

Fatty acid composition of curd spread with different flax oil content

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Abstract

The creation of new types of dairy products for functional purposes with the addition of unconventional oils as sources of polyunsaturated fatty acids (PUFA) is a promising and relevant research sphere. The study aimed to investigate the fatty acid composition of experimental samples of curd spread with different content of flax oil. The fatty acid composition was determined on a Hewlett Packard HP-6890 chromatograph with a flame ionization detector equipped with a 100 m long SP-2560 capillary column. It is established, that the total content of saturated fatty acids in curd spread containing 8 %, 10 %, and 12 % of flax oil was reduced, and the general total content of unsaturated fatty acids increased accordingly by 5.73 %, 6.94 % and 7.31 %, compared to the control sample without flax oil. The gas-chromatographic analysis showed that flax oil is rich in omega-3 PUFA due to its high content of α -linoleic acid, so adding flax oil to the spread led to an increase in its content of α -linolenic acid and, accordingly, increased the content of PUFA of the omega-3 family. Thus, adding 8 %, 10 % and 12 % of flax oil to the curd spread, the content of α -linolenic acid in it increased accordingly by 3.91 %, 4.52 %, and 4.69 %, compared to the control sample. Curd spread with 10 % content of flaxseed oil is characterized by the most optimal fatty acid composition. The ratio of saturated fatty acids to unsaturated in this curd spread is 1.9 : 1, and the ratio between PUFAs of the omega-3, -6, and -9 families are 1.3 : 1: 5.3.

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Introduction

Preserving health and expanding the duration of human life is one of the modern issues. One of the key ways of tackling this issue is the creation and active introduction of those foods of mass consumption, which are not only reached in energy and plastic material but also an important source

of physiologically functional ingredients into the diet. They are polyunsaturated fatty acids (PUFA), fat-soluble vitamins, phospholipids, and other biologically active components (Goyal *et al.* 2014; Kukhtyn *et al.* 2018a).

The creation of new types of dairy products for functional purposes with the addition of unconventional oils as sources of PUFA is

a promising and relevant research sphere (Bermúdez-Aguirre and Barbosa-Cánovas 2011; Ganesan *et al.* 2014; Dal Bello *et al.* 2015). On the one hand, it is because of the presence of lactic acid microorganisms, which provide a useful antagonistic effect on the conditionally pathogenic gut flora (Prado *et al.* 2015; Kukhtyn *et al.* 2018b), and on the other hand, due to the increased content of PUFA, especially the omega-3 family, namely linoleic acid, which cover the deficit of these fatty acids in the diet (Lane *et al.* 2014; Dal Bello *et al.* 2017). This approach in the technological introduction of flax oil gives the prospect of making enriched cheese paste a biologically valuable functional food product.

It is known that PUFAs of the omega-3 family enter our body either with fat from the fish of cold seas (which are eicosapentaenoic and docosahexaenoic fatty acids) or with vegetable oils such as flax, sesame, rapeseed, pumpkin, soybeans, and others, which contain different amounts of linoleic acid (Bermúdez-Aguirre and Barbosa-Cánovas 2012; Jandacek 2017). Reference data (Asuming-Bediako *et al.* 2014; Suksombat *et al.* 2014; Ayyildiz *et al.* 2015; Lewinska *et al.* 2015) indicates that sunflower and corn oils contain a high amount of ω -6 acids and very small amount of ω -3 acids and, accordingly, do not have the appropriate fatty acid composition. Soybean oil has a recommended for consumption ratio of ω -3/ ω -6 PUFA (1 : 10). Rapeseed and mustard oils are characterized by a relatively low level of saturated fatty acids (4 – 7 %), a high level of oleic acid (33 – 59 %) and an average level of linolenic acid (9 – 11 %) and, accordingly, a favorable ratio of ω -3/ ω -6 as 1: 1 – 2. Olive oil is characterized by a high content of oleic acid and a low level of PUFA. The content of essential α -linolenic acid in flax oil significantly exceeds the recommended levels, which indicates their high physiological value and feasibility of use as a lipid supplement to enrich food with ω -3 acid. Essential γ -linolenic acid (18 %) was detected only in cedar oil. Walnut and hemp oils have a fairly high content of α -linolenic acid, but their use is limited by high cost and low prevalence. Therefore, scientists (Goyal *et al.* 2014; Lewinska *et al.* 2015;

Kanakri *et al.* 2017) believe that flaxseed oil in its biological value is in the first place to provide the body with omega-3 PUFA and recommend it enter into the daily diet.

The adequate content of PUFAs of the omega-3 family in the diet provides a whole range of functions in a healthy body due to the high, genetically determined content of these PUFAs in the membranes of all cells and the main pools of the organism (El Abed *et al.* 2008; Albracht-Schulte *et al.* 2018; DiNicolantonio and O'Keefe 2018). Also important is their role as derivatives for the formation of cellular hormones, such as prostaglandins, leukotrienes, and thromboxanes, which regulate the course of physiological and biochemical processes in cells and tissues both in normal and in various pathologies (Gogus and Smith 2010; Browning *et al.* 2012; Calder 2015).

Therefore, PUFAs, which are rich in omega-3s, are now regarded as "healthy fats" with several physiological benefits. In particular, consumption of products with such content helps to maintain the physiological level of triglycerides in the blood and blood pressure prevents the development of cardiovascular diseases (Chowdhury *et al.* 2014; Farvid *et al.* 2014). Also, it has been reported that regular consumption of omega-3 fatty acids has a positive effect on the brain and nervous system activity (Gogus and Smith 2010; Drapkina and Shepel 2015).

Based on the above mentioned, we have developed a curd spread with additional content of flax oil as a source of omega-3 PUFAs (Lialyk *et al.* 2019). The study aimed to investigate the fatty acid composition of cottage cheese, flax oil, and developed curd spread with different content of flax oil.

Experimental

The work was carried out at the Ternopil Ivan Puliuj National Technical University in the laboratories of the Department of Food Biotechnology and Chemistry.

In the process of developing the technology of a particular food product, especially with high-fat content, it is advisable and important to determine the fatty acid composition of such a product. To create the curd spread according

to the recipe low-fat cottage cheese was chosen, which meets the requirements according to the requirements of SSU (State Standards of Ukraine) (SSU 2007). In the first stage of the experimental part of the study, the fatty acid content of raw milk and the cottage cheese of the trademark "Molokiiia" (which was used as a basis for the production of curd spread rich in omega-3 fatty acid) were investigated. In the second stage, the fatty acid content of flax oil was investigated. On the third stage, the fatty acid composition of curd spread with a flax oil content of 8 %, 10 %, and 12 % was investigated. Gas-chromatographic analysis of raw milk, low-fat cottage cheese of trademark "Molokiiia", flax oil and curd spread with different content of flax oil was investigated using gas-liquid chromatography on Hewlett Packard HP-6890 gas chromatograph with flame-ionization detector equipped with open tubular column SP-2560 with a length of 100 m (Holubets and Vudmaska 2015).

The process of making curd spread with linseed oil included the following technological operations: 1) Selection of a mixture for melting (low-fat cottage cheese and linseed oil were subjected to organoleptic evaluation and laboratory methods of quality research); 2) Grinding of raw materials (raw materials were grounded into particles with a diameter of 5 – 8 mm). 3) Compounding of the mixture. 4) Introduction

of melting salts (melting salts-sodium citrate was added to the cheese mass to increase the pH, partial transition of proteins to the soluble state and improve the melting process of the cheese mass); 5) Maturation of curd mass (duration of exposure 2 h); 6) Melting of the curd mass (melting time 15 min, at a temperature of 82 °C (PS-10, "Ukrtechprom" Ukraine)); 7) Homogenization of the melted mass (duration of homogenization at $P = 9.81$ MPa on MICROTRON MB 800, Germany); 8) Packaging (packaging of the curd product was carried out in hot way at a temperature of +60 – +75 °C in foil. The weight of the package is 50 g). 9) Cooling and storage of the curd product (up to a temperature of +2 – +4 °C).

Statistical processing of the results was carried out using methods of variation statistics using the program Statistica 9.0 (StatSoft Inc., USA). Non-parametric methods of research were used (Wilcoxon-Mann-Whitney test). The arithmetic mean (\bar{x}) and the standard error of the mean (SE) were determined. The difference between the comparable values was considered to be significant for $P < 0.05$.

Results and Discussion

As a result of gas chromatographic analysis of milk fat, 39 peaks were found, which corresponded

Table 1. The fatty acid composition of low-fat cottage cheese of trademark "Molokiiia" and raw milk materials ($\bar{x} \pm SE$, $n = 5$).

Name of fatty acids	Code of fatty acids	Mass content of fatty acids [%]	
		Cottage cheese	Control sample, raw milk
<i>Saturated</i>			
Maslinic	C 4 : 0	3.16±0.11	3.55±0.12
Capronic	C 6 : 0	1.82±0.13	2.10±0.08
Caprylic	C 8 : 0	1.03±0.07	1.14±0.06
Caprinic	C 10 : 0	2.60±0.11	2.41±0.11
Lauric	C 12 : 0	2.67±0.07	2.66±0.08
Myristic	C 14 : 0	11.45±0.12	11.45±0.12
Palmitic	C 16 : 0	33.62±0.14	33.44±0.15
Stearic	C 18 : 0	9.75±0.11	9.68±0.16
Other acids		6.76±0.10	6.56±0.11
In total saturated		72.86±0.14	72.98±0.16
<i>Unsaturated</i>			
Oleic	C 18 : 1	22.07±0.02	21.67±0.01
Linolic	C 18 : 2	3.751±0.012	3.69±0.01
Linolenic	C 18 : 3	0.845±0.100	0.83±0.00
Arachidonic	C 20 : 4	0.07±0.03	0.06±0.00
Other acids		0.42±0.09	0.77±0.07
In total unsaturated		27.14±0.16	27.12±0.12

to saturated and unsaturated fatty acids and their isomers. Table 1 shows the main fatty acids. From the presented data it can be seen that in the low-fat cottage cheese of trademark "Molokiia". Palmitic, myristic, and stearic acids were dominant among saturated fatty acids, whereas oleic and linolenic were dominant among unsaturated fatty acids.

The ratio between saturated and unsaturated fatty acids in low-fat cottage cheese of the trademark "Molokiia" was 2.7 : 1. It should be noted that among unsaturated fatty acids in cottage cheese, polyunsaturated fatty acids of the omega-6 family are dominated, accounting for 26 % of the total of all fatty acids or 96 % of polyunsaturated fatty acids. The analysis of the obtained results shows that this cottage lacks the polyunsaturated fatty acids of the omega-3 family. The content of the latter in this study product is only 0.8 % of all fatty acids. Thus, it can be argued that this cottage cheese is deficient in the content of PUFAs of the omega-3 family. Therefore, when creating a curd spread based on this cottage cheese, our task was to enrich its PUFA of the omega-3 family.

For the enrichment of cottage cheese with omega-3 PUFA in the process of making curd spread, we have chosen flax oil, which is known to be one of the richest in omega-3 family PUFA because of its high content of α -linolenic acid. Since the fatty acid composition of oils, including flax oil, depends on many characteristics, we have chosen flax one, which is made from seeds of the "Debiut" breed and its fatty acid composition was investigated. The results obtained are presented in Table 2. As can be seen, flax oil obtained from the seeds of flax breed "Debiut" is characterized by a high content of the omega-3 family PUFA due to linolenic acid, which is 53.5 % of the total

content of all fatty acids. The ratio of PUFAs of the omega-3, -6, and -9 families in the studied flax oil is 4 : 1 : 1.5. In general, the results of the study of the fatty acid composition of flax oil confirm the high content of α -linolenic acid, which allows it to be reasonably used for the enrichment of curd spread.

The next stage of our research was the development of technology for the production of curd spread with different contents of flax oil. The samples of cottage cheese products contained 8 %, 10 %, and 12 % of flax oil. As a result, curd products had a creamy-white color that was smooth all over and with specific for curd and slightly mustard-like taste of flax oil, without excess acidity taste. The results of the study of the fatty acid composition of curd spread with different flax oil content are presented in Table 3.

Table 3 shows that the fatty acid composition of the studied curd spreads varied significantly depending on the content of flax oil. Thus, in general, in all tested samples of curd spread with the addition of 8 %, 10 % and 12 % of flax oil the content of such saturated fatty acids as palmitic and stearic increased and the content of other, low-molecular acids, such as oil, caprylic, capronic, caprinic, lauric and myristic, decreased. In general, the total content of saturated fatty acids in the curd spread with the addition of 8 %, 10 % and 12 % of flax oil decreased by 5.73 %; 6.94 % and 7.31 %, respectively compared to the control sample (without flax oil). The content of unsaturated fatty acids according to Table 3, respectively, increases due to oleic, linolic, and linolenic acids, and this increase is directly correlated with the increase in the content of flax oil in curd spread. These fatty acids are a key factor to a particular class of omega-3, -6, or -9 polyunsaturated fatty acids, so the ratio between these classes of omega PUFAs has changed accordingly. The general total content of unsaturated fatty acids in curd paste with the addition of 8 %, 10 % and 12 % of flax oil increased by 5.73 %; 6.94 % and 7.31 %, respectively compared to the control sample of curd spread without the addition of linseed oil.

Considering that flax oil is rich in omega-3 PUFA due to the high content of α -linolenic acid, the addition of flax oil in the spread, in the first place, will lead to an increase in the content

Table 2. The fatty acid composition of linseed oil by the method of cold-pressed flax seeds "Debiut" ($x \pm SE$, $n = 5$).

Name of fatty acids	Code of fatty acids	Content of fatty acid [%]
Myristic	C 14 : 0	trace amount
Palmitic	C 16 : 0	7.40
Stearic	C 18 : 0	4.20
Arachidic	C 20 : 4	0.50
Palmitelaidic	C 16 : 1	0.20
Oleic	C 18 : 1c	21.40
Linolic	C 18:2c,12c	12.80
Linolenic	C 18:3c,12c, 15c	53.50

Table 3. The fatty acid composition of curd spread (CS) with different flax oil content ($x \pm SE$, $n = 4$).

Name of fatty acid	Mass content of fatty acids [%]			
	Control sample of CS without flax oil	CS with 8 % of flax oil	CS with 10 % of flax oil	CS with 12 % of flax oil
<i>Saturated</i>				
Maslinic, C 4 : 0	3.21±0.42	2.52±0.24*	2.16±0.19*	2.04±0.21*
Capronic, C 6 : 0	1.82±0.11	1.25±0.15*	0.78±0.13*	0.63±0.14*
Caprilic, C 8 : 0	1.03±0.01	0.72±0.07*	0.61±0.05*	0.54±0.04*
Caprinic, C 10 : 0	2.60±0.19	2.16±0.13*	1.77±0.21*	1.52±0.18*
Lauric, C 12 : 0	2.67±0.02	2.03±0.25*	1.63±0.17*	1.54±0.16*
Myristic C 14 : 0	11.45±0.09	10.12±0.12	9.86±0.24	9.72±0.18
Palmitic C 16 : 0	33.62±0.21	34.04±0.18	34.19±0.28	35.04±0.35
Stearic C 18 : 0	9.75±0.08	10.06±0.11	10.15±0.22	10.03±0.18
Other acids	6.76±0.13	5.04±0.27	4.82±0.36	4.54±0.10
In total saturated	72.91±0.54	67.18±0.52	65.97±0.34	65.60±0.37
<i>Unsaturated</i>				
Oleic C 18 : 1 (ω -9)	22.01±0.25	23.05±0.02	23.52±0.13	23.57±0.14
Linolic C 18 : 2 (ω -6)	3.75±0.12	3.97±0.15	4.40±0.26	4.51±0.33
Linolenic C 18 : 3 (ω -3)	0.85±0.06	4.76±0.12	5.77±0.02	6.04±0.31
Arachidonic C20 : 4 (ω -6)	0.07±0.01	0.07±0.01	0.06±0.02	0.06±0.01
Other acids	0.41±0.02	0.21±0.03	0.28±0.05	0.22±0.03
In total unsaturated	27.09±0.25	32.06±0.36	34.03±0.26	34.40±0.27
Total omega-3	0.85±0.06	4.76±0.12	5.77±0.02	6.04±0.31
Total omega-6	3.82±0.12	4.04±0.15	4.46±0.26	4.57±0.33
Total omega-9	22.01±0.25	23.05±0.02	23.52±0.13	23.57±0.14
ω -3/ ω -6	1 : 4.5	1.17 : 1	1.29 : 1	1.32 : 1
The ratio of saturated to unsaturated FAs	2.7 : 1	2.1 : 1	1.9 : 1	1.9 : 1

* $P < 0.05$ – compared to control.

of α -linolenic acid and, accordingly, an increase of the content of omega-3 family PUFA. Thus, when 8 %, 10 %, and 12 % of flax oil is added to the curd spread, the content of α -linolenic acid in the curd spread increases by 3.91 %; 4.52 % and 4.69 %, respectively compared to the control sample.

We support the view of researchers (Sioen *et al.* 2009; Vella *et al.* 2013) that the consumption of products containing PUFA of the omega-3 in the world is insufficient to provide at least 10 % of the daily rate of the recommended consumption of 2 g/day of α -linolenic acid according to EU Regulation No. 1924/2006 and No. 432/2012. Therefore, the development of curd spread with flax oil content is intended to cover the deficiency in the PUFA of the omega-3 family and may be a good alternative to enrich the diet with biologically active ingredients.

An important indicator characterizing the biological and functional value of a food product in terms of its fatty acid composition is the ratio of saturated fatty acids to unsaturated. Thus, in the curd spread containing 8 %, 10 % and 12 % of flax oil the ratio between saturated

and unsaturated fatty acids was 2.1 : 1, 1.9 : 1 and 1.9 : 1, compared to the control group with the ratio of 2.7 : 1. Another important indicator of a food product is the ratio between omega-3 and omega-6 PUFA. Thus, in a curd spread containing 8 %, 10 % and 12 % flax oil, the ratio between omega-3 and omega-6 PUFA was 1.17 : 1, 1.18 : 1 and 1.21 : 1.

Studies by other scientists (Dal Bello *et al.* 2017) also indicate a probable increase ($P < 0.05$) in the content of omega-3 and omega-6 PUFAs in dairy products with the addition of different content of flax oil. However, studies (Lerch *et al.* 2012; Puppel *et al.* 2013; Suksombat *et al.* 2014) report that the fatty acid composition of milk and dairy products can be improved (increase omega-3 fatty acids) in a natural way, by the adjustment of cows' diets and feeding them on raw materials rich in linolenic acid (rapeseed, flax). We believe that this method is promising, but it requires sufficient scientific justification and the possibility of large-scale production of such milk. Therefore, we believe that our studies are consistent with the data by the authors

(Bermúdez-Aguirre *et al.* 2012; Dal Bello *et al.* 2015, 2017) about the need for enrichment of yogurt, cheese, etc., with vegetable raw materials rich in PUFA. Also, our previous studies found (Lialyk *et al.* 2019) that the curd spread with the content of flax oil after 14 d of storage contained at least 10^7 CFU.g⁻¹ of viable lactic acid bacteria, making it a functional product.

All in all, the developed curd spread with the 10 % content of flaxseed oil is characterized by the most optimal fatty acid composition, based on the biological and functional value of the food product and cost-effectiveness. The ratio of saturated fatty acids to unsaturated in this cheese paste is 1.9 : 1, and the ratio between PUFAs of the omega-3, -6, and -9 families is 1.3 : 1 : 5.3. Considering the significant deficiency in omega-3 PUFAs in the diet in Ukraine and a little less visible omega-9 PUFA deficiency, a functional food product, which is flax curd spread, will be one of the alternatives to address the deficiencies in these PUFAs. The food product developed by us is patented, the standard documentation for production according to the legislation of Ukraine is issued and it received the name "Curd spread enriched with omega-3 fatty acids" Longevity".

Conclusion

It was found that the studied flax oil was characterized by a high content of such polyunsaturated fatty acids as α -linolenic acid, oleic and linoleic acids, the relative content of which was 53.5 %, 21.4 % and 12.8 %, respectively. The ratio of PUFAs of the omega-3, -6, and -9 families in the studies flax oil is 4 : 1 : 1.5.

It was found that the total content of saturated fatty acids in curd spread with 8 %, 10 %, and 12 % of flax oil decreased, and the general total content of unsaturated fatty acids increased by 5.73 %, 6.94 % and 7.31 % respectively compared to the control sample.

Adding 8 %, 10 %, and 12 % of flax oil to the curd spread, the content of α -linolenic acid in the curd spread changed the most and increased accordingly by 3.91 %, 4.52 % and 4.69 %, compared to the control sample.

Curd spread with 10 % content of flaxseed oil is characterized by the most optimal fatty acid composition, based on the biological and functional value of the food product and cost-effectiveness. The ratio of saturated fatty acids to unsaturated in this curd spread is 1.9 : 1, and the ratio between PUFAs of the omega-3, -6, and -9 families is 1.3 : 1 : 5.3.

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Conflict of interest

The authors declare that they have no conflict of interest.

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