THEORETICAL AND PRACTICAL ASPECTS OF THE DEVELOPMENT OF A BALANCED LIPID COMPLEX OF FAT COMPOSITIONS

L. V. Tereshchuk

Kemerovo Institute of Food Science and Technology,
bul'v. Stroitelei 47, Kemerovo, 650056 Russia
phone: +7(3842) 39-68-51, e-mail: terechuk_l@kemtipp.ru

(Received March 3, 2014; Accepted in revised form April 14, 2014)

Abstract: In the paper, the effect of the lipid complex in fats and oils on human organism and their role in physiology of nutrition are reviewed. Aspects of impairment of the nutritional status upon fat consumption, in particular, the excess consumption of saturated fats, *trans*-isomers of fatty acids, and cholesterol and the deficiency of polyunsaturated fatty acids and phospholipids, are discussed. Data on oil and fat in modern structure of nutrition are described. Aspects of the development of balanced fat compositions, accounting for normal physiological needs of modern people for lipids and their structural components, are reviewed. Data on the construction of fatty bases from milk fat, natural, and modified vegetable oils and fats providing for predetermined consumer properties of functional fatty milk products are presented.

Keywords: fat consumption; nutritional status; saturated, monounsaturated, and polyunsaturated fatty acids; balanced fat compositions; development of fatty bases

UDC 664.3:577.15
DOI 10.12737/5461

INTRODUCTION

Development of new technologies in food industry and creation of a wide range of qualitatively new products with controlled modification of the chemical composition and properties is an important direction of modern nutritiology aiding the improvement of nutrition and preservation of health of the population.

Purposeful modification of fatty acid composition of lipid fraction is one of the main conditions in design of balanced food product compositions to approach the optimal ratio between the saturated, monounsaturated, and polyunsaturated fatty acids.

The concept of the development of an assortment of dairy products with increased content of milk fat identifies a number of directions, among which preferable are the directed regulation of fatty acid composition of the product by means of introduction of vegetable oils or compositions of non-milky fats, decrease of the calorific index due to the change of the ratio between fat and non-fat components for the benefit of the latter ones and allowance and feasibility of application of fatty bases improving agents, including the structure stabilizers, antioxidants, etc., for which the main principles of selection are oriented at the group of compounds of natural origin possessing maximal functionality.

The area of combining milk and plant raw materials seems promising for the development of qualitatively new dairy products of modified composition and properties. This methodology provides for a potential possibility of mutual enrichment of the products' ingredients with one or several essential factors and allows for the development of balanced-composition products, including products developed for specific needs.

Therefore, optimization of the composition and properties for the development of products that meet the formula of balanced nutrition the most predetermines the directions of new technology advancement. Design of the composition of products and diets in adherence with the requirements on balance of fatty acid, amino acid, mineral, and vitamin composition is the subject of priority in scientific and applied research [3].

THEORETICAL ASPECTS OF THE DEVELOPMENT OF A BALANCED LIPID COMPLEX OF FAT COMPOSITIONS

When characterizing the lipid component of milk fat, it should be noted that the question of modification of its fatty acid composition is a timely one. Special attention is paid to the development of new types of fat products using fatty compositions of milk fat with vegetable oils and fats.

Earlier studies on the increase of food and biological value of milk fat provided ground for the development of a new group of products, that is, spreads with modified fat phase, including milk fat and compositions of non-milk fats. Selection of the components of fat phase should be performed according to scientific principles, which are based on the requirement of preservation of the nutritive value of milk products and their organoleptic parameters with possible correction of the negative properties of milk fat. Rational combining of several sources of lipids is important from the economical point of view since it allows the producers to minimize the costs spent on raw materials and decrease the dependence of the production on seasonal fluctuations of milk input.

The need for a comprehensive evaluation of nutritive value of fats is connected with the fact that they hold an important place in human diet.

Considerable amount of research is dedicated to the investigation of the multifaceted role of lipids in vital processes [3].

According to the modern concepts, food fats are not only a concentrated form of energy, exceeding the energy content of all other food substances (oxidation of 1 g of fat in the organism yields 37.66 kJ or 9 kcal), but also a carrier of essential nutrition factors. Lipids are cell components playing an important role in membrane organization; they are solvents for vitamins A and D providing for their consumption; finally, they influence the intensity of protein and carbohydrate metabolism. A number of biologically active compounds enter the organism together with the fats; these include polyunsaturated fatty acids, phospholipids, sterols, fat-soluble vitamins, and other compounds possessing targeted functional effects. The role of lipids as a material for structural organization, first of all, the obligatory elements of biological membranes and the associated biosynthesis of physiologically active peroxidized lipids, by its importance has been compared by the scientists with the plastic function of proteins. This justified the establishment of the plastic function of lipids in the organism. While all fatty acids fit for utilization as an energy source, a specialized set of fatty acids is required for the plastic processes. The fraction of polyunsaturated acids with 20–22 carbon atoms, the most important representative of which is the arachidonic acid $C_{20:4}$, is well represented in the structure of cell membrane. These acids arrive in small amounts with food and are products of biosynthesis from their elementary precursors, linoleic $C_{18:2}$ and linolenic $C_{18:3}$ acids, in the organism. A smaller fraction of membrane lipids is represented by the products of metabolism of oleic acid $C_{18:1}$ [4].

Fat improves the taste properties of food and increases its nutritive value. Insufficient fat supply may lead to a number of disorders of the central nervous system, weakening of the immunobiological mechanisms, and other negative consequences. Excess fat consumption, especially, the animal fat, is unadvisable and leads to the risk of obesity, cardiovascular, and other diseases. A correlation between excess consumption of animal fat components and atherosclerosis progression has been established [2, 4].

Biological efficiency of lipids is determined on one hand by the structural characteristics of fatty acids, and on the other, by the ratio and content of components of various nature and functionality in fat.

A special role in fat composition belongs to essential polyunsaturated fatty acids, linoleic $C_{18:2}$, linolenic $C_{18:3}$, and arachidonic $C_{20:4}$. These fatty acids, as well as some amino acids of proteins, are referred to as essential and are not synthesized in the organism; the requirement for them may be satisfied only with food. Arachidonic acid is synthesized from linoleic acid with the involvement of pyridoxine (vitamin B6) and tocopherols. Tocopherol not only helps the transformation of linoleic acid to arachidonic, but also activates it. By their biological properties, these polyunsaturated fatty acids are referred to the vitally important nutrients, and thus are being proposed as a vitamin F complex [4].

The most important biological property of polyunsaturated fatty acids (PUFA) is their participation as structural elements in highly active biological complexes, such as phospholipids, lipoproteins, etc. PUFAs are an essential element of the myelin sheath of the connective tissue. In the organisms, hormone-like organic compounds prostaglandins, which are involved in regulation of intracellular metabolism, blood pressure, and platelet aggregation, are synthesized from arachidonic acid and influence smooth musculature and vitally important secretory functions [8]. Connection between PUFAs and cholesterol exchange manifested in the ability to increase cholesterol clearance from the organism by transformation into labile, easily soluble forms thus preventing and alleviating atherosclerosis has been established. In the absence or lack of PUFAs, cholesterol is considered to form esters with saturated acids, which are hardly oxidized in the metabolism and, due to their chemical stability, accumulate in blood and are deposited on artery walls. Essential acids, when in sufficient amounts, form esters with cholesterol that are oxidized to low molecular weight compounds in the course of the metabolism and are easily eliminated from the organism [2, 10].

In this connection, there is a need for increased PUFAs in the diet to prevent cardiovascular and other diseases. Besides, PUFAs increase the organism resistance to infections. The effect consists in suppression of pathogenic microorganisms due to replacement of bacterial lipids with PUFAs.

PUFAs produce normalizing effect on blood vessel walls, increase their elasticity, decrease permeability, participate in the exchange of vitamins of group B (pyridoxine, thiamine) and choline, which, under conditions of lack of PUFAs, decreases or looses completely its lipotropic properties. Data on stimulatory role of PUFAs in protective functions of the organism, in particular, increase in the stability of infectious diseases and γ-radiation effects, were obtained. All these functions are performed only by *cis*-isomers of PUFAs.

Vegetable oils are among the most PUFA-rich food products with linoleic acid contents reaching 50–60%; spreads contain up to 20% PUFAs, and animal fats, 3–5%.

In terms of biological activity, linolenic acid is 9-fold less active than linoleic acid. According to some reports, linolenic acid is transformed to arachidonic acid only partially in the organism. It occurs in vegetable oils in comparatively small amount, except for linseed (60%), hempseed (18%), soybean (10%), and rapeseed (9%) oils [6].

Oleic acid does not possess the activities of the essential acids, but enhances the effects of linoleic acid acting as its synergist.

The greatest biological effect is produced by arachidonic acid. It is not contained in plant products and in animal fats its content is insignificant: 0.25% in dairy butter, 0.6% in beef fat, and 2.1% in pork fat. However, as indicated above, arachidonic acid may be formed from linoleic acid thus satisfying the organism's need for the essential fatty acids.

For quantitative evaluation of how well fatty acid composition of food fats matches the organism's requirements, a parameter termed coefficient of metabolization efficiency (CME) of essential fatty acids was introduced. Violation of the optimal proportions of fatty acids in the diet or a specific metabolic situation in the organism may cause replacement of arachidonic acid by other PUFAs with 20–22 carbon atoms, which are products of metabolism of oleic and linolenic acids. These modifications cause changes of the CME value, which is the ratio of arachidonic acid fraction in cell membrane lipids composition to the sum of fractions of other 20–22 carbon atom PUFAs. CME is in a tight correlative bond with an integral parameter of the efficiency of plastic processes—gain of body wait of rapidly growing organisms,—as well as multiple parameters of membrane functional state. Unsaturated fatty acids with the double bond position between the third and the fourth carbon atoms, ω-3 fatty acids (linolenic, eicosapentaenoic, and docosahexaenoic acids), have been established to be the most effective ingredients of the group. Fatty acids with double bond position between the sixth and the seventh carbon atoms (numeration starts from carbon atom of the methyl group) belong to the ω-6 family and include linoleic, γ-linolenic, and arachidonic acids.

The recommended ω-6/ω-3 ratio in the diet of a healthy man is 10 : 1, and in a dietotherapy, from 3 : 1 to 5 : 1 [5].

Fatty acids of the ω-6 family—eicosapentaenoic and docosahexaenoic—are present in the lipid complex of fish and marine animals. The exclusion of PUFAs (linoleic, linolenic, and arachidonic) from animal and human diet leads to impairment of vital processes: retardation of growth and development, dermatitis, liver and kidney disorders, changes in cell membranes and their properties, declination of the reproductive function, etc. In the course of detalization of the issue, it was noted that only linoleic and arachidonic acids possess the high level of physiological activity. Linolenic acid, initially considered essential, is only a substituent for linoleic acid in case the latter one is absent. In the case of the presence of both acids, their transformations in the organism compete with each other due to the commonness of the enzymatic systems responsible for their transformations, which ultimately decreases the biological efficiency of fat. Taking into account that arachidonic acid is synthesized from linoleic acid by the organism, linoleic acid is the very essential polyunsaturated fatty acid.

Multiple studies are focused on the establishment of the sufficient level of linoleic acid in the organism. The level has been determined as 5–8% of calorific value of the diet, which makes 8–10 g linoleic acid per day on average (in individual cases linoleic acid content may be increased to 20 g). For children, the values of physiological needs in fatty acids of the ω-6 and ω-3 groups are 4–12 and 1–2% to the calorific value of a daily ration, respectively [5].

Excess consumption of linoleic acid by the organism is not desirable, which is due to its high proneness to oxidation and the ability to form free radicals, hampering normal course of the metabolic processes in the organism.

Previously, the data on linoleic acid content in this or that fatty product were the main characteristics of its biological properties. The results of the studies performed in the recent decades proved that not only the absolute amount of linoleic acid, but also its combination with other acids is considerably important upon determination of the efficiency of food fats. The ratio between linoleic and linolenic acids in an ideal fat should be close to 10 : 1.

The next step on the way to elucidation of the effect of fatty acid composition of food fats on the nature of their biological effects was the establishment of the physiological role of isomers of unsaturated acids. The question on the nature of the biological effect of fatty acid isomers has a practical importance, since *trans*-isomers of monoene and diene acids are present in many natural and modified fats. For example, the presence of up to 40% *trans*-isomers in the total amount of linoleic acid in milk fat makes the product an even more insignificant nutrition factor. Modification of the spatial configuration of fatty acids comprising triglycerides occurs under the effect of a number of factors: high temperature, effect of catalysts, etc. In this connection, modified vegetable oils and fats contain various amounts of *trans*-isomerized fatty acids [11].

Most authors consider hydrogenated fats possess lower nutritive and biological value than the intact vegetable oils. In the course of hydrogenation, *cis/trans*-isomerization of unsaturated acids is possible, which makes linoleic and linolenic acids physiologically inactive. While *trans-cis* or *cis-trans* linoleic acid possesses lower biological activity, *trans-trans* linoleic acid completely loses it and is not converted to arachidonic acid, which may damage biomembrane structure and prostaglandin synthesis.

Studies on the metabolic fate of *trans*-isomers of monoene and polyene fatty acids demonstrated considerable differences in the amount of *cis*- and *trans*-forms incorporated into tissue lipids of the organism. It was found that the more specialized are the membrane structures, the less is the fraction of *trans*-isomers in them. No considerable increase in their incorporation in membrane lipids occurs upon the increase in the content of *trans*-isomers in diet, which evidences the presence of some limiting factors. The effect of spatial configuration of fatty acids on the level of activation of the enzymes involved in cholesterol esterification and in the processes of dehydrogenation and chain elongation of fatty acids was noted. In this connection, the content of *trans*-isomers of fatty acids in food fats and products is regulated [2, 11].

The nature of saturated acids contained in fat products can also considerably affect the nature of biological effect of the fat. In this connection, fatty acids with intermediate carbon chain length—caprylic $C_{8:0}$, capric $C_{10:2}$, lauric $C_{12:0}$, and myristic $C_{14:0}$ acids—should be pointed out.

These fatty acids are present in sufficient amounts only in milk fat and coconut butter. Coconut butter served source for preparation of new types of fat products, investigation of which showed that they are consumed in the digestive tract without the involvement of fatty acids and pancreatic lipase. Upon entering the internal medium of the organism, they are not deposited but rather subjected to β-oxidation. Transformation of intermediate chain length fatty acids produces a pronounced effect on biosynthesis of exogenous fatty acids and cholesterol. The indicated specific features of metabolization of intermediate chain length fatty acids provided ground for the attempts to use them in dietary correction of a number of lipid exchange disorders. Their content in usual diets also cannot be ignored upon evaluation of biological properties of fat components of food.

Animal fats may contain saturated fatty acids with chain length of twenty and over carbon atoms, they are characterized by solid texture and high melting temperature. The fats include lamb, beef, pork fats, etc. High consumption of saturated fatty acids is a risk factor in the development of diabetes, obesity, cardiovascular, and other diseases.

Saturated fatty acid consumption for adults and children should make not more than 10% to the calorific value of daily diet.

Taking as an axiom the thesis that lipids are absorbed at the minimal level for each of the fractions (that is, if $C_{i1} < C_{i2} < C_{i3}$, then all fatty acid fractions are absorbed at the level C_{i1}, and the excess of each fraction equal to $(C_{i2} - C_{i1})$ and $(C_{i3} - C_{i1})$ is deposited in the organism or spent on energy needs), lipid utilization coefficient is calculated similar to that of proteins. For a proposed arbitrary etalon, $C_{i1} = C_{i2} = C_{i3} = 1$ and the coefficient of utilization is also equal to 1. Although the fatty acid formula is the important characteristics of fat products, it is not a comprehensive one. Such constituents of lipocomplex as phospholipids, sterols, and fat-soluble vitamins also produce a pronounced effect on the nature of biological effects of food fat [3].

None of the fats individually can completely provide for the organism's need for nutrients. Animal fats, including milk fat, contain vitamins A and D, as well as lecithin, possessing a lipotropic effect. However, they contain little essential PUFAs and cholesterol. Vegetable oils contain enough PUFAs and tocopherols (vitamin E). The presence of β-sitosterol, promoting normalization of cholesterol exchange in the organisms, and insignificant amounts of vitamins A and D have been noted in them.

According to the modern perception, the most appropriate is the consumption of a balanced composition of fats with each meal rather than fat products of different composition throughout the day.

An important group of lipids are the phospholipids. Being part of cell membranes, they play a considerable role in membrane permeability and exchange of compounds between the cells and intercellular space, promoting better absorption of fats and preventing liver fattening, exhibiting pronounced lipotropic effect, and preventing cholesterol accumulation in the organism enhancing its elimination [2, 10].

The highest content of phospholipids is noted in unrefined vegetable oil, 1–2% (up to 6% in soybean oil). The content of phospholipids of 5–7 g/day is considered optimal in the diet of an adult.

The physiological role of cholesterol contained in the products of animal origin should also be noted. Cholesterol is a precursor in biosynthesis of vitamin D and a number of hormones and is involved in bile acids exchange. At the same time, it is known that high blood level of cholesterol is known to be a factor of atherosclerosis development. Approximately 80% of cholesterol is formed in the organism, and we receive 20% with food. The amount of cholesterol in a daily ration of adults and children should not exceed 300 mg. The same amount of vegetable sterols (phytosterols) is required [7].

Together with the large number of works confirming the positive effects of PUFAs on human body and firstly their anti-atherosclerotic effects, there are studies proving negative effect of diets in which fat composition is based exclusively on vegetable oil. Vegetable oil contains little acids with short or intermediate chains and many polyunsaturated acids that may cause negative effects due to formation of excess peroxides. None of the vegetable oils contains cholesterol, which is required for a growing organism for the development of immune system to protect the organism from a number of diseases in the following life.

The presented characteristics of the main components of fats evidence that man equally needs animal and vegetable fats. In this connection, the design of biologically comprehensive combined fat products is timely and practically important.

PRACTICAL ASPECTS OF THE DEVELOPMENT OF A BALANCED LIPID COMPLEX OF FAT COMPOSITIONS

The following ratio of balanced fatty acids may be considered a biologically optimal formula: 10–20% polyunsaturated fatty acids (PUFA), 30–40% saturated fatty acids (SFA), and 50–60% monounsaturated fatty acids (MUFA). On average, this is provided by the ratio of 50% animal and 50% vegetable fat in the diet.

The presented ratio between the lipid fractions depends considerably on the target designation of the developed fatty composition and may change in a defined range. For dietary nutrition of people with impaired fat exchange and atherosclerosis patients, fats with increased content of linoleic acid (at least 40%) and the ratio between saturated and unsaturated fatty acids of 1 : 2 are needed.

Among the diversity of food fats, milk fat is the most valuable by its biological and dietary properties. It is absorbed by human organism better than any other fat. This is promoted by a rather low fat melting temperature (28–33°C), as well as its being presented in a finely dispersed phase in milk. Biological value of milk fat is increased by the presence of considerable amount of phosphatides (up to 400 mg %) and tocopherols (2–5 mg %), arachidonic acids, and vitamins A and D in it. Due to its good organoleptic properties and favorable compatibility with other food products, milk fat has a rather wide range of applications.

In recent years, a tendency of decreased milk fat consumption has been observed, which is in connection with its critics as of a factor increasing blood levels of cholesterol. Therefore, increasing attention is paid to the problems of milk fat composition correction to get the required ratio between the fatty acids.

Saturated acids dominate the fatty acids involved in formation of glycerides of milk fat, with saturated acid content in summer period being 62.9–67.3% and in winter period, 65.9–75.9%, and low molecular weight saturated acid content being 5.6–7.6% and 7.61–10.8%, respectively.

The content of unsaturated fatty acids in milk fat of the summer period is within the range from 33.1 to 36% and in the winter period, from 18.6 to 27.9%. The amount of polyunsaturated essential fatty acids in the milk fat in summer is 3.9–6.5%, and in winter, 2.9–3.8% [1]. Contents of these fatty acids do not meet modern medical and biological requirements of balanced nutrition.

Daily need for such vitally important compounds as phospholipids and PUFA exceeds considerably their content in consumed amounts of milk and dairy products. In these connection, to increase the nutritive value of these products, mass fraction of phospholipids and PUFAs in them should be increased.

Regulation of the fatty acid composition of milk products may be performed in three ways:
1) introduction of special feed supplements with high content of PUFAs to cow nutrition;
2) chemical modification of milk fat, with fractionation and re-esterification being the most common methods; and
3) partial substitution of milk fat with fat of a different origin.

The first two directions did not find wide application due to their low efficiency. In the first case, there is a need to correct the amount of feed supplements introduced in accordance with seasonal and regional factors, as well as the breed, age, and lactation stage of the animals. Also, it has been found that unsaturated fatty acids may pass to milk in an unchanged form, therefore, fat of such milk differs from the normal milk fat. Products produced from the modified milk have a more pronounced tendency to separation of a liquid phase at room temperature than the products prepared from normal milk [1].

In the case of correction of fatty acid composition of milk fat by its fractionation, there is a need to find rational use for solid fractions, which leads to increased product cost.

The method of milk fat composition and properties modification by mixing with fats of non-animal origin found the widest appreciation. Many years of studies on the chemical composition and physicochemical properties of food fat and lipocomplex of dairy products allowed to prove theoretically the possibility to use fat of non-animal origin in production of fat-containing dairy products with partial substitution of milk fat with vegetable oils, modified fats, or mixtures thereof taking into account the formula of balanced fatty acid composition. This method is available and convenient for use under industrial settings.

To regulate the fatty acid composition of dairy products, various vegetable oils and fats are used, including sunflower-seed, soybean, rapeseed, maize, palm, and other oils and mixtures thereof. A specially selected mixture of modified fats and oils may be used.

By the content of PUFAs, vegetable oils are divided into three main groups:
– with very high PUFA content (80% and more to the total content of fatty acids), linseed and hempseed oils;
– with high PUFA content (40–60%), sunflower-seed, soybean, cotton, and maize oils;
– with low PUFA content, but high content of oleic acid (80% and more), olive, earth-nut, and almond oils.

Fatty acid composition is an important characteristics of fat products, and such lipid fractions as phospholipids, sterols, and fat-soluble vitamins determine the biological effect of food fat.

Phospholipids are an important part of vegetable oils. The highest content of phospholipids is present in soybean (6%), cotton (up to 2.5%), sunflower-seed (up to 1.5%), and maize (up to 1.5 mg %) oils. High content of phospholipids is noted in unrefined oils. In the process of refining, vegetable oils get completely free of phospholipids [6].

The third biologically active component of vegetable oil is sterols, the best known of which is β-sitosterol. It normalizes cholesterol exchange forming insoluble complexes with cholesterol that prevent cholesterol absorption. By the content of sterols, vegetable oils are divided into the following groups:
– with very high content of sterols (1000 mg/100 g and more), wheat germ and maize oils;
– with high content of sterols (300 mg/100 g and more), sunflower-seed, soybean, rapeseed, linseed, and olive oils;
– with intermediate content of sterols (200 mg/100 g and more), earth-nut and cacao oils;
– with low content of sterols (60 mg/100 g), palm and coconut oils.

Considerable part of sterols is lost upon refining, which is why refined deodorized oils contain less sterols. Vegetable oils are completely free from cholesterol.

The fourth group of biologically active compounds present in vegetable oils is fat-soluble vitamins: tocopherols and carotenoids. High content (100 mg/100 g and more) of tocopherols is typical of wheat germ, soybean, and maize oil; sunflower-seed, cotton, and rapeseed oils are characterized by somewhat lower content of tocopherols (60 mg/100 g and more); insignificant amount of tocopherols is contained in olive and coconut oil.

Due to the absence of water and mineral substances, vegetable oils are not affected by microorganisms. During storage, only chemical changes occur with oxidation being the most important. Self-oxidation happens upon product contact with oxygen contained in the air, and the effect of oxygen targets the unsaturated double bond of fatty acids. In the process of the reaction, lipids, fatty acids, fat-like compounds, and vitamins are destroyed. Decay products with specific taste and smell that may be toxic are formed. The oxidation processes are catalyzed by enzymes, heavy metal ions, light, and heat [3]. In this connection, to prevent oxidative destruction of fat products it is reasonable to add antioxidants–or substances that enter the self-oxidation process with the formation of stable intermediates, thus blocking the chain reaction of oxidation. Intact vegetable oils contain certain amount of natural antioxidants, among which tocopherols (vitamin E) and carotenoids play the most important role. However, upon refining and deodoration, vegetable oils are freed from their natural protective properties.

Analysis of composition and properties of fat raw materials (Table 1) allows for a conclusion that in nature there are no fats and oils that would completely meet the requirements of a hypothetically ideal fat. Liquid vegetable oils are rich in polyunsaturated fatty acids, but they lack saturated acids, the content of which is rather high in milk fat. Therefore, combining milk fat with vegetable oils and fats of this or that group provides for a possibility to bring the fatty acid composition of a product closer to the hypothetically ideal fat. Upon correction of the optimal ratio of milk fat–vegetable oil, it is important to take into account not only the structural and rheological characteristics of the product, but the medical and biological requirements on consumption of this or that essential acid as well.

Table 1. Fatty acid composition of fats and oils

Product	Fatty acids		
	saturated	monounsaturated	polyunsaturated
Milk fat	67.7	28.6	3.7
Sunflower-seed oil	10.1	26.8	63.1
Soybean oil	14.7	20.9	61.2
Rapeseed oil			
low erucidic acid	7.0	59.1	33.9
high erucidic acid	3.1	73.4	23.5
Olive oil	12.5	70.9	16.6
Palm oil	50.0	39.0	11.0
Hydrogenated fat	13.0	82.0	5.0
Re-esterified fat	27.0	50.0	23.0
Palm olein	35	53.5	11.5

Based on the facts presented above, we attempted to model the lipid constituent of fatty bases which would maximally resemble the hypothetic ideal fat with the following fatty acid composition: 30% saturated fatty acids, 60% monounsaturated acids, and 10% polyunsaturated fatty acids. Not only the amount, but also qualitative composition should be taken into account. An obligatory controlled parameter for a fatty base under development is the content of *trans*-isomerized acids.

As found in practice, in order to regulate their fatty acid composition it is reasonable to formulate binary and multicomponent compositions in two stages: determination of optimal content of the ingredients and evaluation of the efficiency of lipid constituent of the designed composition.

At the first stage of practical studies, binary mixtures of milk fat and liquid vegetable oil of various fatty acid groups are discussed as raw components to design fatty bases for optimization of their fatty acid composition.

Table 2 presents the physicochemical parameters of fatty bases prepared from milk fat and liquid vegetable oils [4].

In the composition, oils of various fatty acid groups were used, including the linoleic–linolenic (soybean oil), linoleic–oleic (sunflower-seed oil), oleic–palmic (olive oil), and erucidic (rapeseed oil) groups. The fraction of vegetable oil in the binary composition varied from 5 to 25%. Alteration of the quantitative ratio of milk fat–vegetable oil changes the fatty base characteristics, which ultimately determines the designation and area of application of the products.

Introduction of 20–25% vegetable oil into a composition allows for production of a fatty base characterized by a rather soft texture with firmness of 25–42 g/cm in function of the oil used. The base comprising partially hydrogenated oils possessed the highest firmness value. Decrease in the fraction of vegetable oil to 5–10% allows to produce a product of dense texture with firmness of 80–98 g/cm. The best qualitative characteristics are typical of compositions of milk fat with sunflower-seed, rapeseed, and partially hydrogenated vegetable oils [4].

Analysis of physicochemical parameters of a fatty base comprising milk fat and a liquid vegetable oil demonstrated the impossibility of preparation of a product with balanced composition and the required melting temperature and firmness indicated in Table 2.

Introduction of a vegetable oil in the amount of 10–15% allows for bringing the product fatty acid composition closer to a hypothetically ideal by only one set of acids, that is, polyunsaturated acids, while the content of saturated and monounsaturated acids is insignificantly modified.

Therefore, binary fatty compositions do not ensure the desirable ratio of the controlled output parameters and do not allow for the design of a product with the necessary range of parameters and of predetermined composition and quality.

This fact implies the need for the development of a fatty composition that would take into account two issues (raw material- and technology-related) and ensure a reasonable compromise in the design of a combined fatty composition.

Table 2. Physicochemical parameters of fatty bases from milk fat and liquid vegetable oils

Milk fat fraction, %	Vegetable oil fraction,%	Parameters of the fatty base of a combined oil				
		Melting temperature, °C	Firmness, g/cm	Fatty acid composition		
				SFA	MUFA	PUFA
With sunflower seed oil						
95	5	30.9	93	64.9	28.5	6.6
90	10	29.8	77	62.1	28.3	9.6
85	15	28.7	61	59.3	28.1	12.6
80	20	27.6	45	56.5	27.9	15.6
75	25	26.5	30	53.7	27.8	18.5
With rapeseed oil						
95	5	31.2	96	64.6	30.2	5.2
90	10	30.2	81	61.6	31.7	6.7
85	15	29.4	67	58.6	33.2	8.2
80	20	28.6	52	55.5	34.8	9.7
75	25	27.8	37	52.5	36.3	11.2
With soybean oil						
95	5	30.8	90	65.1	28.2	6.7
90	10	29.6	74	62.4	27.8	9.8
85	15	28.4	57	59.7	27.5	12.8
80	20	27.2	41	57.1	27.1	15.8
75	25	26.0	25	54.4	26.9	18.7
With olive oil						
95	5	31.2	96	64.5	31.2	4.3
90	10	30.4	82	62.2	32.8	5.0
85	15	29.6	68	59.4	35.0	5.6
80	20	28.7	53	56.6	37.1	6.3
75	25	28.1	39	53.9	39.2	6.9

At the next stage, study on the design of fatty bases comprising milk fat and natural and modified solid vegetable fats and oils was performed.

The main constituents of combined fatty phases are the milk fat, natural and modified vegetable oils, and fats, physicochemical and rheological properties of which determine directly the properties of the final product. Varying the ratio of the components one may obtain a wide range of combined fat phases with required properties.

In the world practice, a wide array of dairy products has been developed and studied using solidified modified fats obtained in the process of hydrogenation, re-esterification, and fractionation. The development and assimilation of production of products with combined fatty phase, on one hand, promotes the realization of the requirements of balanced nutrition with respect to fatty acid composition, and on the other, is promising from the positions of decrease of the production raw material capacity. Important are the studies on composition and properties of natural and modified fats and oils.

Taking into account the requirements on limitation of the content of *trans*-isomers in fatty products, quantitative determination of fatty acids with *trans*-configuration is needed in frames of the studies of fatty acid composition of modified fats. This is essential for the establishment of the regulated quantity of hydrogenated fatty source used in the receipt composition of combined products.

Therefore, the mass fraction of *trans*-isomerized fatty acids in the starting raw materials (hydrogenated, hydro-re-esterified, and re-esterified fats) determines the specific features of the fatty base design, taking into account the medical and biological requirements for the content of lipocomplex constituents in the final product.

In selection of fat constituents for a fatty phase, one should perform a complex evaluation of composition and properties of each of the raw materials determining the quality of produced combined products.

Two aspects of the design of fatty base should be noted. The first one is aimed at the solution of the problem of development of balanced product in terms of its food and biological value, including products for prophylaxis and dietary nutrition. The second one is technological, allowing the production of a product with the required structural and rheological parameters, of defined composition and properties, and taking into account its designation and specificity of use even upon changes in quantitative ratio of the fatty acid set.

To reach the high consumer appeal of combined fatty phases, multicomponent fatty bases incorporating raw milk (milk fat, dairy butter, cream), vegetable fats, and oils, both natural and modified, should be used.

Important parameters of a fatty base are the melting temperature, firmness, and the solid phase content in a certain range of temperatures.

Fatty phase melting temperature determines the fusibility of a product, which is characterized by completeness of fat melting at physiological temperature. This parameter should be in the interval of temperatures below 36°C. Use of high-melting fats not melting at the temperature of 35–36°C in the fatty composition worsens the parameters of the final product imparting it with tallow flavor [4].

Firmness of the fatty base, determined at 15°C, may be corrected by the content of the solid phase; it characterizes one of the important properties of solid fats and oils— its ability to attain required structure at given temperature. The higher is the content of the solid phase in a fat, the higher is its firmness. At solid phase content of 30, 40, and 50% firmness of fatty base makes 75, 200, and 300 g/cm, respectively.

The content of a solid phase in the range of temperatures form 5 to 35°C determines the plasticity of fatty product, which characterizes the ability of fat, under mechanical effect, change shape without fracturing, that is to maintain shape upon the stress removal. Fat with good plasticity does not change the ratio between solid and liquid glyceride content in a wide temperature range. The good elastoplastic properties of butter are determined by the composition of its solid fraction, which is heterogeneous and is transformed to liquid phase in a wide temperature range. In this connection, butter is easily deformed upon mechanical action.

For a dietary nutrition of individuals with impaired lipid exchange, fatty bases typically contain increased amount of natural vegetable oil, with the linoleic acid content reaching 20% to the total fatty acid content. Fatty bases with increased content of glycerides of linoleic acid have decreased firmness (30–50 g/cm).

At the same time, introduction of much liquid vegetable oils decreases the fat resistance to oxidation. In this connection, special attention should be paid to selection of efficient compositions of antioxidants, determining the stability of the fatty phase of the product during storage.

Performing a complex evaluation of each of the raw material factors, it should be noted that upon the fatty base construction the quality, composition, and properties of each of the ingredient should be taken into account.

Considerable amount of monounsaturated fatty acids (up to 75%) in hydrogenated fats increases the fatty phase stability to oxidation. The content of hydrogenated fat in the compositions is regulated and determined based on the mass fraction of *trans*-isomerized fatty acids in them; the amount of the latter in final product should not exceed 8%.

A distinctive feature of re-esterified fats is their high plasticity and the ability to crystallize into a stable finely crystalline polymorphous form. Introduction of such fats into a fatty base considerably improves the structural and mechanical properties of the final creamy vegetable spreads and allows producing various products from a limited assortment of raw fat.

Variation of the fraction of liquid vegetable oil produces considerable effect on texture of the fatty phase, changing it from dense to plastic and soft. The quantitative ratio of solid fats and liquid vegetable oils not only influences the structure and texture of final product, but also determines the essential factor and how well the fatty composition is balanced.

Therefore, the most important quality parameters—melting temperature, solid fat content, and firmness—are determined by the crystalline structure of the base, formation of which causes a number of interrelated factors, the determining of which is the chemical composition of the formulation and, particularly, the content of saturated and unsaturated acids.

Table 3 presents the composition and properties of fatty bases utilizing various compositions of milk fat with natural and modified oils and fats [4].

Table 3. Fatty acid compositions based on milk fat, vegetable oil, and modified fats

Fatty phase components	Number of components	Melting temperature, °C	Firmness, g/cm	Fatty acid composition, %			*Trans*-isomer content, %
				SFA	MUFA	PUFA	
Milk fat Palm oil Sunflower-seed oil	50 30 20	30.0	59	51.2	36.7	72.1	3.6
Milk fat Palm oil Rapeseed oil	30 50 20	30.7	61	47.0	39.7	13.3	1.2
Milk fat Palm olein Re-esterified fat	50 20 30	28.9	96	48.8	39.7	11.5	6.5
Milk fat Palm olein Sunflower-seed oil	50 40 10	28.6	65	48.9	37.4	13.7	2.0
Milk fat Hydrogenated fat Palm olein	20 23 57	29.2	86	36.4	53.6	10.0	7.7
Milk fat Re-esterified fat Palm olein	20 30 50	28.5	70	38.6	46.8	14.6	5.3
Milk fat Re-esterified fat	85 15	31	115	59.1	28.4	12.5	3.2
Milk fat Re-esterified fat Sunflower-seed oil	50 45 5	30.9	97	46.5	38.3	15.2	2.1

Analysis of the compositions demonstrates that the modification of structural and rheological properties in fatty models milk fat–re-esterified fat–liquid vegetable oil and milk fat–palm oil–liquid vegetable oil is affected by the mass fraction of vegetable oil since the values of firmness, melting temperature, and solid glyceride content for milk and re-esterified fats and palm oil are in the same range and practically match each other.

In this connection, in this block of work, the following fatty system was studied: milk fat–re-esterified fat–palm olein.

Analysis of the results of performed studies allowed for a design of multicomponent fatty bases with composition corresponding to the medical and biological requirements. Realization of the principle of balanced ratio between the saturated, monounsaturated, and polyunsaturated fatty acids allowed to design the formulations of fatty phases with the required structural, rheological, and physicochemical parameters.

The data of the literature review and a complex of studies on the topic discussed allows for a conclusion that the production of products with combined fatty phase may be a subject of further scientific research and technological studies aimed at providing for healthy nutrition.

REFERENCES

1. Vyshemirskii, F.A., *Maslo iz korovégo moloka i kombinirovannoe* (Cow milk and combined butter) (GIORD, Saint-Petersburg, 2004).
2. Ipatova, L.G., Kochetkova, A.A., Nechaev, A.P., and Tutel'yan, V.A., *Zhirovye produkty dlya zdorovogo pitaniya. Sovremennyi vzglyad* (Fat products for healthy nutrition. Modern view) (DeLi Print, Moscow, 2009).
3. Kornena, E.P., Kalmanovich, S.A., Martovshchuk, E.V., et al., *Ekspertiza masel, zhirov i produktov ikh pererabotki* (Regulatory analysis of oil, fat, and processing products), ed. by Poznyakovskii, V.M. (Sib. Univ. Izd., Novosibirsk, 2007).
4. Tereshchuk, L.V., *Teoreticheskie i eksperimental'nye issledovaniya po sozdaniyu kombinirovannykh masel iz molochno-rastitel'nogo syr'ya* (Theoretical and experimental studies on development of combined butters from milk and vegetable raw materials), doctor of technical sciences thesis, Kemerovo, 2002.
5. Tutel'yan, V.A., *Gosudarstvennaya politika zdorovogo pitaniya naseleniya: zadachi i puti realizatsii na regional'nom urovne: Rukovodstvo dlya vrachei* (State policy on the healthy nutrition of the population: Problems and possible solutions at regional level: Guidance for doctors), ed. by Tutel'yan, V.A. and Onishchenko, G.G. (GEOTAR-Media, Moscow, 2009).
6. *Khimicheskii sostav i energeticheskaya tsennost'pishchevykh produktov: Spravochnik Makkansa I Uiddounsa* (McCance and Widdowson's Chemical Composition of Foods, 6th edition), translated from English, ed. by Baturin, A.K. (Professiya, Saint-Petersburg, 2006).
7. *Khimiya pishchevykh produktov* (Fennema's Food Chemistry), translated from English, ed. by Damodaran, S., Parkin, K.L., and Fennema, O.R. (Professiya, Saint-Petersburg, 2012).
8. Chavarro J.E., Rich-Edwards, J.W., Rosner, B.A., and Willet, W.C., Dietary fatty acid intakes and the risk of ovulatory infertility, *Am. J. Clin. Nutr.,* 2007. V. 85, no. 1, P. 231–237.
9. Kiihn, M.C., European Functional Foods: Challenges Beyond the Regulatory Milestone, *Food Highlights*, 2007, NM5.
10. Handbook of Nutriceuticals and Functional Foods, ed. by Wildman, R.E.S. (CRC Press, New York, 2007).
11. Chajès, V., Thiébaut, A.C., Rotival. M., Gauthier, E., Maillard, V., Boutron-Ruault, M.C., Joulin, V., Lenoir, G.M., Clavel-Chapelon, F., Association between serum trans-monounsaturated fatty acids and breast cancer risk in the E3N-EPIC Study, *Am. J. Epidemiol.*, 2008. V. 167, P. 1312–1320.