Nagoya Univ., 30 (2), 200-244 (1978).
- [29] M.Ja. Vysheslavova, Vlijanie podsolnechnogo masla s raznoj stepen'ju okislenija na indukciju 2-acetilaminofluorenom opuholej u krys, Effect of sunflower oil with different degrees of oxidation on the induction of 2-acetylaminofluorene tumors in rats, *Voprosy onkologii, Oncology issues*, **15**, 4, 66-70 (1969).
- [30] T. Sanders, Toxicological considerations in oxidative rancidity of animal fats, *Food Sci. and Technol. Today*, **1**, 3, 162-164 (1987).
- [31] K.K. Carroll, Dietary fats and energy in relation to carcinogenesis, *New Era Global Harmony Nutr.: Proc. 14th Int. Congr. Nutr.*, Seoul, **1**, 493-496 (20-25 August 1989).
- [32] G. Poli, G. Leonarduzzi, F. Biasi, E. Chiarotto, Oxidative stress and cell signaling, *Current Med. Chem*, **11**, 1163 (2004).
- [33] V.K. Kazimirko, V.I. Mal'cev, Antioksidantnaja sistema i ee funkcionirovanie v organizme cheloveka, Antioxidant system and its functioning in the human body [Electronic resource]. Available at: <http://www.health-ua.com/2004> (Accessed: 28.02.2019).
- [34] V.A. Kurashvili, Kupirovanie oksidativnogo stressa s pomoshh'ju natural'nyh antioksidantov, Relieving oxidative stress with natural antioxidants [Electronic resource]. Available at: <http://www.vitadoctor.com.ua> (Accessed: 28.02.2019).
- [35] I.V. Simakova, *Nauchnye i prikladnye aspekty obespechenija bezopasnosti produkcii bystrogo pitaniya*, Avtoref. diss. dokt. tekhn. nauk, Scientific and applied safety aspects of fast food products, Orel, 462 (2015).
- [36] K. Rjuben, *Antioksidanty*, Sankt- Peterburg: Kron-Press, 224 (2006).
- [37] B.S. Litvin, Vpliv kompleksnoj medikamentoznoj terapii na okisnij gomeostaz u ditej z vegetativnimi disfunkcijami, Influence of complex medical therapy on oxidative homeostasis in children with autonomic dysfunctions, *Pediatrica, akusherstvo ta ginekologija, Pediatrics, obstetrics and gynecology*, **2**, 16-18 (2007).
- [38] Ja.V. Olijnik, Porushennja perekisnogo okislenija lipidiv ta ih korekcija u ditej, hvorih na atopichnij dermatit, Disorders of lipid peroxidation and their correction in children suffering from atopic dermatitis, *Visnik naukovih doslidzhen', Bulletin of scientific research*, **3**, 39-42 (2007).
- [39] G.P. Novozhilova, V.M. Aksenova, L.A. Mozgovaja, Sostojanie perekisnogo okislenija lipidov i antioksidantnoj sistemy v plazme, jeritrocitah i sljune ditej s patologiej organov polosti rta, otjagoshhennoj disbiozom kishchnika, The state of lipid peroxidation and antioxidant system in plasma, erythrocytes and saliva of children with diseases of the oral organs, aggravated by intestinal dysbiosis [Electronic resource]. Available at: <http://www.stomatburg.ru/articles/klin> (Accessed: 25.02.2019).
- [40] J. Velasco, S. Marmesat, O. Berdeaux, G. Marquez-Ruiz, M.C. Dobarganes, Formation and evolution of monoepoxy fatty acids in thermoxidized olive and sunflower oils and quantitation in used frying oils from restaurants and fried food outlets, *Journal of Agricultural and Food Chemistry*, **52**, 14, 4438-4443 (2004).
- [41] J. Velasco, S. Marmesat, O. Berdeaux, G. Marquez-Ruiz, M.C. Dobarganes, Quantitation of short-chain glycerol-bound compounds in thermoxidized and used frying oils, A monitoring study during thermoxidation of olive and sunflower oils, *Journal of Agricultural and Food Chemistry*, **53**, 4006-4011 (2005).
- [42] J.F. Greene, Toxicity of epoxy acids and related compounds to cells expressing human soluble epoxide hydrolase, *Chem. Res. Toxicol.*, **13**, 217-226 (2000).
- [43] E. Goicoechea, M.D. Guillen, Analysis of hydroperoxydes, aldehydes and epoxydes by <sup>1</sup>H nuclear magnetic resonance in sunflower oil oxidized at 70 and 100 °C, *Journal of Agricultural and Food Chemistry*, **58**, 6234-6245 (2010).
- [44] V.A. Kocur, D.F. Valiulina, Oksidativnyj stress i antioksidantnaja zashhita organizma, Oxidative stress and antioxidant defenses, Prirodnosursnyj potencial, jekologija i ustojchivoe razvitie regionov Rossii: sbornik statej XVI Mezhdunarodnoj nauchnoprakticheskoy konferencii, Natural resource potential, ecology and sustainable development of Russian regions: a collection of articles of the XVI International Scientific and Practical Conference, Penza, 50-52 (2018).
- [45] J.K. Andersen, Oxidative stress in neurodegeneration: cause or consequence?, *Nature Reviews Neuroscience*, **5**, 18-25 (2004).
- [46] H. Sies, Oxidative stress, From basic research to clinical application, *Am. J. Med*, **91**, 31 (1991).
- [47] I.V. Simakova, R.L. Perkel', V.V. Zakrevkij, M.N. Kutkina, Issledovanie intensivnosti patogenezha v zavisimosti ot stepeni okislenija pal'movogo masla, The study of the intensity of pathogenesis, depending on the degree of oxidation of palm oil, *Voprosy pitaniya, Nutrition Problems*, **85**, 2, 36 (2016).
- [48] I.V. Simakova, Ju.Ju. Eliseev, R.L. Perkel', I.Ju. Domnickij, A.A. Terent'ev, V.N. Strizhevskaja, A.N. Makarova, Ocenka sanitarnotekhnologicheskoy bezopasnosti zhirovogo komponenta nekotoryh vidov snekov i muchnyh konditerskih izdelij s dlitel'nym srokom

hranjenja, Evaluation of sanitary and technological safety of the fatty component of certain types of snacks and flour confectionery products with a long shelf life, *Saratovskij nauchno – medicinskij zhurnal, Saratov Scientific Medical Journal*, **12**, 3, 333-339 (2016).

- [49] R. Wilson, Dietary epoxy fatty acids are absorbed in healthy women, *Eur. J. Clin. Invest.*, **32**, 2, 79-83 (2002).