Application of milk protein concentrates in preparation of reduced fat sour cream

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Abstract

Introduction. It was shown the expediency of using protein-containing ingredients of dairy origin in the production of reduced fat sour cream.

Materials and methods. The fermentation kinetic of sour cream mixes was determined by the changes in titrated acidity. The microstructure of sour milk clots was studied using a light microscope. Rheological characteristics of reduced fat sour cream were determined using a rotational viscometry.

Results and discussion. The rational doses of milk-protein ingredients in reduced fat sour cream that prevent excessive acidity of milk cream during fermentation, structure and stabilize this product during 5 days of storage, are the following: skimmed milk powder, 1%, sodium caseinate, 0.5%, caseinate calcium, 0.75%, whey protein concentrate, 1%, hydrolyzed whey concentrate, 30%. According to the level of inhibition of the lactic acid fermentation, milk-protein concentrates in the specified quantities can be arranged in the following sequence: skimmed milk powder → whey protein concentrate → caseinate calcium → hydrolyzed whey concentrate → sodium caseinate.

By microstructural analysis of reduced fat sour cream, it was determined that 1% whey protein concentrate ensures proper moisture binding in the sour milk clot and contributes to the formation of a delicate structure with finely dispersed cells, while the use of 30% hydrolyzed whey concentrate forms a more viscous consistency of the product due to the presence of monosaccharides in it, which have a higher adsorption capacity for free moisture. The greatest structuring ability of caseinates and the most significant influence of whey proteins on the thixotropic properties of the reduced fat sour cream have been proved. A comprehensive indicator of the quality of reduced fat sour cream with milk-protein concentrates was calculated. Samples with 1% whey protein concentrate and 30% hydrolyzed whey concentrate had the most attractive sensory indicators, and got the highest score.

The chemical composition of reduced fat sour cream samples with whey proteins was studied. It was found that 1% of whey protein concentrate increases the biological value by 1.3%, while 30% of hydrolyzed whey concentrate decreases it by 3.5%. According to the research results, whey protein concentrate was classified as a biological enhancer with moderate technological properties, and hydrolyzed whey concentrate as an effective technological additive that imitates the quality indicators of an analogue with medium fat content of 18-20%.

Conclusions. The technological advantages of using whey concentrates in the composition of reduced fat sour cream as multifunctional ingredients have been shown.

Introduction

Sour cream is a sour milk product obtained by fermentation of milk cream, during which the process of lactic acid fermentation of milk sugar and coagulation of the casein fraction takes place, followed by the completion of structure formation during cooling and ripening at low temperatures (Chandan, 2015). Fat and milk proteins are mainly involved in the formation of the internal structure of sour cream (Narvhus et al., 2019). Thus, a high fat content provides an increase in the strength of the structure and viscosity of the finished product as a result of solidification and crystallization of milk cream (Buldo et al., 2013). That is why low-fat and reduced fat sour cream needs to rationalize its formulation in the absence of a sufficient amount of fat agglomerates, which are formed during the cooling of the sour milk clot and additionally stabilize its structure (Danylenko et al., 2020; Jervis et al., 2014).

According to the USDA Specifications for sour cream and acidified sour cream, sour cream with 10% of fat is a product that can be classified as "reduced fat" compared to its full-fat counterpart, which must contain at least 18% fat. At the same time, the Technical Regulations of the Customs Union (TR CU 033/2013) regulates the definition of sour cream as a product containing at least 10% milk fat. The release of low-fat and reduced fat types of sour cream is justified by the desire of manufacturers to meet the demand for low-calorie products, especially for people who follow a diet with a limited amount of saturated fat (Silva et al., 2020). However, various types of low-fat sour cream often have the defect of excessive acidity, which negatively affects the quality of the finished product (Fuquay et al., 2011). At the same time, scientists reported that milk protein concentrates in the composition of fermented milk products are able not only to effectively bind free moisture, but also to influence the activity of lactic acid microorganisms and, as a result, to regulate the product acidity during its production (Ağagündüz et al., 2021; Emkani et al., 2022). During production of sour cream with low content of protein or total solids, skimmed milk powder is usually added to the cream before fermentation, which has moderate techno-functional properties compared to highly purified milk protein concentrate (Christiansen et al., 2022; Crowley et al., 2016).

The use of whey proteins in the composition of a sour-milk dessert helps to obtain a delicate homogeneous consistency of the clot due to the high dispersion of micelles of whey proteins and the peculiarities of the gelation process (Izsó et al., 2020). In addition, whey proteins in a rational content prevent the syneresis of the clot, and are also one of the best fortifiers, which is related to their high biological value. At the same time, it is known that sodium, calcium, and ammonium caseinates have pronounced techno-functional properties (Abril et al., 2022; Mishyna et al., 2021), such as foam and gel formation, a high degree of free moisture binding (Khwaldia et al., 2004). Zhao et al. (2018) reported that 0.9% sodium caseinate in a whipped cream dessert leads to an increase in the density of the structure, viscosity of the consistency and is not inferior in its properties to whey proteins (O'Regan and Mulvihill, 2009). Li et al. (2020) proved that calcium caseinate increases the whipness of creamy desserts and stabilizes their structure, while sodium caseinate has a more moderate stabilizing ability. Another study indicated that potassium, sodium and ammonium caseinates are able to imitate the structure of full-fat analogues in imitation sour cream products or low-fat sour cream desserts (patent 3391002A US "Process for making imitation sour cream"). To achieve such an effect, their mass fraction should be at least 0.5%. However, it is known that caseinates, obtained by treating casein with alkalis, can significantly worsen the taste properties of food products, which makes it necessary to find their optimal doses (Polishchuk et al., 2020).

The use of liquid milk protein concentrate in the composition of reduced fat sour cream has not become widespread, which is due to the lack of scientific data on their techno-functional properties in the composition of the product, as well as their limited availability. It was reported about reduced fat sour cream, in the production of which it is allowed to use skimmed sweetened condensed milk, sodium caseinate from curd, prepared by wet heating method, liquid natural casein concentrate and others. At the same time, the authors of the article developed a method of obtaining liquid low-lactose whey concentrates (Osmak et al., 2021), which are appropriate for use in reduced fat products, which determines the scientific interest of this study.

The analysis of scientific and technical literature regarding the potential advantages of using milk protein concentrate in reduced fat sour cream technology makes it possible to single out the most technologically important of them:

- the possibility of preventing excessive acidity of milk cream during fermentation and storage of the finished product (Fuquay et al., 2011);
- formation of sensory indicators of reduced fat sour cream, similar to the full-fat product (Kew et al., 2020);
- the possibility of producing a dietary product of guaranteed quality with a mass fraction of fat 10% by a more progressive reservoir method (Osmak et al., 2021);
- improvement of consistency in terms of density, homogeneity, glossiness of the surface (Agarwal et al., 2015);
- the possibility of using completely natural ingredients of dairy origin (Early et al., 2012).

The aim of the work was to study the techno-functional properties of milk protein concentrate in the recipe composition of reduced fat sour cream with different amounts of their introduction.

To achieve the goal, the following tasks were defined:

1. To investigate the effect of milk protein concentrate in their variable amount on the activity of the development of lactic acid bacteria during the fermentation of cream mixes, and to choose a rational dose for each ingredient.
2. Determine the sensor and physicochemical indicators of reduced fat sour cream with the recommended content of milk protein concentrate.
3. To measure chemical composition of reduced fat sour cream samples with milk protein concentrate and calculate their biological value.

Materials and methods

Raw materials

For the production of reduced fat sour cream, milk cream with a fat content 10% was used. To normalize the mixes before fermentation, taking into account its dilution with protein-containing ingredients, cream with a fat content 20% was used.

The following milk-protein ingredients were selected: skimmed milk powder with a protein content 32%, sodium and calcium caseinates with a protein content 96%, whey protein concentrate obtained by ultrafiltration with a protein content 70%. Hydrolyzed whey concentrate with 40% of total solids (degree of lactose hydrolysis is 85%) was obtained by reconstitution in distilled water of demineralized dry sweet whey with a degree of demineralization 90% (content of ash no more than 2.5%, content of lactose no less than

79%, content of protein at least 10.7% in terms of total solids) according to the technology developed at the previous stage of scientific research (Osmak et al., 2021). To carry out the hydrolysis of whey concentrate with 40% of solids, the liquid preparation *β-D-galactosidase-hydrolase* "GODO-YNL2" ("Danisko", Denmark) with the recommended dosage at the level of 100 g of the preparation per 100 l of milk and single-strain lyophilized starter culture "*L. acidophilus LYO 50 DCU-S*" ("Danisko", Denmark) at the recommended dose of 5 g of the drug per 100 liters of milk were used.

A starter culture with the following composition was selected for the fermentation of milk cream: *Lactococcus lactis, L. cremoris, L. diacetylactis,* and *Streptococcus thermophilus*. This composition of lactic acid microorganisms ensures the intensification of the lactic acid fermentation process. The manufacturer's recommended amount of the preparation is 0.5 g per 1 liter. Before adding to the cream mix, the starter culture was activated in a nutrient medium. With a scalpel, heated over an open fire, the lyophilized starter was weighed and added to the pre-calculated amount of milk, which was pasteurized at a temperature of 84–88 °C with a duration of 3–5 min and cooled to a fermentation temperature of 28–32 °C. The duration of fermentation was an average of 6–8 hours until the titrated acidity of 60 °T was reached.

Preparation of samples

Samples of reduced fat sour cream contained:

- 10% milk fat, which makes it possible to classify this type of product as reduced fat;
- not less than 17.3% of total solids, which ensures the formation of the proper structure of the product;
- not less than 2.6% of protein, which corresponds to the well-known recommendations for the production of sour cream.

For the production of reduced fat sour cream samples, milk protein concentrate was dissolved directly in cream with a fat content 10% at a hydromodule of 1:10 and a temperature of 40 °C with a duration for 30–40 min for preliminary swelling, followed by heat treatment at a temperature of 85–90 °C for 2–3 min to ensure microbiological purity and effective dissolution of protein ingredients.

Milk protein concentrate mixes were filtered, cooled and added during mixing to milk cream that was pasteurized at temperatures of 85–90 °C with a duration of 15–20 s, followed by cooling to the fermentation temperature and normalization with cream with a fat content of 20%, after which the mix was fermented. During the first three hours, the cream mix was thoroughly stirred every hour and then left until the end of fermentation process.

Fermentation of cream mixes was carried out at a temperature of 28–32 °C for 4–12 h until the titrated acidity of 60–75 °T was reached, followed by cooling and ripening at a temperature of 4–8 °C for 6–8 h. Experimental samples of reduced fat sour cream were stored for 5 days.

Research methods

Titrated acidity. The titrated acidity of the clots during fermentation, after ripening and during storage was determined using a method (Tomovska et al., 2016).

Syneresis of sour milk clots. Syneresis of sour milk clots was determined by the centrifugal method. The same amount of product was weighed into two glass tubes with a capacity of 10 cm^3, closed with stoppers and centrifuged for 10 min at a speed of 1000 min^{-1}. The layer of whey, that settled on top of the sample, was determined on a scale in cm^3.

Microstructure of sour milk clots. The microstructure of sour milk clots was studied by microscopy of preparations using a light microscope at a magnification of 10×15. A clot sample was taken and covered with a cover glass. Photomicrographs were obtained using an Olympus CX 41 light microscope and a digital camera.

Fat content. The mass fraction of fat was determined by the acid method, which is based on the separation of fat under the action of sulfuric acid and isoamyl alcohol, followed by centrifugation and calculation.

Protein content. The mass fraction of protein in reduced fat sour cream sampled with milk protein concentrate was determined by the Kjeldahl method.

Total content of solids. The determination of the mass fraction of solids in reduced fat sour cream with milk protein concentrate was carried out using a drying cabinet according to the traditional method proposed by the Association of Official Analytical Chemists (2016) and the methodology defined by the Adolfo Lutz Institute (Zenebon and Pascuet, 2005).

Viscosity-speed characteristics. The effective viscosity of reduced fat sour cream samples was determined on a rotary viscometer with a "cylinder-cylinder" system by measuring the kinetics of deformation. Shear stress τ (Pa) was measured at a temperature of 20 °C at twelve values of the shear rate gradient (γ) in the range from 3 to 1312.2 s^{-1} during forward and reverse motion (Bass et al., 2017). The maximum effective viscosity of an almost undamaged structure ($\gamma = 3\ s^{-1}$), the minimum effective viscosity of an extremely damaged structure ($\gamma = 1312.2 s^{-1}$) and the effective viscosity of a restored structure ($\gamma = 3\ s^{-1}$) were determined. The thixotropic ability of the test samples was determined as a percentage by the difference in the values of the effective viscosity of the practically intact structure at the beginning and at the end of the measurement at a shear rate gradient ($\gamma = 3\ s^{-1}$).

Comprehensive quality indicator. The overall comprehensive quality indicator (K) of the samples was determined as a set of the following characteristics: nutritional value (K_1), sensory indicators (K_2), viscosity-speed characteristics (K_3).

The overall comprehensive quality indicator was determined according to the equation:

$$K = K_1 \times M_1 + K_2 \times M_2 + K_3 \times M_3,$$

where K is a general complex indicator;

$M_{1,2,3}$ are coefficients of importance for each of the groups of indicators $K_{1,2,3}$.

Biological value. The amino acid composition of experimental samples of reduced fat sour cream was determined by a special method (Bobel et al., 2022). Based on the obtained values, the amino acid score was calculated, which is the ratio of the content of the essential amino acid product to the content of the corresponding essential amino acid of the "ideal protein" according to the FAO/WHO scale (Kowalczewski et al., 2019). The coefficient of difference of amino acid score and biological value was calculated according to the method of M. M. Chernikov.

Statistical processing. The obtained results were calculated and graphically displayed using the standard program Microsoft Office Excel 2016. The accuracy of the obtained results was ensured by threefold repetition of the experiment.

Results and discussion

Effect of milk protein concentrate on the fermentation process of sour milk mixes

The viscosity and consistency of sour cream depend on the chemical composition and efficiency of the fermentation process. As a result of coagulation of the protein fraction of casein, a milk clot is formed and the high-melting glycerides of fat globules solidify, which affects the reduction of the negative charge of fat globules and the formation of "fat clusters" (Jollès, 1975). Fat globules are part of protein molecules and gradually form connecting bridges with them (Farrell et al., 2006), which ensures the formation of a stronger milk clot. In low-fat or reduced fat sour cream, due to the small number of fat balls, a liquid consistency is formed. As a result, milk clot is not dense and has a high degree of syneresis. The milk clot can reach the highest density at the isoelectric point of plasma proteins and fat globule shells (4.6–4.7 pH) (Bozoglu and Erkmen, 2016), which confirms the need to end the fermentation process when the titrated acidity values are reached at the level of 60–75 °T with taking into account the fact that during the slow cooling of the clot, partial ripening of sour cream occurs.

The use of milk proteins in the formulation of reduced fat sour cream slows down the process of moisture separation due to its effective binding during hydration, which can somewhat inhibit the development of lactic acid microflora during fermentation (Lucey, 2002). Considering, that the production of reduced fat sour cream is often associated with the formation of excessive acidity, this property of milk proteins can help in its regulation. However, in the scientific literature there is a lack of data on the fermentation process of milk mixes in the presence of milk protein concentrate. That is why it was decided to investigate in more detail way the dependence of the change in the titrated acidity of sour milk mixes with different milk protein concentrate at a variable amount during fermentation for 12 hours. The dosage ranges for each of the milk protein concentrate were as follows: skimmed milk powder, 1–2%, sodium caseinate, 0.5–1%, calcium caseinate, 0.5–1%, whey protein concentrate, 0.5–1%, hydrolyzed whey concentrate, 20–40%. The selection of the indicated ranges is due to the generally accepted recommendations for the use of the selected concentrates and ensuring the protein content in quantities of at least 3%. Thus, the mass fraction of milk proteins in the selected ranges of milk protein concentrate content was: skimmed milk powder, 3–3.29%, sodium caseinate and caseinate calcium, 3.16–3.64%, whey protein concentrate, 3.03–3.38%, hydrolyzed whey concentrate, 3.04–3.37%.

Data on the study of the fermentation kinetics of sour milk mixes are given in Table 1.

It can be concluded that in the presence of 1–1.5% of skimmed milk powder lactic acid microflora is quite active, as evidenced by the achievement of the recommended values of titrated acidity already at the 6th hour of fermentation (Table 1). With a further increase in the dosage of skimmed milk powder, the process of lactic acid fermentation is significantly activated, which is evidenced by the excess of the recommended values of titrated acidity at the indicated moment of fermentation. This effect can be explained by the presence of skimmed milk powder in the product as a source of lactose and minerals, which are a nutrient medium for microorganisms of the starter culture and stimulate their development (Lante et al., 2006).

Despite the fact that skimmed milk powder is one of the cheapest and most accessible types of protein-containing dairy ingredients, its use will not prevent significantly excessive acidity. Instead, the introduction of such protein ingredients as sodium caseinate, caseinate calcium, whey protein concentrate into the composition of sour milk mixes inhibits the process of lactic acid fermentation, which is mainly due to their ability to actively bind free moisture.

Table 1

Titrated acidity of sour milk mixes during fermentation at different doses of protein concentrates, °T, ($P \geq 0.95$; $n = 3$)*

Mass fraction of milk protein concentrate, %	Duration of fermentation, hours				
	4	6	8	10	12
Sour cream					
-	43	74	86	92	97
Sour cream with skimmed milk powder					
1.0	42	72	86	92	96
1.5	44.5	75	89	93	99
2.0	46	79	92	98	103
Sour cream with sodium caseinate					
0.5	37	67	74	87	91
0.75	31	49	64	75	81
1	30	44	56	67	74
Sour cream with caseinate calcium					
0.5	37	71	83	88	93
0.75	34	65	75	83	88
1	32	58	68	74	79
Sour cream with whey protein concentrate					
0.5	36	65	80	87	90
0.75	35	64	75	84	87
1.0	30	59	69	78	82
Sour cream with hydrolyzed whey concentrate					
20	37	65	78	84	87
30	33	58	70	79	84
40	27	51	59	65	71

* Note: titrated acidity values corresponding to the recommended acidity range (60–75 °T) for sour cream with 10% of fat are highlighted with a gray background

The use of hydrolyzed whey concentrate significantly increases the total solids. As a result, with an increase in the dose of milk protein concentrate, the osmotic pressure increases, which suppresses the development of lactic acid microorganisms. According to the degree of inhibition of the process of lactic acid fermentation, milk protein concentrate can be arranged in the following sequence according to the degree of growth: 1% skimmed milk powder → 1% whey protein concentrate → 0.75% caseinate calcium → 30% hydrolyzed whey concentrate → 0.5% sodium caseinate. Despite the higher protein content in hydrolyzed whey concentrate, compared to other protein ingredients, it inhibits the fermentation process less actively than sodium caseinate at a lower dose, which can be justified by the presence of lactose hydrolysis products in it, namely the monosugars – glucose and galactose. It is known that they are a nutrient medium for lactic acid microorganisms and stimulate their development more actively than the presence of milk sugar (Sharma et al., 2017).

A similar dynamic of partial inhibition of the fermentation process of the sour milk mix using liquid whey-based concentrates was also noted in the study of yogurt mixtures (Wherry et al., 2019). However, during 6–6.5 hours of fermentation, the acidity reached 80–85 °T, which is much higher than the obtained results and is a consequence of the use of acid whey instead of sweet. According to well-known recommendations for the production of reduced sour cream, the fermentation process should last at least 6 hours until the titrated acidity value of 60–75 °T is reached (Anderegg et al., 1929). Its further growth to the value of the isoelectric point of casein can lead to the restart of the protein fraction and, as a result, the destruction of energy bonds, the loss of thixotropic ability and the formation of a loose clot consistency. For further research, the optimal dosage for each of the milk protein concentrate was chosen based on the data on the dependence of the fermentation of the sour milk mix on the amount of the protein ingredient, which aimed to ensure a proper correlation between the desire to achieve the set technological effect and simultaneously increase the biological value of the finished product. For skimmed milk powder, a mass fraction of 1% was determined as the one that does not contribute to the intensification of the lactic acid fermentation process. For sodium caseinate and caseinate calcium their ability to negatively affect organoleptic indicators, namely to worsen the taste of the finished product, which is associated with the technology of obtaining caseinates from the use of alkalis, was additionally taken into account. Sodium caseinate has a more pronounced alkaline-bitter taste than caseinate calcium, so its maximum dose should not exceed 0.75% of the composition of dairy products (Polishchuk et al., 2021). Considering the fact that sodium caseinate inhibits the process of development of microorganisms to a greater extent than caseinate calcium, its dose was chosen at the level of 0.5%, and caseinate calcium, 0.75%. The mass fraction of whey protein concentrate as the one that least inhibits the development of lactic acid microorganisms, was chosen at the level of 1%. For hydrolyzed whey concentrate, the optimal amount was set at the level of 30%. Increasing the dose to 40% makes it possible to reach the recommended value of titrated acidity only during 12 hours of fermentation, which is impractical from an economic point of view.

Quality indicators of reduced fat sour cream with different amounts of milk protein concentrate

The consistency of reduced fat sour cream with an increase in the content of total solids improves due to the increase in viscosity and the formation of a dense structure. In order to verify this statement, the microstructure of the sour cream clots with milk protein concentrate was investigated (Figure 1).

A sample of reduced fat sour cream with 1% whey protein concentrate is the most homogeneous (Figure 1), which causes maximum moisture retention. The sour cream with 0.75% caseinate calcium is characterized by a lower ability to form a homogeneous clot (Figure 1), which is associated with its high gel-forming properties, as a result of which it forms a fairly dense gel network with larger cells, compared to the sample with whey protein concentrate. At the same time, 0.5% sodium caseinate exerts a more moderate synergistic effect on the structure of the sour milk clot due to the formation of cells of slightly different sizes with a lower density of the structure than in the case of using caseinate calcium. The addition of 1% skimmed milk powder slightly reduces the size of cells with a moisture in clot compared to the control, but this dose is not sufficient to prevent syneresis. At the same time, an increase in the content of skimmed milk powder in the reduced fat sour cream can lead to an increase of acidity.

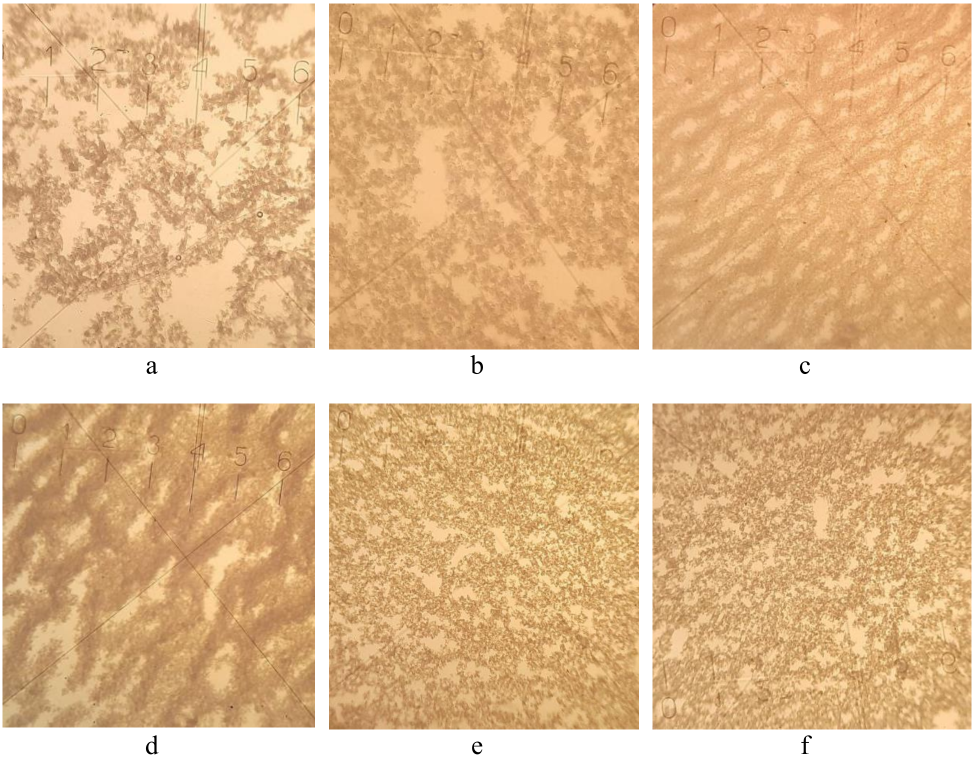

Figure 1. Microstructure of reduced fat sour cream with and without milk protein concentrate: a, control, b, 1% skimmed milk powder; c, 0.5% sodium caseinate; d, 0.75% caseinate calcium; e, 1% whey protein concentrate; f, 30% hydrolyzed whey concentrate.

The use of 30% hydrolyzed whey concentrate, despite the high content of solids, in particular protein, leads to the formation of a homogeneous and viscous consistency. Hydrolyzed whey concentrate is somewhat inferior to whey protein concentrate and caseinate calcium in terms of the dispersion of free moisture and its distribution in the clot, but it is able to form a more delicate, cream-like structure of the product, unlike sodium caseinate and caseinate calcium. Augustin et al. (2003) obtained yogurt with an improved consistency because of the use of whey protein concentrate (25–56% protein), the clot of which had a low level of whey separation. At the same time, the use of whey protein concentrate with a high protein concentration (63–64%) did not always have a positive effect on the sour milk clot, which differs from the results obtained in this study and can be explained by the specific interaction of proteins and fat globules at their high concentration, in compared to low-fat yogurt.

Sour milk clot with hydrolyzed whey concentrate is less liquid than clot with whey protein concentrate, which can be explained by the presence in it of monosugars – glucose and galactose, which have an increased degree of adsorption of free moisture (Qi and Tester, 2019), but this information requires additional research.

For this purpose, the effective viscosity of the studied samples of reduced fat sour cream with different milk protein concentrate was investigated. The viscosity-speed characteristics of sour cream clots with different milk protein concentrate in recommended quantities are shown in Table 2.

Table 2

Viscosity-speed characteristics of reduced fat sour cream with different milk protein concentrates ($P \geq 0.95$, $n = 3$)

Type of milk protein concentrate in reduced fat sour cream	Effective viscosity (mPa·s) under variable shear rate gradient			The time of ultimate destruction of the structure ($\gamma = 1312.2\ c^{-1}$), min	The degree of structure recovery, %
	$\gamma = 3\ c^{-1}$ (straight)	$\gamma = 1312.2\ c^{-1}$	$\gamma = 3\ c^{-1}$ (reverse)		
1	2	3	4	5	6
control	210.2±11.6	15.0±1.1	80.2±9.1	2.0±0.1	38.2
1% SMP	298.4±12.5	20.1±1.0	120.3±5.2	3.2±0.2	40.3
0.5% SC	329.1±10.4	25.5±1.5	156.1±11.0	6.0±0.3	47.4
0.75% CC	313.4±14.5	24.8±1.1	142.7±9.2	7.0±0.2	45.5
1% WPC	289.2±11.3	18.7±0.9	148.3±5.5	5.4±0.1	51.3
30% HWC	298.0±10.9	19.8±1.0	157.8±6.8	5.8±0.2	52.9

Note: MPC, milk protein concentrate; SMP, skimmed milk powder; SC, sodium caseinate; CC, caseinate calcium; WPC, whey protein concentrate; HWC, hydrolyzed whey concentrate.

The available milk proteins in reduced fat sour cream without milk protein concentrate (control) do not provide proper structuring and high thixotropy ability of sour cream clot (Table 2). Skimmed milk powder slightly increases structuring in reduced fat sour cream, but the ability to recover increases insignificantly, compared to the control sample. Milk protein concentrate based on whey proteins (whey protein concentrate, hydrolyzed whey concentrate) show a structuring ability at the level of skimmed milk powder, but the thixotropy of the structure of destroyed clots with these concentrates is the largest among all the studied samples and reaches values of 51.3–52.9%. This property is very important in the technology of sour cream and sour cream analogues, because when they are pumped into the hopper of the packaging machine with the help of a pump, clot of low-fat or reduces fat sour cream are usually partially or irreversibly destroyed. This leads to the loss of consumer properties characteristic of the product. Danylenko et al. (2020) reported the ability of reduced fat sour cream (10–15% fat) to show thixotropy, however, in the presence of hydrocolloids, but it is significantly less than in presence of milk protein concentrate. In addition, to establish the necessary viscosity indicators, the fermentation process should last at least 8–9 hours instead of 6 hours.

Sodium caseinate and caseinate calcium have the highest structuring ability due to their specific gel-forming ability (Table 2). At the same time, thixotropic properties of samples with caseinates occupy an intermediate place between skimmed milk powder, whey protein concentrate, and hydrolyzed whey concentrate. The highest thixotropy of samples with whey protein concentrate and hydrolyzed whey concentrate can be explained by their specific ability to evenly distribute fat and free moisture in protein matrices (Relkin et al., 2006), which contributes to the formation of more contacts between protein macromolecules and, accordingly, increases the ability to restore of sour milk clots. In the case of sodium caseinate and caseinate calcium, the formation of a dense structure with an uneven distribution of components in the spatial matrix of the product somewhat reduces the ability to self-restore the structure of destroyed clots, compared to milk protein concentrate based on whey proteins. Patterns of structuring of samples with different milk protein concentrate are also confirmed by the different time of ultimate destruction of the structure at the maximum shear rate gradient, which is minimal for the control sample and maximal for samples with caseinates.

At the next stage, the dynamic of changes in titrated acidity and the degree of syneresis of reduced fat sour cream with milk protein concentrate during 5 days of storage was studied. The highest acidity was observed when using 1% skimmed milk powder, which during 5 days of storage reached 101 °T. Such result is a defect of excessive acidity. The application of 1% whey protein concentrate is characterized by a stable increase in acidity throughout the entire storage period, while for 0.75% sodium caseinate and 0.5% caseinate calcium, after the 3rd day of storage, a slowdown in titrated acidity growth is observed. The lowest acidity was established for sour cream with 30% hydrolyzed whey concentrate, which steadily increased to 88 °T. Inhibition of the process of increasing acidity in samples with sodium caseinate, caseinate calcium, and hydrolyzed whey concentrate during storage is a consequence of the increased protein content, which affects the reduction of lactic acid production, as a result of which the concentration of hydrogen ions increases (Wherry et al., 2019). The degree of syneresis of reduced fat sour cream with milk protein concentrate for all samples increased during the storage period (Figure 2).

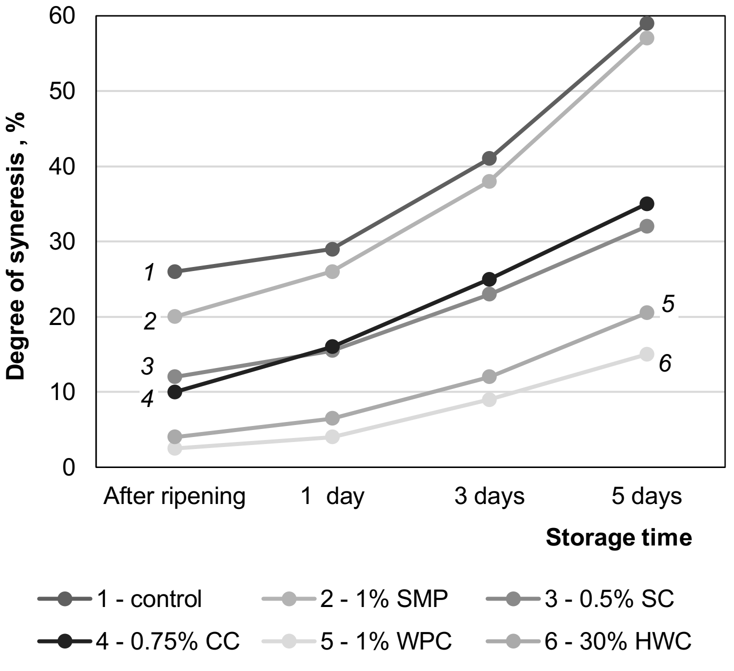

Figure 2. Degree of syneresis of reduced fat sour cream samples during 5 days of storage, % (P ≥ 0.95, n = 3). SMP, skimmed milk powder; SC, sodium caseinate; CC, caseinate calcium; WPC, whey protein concentrate; HWC, hydrolyzed whey concentrate.

The highest value (59%) was recorded for the control sample at the end of the storage period. The addition of 1% skimmed milk powder slightly reduced the whey separation after production, but later the syneresis value approached the control sample. It is interesting that for the sample with 0.75% caseinate calcium, the degree of syneresis after sour cream ripening was lower than for the sample with 0.5% sodium caseinate. After the 1st day of storage, this indicator became higher for the sample with caseinate calcium, which can be justified by the presence of large cells with free moisture, which was confirmed by the results of the microstructure analysis of the sample with 0.75% sodium caseinate. The greatest retention of whey was provided by 1% whey protein concentrate (degree of syneresis on the 5th day – 15%) due to the finely dispersed distribution of moisture in the product. For 30% hydrolyzed whey concentrate, this indicator was slightly higher than whey protein concentrate, and during storage, this difference increased insignificantly. The decrease in the degree of syneresis in test samples with milk protein concentrate also occurs due to the increased moisture-binding capacity of protein ingredients, which for milk protein concentrate based on whey proteins is significantly higher than other protein ingredients (Akalin et al., 2012; Tirado et al., 2007).

It was established that the use of protein concentrates (whey protein concentrate, caseinate calcium, sodium caseinate, hydrolyzed whey concentrate) in reduced fat sour cream helps not only to regulate the increase in acidity during lactic acid fermentation, but also during the storage period up to 5 days.

Physicochemical indicators of test samples are given in Table 3.

Table 3

Physicochemical indicators of reduced fat sour cream with milk protein concentrates (P ≥ 0.95; n = 3)

Indicator	Samples					
	Control	1% SMP	0.5% SC	0.75% CC	1% WPC	30% HWC
Total content of solids, %, not less	16.9 ±0.1	18.5 ±0.0	18.1 ±0.1	18.3 ±0.0	18.4 ±0.0	27.8 ±0.0
Protein content, %, not less	2.6 ±0.0	3.0 ±0.1	3.2 ±0.0	3.4 ±0.0	3.4 ±0.0	3.2 ±0.0
Fat content, %, no less	10.1±0.0					

Note: SMP, skimmed milk powder; SC, sodium caseinate; CC, caseinate calcium; WPC, whey protein concentrate; HWC, hydrolyzed whey concentrate.

Protein content is the largest in samples of reduced fat sour cream with caseinate calcium, whey protein concentrate, and hydrolyzed whey concentrate. Taking into account the high percentage of use of hydrolyzed whey concentrate (30%) in the reduced fat sour cream recipe, compared to other milk protein concentrate, the sample with it has the highest solids content (27.8%), which at this level corresponds to the indicator of sour cream with a mass fraction of fat 18–20%. Due to use of hydrolyzed whey concentrate it is possible to obtain a reduced fat product, which is an analogue of a full-fat product according to certain physicochemical parameters. The use of 1% skimmed milk powder makes it possible to obtain a product with a higher content of solids than in traditional sour cream with 10% of fat with a large proportion of carbohydrates in its composition. The content of total solids in samples with whey protein concentrate, caseinate calcium, and sodium caseinate is somewhat lower, although it is within the recommended range of values.

In order to evaluate the effect of milk protein concentrate on the characteristics of reduced fat sour cream, the nutritional value was calculated, a sensory evaluation was carried out and the results of the rheological indicators were taken into account, based on the results of which a comprehensive quality indicator was calculated (Table 4).

Table 4

Comprehensive indicator of the quality of reduced fat sour cream product samples, points

Indicator	Coefficients of importance	Samples					
		Control	1% SMP	0.5% SC	0.75% CC	1% WPC	30% HWC
Nutritional value	0.3	1.0	1.04	1.03	1.04	1.05	2.09
Sensory indicators	0.4	0.62	0.7	0.78	0.73	0.98	0.9
Viscosity-speed characteristics	0.3	1.0	1.28	2.12	2.35	2.03	2.14
Comprehensive assessment (K)		0.85	0.97	1.26	1.31	1.38	1.87

Note: SMP, skimmed milk powder; SC, sodium caseinate; CC, caseinate calcium; WPC, whey protein concentrate; HWC, hydrolyzed whey concentrate.

Reduced fat sour cream with 30% hydrolyzed whey concentrate and 1% whey protein concentrate received the highest number of points. At the same time, it was found that whey protein concentrate gives the product an astringent aftertaste, which is caused by the whey protein extraction technology (Childa and Drake, 2010). In contrast, hydrolyzed whey concentrate gave the product a sweet aftertaste, which is justified by the higher degree of sweetness of glucose and galactose in its composition (Helstad, 2019). In addition, the use of both whey protein concentrate and hydrolyzed whey concentrate gives the product a yellowish tint, which is due to the chemical properties of the whey.

An important indicator of the quality of reduced fat sour cream is the milky or creamy taste (Jervis et al., 2014), which was noted for the use of milk protein concentrate based on whey proteins, because they have ability to mimic milk fat. Sodium caseinate, even at a reduced dose of 0.5%, somewhat gives a slight bitter aftertaste, while caseinate calcium excessively thickens the product to the formation of an overly dense structure. The nutritional value of the sour cream product increases by 1.03–1.05 times and by 2.09 time for the sample with hydrolyzed whey concentrate, which is due to the high content of carbohydrates and protein in its chemical composition.

Biological value of reduced fat sour cream with milk protein concentrates

According to the results of the comparison of quality indicators, samples of reduced fat sour cream with 1% whey protein concentrate and 30% hydrolyzed whey concentrate were selected for further investigation of their biological value, as those that differ in high protein content and have the most attractive taste qualities for the consumers. In order to determine the biological value of the developed compositions of reduced fat sour cream, the content of amino acids in 3 samples was determined: control, 1% whey protein concentrate, 30% hydrolyzed whey concentrate. The calculation of the amino acid score of essential amino acids was carried out and then their content was compared to the reference values of the FAO/WHO (Table 5).

It can be concluded that the limiting amino acid in all experimental samples is valine (Table 5). However, the score value for each of the essential amino acids does not provide a complete understanding of the biological value of the finished product, so the coefficient of difference of amino acid score (CDAAS) was calculated according to the method of M. P. Chernikov (Figure 3).

Table 5

Amino acid score of experimental samples, %

Amino acid	FAO/WHO standard, g/100g of "ideal protein"	Amino acid score, %		
		Control	1% WPC	30% HWC
lysine	5.5	78.2	79.8	74.6
threonine	4.0	62.5	63.8	64.8
methionine + cystine	3.5	97.1	98.6	92,7
valine	5.0	52.0	53.1	50.1
isoleucine	4.0	52.5	54.0	51.8
leucine	7.0	68.6	70.5	66.0
Phenylalanine + tyrosine	6.0	76.7	77.9	64.7

Note: WPC, whey protein concentrate; HWC, hydrolyzed whey concentrate.

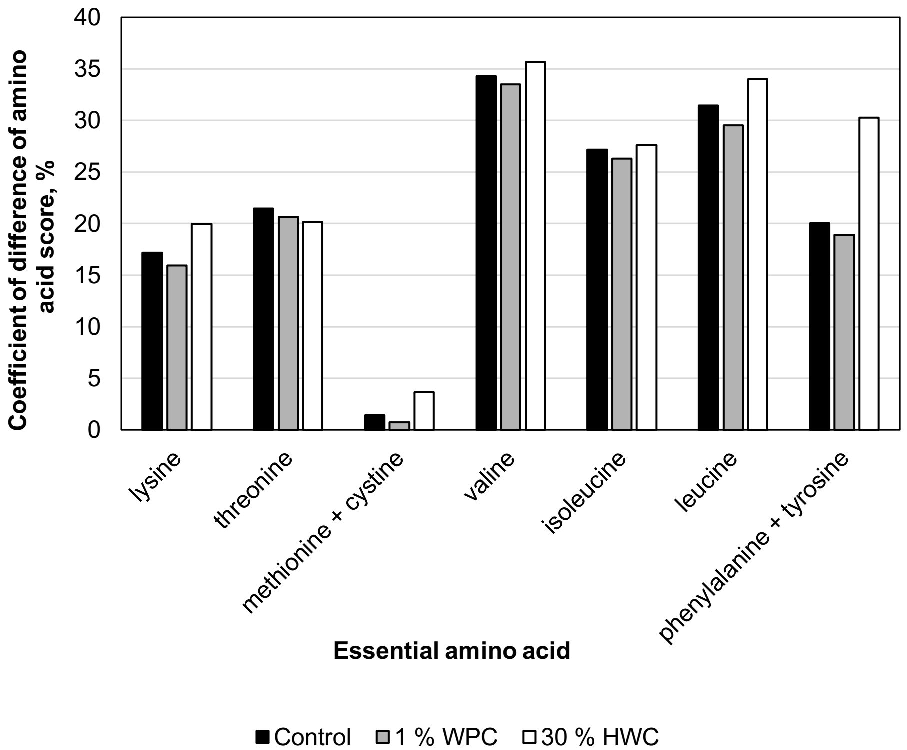

Figure 3. Coefficient of difference of amino acid score in experimental samples, % . WPC, whey protein concentrate; HWC, hydrolyzed whey concentrate.

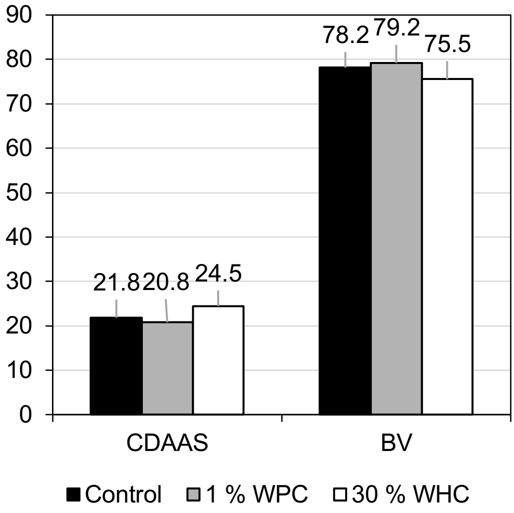

Figure 4. Biological value of reduced fat sour cream, %. WPC, whey protein concentrate; HWC, hydrolyzed whey concentrate.

The maximum excess for all samples is provided by valine (Figure 3). Thus, the smaller the value of the CDAAS, the more fully the essential amino acid is used for the needs of biosynthesis, which is shown in Figure 4.

For control sample the biological value is 78.2% (Figure 4). Addition of 1% whey protein concentrate leads to its increase by 1.3%, while the use of 30% of hydrolyzed whey concentrate reduces it by 3.5%. This trend can be explained by the fact that the percentage of substitution of milk cream, which is a source of high-quality protein, with hydrolyzed whey concentrate in the recipe composition of reduced fat sour cream reaches 30%.

However, the rationale for using both whey protein concentrate and hydrolyzed whey concentrate in reduced fat sour cream technology should be considered comprehensively. Whey protein concentrate ensures an increase in the biological value of the finished product and contributes to the stabilization of acidity during production and further storage. At the same time, the use of hydrolyzed whey concentrate, in addition to stabilizing acidity, makes it possible to obtain a product with a mass fraction of total solids and taste qualities corresponding to such the full-fat analogue as sour cream with fat 18–20%, but with an insignificant decrease in biological value.

Conclusions

1. The rational doses of milk protein concentrate in the composition of reduced fat sour cream, which ensure the achievement of the recommended value of titrated acidity of 60–75 °T in 6–8 hours of fermentation, for the selected protein ingredients are the following: skimmed milk powder, 1%; sodium caseinate, 0.5%; caseinate calcium, 0.75%; whey protein concentrate, 1%; hydrolyzed whey concentrate, 30%.
2. The use of milk protein concentrate allows to stabilize the acidity of the product during storage for 5 days. The most uniform distribution of moisture in the matrix of the protein

clot was observed for the sample with 1% whey protein concentrate, while the best adsorption of free moisture was noted for the sample with 30% hydrolyzed whey concentrate. The protein content is the largest in samples with caseinate calcium, CWP, and hydrolyzed whey concentrate and is 3.4, 3.38, and 3.22%, respectively, while the total solids is the largest in the sample with 30% of hydrolyzed whey concentrate. A comprehensive quality indicator was calculated, which is the highest for reduced sour cream samples with 1% whey protein concentrate and 30% hydrolyzed whey concentrate.

3. Addition of 1% whey protein concentrate to reduced fat sour cream increases biological value by 1.3%, while using 30% hydrolyzed whey concentrate decreases it by 3.5%. Thus, whey protein concentrate is a biological enricher with moderate technological properties, while hydrolyzed whey concentrate is a highly effective technological ingredient that allows to obtain an analogue of a full-fat sour cream, with an insignificant decrease in biological value.
4. The perspective of further research consists in scientific substantiation of recipes of reduced fat sour cream with taste-aromatic ingredients of plant origin.

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