potravinárstvo®
OPEN ACCESS
Received: 14.1.2023
Revised: 12.2.2023
Accepted: 15.2.2023
Published: 1.3.2023

Slovak Journal of Food Sciences

Potravinarstvo Slovak Journal of Food Sciences
vol. 13, 2023, p. 159-169
https://doi.org/10.5219/1849
ISSN: 1337-0960 online
www.potravinarstvo.com

Development of sour cream with vegetable oils using a food emulsion stabilised by an emulsifying complex

Ihor Ustymenko, Larysa Bal-Prylypko, Mykola Nikolaenko, Anastasiia Ivaniuta, Nina Tverezovska, Ivan Chumachenko, Oksana Pylypchuk, Tatyana Rozbytska, Mykola Gruntovskyi, Viktoriia Melnik

ABSTRACT

This scientific work describes the research that aims to study the use of a finely dispersed, aggregately stable food emulsion with a mass fraction of blended oil of 50% and xanthan gum in the composition of sour cream with vegetable oils as an analogue of traditional sour cream. The samples of fat-containing fermented-milk bases as a component of sour cream with vegetable oils with a fat content of 10-20% were obtained using two methods. The first method consists in normalising the fat content of the fermented-milk base obtained by fermentation of skimmed cow's milk with a food emulsion, and the second one – is in the fermentation of a normalised mixture consisting of a food emulsion and skimmed cow's milk. When comparing the duration of fermentation of skimmed cow's milk and normalised mixtures with a fat content of 10 to 20%, it was established that in order to achieve the minimum value of the titrated acidity of the clot of 60 °T, the duration of fermentation of skimmed cow's milk is 6 hours, of a normalised mixture with a fat content of 10% – 8 hours, 15% – 12 hours, 20% – 16 hours. According to the organoleptic quality indicators, the samples of fat-containing fermented-milk bases with a fat content of 20%, obtained by two methods, had an indiscrete but unsuitable thick consistency, which was adjusted using xanthan gum. According to the organoleptic quality indicators, it was established that in order to obtain a sour cream with vegetable oils with an indiscrete and thick consistency, 0.15% of xanthan gum should be added to the fat-containing base obtained by the first method, and 0.20% – to the fat-containing base obtained by the second method. The study of determining the content of polyunsaturated fatty acids in sour cream with vegetable oils with a fat content of 20% shows an increased content of omega-3 and omega-6 fatty acids – 2.13% and 10.88%, respectively, compared to sour cream obtained by the traditional technology.

Keywords: food emulsion, fermented milk product, sour cream, polyunsaturated fatty acids, xanthan gum

INTRODUCTION

To date, the issue of resource conservation in the milk processing industry is relevant due to the decrease in the production of cow's milk as a raw material **[1]**. Instead, there is a tendency to increase the production of milk-containing products, in the content of which fats of vegetable origin replace milk fat. Accordingly, considering the acceptable price and comparing it with milk products, the demand for such products also increased **[2]**.

Thus, the technology of milk-containing products is rapidly developing to provide consumers of all social groups with high-grade food products.

It should be noted that one of the ways to resolve the bacterial equilibrium problem in the human body is to include fermented milk products in the diet, as they contain probiotics that have a positive effect on the gut

microflora **[3]**. Sour cream is a fermented milk product **[4]**. In the production technologies of sour cream and sour creamy consistency products, fats of non-dairy origin are usually used, such as palm and coconut fats and milk fat substitutes **[5]**. However, such fatty components may not satisfy the human body's needs, particularly polyunsaturated fatty acids in vegetable oils **[6]**. The constant analysis of the structure of the population's nutrition indicates a deficiency of polyunsaturated fatty acids, especially omega-3, in the presence of consuming an excess amount of saturated fatty acids **[7]**. Usually, in the technologies of sour creamy consistency products, fat components are added to skimmed milk, and the normalised mixture total volume dispersion is carried out by stirring, which is a rather energy-consuming process. In such cases, the obtained fat products may have unsatisfactory quality during storage because fat globules without stabilisation by emulsifiers may be unevenly distributed in normalised mixtures and have an average size of more than 2 μm. The fat phase dispersion with obtaining fat globules with an average size of not more than 2 μm increases the nutritional value, improves organoleptic and improves the finished product's physical and chemical quality indicators **[8]**. Therefore, using vegetable or blended oils precisely in dispersed form is relevant to obtain new types of sour creamy consistency products. There is the technology of a food emulsion with a mass fraction of fat of 50%. The food emulsion contains blended oil and is an emulsion-type fat concentrate with an average size of fat globules of not more than 2 μm and a stability index of 100%. Such parameters of the food emulsion are achieved due to the use of an emulsifying complex (sodium caseinate + a mixture of polyglycerol and higher fatty acids) and established homogenisation modes **[9]**. Also, since vegetable oils, compared to milk fat **[10]**, cannot structure food systems, stabilisers or thickeners should be used **[11]**. Using stabilisers and thickeners makes obtaining a sour creamy consistency product with high consumer properties possible.

Scientific Hypothesis

The research work hypothesis was based on the assumption that using a food emulsion in the technology of a fermented-milk sour creamy consistency product would avoid dispersing the total volume of the milk-and-vegetable mixture. Accordingly, such a solution would ensure a reduction of the technological process and increase the content of polyunsaturated fatty acids. Using stabilisers and thickeners would allow for obtaining a product with high organoleptic quality indicators.

MATERIAL AND METHODOLOGY

Samples

The research work was carried out with samples, the composition of which is given in Table 1.

Table 1 Formulations of test samples and control samples.

Components	Fat Mass Fraction, %			
	0.0	**10.0**	**15.0**	**20.0**
Control Sample*				
Cream obtained from cow's milk (with a fat mass fraction of 20%)	-	-	-	100.0
Total	-	-	-	100.0
Fat-Containing Fermented-Milk Base No. 1*				
Skimmed cow's milk	100.0	80.0	70.0	60.0
Food emulsion (with a fat mass fraction of 50%)	-	20.0	30.0	40.0
Total	100.0	100.0	100.0	100.0
Fat-Containing Fermented-Milk Base No. 2				
Fermented skimmed cow's milk	-	80	70	60
Food emulsion (with a fat mass fraction of 50%)	-	20	30	40
Total	-	100.0	100.0	100.0

Note: Direct application bacterial preparation. It is not indicated in the formulated composition.

Chemicals

Distilled water, H_2O (TOV Novokhim, Ukraine).
Phenolphthalein alcoholic solution, $C_{20}H_{14}O$, 1.0% (Shostka Chemical Reagents Plant, Ukraine).
Sodium hydroxide, NaOH, 0.1 N (TOV Khimlaborreaktiv, Ukraine).
Cobalt sulphate solution, $CoSO_4$, 2.5% (TOV Khimlaborreaktiv, Ukraine).
Sodium methylate, CH_3ONa (ATK Ukraine, Ukraine).
Sodium sulphate, Na_2SO_4 (AT ZPD, Denmark).
MRS-agar (Conda, Ukraine).

Animals, Plants and Biological Materials

Iprovit SSK bacterial preparation (Institute of Food Resources NAAS of Ukraine, Ukraine) containing *Lactococcus lactis* ssp. *lactis; Lactococcus lactis* ssp. *cremoris; Lactococcus lactis* ssp. *diacetilactis; Streptococcus salivarius* ssp. *thermophilus*.

Instruments

Laboratory thermometer, (TOV Standard-Lab).
Mohr pipettes, (TOV SkyLab).
Bunsen beaker, (TOV SkyLab).
Conical flask, (TOV SkyLab).
Glass rods, (TOV SkyLab).
Titration assembly, (TOV Labour-Technik).
Thermostat TSO-80, (TOV Ukragrotest).
Gas chromatograph (GE LifeSciences BPG 100/500, Germany).
Petri dish (TOV Termolab).
Counter of colonies of microorganisms JL-1C (TOV Spectrolab).
Microscope XS-5520 LED (TOV Micromed).

Laboratory Methods

The titrimetric method determined the titrated acidity, which is based on the neutralisation of acids contained in the investigational product with a sodium hydroxide solution in the presence of an indicator, according to GOST 3624 **[12]**. The fatty acid content was determined by chromatographic according to DSTU ISO 15885/IDF **[13]**. Organoleptic quality indicators were assessed by tasting and compared with standard indicators according to DSTU 4418 **[14]**. The number of viable lactic acid bacteria was determined by the method of sowing serial dilutions in agar nutrient media according to GOST 10444.11 **[15]**.

Description of the Experiment

Sample preparation: Food emulsion with a mass fraction of blended oil (sunflower oil and linseed oil (85:15)) of 50% was obtained by homogenisation of a coarsely dispersed mixture, which consists of a previously prepared fat component and the obtained aqueous solution of sodium caseinate **[16]**. The fat-containing fermented-milk bases and the control sample were obtained by the fermentation of a normalised mixture (the fat-containing fermented milk base No. 1), cream, and by the normalisation of fermented skimmed cow's milk with a food emulsion (the fat-containing fermented milk base No. 2), according to the formulations given in Table 1. Xanthan gum was added to fat-containing fermented-milk bases with a fat content of 20% No.1 and No. 2 with mass fractions from 0.1 to 0.3% at 20 °C and stirred for 5 minutes.

Number of samples analysed: During experimental investigations, 9 samples were used, and the titrated acidity and organoleptic quality indicators were determined in 7 samples, of which and the fatty acid composition was determined in 2 samples.

Number of repeated analyses: All measurements were performed 3 times.

Number of experiment replication: The number of replicates of each experiment to determine one value was 5 times.

Design of the experiment: Normalised mixtures and skimmed cow's milk were fermented in a thermostat at a temperature of 30 °C for 16 hours. Every two hours of the fermentation process, the titrated acidity was determined in normalised mixtures and skimmed cow's milk according to the method **[12]**. The normalisation of fermented skimmed cow's milk with a food emulsion was carried out by stirring at a temperature of 20 °C for 5 minutes. A sour cream with vegetable oils was obtained by adding xanthan gum to fat-containing fermented-milk bases No. 1 and No. 2 (with a fat content of 20%) at a temperature of 20 °C and stirring for 5 minutes. Determination of the number of viable lactic acid bacteria in fat-containing fermented-milk bases No. 1 and 2 was carried out according to the method **[15]**. The organoleptic quality indicators of fat-containing fermented-milk bases No. 1 and No. 2 were assessed by tasting and compared with standard indicators in the regulatory documentation **[14]** for sour cream as traditional one. The chromatography method determined the content of omega-3 and omega-6 polyunsaturated fatty acids in the sour cream with vegetable oils and the control sample **[13]**.

Statistical Analysis

The STATISTICA Microsoft Excel editor combined with XLSTAT processed experimental data using mathematical statistics methods. The accuracy of the obtained experimental data was determined using the Student's t-test with a confidence coefficient ≤0.05 with many parallel definitions of at least 5 (confidence probability $p = 0.95$).

RESULTS AND DISCUSSION

The methods of obtaining a fat-containing fermented-milk base for sour cream with vegetable oils, consisting of skimmed cow's milk and a food emulsion, were substantiated at the first stage of the research investigation. Figure 1 shows the value of the titrated acidity of samples of normalised mixtures and skimmed cow's milk during fermentation at 30 °C.

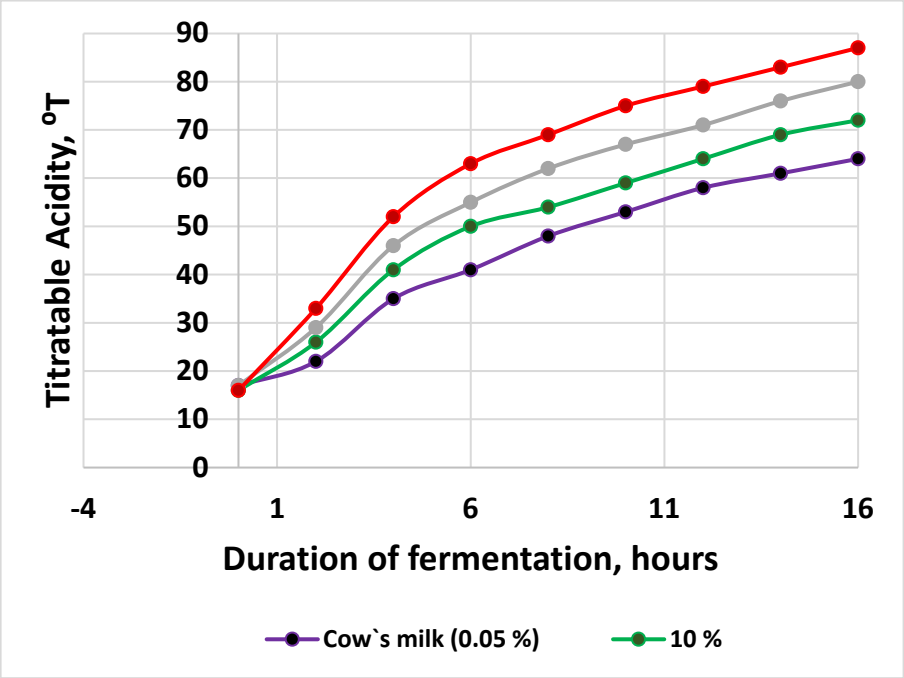

Figure 1 Values of the titrated acidity of samples of normalised mixtures with a fat content of 10, 15, 20% and skimmed cow's milk during the fermentation process.

According to Figure 1, it is clear that during the fermentation, a fermented-milk coagulum with a titrated acidity of 60 °T was obtained from all test samples, which meets the regulatory requirements according to DSTU 4418 **[14]**.

However, the fermentation time of the samples to reach the specified acidity value was different. Thus, to achieve the minimum value of the titrated acidity of the coagulum (60 °T), the duration of fermentation of full-fat cow's milk is 6 hours, and of a normalised mixture with a mass fraction of blended oil of 10% is 8 hours, of 15% – 12 hours, of 20% – 16 hours. Therefore, the components of a food emulsion inhibit the development of lactic acid microflora compared to the duration of the skimmed cow's milk fermentation.

Sour cream, according to the traditional technology, is obtained by the fermentation of cream with bacterial cultures **[17]**, and sour creamy consistency products are usually obtained from a mixture consisting of skimmed milk and vegetable oils (fats), and bacterial cultures **[18]**, **[19]**.

It should, however, be noted that the fermentation process of cream containing milk fat (of 10-40%) and used in the production of sour cream according to the traditional technology is longer compared to the fermentation process of cow's milk with a fat content of 0.05%-2.5% due to deteriorating the fermentation microflora **[20]**. Also, not only milk proteins but also the fat phase are involved in the formation of the fermented-milk coagulum and its quality indicators **[21]**.

With this in mind, it is possible to obtain a fat-containing fermented-milk base by fermenting a mixture normalised by the content of blended oil (skimmed cow's milk + a food emulsion) or by mixing a previously obtained fermented milk base (skimmed cow's milk fermented with a bacterial preparation) with a food emulsion, that should be tested experimentally.

The Iprovit SSK bacterial preparation specification states two fermentation temperature regimes 30-34 °C and 36-38 °C **[22]**. Linseed oil in a food emulsion blended as a fat phase is vulnerable to the oxidative deterioration **[23]**, **[24]**. According to the regulatory requirements for blended oil **[25]** contained in a food emulsion, its storage temperature is up to 30 °C. Therefore, the fermentation of the normalised mixture was carried out at a temperature of 30 °C to avoid oxidative deterioration of linseed oil.

Also, it should be noted that the lactose content, which ensures the process of lactic-acid fermentation **[26]**, **[27]** in normalised mixtures, is sufficient to obtain fermented milk coagulum with a titrated acidity of 60 °T.

The number of viable lactic acid bacteria in fat-containing fermented-milk bases and their organoleptic quality indicators are shown in Table 2 and Table 3.

Table 2 Number of viable lactic acid bacteria in fat-containing fermented-milk bases.

Sample		Number of viable lactic acid bacteria, CFU/g
The norm, no less than [14]		1.0×10^7
Fat-Containing Fermented-Milk Base No. 1	fat content 10 %	10^8
	fat content 15 %	
	fat content 20 %	
Fat-Containing Fermented-Milk Base No. 2	fat content 10 %	
	fat content15 %	
	fat content 20 %	

Table 2 shows that all samples of fat-containing fermented-milk bases after fermentation have a standard amount of viable lactic acid bacteria as for classic sour cream.

According to the research results given in Table 3, it was established that the deterioration in consistency is observed with the increase in the mass fraction of blended oil in the fat-containing fermented milk base No. 1. Thus, the fat-containing fermented milk base with a mass fraction of fat of 20% acquired an unsuitable thick consistency. All three samples of the fat-containing fermented milk base No. 2 acquired an unsuitable thick consistency. This consistency characteristic is explained by the fact that blended oil is not a fat phase capable of forming and texturing this food system, compared with milk fat **[28]**, **[29]**.

Table 3 Organoleptic quality indicators of fat-containing fermented-milk bases.

Indicator	Blended Oil Mass Fraction, %		
	10	**15**	**20**
	Fat-Containing Fermented-Milk Base No. 1		
Appearance and consistency	Homogeneous mass with a glossy surface, thick		Homogeneous mass with a glossy surface and unsuitable thick consistency
Taste and smell	Pleasant, fermented-milk, slightly nutty		
Colour	White with a cream shade, equal throughout the mass		
	Fat-Containing Fermented-Milk Base No. 2		
Appearance and consistency	Homogeneous mass with a glossy surface and unsuitable thick consistency		
Taste and smell	Pleasant, fermented-milk, slightly nutty		
Colour	White with a cream shade, equal throughout the mass		

Therefore, there is a need to improve the consistency of samples with mass fractions of blended oil of 20%, obtained by various methods using a thickener and structure stabiliser, which will allow obtaining finished products with the maximum possible content of polyunsaturated fatty acids. The use of thickeners and/or stabilisers is widely used to improve the technology of sour cream **[30]**, which contributes to obtaining higher quality indicators, particularly the consistency of finished products.

At the research second stage, the composition of sour cream with vegetable oils using xanthan gum as a natural thickener and structure stabiliser was substantiated **[31]**, **[32]**.

Xanthan gum forms a substance that is similar to a gel **[33]**, but its solution has great mobility - under mechanical action, the viscosity decreases. After stopping the action, the viscosity returns to the previous one **[34]**, **[35]**, which will positively affect a sour cream with vegetable oils.

Organoleptic quality indicators of samples of sour cream with vegetable oils with a mass fraction of blended oil of 20% based on the fat-containing fermented-milk bases No. 1 and 2 with different xanthan gum content are given in Table 4.

As can be seen from Table 4, to obtain an homogeneous, thick consistency, 0.15% of xanthan gum should be added to the fat-containing base No. 1, and 0.20% – to the fat-containing base No. 2. The different content of the used xanthan gum in the composition of fat-containing fermented-milk bases is explained by the fact that the fat-containing base No. 2 has a more unstructured consistency due to adding a food emulsion separately to the fermented-milk base made from skimmed cow's milk. At the same time, during the fermentation process, the normalised mixture No. 1 formed a more structured fermented milk coagulum involving fat globules with partially coagulated protein **[36]**, **[37]**.

Table 4 Organoleptic quality indicators of samples of sour cream with vegetable oils with a mass fraction of blended oil of 20% with different contents of xanthan gum.

Indicator	Xanthan Gum Content, %				
	0.10	0.15	0.20	0.25	0.30
Fat-Containing Fermented-Milk Base No. 1					
Appearance and consistency	Homogeneous mass with a glossy surface and unsuitable thick consistency	Homogeneous mass with a glossy surface, thick	Homogeneous mass with a glossy surface, viscous		Homogeneous mass, gel-like
Taste and smell	Pleasant, fermented-milk, slightly nutty				
Colour	White with a cream shade, equal throughout the mass				
Fat-Containing Fermented-Milk Base No. 2					
Appearance and consistency	Homogeneous mass with a glossy surface and unsuitable thick consistency	Homogeneous mass with a glossy surface and unsuitable thick consistency	Homogeneous mass with a glossy surface, thick	Homogeneous mass, viscous	
Taste and smell	Pleasant, fermented-milk, slightly nutty				
Colour	White with a cream shade, equal throughout the mass				

The fat content of sour cream with vegetable oils (20%) corresponds to the average fat content of sour cream, which is a positive point since there is an adverse reaction to a low-fat diet with the recognition that the consumption of foods, which are high in carbohydrates, is probably harmful **[38]**.

The content of omega-3 and omega-6 polyunsaturated fatty acids in sour cream with vegetable oils is shown in Figure 2.

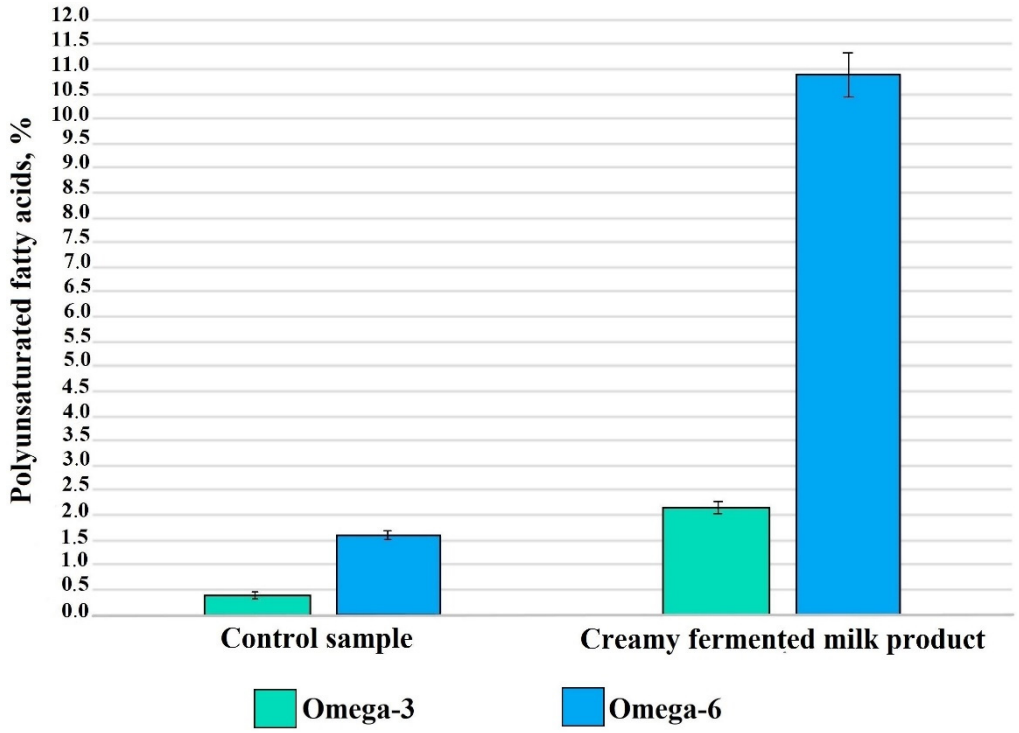

Figure 2 The content of omega-3 and 6 polyunsaturated fatty acids in sour cream with vegetable oils compared to the control one.

As can be seen from Figure 2, the content of omega-3 and omega-6 polyunsaturated fatty acids in sour cream with vegetable oils is higher compared to sour cream obtained by traditional technology and is 2.13% and 10.88%, respectively.

As is known **[39]**, polyunsaturated fatty acids, especially omega-3 and omega-6, are not synthesised by the human body and must be obtained with food. The important role of polyunsaturated fatty acids in preventing and treating many diseases has been proven **[40]**. According to the content of omega-3 and omega-6, their ratio in sour cream with vegetable oils is 1:5, due to the use of blended oil **[41]**, which corresponds to the recommendations of the World Health Organisation regarding this ratio (1: (5-15)) for widely consumed food products **[42]**.

CONCLUSION

The research was conducted on the possibility of using a food emulsion with a mass fraction of blended oil of 50%, with an average size of fat globules of not more than 2 μm and xanthan gum, and as a natural thickener and stabiliser in the composition of sour cream with vegetable oils as an analogue of traditional sour cream. The first method of obtaining a fat-containing fermented-milk base for sour cream with vegetable oils, consisting of a food emulsion and fermented skimmed cow's milk, and the second method of obtaining a fat-containing fermented-milk base, consisting of a normalised mixture, which contains a food emulsion and skimmed cow's milk, are substantiated. The duration of skimmed cow's milk fermentation is 6 hours, of normalised mixture with a fat content of 10% – 8 hours, 15% – 12 hours, 20% – 16 hours. A deterioration in consistency is observed with an increase in the mass fraction of blended oil in the fat-containing fermented-milk base from 10 to 20%. Thus, the fat-containing fermented-milk base obtained by the first method with a fat content of 20% and the fat-containing fermented-milk bases with a fat content of 10-20% obtained by the second method acquired an unsuitable thick consistency. To obtain a sour cream with vegetable oils with an indiscrete and thick consistency, 0.15% of xanthan gum should be added to the fat-containing base with a fat content of 20%, obtained by the first method, and 0.20% – to the fat-containing base with a fat content of 20%, obtained by the second method. It was found that the content of omega-3 and omega-6 polyunsaturated fats is 2.13% and 10.88%, respectively, which is higher compared to sour cream with a fat content of 20% obtained by the traditional technology, in a sour cream with vegetable oils, which includes fat-containing bases obtained by two methods. Thus, the possibility of using food emulsion and xanthan gum as part of sour cream with vegetable oils with a fat content of 20% has been proven. Under the industrial production conditions of the developed sour cream with vegetable oils, the product label will indicate that it is a product made from raw dairy materials with a complete replacement of milk fat with vegetable oils. The developed sour cream with vegetable oils makes it possible to expand the range of milk-containing fermented-milk products with increased polyunsaturated fatty acids. Also, it is recommended to be used both as a finished product and as a semi-finished product for obtaining food-fermented products with the content of plant raw materials by including vegetable, fruit, and berry heterogeneous or homogeneous fillers.

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Funds:

This research received no external funding.

Acknowledgments:

We would like to thank you to Dr. for Larysa Bal-Prylypko.

Conflict of Interest:

The authors declare no conflict of interest.

Ethical Statement:

This article does not contain any studies that would require an ethical statement.

Contact Address:

***Ihor Ustymenko**, National University of Life and Environmental Sciences of Ukraine, Faculty of Food Technology and Quality Management of Agricultural Products, Department of Technologies of Meat, Fish and Marine Products, Polkovnika Potekhina, Str.16, 03041 Kyiv, Ukraine,
E-mail: ustymenko_ihor@ukr.net
ORCID: https://orcid.org/0000-0003-0171-5780

Larysa Bal-Prylypko, National University of Life and Environmental Sciences of Ukraine, Faculty of Food Technology and Quality Management of Agricultural Products, Department of Technologies of Meat, Fish and Marine Products, Polkovnika Potekhina, Str.16, 03041 Kyiv, Ukraine,
E-mail: bplv@ukr.net
ORCID: https://orcid.org/0000-0002-9489-8610

Mykola Nikolaenko, National University of Life and Environmental Sciences of Ukraine, Faculty of Food Technology and Quality Management of Agricultural Products, Department of Technologies of Meat, Fish and Marine Products, Polkovnika Potekhina, Str.16, 03041 Kyiv, Ukraine,
E-mail: mykola.nikolaenko.nubip@gmail.com
ORCID: https://orcid.org/0000-0003-2213-4985

Anastasiia Ivaniuta, National University of Life and Environmental Sciences of Ukraine, Faculty of Food Technology and Quality Control of Agricultural Products, Department of Technology of meat, fish and marine products, Polkovnika Potekhina Str., 16, Kyiv, 03040, Kyiv, Ukraine,
E-mail: ivanyta07@gmail.com
ORCID: https://orcid.org/0000-0002-1770-5774

Nina Tverezovska, National University of Life and Environmental Sciences of Ukraine, Faculty of Humanities and Pedagogy, Department of Social Work and Rehabilitation, Heroes of Defense, Str.15, 03041 Kyiv, Ukraine,
E-mail: tverezovskaya@gmail.com
ORCID: https://orcid.org/0000-0002-0672-9308

Ivan Chumachenko, University of Life and Environmental Sciences of Ukraine, Faculty of Livestock Raising and Water Bioresources, Department of Dairy and Beef Production Technology, Heroes of Defense Str., 15, 03041, Kyiv, Ukraine,
E-mail: chumach_08@ukr.net
ORCID: https://orcid.org/0000-0002-2816-5195

Oksana Pylypchuk, National University of Life and Environmental Sciences of Ukraine, Faculty of Food Technology and Quality Management of Agricultural Products, Department of Technologies of Meat, Fish and Marine Products, Polkovnika Potekhina, Str.16, 03041 Kyiv, Ukraine,
E-mail: pilipchuk_os@ukr.net
ORCID: https://orcid.org/0000-0002-2757-6232

Tatyana Rozbytska, National University of Life and Environmental Sciences of Ukraine, Faculty of food technologies and quality management of products of agricultural products, Department of Standardization and certifying of agricultural products, Heroiv Oborony Str.15, 03041, Kyiv, Ukraine,
E-mail: roirf1991@gmail.com
ORCID: https://orcid.org/0000-0003-0098-927X

Mykola Gruntovskyi, National University of Life and Environmental Sciences of Ukraine, Faculty of Livestock Raising and Water Bioresources, Department of Technologies in Poultry, Pig and Sheep Breeding, Heroiv Oborony str., 12b, Kyiv, 03041, Ukraine,
Tel.: +38 (0987691099)
E-mail: kolya_gr26@ukr.net
ORCID: https://orcid.org/0000-0002-6969-2987

Viktoriia Melnik, National University of Life and Environmental Sciences of Ukraine, Faculty of Livestock Raising and Water Bioresources, Department of Technologies in Poultry, Pig and Sheep Breeding, Heroyiv Oborony Str., 15, Kyiv, 03041, Ukraine,
E-mail: MelnikVika@nubip.edu.ua
ORCID: https://orcid.org/0000-0002-8782-1236

Corresponding author: *