CURRENT TRENDS IN NONFAT DAIRY PRODUCTION

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Abstract: This article is dedicated to the development of new nonfat dairy products and methods of improving the quality of low-calorie foods. Advantages and drawbacks of the consumer properties of nonfat dairy products are shown. Some carbohydrate and protein fat imitators are characterized. The advantages of protein fat imitators are shown that are able not only to increase the protein content but also to add a creamy flavor to nonfat products. Possible options of using whey protein microparticulates as fat imitators in the production of nonfat dairy products are considered. The research findings are given on the use of whey protein microparticulates in the production of dairy products with higher protein contents: curd products, sweetened condensed milk, and natural cheeses: thermal-acid, soft acid-rennet, and brined.

Keywords: nonfat dairy products, butterfat imitator, whey protein microparticulate, milk-protein product, soft acid-rennet cheese, brined cheese, thermal-acid cheese, curds, condensed milk

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INTRODUCTION

Among the distinctive features of the food patterns of economically developed countries, including the Russian Federation, is a high energy capacity of the food ration. Taking into account decreased physical loads, prevailing trends toward sedentary lifestyles, and the increased share of intellectual work, the excessive consumption of food nutrients, particularly fats and carbohydrates, is becoming a very urgent problem. According to the formula of balanced nutrition, the daily demand of the human organism for fats is 102 g; however, the analysis of the macronutrient status of Russians shows the exceedance of this indicator by more than two times. The World Health Organization registers a firm growth in the number of people with progressing civilizational diseases: obesity, diabetes mellitus, and cardiovascular diseases [1].

Western countries and the United States faced long ago the consequences of overweight, which may lead to hypertension, coronary heart disease, stroke, gall-bladder disease, osteoarthritis, dyspnea, breast cancer, rectal cancer, diabetes, asthma, hormonal disorders, and reproduction problems, to say nothing of psycho-logical stresses and complexes, developing against the worsening outer appearance.

In this context, the reduction of the caloricity of food rations, in particular, by reducing the consumption of fats, is very opportune. The reduction of the calori-city of dairy products at least by 25–50% can largely contribute to the prevention of obesity and other alimentary diseases. In addition, all other components (proteins, vitamins, minerals, and microelements) in low-calorie dairy products should be preserved, consequently, retaining the nutritive value of these products and their health benefits. Developed countries of the world have long ago switched to the preemptive production of low-calorie dairy products, which constitute more than 90% of the total dairy output.

The development of new low-calorie dairy products with considerably reduced fat contents is associated with a number of difficulties, the most problematic of which is the reproduction of the organoleptic properties of traditional full-fat products. Defatted dairy products most often have a number of flaws: too hard, resilient, or coarse consistency, poor taste and aroma; for nonfat curds, it is mealiness and the appearance of curd semolina. The more these flaws are expressed, the less fat content is in the product [2].

A way to improve the organoleptic properties of nonfat dairy products is the use of fat imitators in dairy production.

Fat imitators are substances that create the illusion of fat presence in the mouth when consumed. In addition, they either contain no calories or very few of them.

Of special importance here is the search for effective fat imitators, whether artificial or, which is more preferable, natural food components that preserve to the maximum the sensory properties of nonfat products, mainly, their texture, and simultaneously reduce their energy value [1].

Fat imitators are produced on carbohydrate, protein, and fatty bases or their combinations.

Most widespread as butterfat imitators are vegetable fats and oils. Their use makes it possible to increase the amount of deficient polyunsaturated fatty acids and improve the biological effect indicator. However, the caloricity of products on their basis does not change [1].

Among the most progressive and innovative methods of improving the quality of low-calorie foods, we may distinguish low-calorie fat imitators, namely, carbohydrate- and protein-based.

Carbohydrate fat imitators are made from gums, vegetable gel, modified food starch, or grain fibers. Carbohydrate fat substitutes absorb water and imitate fat volume and structure; they are used in the production of baked goods, prefabricated meat products, spreads, soups, salad dressings, icings, and frozen desserts [3].

In 1990, Cerestar Deutschland GmbH proposed an edible fat substitute, Snowflake-01906, which represented a product of enzymatic cleavage of potato starch with high maltodextrin content. The product had a 50% reduced caloricity compared to that of fats, neutral taste and odor, and a high plasticity [4].

Fat substitutes have been developed with physical and functional properties similar to butterfat: Oatrim [5] is oat maltodextrin, containing 1–12% of soluble beta-glucan particles, and, depending on the oat grain type, Opta Grade [6], which is based on cornstarch.

A new fat substitute based on wheat starch, Gludamin, contains 96.5% of products of the destruction of starch polysaccharides with a certain distribution of molecules by size; its use reduces fat contents in products by 15–40% [7].

L.P. Kleman and J.W. Finley have developed low-calorie fat substitutes containing carboxy/carboxylate esters. These compounds have low caloricity, and their use eliminates problems related to metabolism deterioration [8].

In order to obtain good-quality low-calorie milk-protein products with reduced fat contents, it is necessary to create conditions for the formation of acceptable organoleptic indicators, in particular, the same effect of casein hydrolysis as in fat cheeses and the introduction into the product structure of components that act as separators (breakers) of the structure of protein fibers, that have a water-holding ability, and that are taste carriers in order to replace fat as a taste substance solvent and a lubricating factor [9].

These conditions are, no doubt, met by milk-protein concentrates, obtained by protein microparticulation, the so-called fat imitators.

Protein fat imitators are produced by heating and fine-crushing (microgranulating) of milk and albumen, or whey and egg proteins, and xanthan gums. However, they are neither suitable for baking nor good as deep fat, because proteins denature at a high temperature, their structure destroys, and they lose their ability to imitate fat [3].

The idea of the use of microgranulated proteins as fat imitators was first proposed in 1984. Canadian inventors Norman S. Singer, Shoji Yamamoto, and Joseph Latella have established that spherical particles of 1 μm in size are felt as fat during chewing [10]. Their invention underlay the present industrial production of various brands of fat imitators.

A protein concentrate, Nutrilac-7611, has been developed on the basis of whey protein microparticulation to particle sizes of 1–2 μm, which mimics a butterfat flavor by its organoleptic indicators. Nutrilac-7611 is characterized by hydrophilicity and unlimited swelling, forming high-viscosity colloidal solutions, having the ability of structure formation, and thus ensuring a uniform and creamy consistency of nonfat dairy products [11].

A butterfat substitute technology has been developed on the basis of cheese whey. In order to obtain a whey protein microparticulates (WPMs) of whey proteins with sizes of 1–1.5 μm, the whey is concentrated by ultrafiltration and dispersion. The WPM is characterized by a high biological value, as well as probiotic and hypolipidemic properties; it adjusts and activates the natural habitat of bifid and lactic bacteria in the human organism and can be used to enrich nonfat fermented milk products [12, 13].

The most widespread brands of protein fat imitators are Simplesse®, Dairy-Lo®, K-Blazer®, ULTRA-BAKE™, and ULTRA-FREEZE™[14].

The Dairy-Lo® technology is reduced to the controlled thermal denaturation of milk proteins. K-Blazer® resembles Simplesse®, but it is produced differently. ULTRA-BAKE™ is made from vegetable proteins. ULTRA-FREEZE™ is designed for frozen desserts [15, 16].

Microparticulated whey proteins may be used to solve the following problems:

– to replace casein in products, reducing the cost of raw materials;
– to replace fat in dairy products;
– to improve the organoleptic properties of dairy products;
– to develop new products of sport and functional nutriation; and
– to produce microgels for milk desserts and ice cream.

Unlike European countries, Russia raises more often the question of using sour whey concentrate, since, having a characteristic unpleasant taste, it cannot be added directly to dairy products. In this case, the microparticulation process comes to the rescue.

The microparticulation process is based on the thermal treatment of whey proteins α-lactalbumin and β-lactoglobulin. On exposure to temperature, whey proteins are denatured and aggregated. Then the obtained suspension is treated mechanically to form whey protein agglomerates that are similar to fat globules.

At present the main producers of microparticulation equipment are:

– the Kizel'mash Group of Companies, which markets the Export+ units for the production of microparticulates with a dry matter content of up to 50%, which are recommended for the production of low-fat yoghurts, desserts, sauces, mayonnaises, ice creams, and sport/functional products [17];
– the Alpma Co., which manufactures equipment for the production of the Alpma CreamoProt whey protein concentrate, which contains about 8–10% of crude protein as denatured, spherical proteinaceous matrices in dry matter and which is recommended for use in the production of various dairy products, including cheeses [18];
– the Tetra Pak Co., which manufactures the Tetra Therm Micro Part module for the microparticulation of the Simplesse®-100 whey proteins, made from the dry concentrate of whey protein by dissolving it in water, thermal treatment on a tubular pasteurizer, and homogenization. Simplesse®-100 disperses easily, dissolves quickly without using special equipment, and acts as a surrogate disperse phase, replacing fat droplets and simulating the spreading fatty consistency of a product [19].

The composition and nutritive value of Simplesse®-100 do not differ from the usual whey protein concentrates. Its production technology does not use substances that can change its origin. The properties of Simplesse®-100 are given in Table 1.

Table 1. Properties of the Simplesse®-100 denatured whey protein concentrate [158]

Product characteristics	Value
Chemical properties	
Protein content, mass %	53.0
Fat content, no more than, mass %	4.5
Lactose content, mass %	36.0
Moisture content, no more than, mass %	4.0
Organoleptic properties	
Outward appearance	Power
Color	from white to cream-white
Taste	a light flavor of boiled milk
Technical properties	
Dosage, %	0.5–5.0
Marking	whey protein concentrate; milk protein
Shelf life	no less than 18 months in a dry and cool place

Simplesse®-100 [20] is a multifunctional food additive, which does not differ in its composition and nutritive value from a regular whey protein concentrate. This additive disperses easily and dissolves quickly without using special equipment. The Simplesse®-100 powder is introduced into the formula mix with a sufficient amount of water; the contents of dry substances should be at least 40%. In fatty systems, the powder should be hydrated in the water phase until fat or oil is introduced.

The microgranulated protein Simplesse®-100 acts as a surrogate disperse phase, replacing fat droplets, which traditionally function as a disperse phase, and stimulates the spreading fatty consistency of products. This ability of a fat substitute is predetermined by the size and shape of component particles [9].

The Kemerovo Institute of Food Science and Technology conducts a series of scientific studies dedicated to the development of new low-fat dairy technologies that use whey protein microparticulates.

OBJECTIVE

The objective of this work is to study the technological specifics of microparticulated milk-protein concentrates in improving the biological value of new products, as well as their organoleptic and rheological properties.

The solution of the set objective makes it possible to create new-generation dietary dairy products.

During the development of new milk-protein technologies, we took into account the following requirements:

– the maximum use of milk's protein fraction;
– the exclusion of butterfat from the product composition without degrading its consumer properties;
– the improvement of the organoleptic and structural–mechanical properties of a product by the introduction of whey protein concentrates;
– the improvement of the biological value of a product by the introduction of whey proteins; and
– the minimization of production costs.

The working hypothesis of the research conducted involved the following assumptions:

– the protein content increased in the defatted milk mix owing to the introduction of WPMs into it, making it possible to increase the output of the finished product per unit of raw material and improving the rheological properties of the final products; and
– the dose of milk-clotting enzymes decreased during the coagulation of the defatted milk mix with WPMs in the manufacture of protein milk products (cheeses and curds).

RESULTS AND DISCUSSION

Positive results were obtained by postgraduate student S.V. Manylov using the Simplesse®-100 whey protein microparticulate to produce nonfat curds and thermal-acid cheeses [9].

The author has established the following:

– the rational doses of the used concentrate that make it possible to reproduce to the maximum the properties of analogs with traditional fat contents: for the production of the *Antaeus* cheese, the dose of the denatured whey protein concentrate (DWPC) is (1.1 ± 0.02)%, and, for the *Antaeus* curds, (1.0 ± 0.05)%;
– the optimal technological regimes for nonfat products;
– the organoleptic, physicochemical, and rheological properties of new products;
– safety indicators and guaranteed shelf lives of these products; and
– draft technical documents for the production of the *Antaeus* thermal-acid cheese and the *Antaeus* defatted curds, which have the organoleptic indicators given in Table 2. The physicochemical indicators of the new products are given in Table 3.

Postgraduate student E.E. Rumyantseva proposed using microparticulated whey protein to produce nonfat sweetened condensed milk. The author's studies helped develop the technology of a product called SportMilk.

In order to establish the optimal WPM dose, the organoleptic assessment of various nonfat sweetened condensed milk samples was conducted, and the changes in their taste, odor, and consistency over 30 days were analyzed.

The characteristics of the organoleptic indicators of preserved milk products (taste, odor, consistency, outer appearance, and color) depending on the dose of whey protein microparticulates during storage are given in Figs. 1–3. Nonfat sweetened condensed milk was used as the control option. Whole sweetened condensed milk served as the marker of the reference organoleptic indicators.

Table 2. Organoleptic properties of nonfat milk-protein products

Indicator	Characteristic	
	Antaeus nonfat cheese	*Antaeus* defatted curds
Outer appearance	The rind is wrinkled, with cloth traces or smooth, without a thick subrind layer	A homogeneous mass with an even, glazed surface, without noticeable protein clots
Taste and flavor	Clear, slightly sourish, with an expressed flavor and odor of pasteurization, with a slight flavor of whey proteins	Clear, lactic, without foreign flavors and odors, with an expressed flavor and odor of pasteurization
Consistency	The dough is sufficiently compact, homogeneous	Homogeneous, slightly spreading. Minor whey separations are admissible
Pattern	Irregularly shaped eyes, the absence of eyes is admissible	–
Test color	White, uniform throughout its mass	White, uniform throughout its mass

Table 3. Physicochemical indicators of nonfat milk-protein products

Indicator	Value	
	Antaeus nonfat cheese	*Antaeus* defatted curds
Moisture content, mass %, no more than	77	73
Protein content, mass %, no more than	18	20
Fat content, mass %, no more than	0.25	0.5
Common salt content, mass %	1.6-2.0	-

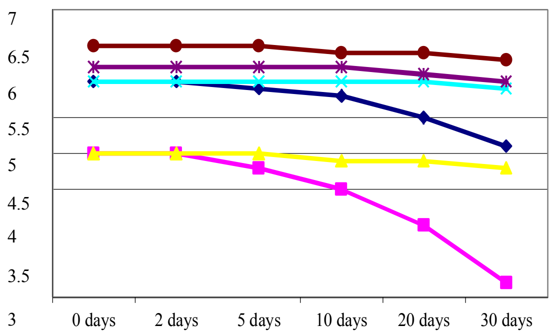

Fig. 1. Taste and odor of sweetened preserved milk products, depending on the WPM dose and storage duration.

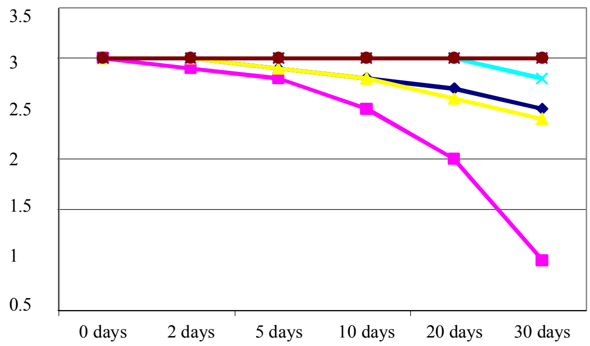

Fig. 2. Consistency and outer appearance of sweetened preserves, depending on the WPM dose and storage duration.

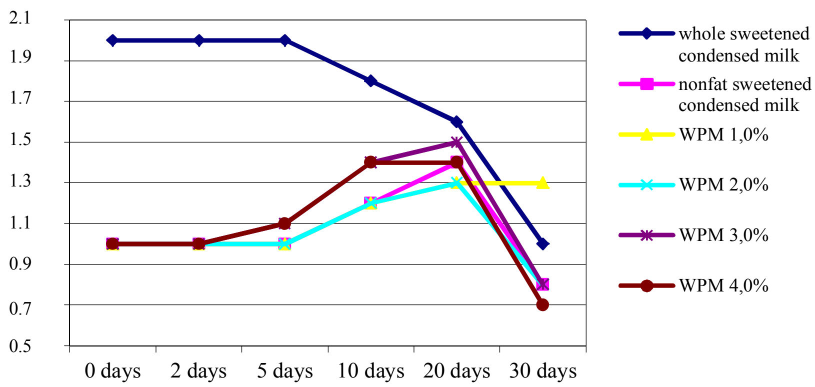

Fig. 3. Color of sweetened milk preserves, depending on the WPM dose and storage duration.

The introduction of Simplesse®-100 made it possible to improve the taste profile of condensed milk, since, during the production of this WPM, the whey proteins are thermally denatured and the sulfhydryl groups are released. In addition, the concentrate acquires a specific taste of "boiled milk" or a pasteurization flavor. This flavor is preserved in nonfat dairy products produced using Simplesse®-100 and is intensified during repasteurization. This is especially important in the production of nonfat preserved milk products, because they are characterized by the insufficiently expressed odor, taste, and aroma.

The main taste defect, which is intensified during storage, is a caramelization flavor, which is associated with a higher content of whey proteins.

The introduction of Simplesse®-100 improved the consistency of preserved milk products and prevented product solidification owing to the strong hydrophilic properties of a whey substitute of fat. However, at a WPM dose of 6.5% and higher, an insignificant amount of protein deposited on the bottom of a jar, slightly impairing the consumer properties of the product.

The color during the storage of milk preserves changed significantly; darkening was noticed ten days after. The addition of Simplesse®-100 made this effect come the earlier the larger the dose was introduced. This made it possible to mimic the color characteristic of whole condensed milk or condensed cream.

The studies conducted by the author resulted in proving the possibility to use the Simplesse®-100 WPM as a butterfat imitator in the production of nonfat sweetened condensed milk with high organoleptic properties, close to whole sweetened condensed milk. The optimal WPM dose of 2.0% in the finished product was established.

In the work by D.A. Smirnov, it was proposed to use whey protein microparticulates in the production of nonfat soft acid–rennet and brined cheeses in order to improve their organoleptic characteristics:

– the recommended doses for the introduction of WPMs were established: for the production of soft acid–rennet cheese, the dose is (0.5 ± 0.1)%, and for brined cheese, (0.6 ± 0.1)%;

– the specifics of the coagulation of defatted milk mixes with WPMs were investigated by rennin and Fromase, and it was established that (0.5 ± 0.2) g of rennin for 1000 kg of the mix were required for the coagulation of defatted mixes with WPMs;

– the optimal technological parameters of the manufacture of new products were established; and

– a draft technical documentation was developed for the production of the *Ichigo* soft acid–rennet cheese and the *Fort* brined cheese, which have organoleptic indicators given in Figs. 4 and 5.

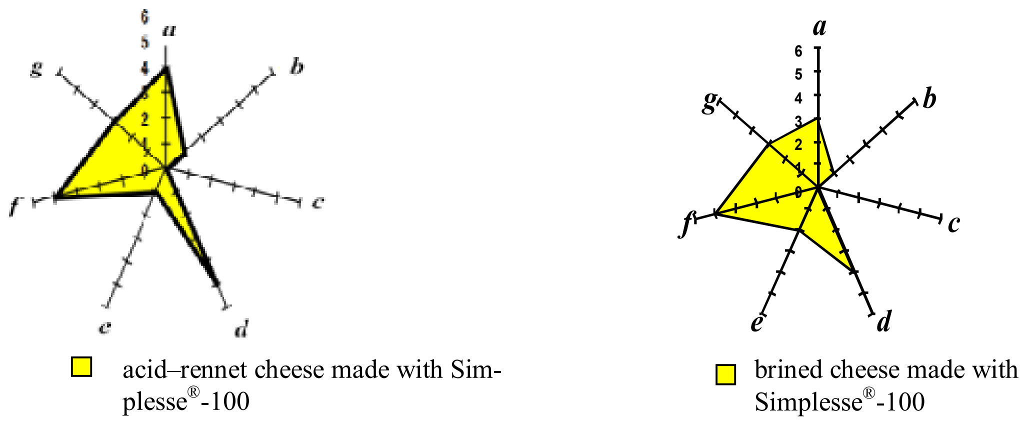

Fig. 4. Profilograms of the outer appearance, pattern, and consistency of cheeses, where: *(a)* surface insularity; *(b)* pimple surface; *(c)* moisture in the cross section; *(d)* cheese-dough density; *(e)* cheese-dough openness; *(f)* creaminess; and *(g)* cream tint.

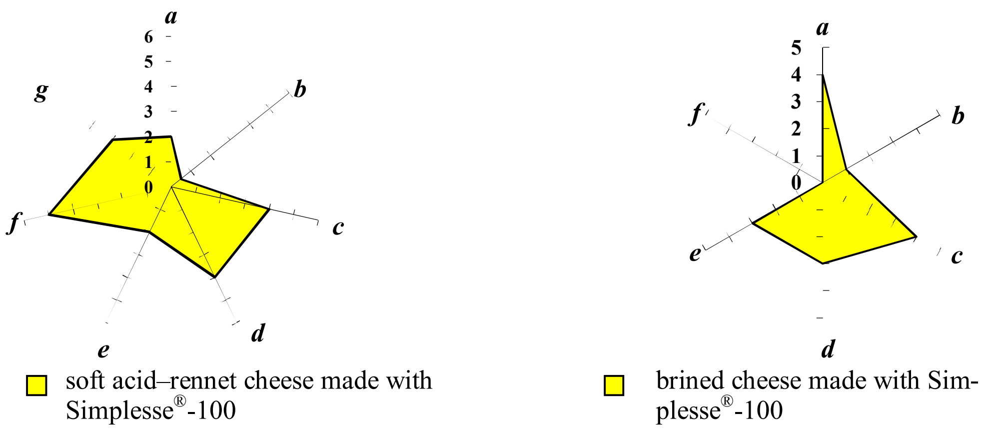

Fig. 5. Profilograms of cheese tastes and odors, where: *(a)* sour taste; *(b)* foreign taste; *(c)* clear milky taste and odor; *(d)* pasteurization flavor; *(e)* spicy flavor; and *(f)* watery flavor.

Characterizing the outer appearance, pattern, and consistency, we may conclude that cheeses made with the Simplesse®-100 whey protein concentrate (WPC) meet all the necessary requirements: their surface was insulated quite well with no signs of pimpling; the cheese dough was sufficiently compact, oozing no moisture when cut, and with a creamy consistency.

The assessment of the taste and odor of (both brined and acid–rennet) cheeses produced with WPCs is quite high: no unwanted flavors were detected in them, and at the same time the cheeses had the pleasant flavors of certain spiciness and pasteurization.

The physicochemical indicators of the new products are given in Table 4.

Table 4. Physicochemical indicators of cheese

Indicator	Indicator value	
	Soft acid–rennet cheese	Brined cheese
Moisture content, mass%, no more than	67.0	50.0
Fat content in dry matter, mass %, no more than	1.0	1.0
Common salt content, mass %	1.6–2.0	2.0–5.0

The findings show the practicability of using microparticulated whey proteins in the production of nonfat dairy products.

Summarizing the above, we may conclude that the use of microparticulated whey protein concentrates in nonfat protein dairy products is quite advisable: they positively affect the product output, increase the product's biological value, and improve its organoleptic indicators.

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