CHAPTER 1

Innovative technologies of fermented dairy-plant-based products for functional purposes

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Abstract

The development of innovative technologies for functional dairy products, as well as the improvement of traditional formulations in accordance with modern healthy nutrition requirements, represents one of the priority directions in the advancement of food science and industry. In the context of the increasing prevalence of diet-related diseases, the creation of next-generation products with enhanced biological and physiological value is of particular importance.

A significant share of functional products consists of enriched items formulated with natural additives in various physical forms, including powders, extracts, concentrates, and microencapsulated ingredients. Their application contributes to compensating for essential nutrient deficiencies, optimizing fatty acid composition, increasing the antioxidant potential of the diet, and strengthening the body's resistance to adverse environmental factors.

Fermented dairy products, particularly cottage cheese and curd-based products, are traditionally perceived by consumers as components of a balanced diet due to their optimal ratio of proteins, fats, and carbohydrates, high digestibility, and the presence of complete milk proteins. However, their vitamin-mineral composition and profile of biologically active compounds do not always fully comply with contemporary concepts of functional nutrition, which necessitates technological modernization through the incorporation of ingredients with pronounced physiological effects.

A promising approach to addressing this issue is the development of fermented dairy-plant-based products with a combined protein and lipid composition. Recipe

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optimization involves the use of soy-fat concentrate to improve the fatty acid profile and increase the proportion of polyunsaturated fatty acids; chia, quinoa, and flax seeds as natural structure-forming agents and sources of dietary fiber, omega-3 fatty acids, phenolic compounds, and antioxidants; and dihydroquercetin as a natural antioxidant and preservative that enhances oxidative stability and extends shelf life.

The absence of gluten in the investigated plant raw materials creates opportunities for the development of functional curd-based products suitable for individuals with celiac disease and gluten intolerance.

Thus, the integration of traditional curd production technology with modern approaches to functional ingredient incorporation makes it possible to expand the range of domestic dairy-plant products with health-promoting properties, enhance their competitiveness, and adapt them to current consumer demands.

Keywords

Functional foods, curd product, soy-fat concentrate, chia seeds, quinoa, flax seeds, dihydroquercetin, quality, safety, nutritional value, biological value.

1.1 Introduction

The development of new technologies for functional dairy-plant-based products and the improvement of existing ones is an extremely relevant task of modern food science.

Functional foods are aimed at maintaining and strengthening human health, providing the body with essential biologically active substances.

At the present stage of food industry development, the market of functional products is mainly focused on segments related to supporting human health, in particular the cardiovascular and digestive systems, as well as body weight management and strengthening of bone tissue [1].

The largest share among functional foods is represented by fortified products enriched with vitamins, micronutrients, dietary fiber, plant proteins, and other biologically active components. The use of natural additives in various physical forms makes it possible to compensate for deficiencies of essential nutrients and to increase the body's nonspecific resistance to adverse environmental factors [2].

For a long time, fermented dairy products, particularly cottage cheese and products based on it, have been perceived by consumers as being close to a rationally balanced diet, since they provide an optimal ratio of energy-significant nutrients – proteins, fats, and carbohydrates. At the same time, their consumer, vitamin, and mineral characteristics do not fully meet modern requirements of healthy nutrition, which necessitates their improvement through the incorporation of new components with specific physiological effects [3].

To address this issue, the development of new and the improvement of existing technologies for producing fermented dairy-plant-based products using cottage cheese as a base, in particular cheese-based desserts (curd products), is considered promising. The use of emulsion-type fat concentrates to completely replace milk fat with vegetable oils will not only allow targeted correction of the fatty acid composition of curd products and enrichment with biologically active lipid complexes of plant origin, but will also help solve the problem of insufficient milk raw materials and seasonal variations in their chemical composition [4].

In order to increase biological value and impart functional properties to curd products, it is advisable to use chia, quinoa, and flax seeds.

1.2 Justification for the use of raw materials and ingredients to improve the technology of a curd product

The need to combine food products is driven not only by current challenges in the food industry (shortage of high-quality raw materials, their insufficient quality, and incomplete utilization of all constituent components), but also by the necessity to provide consumers with a functional diet against the background of inadequate intake of protein, vitamins, macro- and microelements, and other essential nutrients.

When developing composite mixtures, a comprehensive approach should be followed, taking into account several key requirements: plant-based additives should not only exert a positive effect on biological and physiological processes in the human body, but also be economically feasible, available in the required quantities, consistent in quality, and easily integrated into the technological production process.

1.2.1 Justification for the use of an emulsion concentrate based on corn oil in the curd product formulation

Single-type or blended vegetable oils are widely used in technologies for dairy-plant-based products, particularly in the form of food emulsions, as lipid enrichers, functional ingredients, and structure-forming agents of the fat phase [5–7].

The content of tocopherols is an important indicator of both the biological value of products and their oxidative stability. Natural tocopherols are represented by four structural isomers: α-, β-, γ-, and δ-tocopherols. Although all isoforms are biologically active, α-tocopherol exhibits the highest biological activity in the human body. At the same time, γ- and δ-tocopherols play a leading role in providing antioxidant protection of lipids directly in oils and fat-containing products [8].

Tocopherols are capable of inhibiting lipid peroxidation processes, inactivating free radicals, and interrupting chain reactions of auto-oxidation, thereby increasing oil stability during storage. Due to this, they perform a dual function: on the one hand, they enhance the biological value of functional food products; on the other hand, they contribute to extending their shelf life [9].

The total tocopherol content in refined corn oil is significantly higher compared to other types of vegetable oils (**Table 1.1**), which constitutes a strong argument for selecting this oil for use in the soy-fat concentrate formulation.

Table 1.1 Tocopherol content in corn oil compared with other types of oils

Type of oil	Tocopherol content, mg/kg			Total tocopherols
	α	$(\beta+\gamma)$	δ	
Sunflower	490 ± 24.50	30.8 ± 1.54	10.1 ± 0.50	535 ± 26.75
Corn	207 ± 11.0	592 ± 30.0	30.0 ± 1.50	829 ± 41.45
Rapeseed	162 ± 8.10	174 ± 8.7	136 ± 6.8	472 ± 23.6
Olive	163 ± 38.15	12.3 ± 0.62	1.6 ± 0.08	177 ± 8.85

Source: [9]

Taking this into account, the authors of this scientific work developed a soy-fat concentrate based on corn oil, which represents a food emulsion [10]. The formulation of the soy-fat concentrate is presented in **Table 1.2**.

Table 1.2 Formulation of the soy-fat concentrate

Raw material	Content, %
Refined deodorized corn oil	49.00
Soy milk powder	4.50
Sodium caseinate	0.70
Emulsifier	0.50
Dihydroquercetin	0.012
Drinking water	45.288

Source: [10]

The soy-fat concentrate is characterized by high organoleptic quality indicators and functional properties due to the use of dihydroquercetin, which acts on free radicals by neutralizing them, thereby suppressing the development of various diseases [11]. Dihydroquercetin also exhibits other health-promoting properties, including a positive effect on the cardiovascular system [12].

Dihydroquercetin demonstrates significantly higher antioxidant activity compared to certain other antioxidants. In particular, its antioxidant activity exceeds that of quercetin by 92.412%, vitamin C by 101.062%, and vitamin E by 101.992% [13]. This makes it possible to state that dihydroquercetin is one of the most potent natural antioxidants, and its inclusion in the soy-fat concentrate enables the production of a curd product with functional properties.

1.2.2 Justification for the use of plant-based enrichers in the curd product formulation

In classical technologies for curd spreads, a stabilizer or stabilization system is an essential formulation component. As a rule, multiple binding of free moisture – the main technological effect of such additives – is characteristic of a wide range of polysaccharides (pectin, starch and its chemically modified forms, agar, alginate, carrageenan, gums, etc.), as well as certain protein compounds such as gelatin and milk protein concentrates. Such substances, which are relatively expensive, are typically imported and used according to manufacturers' recommendations in amounts ranging from 0.2% to 1.5% [14]. Therefore, the authors of this scientific work propose reducing the use of synthetic stabilizers in curd product production by applying plant-based raw materials containing gums and mucilaginous substances. These components are capable of improving the rheological properties of mixtures and contributing to the formation of the desired texture. An additional advantage of using plant additives is the enrichment of food products with dietary fiber and other ballast substances, which positively affects their functional value [14].

Thus, a scientific interest lies in analyzing the composition of seeds and pseudocereals such as chia, quinoa, and flax.

The study revealed that the physicochemical and technological properties of seeds largely depend on numerous factors, including varietal characteristics, soil and climatic conditions, cultivation technology, and maturity stage. The macronutrient content and energy value of the studied seed samples are presented in **Table 1.3**. The data in **Table 1.3** indicate that chia, quinoa, and flax seeds are characterized by a low carbohydrate content and an increased content of proteins, lipids, and dietary fiber.

Table 1.3 Comparative characteristics of the chemical composition of seeds

Indicator	Chia	Quinoa	Flax
Protein content (g/100 g dry matter)	15.9 ± 0.08	13.62 ± 0.07	17.8 ± 0.09
Lipid content (g/100 g dry matter)	30.7 ± 0.16	5.92 ± 0.03	41.6 ± 0.21
Carbohydrate content (g/100 g dry matter)	42.8 ± 0.22	67.21 ± 0.34	29.1 ± 0.15
Dietary fiber (g/100 g dry matter)	34.7 ± 0.18	7.4 ± 0.04	27.1 ± 0.14
Energy value (kcal/100 g)	511 ± 2.56	376.60 ± 1.88	562 ± 2.81

Source: [9, 14]

Thus, the protein content in seeds may vary approximately from 14% to 18%, depending on the seed type as well as cultivation conditions, temperature, and humidity. Seed proteins demonstrate good digestibility (78.9%), which is comparable to casein (88.6%) and higher than that of proteins contained in corn (66.6%), rice (59.4%), wheat (52.7%), and even amaranth (90%) [15].

Seeds and pseudocereals are often incorporated into food products to meet consumer demand for gluten-free products. In recent years, this market has shown exponential growth due to the increasing prevalence of gluten-related disorders (celiac disease), non-celiac gluten sensitivity, and wheat allergy, as well as rising demand among population groups that choose a gluten-free diet because it is perceived as healthier [16]. These facts further confirm the feasibility of using seeds as gluten-free enriching ingredients for the development of products with enhanced biological value.

The amino acid composition of proteins from chia, quinoa, and flax seeds is presented in **Table 1.4**.

The analysis of the amino acid composition confirmed the presence of 10 essential amino acids, among which the highest levels were observed for arginine, leucine, phenylalanine, valine, and lysine. Seed proteins are also rich in non-essential amino acids, mainly cystine, tyrosine, and alanine. The differences in the content of individual amino acids between the seeds were not statistically significant ($P < 0.05$). The proportion of essential amino acids relative to the total amino acid content – considered an indicator of protein quality – was 37.87%, 33.76%, and 35.18% for chia, flax, and quinoa seeds, respectively, indicating the high biological quality of these proteins [19].

Particular interest is associated with the fatty acid profile. It is characterized by a high content of polyunsaturated fatty acids (PUFAs), mainly α-linolenic acid (ALA), which accounts for approximately 60% of total fatty acids (**Table 1.5**).

Table 1.4 Content of essential amino acids in seeds, g/100 g

Amino acid	Chia	Quinoa	Flax
Arginine	2.14	0.758	1.92
Histidine	0.53	0.033	0.47
Isoleucine	0.80	0.404	0.90
Leucine	1.37	0.561	1.24
Lysine	0.97	0.480	0.86
Methionine	0.59	5.360	0.37
Phenylalanine	1.02	0.253	0.96
Threonine	0.71	0.071	0.77
Tryptophan	0.44	0.38	0.29
Valine	0.95	0.571	1.07
Cystine	0.41	0.35	0.34
Tyrosine	0.56	0.130	0.49
Alanine	1.04	0.654	0.93

Source: [17, 18]

Table 1.5 Fatty acid content in seeds, g/100 g

Fatty acids	Chia	Quinoa	Flax
Saturated fatty acids (SFAs)			
Palmitic acid (C16:0)	7.1	–	2.17
Stearic acid (C18:0)	3.24	1.03	1.33
Monounsaturated fatty acids (MUFAs)			
Palmitoleic acid (C16:1)	0.2	–	0.09
Oleic acid (C18:1 – ω-9)	10.53	27.6	7.36
Eicosenoic acid (20:1)	0.16	–	0.07
Polyunsaturated fatty acids (PUFAs)			
Linoleic acid (C18:2 – ω-6)	20.37	5.7	5.9
Linolenic acid (C18:3 – ω-3)	59.76	54.9	58.2
Eicosadienoic acid (20:2)	0.08	–	0.07
Total PUFAs	80.4	73.63	60.6
Omega-6/Omega-3 ratio	0.35	0.30	0.32

Source: [17, 19]

Linoleic, oleic, and palmitic acids are present in smaller amounts. Chia seeds contain a higher level of omega-3 fatty acids compared to flax seeds. In general, chia seeds contain several times more fat than cereal grains, with particularly high levels of omega-3 fatty acids, including 41–59% α-linolenic acid (omega-3) and 18–25% linoleic acid (omega-6).

Compared with other products traditionally considered rich in omega-3 fatty acids, the amount of these fatty acids in chia seeds is almost twice that found in salmon roe, three times higher than in cod liver, and 42 times higher than in olive oil. The average omega-3 fatty acid content in chia seeds is about 21%, while in flax seeds it is approximately 17% [20].

Another valuable characteristic of chia, quinoa, and flax additives is their dietary fiber content. Dietary fibers – such as cellulose, pectin, and hemicellulose – contribute to reducing the caloric density of the diet, mitigating the negative impact of excessive fat and carbohydrate consumption on metabolic processes, and regulating intestinal motility. Dietary fibers are also capable of adsorbing and removing various chemical substances, including carcinogens, from the human body.

The presence of chia, quinoa, and flax seeds in curd products may significantly influence microbial growth. On the one hand, due to the presence of antimicrobial compounds, they may reduce total microbial contamination; on the other hand, microbial populations present on the seed surface may increase it. For example, chia seeds contain phenolic compounds (**Table 1.6**) [21].

Table 1.6 Phenolic compound content in chia and quinoa seeds, mg/g

Phenolic compounds	Chia	Quinoa
Chlorogenic acid	0.10–0.23	0.42–0.63
Myricetin	0.11–0.12	0.14–0.19
Quercetin	0.15–0.27	0.19–0.39
Kaempferol	0.36–0.50	0.14–0.21

Source: [22, 23]

Chia, quinoa, and flax seeds also contain natural tocopherols, which increases their value for use in the technology of a new type of curd product (**Table 1.7**). The presence of α-, γ-, and δ-tocopherols allows for a natural increase in the oxidative stability of the fat phase without the addition of synthetic antioxidants [17].

As shown in **Table 1.7**, the highest tocopherol content is observed in chia and flax seeds, while somewhat lower levels are found in quinoa seed lipids. $\beta + \gamma$-tocopherols account for 72–90% of the total tocopherols in flax seeds, 71–75% in quinoa seeds, and 62–92% in chia seeds. This confirms the hypothesis that these seeds possess high biological value and may serve as a potential source of nutraceutical lipids capable of enriching curd products with functional components.

Table 1.7 Tocopherol content in seeds (mg/kg of oil)

Seed type	Tocopherol content, mg/kg			Total tocopherols	Profile characteristics
	α	$(\beta+\gamma)$	δ		
Chia	7–15	400–600	10–25	510–650	γ-tocopherol predominates – high antioxidant activity
Quinoa	40–90	150–300	5–15	200–420	α- and γ-forms predominate
Flax	10–25	300–500	15–35	430–560	High γ and δ content

Source: [17]

Thus, the combination of a favorable amino acid composition, a high content of polyunsaturated fatty acids, dietary fiber, phenolic compounds, and natural tocopherols substantiates the feasibility of using chia, quinoa, and flax seeds in the formulation of functional curd products with enhanced biological value and improved technological properties.

1.2.3 Justification for the use of sea salt in the curd product formulation

To impart a savory character to the curd product, the inclusion of salt in the formulation has been proposed. However, classical curd paste technologies typically use table salt (sodium chloride), and it has been demonstrated [24] that excessive sodium intake contributes to an increased risk of various diseases. Therefore, in order to reduce sodium intake, the use of sea salt is considered relevant. The feasibility of incorporating sea salt into the diet can also be justified from a nutritional perspective, as dietitians recommend reducing sodium content while maintaining the required mass fraction of chloride. In addition, sea salt allows the enrichment of the finished product with essential minerals, particularly potassium, thereby increasing its nutritional value [25].

1.3 Development of the technology for producing a new-generation curd product

1.3.1 Justification of the protein-fat base composition

Initially, the composition of the protein-fat base was substantiated for its subsequent enrichment with plant components to obtain the finished product. Low-fat cottage cheese produced by the acid-rennet method was used as the milk-protein base, in accordance with the requirements of DSTU 4554:2008 "Cottage Cheese. Specifications".

Experimental formulations of the protein-fat base with a specified fat content are presented in **Table 1.8**.

The organoleptic characteristics of the protein-fat base samples compared with the control sample are presented in **Table 1.9**.

Table 1.8 Experimental formulations of the protein-fat base

Formulation components	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
	Corn oil content, %			
	7.0	8.0	9.0	10.0
Low-fat cottage cheese	86.0	84.0	82.0	80.0
Soy-fat concentrate	14.0	16.0	18.0	20.0
Total	100.0	100.0	100.0	100.0

Table 1.9 Organoleptic characteristics of protein-fat base samples

Indicators	Sample				
	Control	No. 1	No. 2	No. 3	No. 4
Consistency, appearance	Crumbly, slight graininess		Slightly softened, spreadable	Excessively softened, non-uniform	
Color	White, uniform throughout			Creamy shade, uniform throughout	
Taste and odor	Characteristic fermented milk flavor, without foreign tastes and odors			Fermented milk flavor with a slight corn oil aftertaste	

According to **Table 1.9**, samples with different fat contents differ significantly in their organoleptic characteristics. As the fat content increases from 7% to 10%, the consistency of the protein-fat base becomes softer and more spreadable, with a more oily texture. The taste acquires a slightly sweet and somewhat bland aftertaste. A significant loss of product homogeneity was observed at a corn oil content above 8%.

The physicochemical parameters of the protein-fat base samples are presented in **Table 1.10**.

According to **Table 1.10**, as the fat content in the protein-fat base increases from 7% to 10%, titratable acidity decreases, reaching nearly half of its initial value. In contrast, active acidity (pH) changes within a narrower range. Despite the relatively high water content in the soy-fat concentrate, increasing the fat content of the samples leads to a decrease in overall moisture against the background of slight softening of consistency. At the same time, the water-holding capacity of samples with different fat contents remains almost identical, which can be explained by the presence of an effective hydrophilic emulsifier – sodium caseinate – in the aqueous phase of the soy-fat concentrate.

Table 1.10 Physicochemical parameters of protein-fat base samples

Indicator	Control / No. 1	Control / No. 2	Control / No. 3	Control / No. 4
Titratable acidity, °T	166.5 ± 3.2 / 164.8 ± 2.9	135.0 ± 2.2 / 132.0 ± 1.9	113.5 ± 3.3 / 109.3 ± 2.4	109.0 ± 2.9 / 96.5 ± 2.7
Active acidity, pH	4.38 ± 0.10 / 4.35 ± 0.09	4.41 ± 0.10 / 4.41 ± 0.19	4.50 ± 0.10 / 4.45 ± 0.08	4.60 ± 0.10 / 4.59 ± 0.09
Moisture content, %	79.3 ± 1.9 / 79.1 ± 1.5	77.2 ± 1.5 / 77.1 ± 1.5	74.2 ± 1.4 / 74.5 ± 1.7	70.1 ± 2.0 / 69.4 ± 1.2
Water-holding capacity, %	70.4 ± 1.9 / 67.8 ± 1.7	72.4 ± 3.1 / 67.1 ± 2.8	74.4 ± 2.6 / 66.8 ± 2.0	73.4 ± 3.3 / 65.4 ± 2.7

Thus, based on the assessment of organoleptic and physicochemical parameters, the feasibility of using the soy-fat concentrate in the protein-fat base has been established, with a recommended fat content range of up to 8.0% for further application in the curd product formulation.

1.3.2 Justification of the degree of grinding of chia, quinoa, and flax seeds prior to incorporation into the protein-fat base

From a technological standpoint, the structure of curd products, particularly combined-composition curd spreads, is one of the key quality indicators. Inconsistencies in their rheological characteristics may lead to an increased proportion of defective products unsuitable for further packaging, storage, and distribution.

To substantiate the feasibility of using plant raw materials in the curd product formulation, a comparative analysis of the structural and mechanical properties of whole and ground seeds was carried out. The following fractions were studied: sample No. 1 (≤ 1.0 mm), sample No. 2 (≤ 0.7 mm), and sample No. 3 (≤ 0.5 mm).

The research results demonstrated that the water-holding capacity (WHC) of the samples is influenced by several factors:

– degree of grinding – smaller particle sizes exhibit significantly higher WHC values;

– hydration temperature – the optimal range is 40–60°C;

– medium pH – the most favorable pH values are 4–5;
– hydration time – the optimal duration is 30–60 minutes.

The results of the study on the water-holding capacity of whole and ground chia, quinoa, and flax seeds are presented in **Table 1.11**.

Table 1.11 Water-holding capacity of whole and ground chia, quinoa, and flax seeds

Seed type	Water-holding capacity (W), %			
	Whole seeds	Sample No. 1 (≤ 1.0 mm)	Sample No. 2 (≤ 0.7 mm)	Sample No. 3 (≤ 0.5 mm)
Chia	820 ± 41	1000 ± 50	1250 ± 63	1470 ± 74
Quinoa	160 ± 8	220 ± 11	280 ± 14	310 ± 16
Flax	340 ± 17	510 ± 26	600 ± 30	750 ± 38

The data presented in **Table 1.11** correlate with the chemical composition of the seeds. In particular, chia seeds contain the highest level of dietary fiber (34.7 ± 0.18 g/100 g dry matter), which explains their superior water-holding capacity (820–1470%). Upon hydration, a gel (dense colloidal system) is formed that can retain large amounts of water even without heat treatment. Quinoa seeds contain approximately 7.4% fiber; therefore, their WHC is lower than that of chia seeds. However, this parameter may increase after thermal processing or enzymatic modification.

The water-holding capacity of flax seeds (340–750%) is determined by the presence of mucilage substances (a mixture of homo- and heteropolysaccharides and polyuronides that easily swell in water), cellulose, hemicellulose, and proteins. Flaxseed mucilage contains fibrous materials (18–45 nm in diameter) that expand in the presence of water [26].

The relationship between water-holding capacity and hydration time for whole and ground seeds is shown in the **Fig. 1.1.**

Seeds contain a significant amount of water-soluble carbohydrate substances, the presence of which determines the degree of swelling and mass increase in all experimental samples (**Fig. 1.1**). Viscous solutions are formed during hydration. It was observed that the amount of gel formed increased in ground seeds compared to whole seeds for all three types. The swelling process of both whole and ground chia seeds occurs most intensively during the first 30 minutes, followed by stabilization of the indicators over the next 30 minutes. The swelling behavior of flax and quinoa seeds is more uniform over time; however, they differ in the amount of gel formed during the study. The lowest swelling indices were observed in quinoa seed samples due to their lower fiber content.

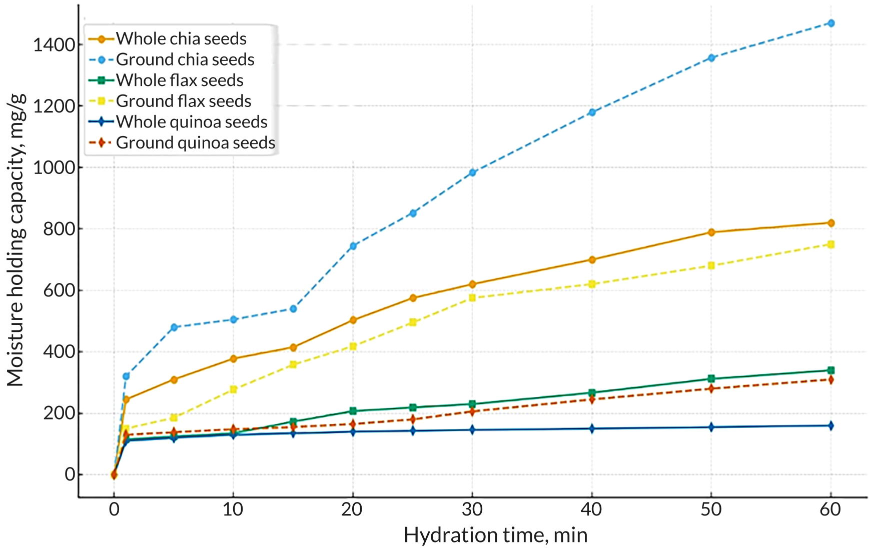

Fig. 1.1 Relationship between water-holding capacity and hydration time of whole and ground chia, quinoa, and flax seeds

Thus, chia, quinoa, and flax seeds should be used in ground form, with a particle size not exceeding 0.5 mm.

1.3.3 Refinement of formulations and technological operations for curd product manufacturing

Based on the results of previous studies, three formulations were developed and the technological parameters for producing new-generation curd products were refined. The formulations are presented in **Table 1.12**.

The manufacturing process of the curd product includes the following operations. Raw materials must comply with current regulatory documentation. Formulation components are weighed according to the developed recipes. Chia, quinoa, and flax seeds are ground to a particle size not exceeding 0.5 mm. Sea salt is sieved. To obtain the protein-fat base, low-fat cottage cheese is homogenized, soy-fat concentrate is added, and the mixture is thoroughly blended. During mixing, ground chia, quinoa, or flax seeds are incorporated into the protein-fat base. The resulting mixture is cooled and packaged.

Table 1.12 Formulations of the curd product

Raw material	Formulation		
	No. 1	No. 2	No. 3
Protein-fat base (fat content 8.0%), %	97.2	94.2	97.2
Chia seeds, %	2.0	–	–
Quinoa seeds, %	–	5.0	–
Flax seeds, %	–	–	2.0
Sea salt, %	0.8	0.8	0.8

1.4 Study of quality and safety indicators of the curd product

The nutritional value of the curd product is presented in **Table 1.13**.

Table 1.13 Nutritional value of the curd product

Indicator	Control	With chia	With quinoa	With flax
Protein (g/100 g dry matter)	17.34 ± 0.88	13.90 ± 0.70	13.68 ± 0.68	13.90 ± 0.70
Fat (g/100 g dry matter)	0.29 ± 0.02	10.03 ± 0.50	9.70 ± 0.49	10.25 ± 0.51
Carbohydrates (g/100 g dry matter)	6.68 ± 0.33	6.09 ± 0.31	8.41 ± 0.42	5.83 ± 0.29
Dietary fiber (g/100 g dry matter)	–	0.74 ± 0.04	0.42 ± 0.02	0.60 ± 0.03
Energy value (kcal/100 g)	98.72 ± 4.94	170.84 ± 8.54	175.66 ± 8.78	171.17 ± 8.56

The data in **Table 1.13** indicate that although the total protein content in the new curd products decreased by approximately 20%, the fat content increased nearly 30-fold due to the use of refined corn oil in the form of soy-fat concentrate.

The value of refined corn oil is determined by its favorable lipid profile, technological stability, and neutral organoleptic properties, making it particularly suitable for use in food products, including functional foods. A key indicator of the biological adequacy of the lipid component of food products is the ratio of omega-6 to omega-3 fatty acids. According to recommendations of the World Health Organization, the optimal ω-6/ω-3 ratio should range from 5 to 8, with the total intake of these polyunsaturated fatty acids providing approximately 1–2% of the daily energy intake [27].

An imbalance toward excessive omega-6 intake is considered one of the contributing factors to the development of chronic non-communicable diseases, including cardiovascular, oncological, inflammatory, and autoimmune disorders, as well as rheumatoid arthritis and asthma. Conversely, increased omega-3 consumption and a reduced ω-6/ω-3 ratio contribute to mitigating these adverse effects [28].

It should be noted that chia, quinoa, and flax seeds significantly influence the lipid profile of curd spreads, as these plant additives are valuable sources of polyunsaturated fatty acids, primarily α-linolenic acid (ω-3). Their high content contributes to enriching curd products with biologically active lipids, improving the ω-6/ω-3 ratio, and enhancing functional value. The presence of oleic acid (ω-9) positively affects fat system stability, while the low proportion of saturated fatty acids does not deteriorate the nutritional and dietary characteristics of the developed product.

Thus, the combination of corn oil with chia, quinoa, and flax seeds enables the formation of a balanced lipid composition in the curd product that meets modern requirements for functional foods, combining technological reliability with enhanced biological value.

The use of these plant ingredients expands the possibilities for developing domestic curd products for therapeutic and preventive purposes, integrating traditional technology with modern approaches to functional food design.

To determine microbiological safety, viable lactic acid bacteria, molds, and yeasts were analyzed two hours after production, along with the presence of coliform bacteria, *Salmonella spp*., and *Staphylococcus aureus*. Other samples were stored at 0–2°C for four days in accordance with DSTU 4503:2005 storage standards [29], with daily microbiological analysis.

The microbiological characteristics of the investigated curd product samples are summarized in **Tables 1.14–1.16**.

The results (**Tables 1.14–1.16**) demonstrate that the formulation components and technological parameters ensure microbiological purity of the curd product throughout the guaranteed storage period, comparable to classical curd paste.

It should be noted that the curd product containing flax seeds showed slightly higher counts of yeasts and molds compared to other samples. This may be explained by the presence of lignans (10.12–17.91 mg/g), mucilage substances, and phenolic compounds in flax seeds, which somewhat inhibit bacterial microflora but simultaneously promote moisture retention, creating favorable conditions for yeast and mold development [26].

Thus, the new type of curd product complies with industrial sterility standards.

Table 1.14 Microbiological parameters of curd product with chia seeds during storage

Parameter	Storage time, days					Standard
	0	1	2	3	4	
Lactic acid bacteria count in 1 g of product	10^7	10^7	10^7	10^7	10^6	$\geq 1 \cdot 10^6$
Coliform bacteria in 0.001 g of product	Not detected					Not allowed
Molds in 1 g of product, CFU	5 ± 0.25	5 ± 0.25	5 ± 0.23	6 ± 0.28	6 ± 0.31	≤ 50
Yeasts in 1 g of product, CFU	23 ± 1.01	23 ± 1.15	23 ± 1.14	23 ± 1.21	24 ± 1.23	≤ 100
Pathogenic micro-organisms, including *Salmonella*, in 25 g of product	Not detected					Not allowed
Staphylococcus aureus in 0.01 g of product	Not detected					Not allowed

Source: [29, 30]

Table 1.15 Microbiological parameters of curd product with quinoa seeds during storage

Parameter	Storage time, days					Standard
	0	1	2	3	4	
Lactic acid bacteria count in 1 g of product	10^7	10^7	10^7	10^7	10^6	$\geq 1 \cdot 10^6$
Coliform bacteria in 0.001 g of product	Not detected					Not allowed
Molds in 1 g of product, CFU	5 ± 0.21	5 ± 0.22	6 ± 0.19	6 ± 0.28	6 ± 0.27	≤ 50
Yeasts in 1 g of product, CFU	25 ± 1.11	25 ± 1.16	25 ± 1.09	26 ± 1.29	26 ± 1.22	≤ 100
Pathogenic micro-organisms, including *Salmonella*, in 25 g of product	Not detected					Not allowed
Staphylococcus aureus in 0.01 g of product	Not detected					Not allowed

Source: [29, 30]

Table 1.16 Microbiological parameters of curd product with flaxseed during storage

Parameter	Storage time, days					Standard
	0	1	2	3	4	
Lactic acid bacteria count in 1 g of product	10^7	10^7	10^7	10^7	10^6	$\geq 1 \cdot 10^6$
Coliform bacteria in 0.001 g of product	Not detected					Not allowed
Molds in 1 g of product, CFU	6 ± 0.12	6 ± 0.21	6 ± 0.18	7 ± 0.28	7 ± 0.29	≤50
Yeasts in 1 g of product, CFU	25 ± 1.01	25 ± 0.98	26 ± 0.99	26 ± 1.10	26 ± 1.12	≤100
Pathogenic micro-organisms, including *Salmonella*, in 25 g of product	Not detected					Not allowed
Staphylococcus aureus in 0.01 g of product	Not detected					Not allowed

Source: [29, 30]

1.5 Conclusions

The effectiveness of using the following ingredients in the technology of a new dairy-plant fermented curd product has been confirmed: soy-fat concentrate based on corn oil, flax seeds, chia seeds, quinoa seeds, and sea salt.

The studied nutritional indicators of the developed curd product demonstrated the advantages of the experimental formulation. Compared with the control, the new product is characterized by a higher content of beneficial fats and dietary fiber.

Comparison of the appearance and organoleptic properties of the developed curd product with those of the standardized sample showed the superiority of the experimental formulation across all studied indicators.

The developed curd product makes it possible to expand the range of functional dairy-plant fermented products.

Conflict of interest

The authors declare that there is no conflict of interest regarding this article or the published research results, including the financial aspects of conducting the study, obtaining and using its results, as well as any non-financial personal relationships.

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The manuscript has no associated data.

Use of artificial intelligence statement

The authors confirm that no artificial intelligence technologies were used in the preparation of this work.

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Authors' contributions

Larysa Bal-Prylypko: Conceptualization, Formal analysis, Supervision.
Halyna Tolok: Validation, Resources, Methodology, Formal analysis.
Semen Tolok: Investigation, Formal analysis.
Ihor Ustymenko: Writing – original draft preparation, Formal analysis.
Ivan Bal: Resources, Methodology.
Oleksandr Kanishchev: Resources, Methodology.

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