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Improving the quality and the technology of processed cheeses

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ABSTRACT

This article investigates processed cheese's nutritional value and safety by adding vegetable additives (dry Spirulina powder). Processed cheese for lunch is taken as a basis for the formulation. As a control, we took cheese made according to classical technology. We used cheeses from cow's milk. We used combined raw materials in the developed technology: cow's and goat's milk cheeses. Spirulina was added to the formulation as an enrichment agent in the 1%, 2%, and 3% ratio, respectively. The sample with a 1% addition was found to be rational according to the results of the organoleptic evaluation. The formulation was optimised in further study by selecting 0.5%, 1.5% and 2%. A centre composite plot was used to add points around the pre-lagged optimum. A regression formula was obtained, and the melting salts and the dosage of the added enrichment agent were determined. Also, the share of cheese from goat's milk in the recipe of processed cheese was determined. The recipe was calculated on the principle of material balance. Experimental samples were examined for fatty acid and amino acid composition. The tables compare the best sample on organoleptic evaluation with the control. It was found that when 3% is added, the cheese acquires a dark green tinge. The colour is deep green when 2% is added; when 1% or less is added, the colour is salad. The dose of melting salts in the recipe was reduced to 2%; in the classic recipe, it was 3.9%. The protein of the experimental sample turned out to be closer to the ideal protein. PDCAAS is equal to 96.9, while in the control sample, PDCAAS is equal to 39.9. Also, when comparing the fatty acid composition, the thrombogenicity coefficient was lower in the experimental sample than in the control.

Keywords: quality, processed cheeses, thrombogenicity factor, utilisation factor, PDCAAS, fatty acid, amino acid, composition

INTRODUCTION

The science of processed cheese is developing rapidly, as evidenced by the rapid increase in articles on this subject in scientific databases. Trends in the development of processed cheese technology are different and act in different directions, such as improving organoleptic characteristics, developing functional processed cheeses, increasing shelf life, reducing the number of emulsifying salts, researching new types of emulsifying salts for different types of processed cheese **[1]**. Expanding the assortment range for processed functional cheeses is becoming increasingly widespread in studying processed cheese technology. For this purpose, the influence of additives increasing the nutritional and biological value on the consistency, shelf life and colour of processed cheeses is studied. The effect of algae such as Chlorella vulgaris was studied. The study revealed that adding 2% Chlorella vulgaris did not affect the overall acceptability of processed cheese, but it significantly increased the protein content and added hardness **[2]**. So, the effect of adding Spirulina platensis (Gomont) Geitler to the recipe of pasty processed cheese: the conclusion was that the addition changes the colour, taste and smell, but at the same time increases the nutritional value, it was found that the addition of 1% dry powder Spirulina platensis is acceptable as to increase the nutritional value and to maintain a pleasant colour and smell **[3]**. Positive results were obtained in cultivating Spirulina fusiformis on a cost-effective medium **[4]**. The study of the influence of adding Spirulina Maxima **[5]** in the formulation of pasty processed cheeses showed that Spirulina Maxima has antioxidant properties and affects the shelf life of processed cheeses. At the same time, the colour becomes dark green at the addition of 3% Spirulina Maxima, so adding 1-2% is recommended for the colour and smell of processed cheeses. The effects of various vegetable additives were studied **[6]** in terms of physicochemical parameters, and changes and increases in the nutritional value of the final product were monitored. All this suggests that the effects of Spirulina on sliced processed cheeses and from non-traditional raw materials have not been studied. Changing the amount of added melting salts in processed cheese formulations or replacing traditional melting salts is also important considering the trend towards safe products. Replacement of salts on calcium chloride, technological aspects at reduction of the dosage of melting salts and the influence on the structure of processed cheese is not studied by many scientists **[7]**, nevertheless it is a significant aspect in manufacture of processed cheeses of functional purpose. Also, there are no articles about processed cheeses from combined raw materials in the scientific world. There are works about the technology of goat's milk cheeses, mainly soft varieties **[8]**, less often about hard ones.

In our case, we use hard cheese from cow's milk and fresh cheese from goat's milk, thereby laying down the question of melting salts used. The ripening time and melting duration are changed. This article aims to address these issues. Many authors study the influence of adding vegetable additives on the composition, but the changes in consistency are left aside. the study of amino acid and fatty acid composition is also one of the aspects of proving the functionality of food products. Processed cheeses are products accessible to a wide segment of the population. Thanks to this quality, processed cheese can be an excellent product for functional use. Also, the bioavailability of elements in the cheese composition should include phytonutrients with high digestibility. In Kazakhstan, the population has many problems due to the environmental situation. Nuclear explosions, nuclear waste, mining of heavy metals, oil, etc., affect the population's health. An important aspect is to cleanse the body from free radicals, radionuclides, heavy metals, toxins, etc. The number of people with cancer is growing yearly, and the disease worsens. The solution to the problem can be products that address at least one of the problems. A good solution may be the addition of Spirulina to processed cheese. The hypothesis is the possibility of combining goat's milk cheese in the recipe of processed cheese and enrichment with Spirulina. The objectives are: development of technology for the production of processed cheese from combined dairy raw materials and enriched with Spirulina; change of amino acid and fatty acid composition compared with processed cheeses made from cow's milk, made by traditional classical technology from local raw materials.

Scientific Hypothesis

Adding 1% Spirulina Maxima to processed cheese from goat's and cow's milk optimizes the composition of amino acids and fatty acids. We chose in the recipe of a new type of processed cheese a combination of vegetable filler – Spirulina Maxima, and soft cheese from goat's milk, as they have excellent functional therapeutic preventive, and antioxidant properties.

MATERIAL AND METHODOLOGY

Samples

Hard cheese from cow's milk and cheese from goat's milk were used to produce processed cheese from combined dairy raw materials, according to the technology proposed in **[9]**. The formulation was calculated by material balance; a mixture of melting salts tripolyphosphate and sodium citrate was used. The proportions of melting salts were selected using laboratory model samples in small volumes. We received reliable results.

The amino acid composition was determined by gas chromatographic method and by measuring the proportion of amino acids by capillary electrophoresis using the capillary electrophoresis system "Kapel", methodology M-04-38-2009.

The fatty acid composition of the substance was analysed by capillary gas chromatography on a Shimadzu instrument, DB-WAX column, length 30 m, inner diameter 0.25 mm. Total lipids were initially extracted using Rose-Gothlib, after which the oily substance was derivatised using MeOH/BF3 (methanol containing 14% boron trifluoride). Fatty acids were analysed as methyl esters. Temperature programme: 50 °C for 2 minutes, rise to 200 °C at a rate of 10 °C/min, rise to 218 °C at a rate of 2 °C/min, rise to 250 °C at a rate of 10 °C/min, hold at 250 °C for 10 minutes.

For the production of processed cheese, we purchased hard cheese from cow's milk and produced cheese from goat's milk with a maturation period of 10 days. Spirulina powder was purchased from Algos, Republic of Kazakhstan.

To assess the organoleptic properties of the processed cheeses, a profillogram, or sensory profile, was established. This involved a comprehensive sensory evaluation conducted by a panel of trained assessors. Each assessor was presented with samples of the processed cheeses and evaluated based on predefined sensory attributes. These attributes encompassed taste, aroma, texture, and overall quality. Sensory attributes were selected based on their relevance to processed cheese quality. These typically included attributes like creaminess, saltiness, bitterness, and specific flavour notes. A structured, numerical assessment scale was employed to score each attribute. Assessors rated the intensity or quality of each attribute for each cheese sample.

The coefficient of concordance (W) was calculated to gauge the degree of agreement among the sensory assessors regarding the sensory attributes. This coefficient is essential in determining the reliability and consistency of the sensory evaluations.

The coefficient of concordance (W) is typically derived from the rankings or scores provided by the assessors. It quantifies the extent to which the assessors' evaluations align with each other. A higher W value suggests a higher level of agreement among the assessors.

The profillogram, which encapsulates the sensory attributes and their associated scores or rankings, visually represents the organoleptic characteristics of each cheese sample.

By examining the profillogram for each sample, it becomes possible to compare the sensory profiles of different cheeses. This aids in making informed decisions regarding product quality, formulation optimization, and potential adjustments.

Melting salts were purchased from Elegita Asia, Almaty, Republic of Kazakhstan. Samples were run according to the formulation presented below in Table 1.

Table 1 Formulation for the cheese "Almaly" with the mass fraction of fat in dry matter of the product 60% (per tonne in kg).

Name of raw material	Weight
Large rennet cheeses: with a mass fraction of dry matter of 60%, fat in dry matter 50%	400
Cheese from goat's milk with a mass fraction of fat of 40%	200.0
Concentrate of plant raw materials with a mass fraction of dry matter of 50%	10
Peasant butter with a mass fraction of dry matter 75%, fat 72.5%	156
Cottage cheese with a mass fraction of dry matter 27%, fat 9%	100
Mixture of sodium tripolyphosphate with sodium citric acid (food grade) with a mass fraction of dry matter 20%	40
Drinking water	104
TOTAL	1010
OUTPUT	1000

Chemicals

All chemicals purchased by „Laborpharma“, Almaty, the Republic of Kazakhstan, were of analytical grade quality.

Laboratory Methods

Organoleptic evaluation: In a closed method, the organoleptic indicators of dairy products were evaluated by profile method using questionnaires. When performing profile analysis, point scales were used to assess the intensity of individual attributes, sensation manifestations were consistently determined, and the results were graphically depicted in the form of a profillogram (profile); When determining organoleptic indicators, the consistency of experts' opinions was assessed by the coefficient of concordance (W). If W <0.6, the consistency of experts' opinions was considered poor, and the next round of surveys was conducted.

Methodology for determining colour characteristics: Characteristics Methodology for determining the colour characteristics of processed cheese samples were examined by CIELAB using a Konica Minolta colourimeter model CR-410, Japan, using the characteristics: colour brightness (L*), red colour components (a*), yellow colour components (b*). The method consists of capturing spectral curves on the reflected surfaces of a sample of processed cheese, with brightness in the visible area of 380-750 nm. The sample is spread out on a board at room temperature, with an area of 18x8x2 cm and a calorimeter, set in the leftmost row and ran, displaying data on a monitor. The process is repeated for the middle and the rightmost row. The data read on the monitor of the colourimeter is indicated as follows: L*=,a*=,b*= where L*–is brightness, a*– presence of red colour, b*– presence of yellow colour.

Amino acid scoring (AAS, AAS): the percentage ratio of AA of the protein under study to the content of the same AA in the "ideal" protein, in which the content of each NSAQ corresponds to the indicators determined by the adequacy scale for animal or human needs **[10]**.

Gas chromatograph GC-17A, Shimadzu (Japan): temperature mode: initial temperature 140C0; delay 1 min; increase 2C0/min to 230C0; delay 27 min; Capillary electrophoresis system "Kapel", RFLaboratory Methods.

Description of the Experiment

Sample preparation: Cheeses were melted according to the recipe, ready samples were stored sealed in disposable special cups weighing 50 g each. They were stored under refrigerated conditions at 4-6 °C.

Number of samples analyzed: We analyzed 4 samples.

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

Number of experiment replication: The number of repetitions of each experiment to determine one value was 3 times.

Design of the experiment: Experimental Design Selection:

Initial Planning: The process commenced with the initial planning stage, where the overall design of the experiment was determined. This included decisions regarding the selection of factors to be studied, their levels, and the experimental goals.

Sample Preparation:

Raw Material Selection: Careful selection of raw materials, including goat's milk cheese and other ingredients, was a fundamental step.

Replicates: Each experimental sample was prepared three times to ensure the reliability of the results.

Data Collection and Processing:

Data Gathering: All three samples for each formulation were examined, and the data were meticulously recorded.

Statistical Processing: Statistical analysis was conducted to determine standard deviations (± SD) and assess the significance of differences between samples and conditions. Statistical software, "STATISTICA 12.0," was employed for this purpose.

Composite Planning Implementation:

Rationale: The concept of composite planning was introduced to rationalize the experimentation process. It involved designing efficient experimental setups to evaluate multiple factors and their interactions with minimal experiments.

Strategic Experiment Selection: Specific experiment points within the design space were strategically chosen to efficiently collect data and make informed decisions regarding recipe adjustments.

Optimization of Formulation:

Formulation Adjustments: The data collected from the experiments were used to optimize the processed cheese formulation by introducing correction points into the experimental plan. A central composite plan was utilized for this purpose.

Surface Response Method Application:

Methodology: The surface response method was employed to identify optimal conditions in the refined model.

Results and Discussion:

Prerequisites and Justifications for Raw Material Selection: Discussion on the selection of raw materials, focusing on the benefits of using goat's milk cheese.

Effect of Goat Milk Raw Material: Examine the impact of different types of raw goat milk material on processed cheese production.

Production of Functional Foods: Exploration of the development of processed cheeses with functional additives for improved nutritional value.

Amino Acid and Fatty Acid Composition Analysis: Discussion on analysing amino acid and fatty acid compositions in the experimental samples.

Statistical Analysis

In our study, we employed several statistical methods to analyze the data. The following statistical tests and methods were used:

Analysis of Variance (ANOVA): ANOVA was utilized to assess the differences among multiple groups, particularly in comparing color attributes among different cheese samples. For example, we conducted ANOVA to determine if there were significant differences in color attributes such as brightness (L*), redness (a*), and greenness (b*) among the various cheese samples.

T-Tests: We performed t-tests to compare specific pairs of cheese samples for parameters such as amino acid composition and fatty acid composition. For instance, we used t-tests to compare the amino acid composition of the experimental sample with 1% Spirulina to the control sample without Spirulina, assessing whether there were statistically significant differences in individual amino acids.

Regression Analysis: Regression analysis was applied to explore the relationships between variables, such as the dose of melting salts and the added vegetable filler, and various characteristics of the processed cheese. We used regression to determine the optimal dosage of these ingredients for achieving desired properties.

Descriptive Statistics: We calculated means and standard deviations to summarize data, particularly when presenting amino and fatty acid composition. These statistics were used to describe the central tendencies and variability of the data.

Hypothesis Testing: Hypothesis testing was employed to assess the significance of observed differences, as indicated by p-values. For instance, we used hypothesis testing to determine whether differences in amino acid composition between samples were statistically significant.

It is important to note that all statistical analyses were performed with a significance level of $p \leq 0.05$, indicating statistical significance when p-values were below this threshold. The choice of statistical methods and parameters tested was determined based on our study's specific objectives and hypotheses.

In this study, "the idea of composite planning" refers to an approach to statistical and experimental design used to rationalise and optimise experiments. Composite planning involves the creation of efficient experimental designs that allow the evaluation of multiple factors and their interactions in a relatively small number of experiments. This approach is particularly useful when dealing with complex systems and many variables.

This study's use of compositional planning aimed to minimise the number of experiments required to optimise a processed cheese formulation. Strategic selection of experiment points in the design space allows researchers to collect data and make informed decisions about recipe adjustments efficiently. This approach saves resources and speeds up the optimisation process. The software package "STATISTICA 12.0" was used for various aspects of data analysis in this study. Although it includes a wide range of statistical functions and tools, the following functions were used: for statistical and regression analysis of the experimental data. This made it possible to evaluate the relationship between the different variables, identify significant factors and determine their influence on the processed cheese formulation; for visual presentation of the data, including profilograms or sensory profiles, which helped to interpret sensory scores; to assess the significance of differences between samples and conditions, various statistical tests such as ANOVA (analysis of variation) or t-tests were performed. Each experimental sample for a particular formulation was prepared 3 times, all 3 samples were examined, and the figures were entered into the planning matrix. The data were then processed, and the formulation was optimised by adding correction points to the experimental plan, using a central-composite plan. All data in the tables are summarised as the mean of 3 trials for each sample ± standard deviation.

RESULTS AND DISCUSSION

Prerequisites and justifications for raw material selection: There are very few works on the production of processed cheeses from goat's milk, because of the high cost of goat's milk cheeses; nevertheless, to produce hypoallergenic products with a higher nutritional value, it is a priority to use fewer products from cow's milk in the technology of processed cheeses. Compared to cow's milk, goat's milk has a higher concentration of short- and medium-chain fatty acids and lipoprotein lipase associated with the fat phase **[11]**. A study on the possibility of producing processed cheese based on mature cheeses from goat's milk **[12]** showed that cheeses with maturation periods of 10, 20 and 40 days are suitable for melting; the final moisture content of the cheese should be 63.0 ±1.0% (p = 0.0008), with a melting temperature of 85.0 ±0.1 °C, within 9.0 ±0.5 min. The cheese was made by analogy. The phosphate salt used in this paper is JOHA (S10 2.5 per cent and HBS 0.3 per cent); sodium phosphate, and polyphosphate salts. In our case, we used a mixture of tripolyphosphate and sodium citrate. Despite this, there is contradictory information about the melting of goat's milk cheese, so **[13]** concluded that the most meltable (e.g. for pizza) goat's milk cheeses should have a moisture content of 48%. Thus, the composition and the type of raw materials play a role in producing processed cheese. The effect of the kind of goat milk raw material for processed cheese production on α and β-casein values was also studied **[10]**, it was found that cheeses (50% of cheese with a maturation period of 10 days, 25% of cheese with a maturation period of 20 days and 25% of cheese with a maturation period of 40 days) had higher α- and β-casein values. This α- and β-casein content is due to the high content of intact casein in cheese with a short maturation time. A technology of production of processed cheese from sheep's milk was also proposed **[14]**, as a result, when compared to processed cheese from cow's milk in terms of whiteness, the best indicators were for the cheese from sheep's milk: fatty acid composition was better, the content of casein was also higher, processed cheese from sheep's milk was also better in all physical indicators.

The production of functional foods has received an impetus to development with the increasing interest of the world's population in healthy lifestyles and quality nutrition. This connection included products with phytofillers (medicinal herbs, phytosterols, algae, etc.) Dry powder of white cabbage and coriander was used in brine cheese **[15]**, wild onion was used in the production of processed cheese **[1]**, rice husk was used in the production of yoghurt **[16]**, amaranth in goat cheese production **[17]**. Thus, we can conclude that using combined raw materials for processed cheeses for functional purposes is still poorly studied, as well as the shelf life of such cheeses and the impact on the composition of the finished product technology and types of raw materials used in the recipe. Developing technology of processed cheeses from combined dairy raw materials, such as cheese from cow's milk and cheese from goat's milk, can be an interesting and promising project. In the development of this technology, the following auspices have been taken into account, and work has been carried out:

Study of the properties of raw materials: Before development began, research was carried out on the properties of cow's and goat's milk cheeses. The fat, protein, lactose and other components of each type of cheese were determined. This helped to understand what changes to the cheese melting and combining process might be required.

Recipe selection: The optimum ratio of raw materials from cow and goat milk was determined to obtain the desired characteristics of processed cheese **[18]**.

Melting and emulsification: Melting is a key step in creating processed cheese. Optimum temperature and time conditions have been developed for melting a mixture of cow's and goat's milk cheeses. Emulsification also plays an important role in creating a homogeneous cheese texture.

Tests and analyses: After developing the technology, exploratory experiments were carried out using the PFE 33 plan to evaluate the quality, texture and flavour. After processing the data obtained, adjustments were made, and the recipe was optimised **[19]**.

Furthermore, the cheeses prepared according to the optimised formulation were subjected to laboratory tests: amino acid and fatty acid composition were determined. During the search experiments, organoleptic parameters were determined, and melting salts were selected. Figure 1 shows the characteristics obtained with Chromometer CR410 **[20]**, colour indices of the experimental sample, which was the most acceptable.

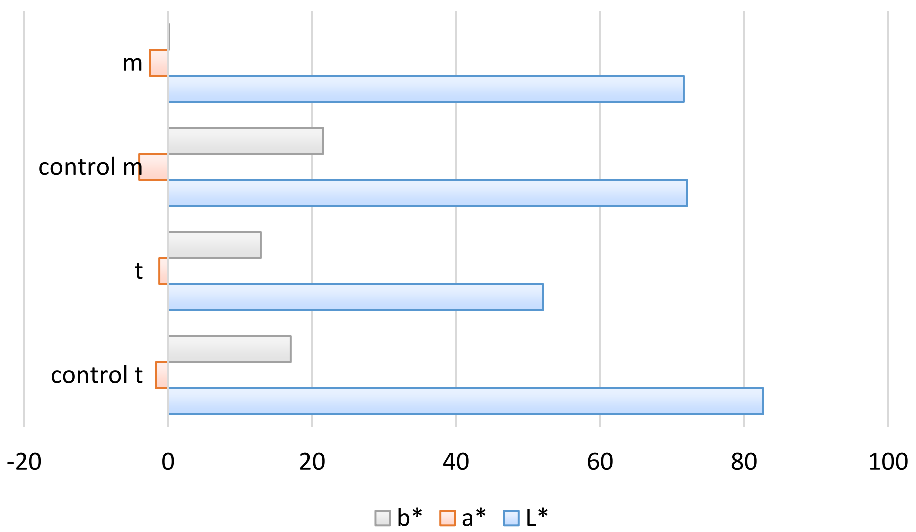

Figure 1 Colour indicators of the finished product.

According to the data presented in Figure 1, it can be seen that processed cheeses do not contain red colour and do not have dark colour (values on the scale a* with a minus sign); the lightest is processed cheese slice control cheese from cow's milk without the addition of vegetable ingredients, the next control m – is a cheese made according to the classical technology with a minimum expansion of vegetable filler, cheese M – is developed according to a new technology cheese prototype with a minimum (1%) addition of vegetable filler, cheese T – experimental sample with adding p, cheese T– experimental sample with adding vegetable filler. Experimental sample T, as seen from the figure, has a saturated green tint, and the colourimeter shows it as the least bright, corresponding to reality.

Figure 2 shows the results of experimental data processing on finding the optimum dose of melting salts and the dose of plant filler.

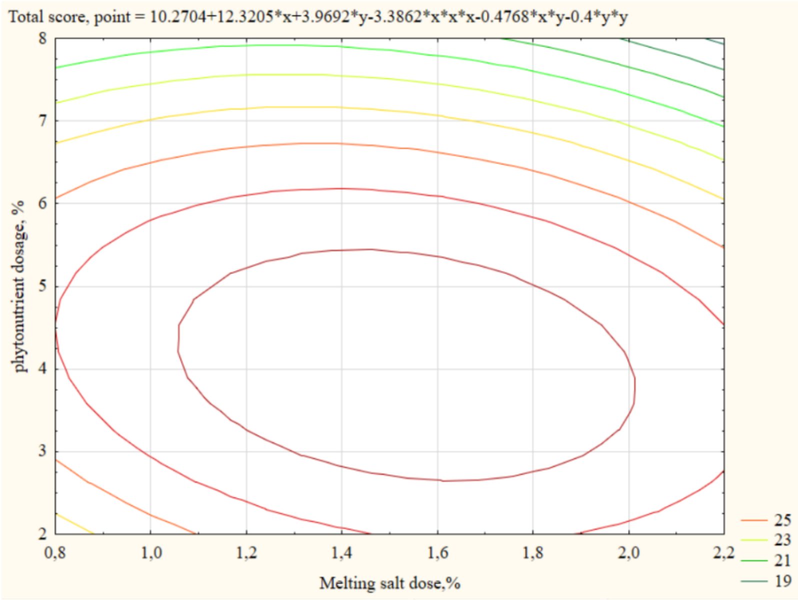

Figure 2 Results of the analysis on finding optimum doses of plant filler and melting salts application.

As can be seen from Figure 2, by adding goat cheese with a maturation period of 10 days and a vegetable filler to the formulation, it is possible to reduce the dose of melting salts to 1.5-2%, and the optimum is the dose of filler 4-5%, but since the analysis of colouring showed that the experimental sample M is close to the control sample, then judging from Figure 2 it is possible to choose the formulation with the addition of 1%, because the red zone is the zone of optimum. Among the various rheological characteristics, the most significant is the effective viscosity **[21]** Figure 3 shows the dependence of viscosity on the dose of melting salts and the added vegetable filler.

Thus, based on the analysis of colour and analysis of organoleptic parameters, it is rational to use melting salts 2%, and the dose of vegetable filler (Spirulina Maxima) – 1%.

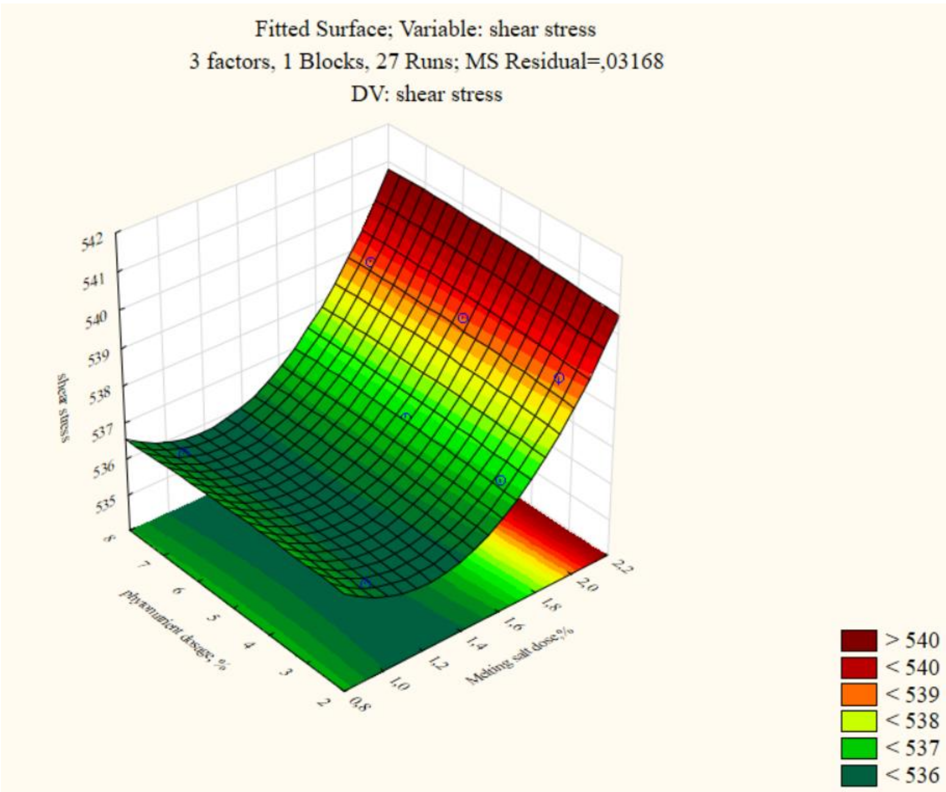

Figure 3 Variation of shear stress values as a function of melter salt dose and vegetable raw material dose.

Amino acid analysis composition: Animal products are undoubtedly one of the human diet's most concentrated sources of essential amino acids (AAs). However, their high price and the diseases associated with their excessive consumption have prompted the consumption of other alternative sources of proteins of animal origin, such as those from marine or aquatic species **[22]**. The amino acid composition of processed cheeses may vary depending on the formulation and composition of the original dairy raw material. However, processed cheeses generally contain various amino acids, the basic building blocks of protein. The amino acid profile of each cheese can vary depending on the type of milk (cow, goat, sheep, etc.), the lactation stage of the animal, milk processing methods, and even added ingredients and additives. The value of amino acid composition is discussed in many articles; for example, **[23]** states that the best indicator of protein quality is calculating the amino acid ratio from the limiting essential amino acid. Also, in 1991, on the initiative of FAO/WHO, the PDCAAS method of protein quality and digestibility was introduced **[24]**. The Protein Digestibility Adjusted Amino Acid Index (PDCAAS) is determined by comparing the amino acid profile of the food product in question with the standard amino acid profile, where 100 is the maximum possible score. This source describes the disadvantages of this method and suggests modification and refinement of the calculation. It is also suggested to study protein quality using the Amino Acid Score Difference Coefficient (ASDC) **[25]**.

"Ideal protein" is a protein with an amino acid composition perfectly balanced for the growth and development of a living organism. The closest to the ideal protein according to the amino acid profile is the base protein of the embryo: egg, or caviar. The main limiting factor is the amino acid lysine. Tables 2 and 3 show the proportions of amino acids in 1 g of "ideal" protein for the body –The perfect protein. Comparative analysis of amino acids in an ideal protein with amino acid data in control and experimental processed cheeses proved that in experimental cheeses, there are more essential amino acids than in control, and therefore a greater index of essential amino acids. The data suggest a high biological value of the developed processed cheeses using goat's milk in the formulation.

Tables 2 and 3 show the analysis of the amino acid composition of the experimental samples according to the recipe "M" processed cheese compared to the control sample from cow's milk and the control sample according to the developed technology without adding vegetable filler. To determine the quality of the experimental protein, we used the method of calculation of KRAS **[26]** and utilitarian coefficient **[27]**, the method of calculation of rationality coefficient **[28]**.

Table 2 Analysis of the amino acid composition of the experimental sample

Name of Essential Amino Acid	The perfect protein	Experimental Protein	Score
	mg/100g	mg/100g	%
isoleucine	40	40 ±0.25	100
leucine	70	140 ±0.31	200
lysine	55	180 ±0.64	327.27
methionine and cysteine	35	71 ±0.39	202.85
phenylalanine and tyrosine	60	120 ±0,8	200
tryptophan	10	10.2 ±0.52	102
threonine	40	98 ±0.25	245
valine	50	140 ±0.35	280
Index of essential amino acids	360	799.2 ±0.87	1.92
rationality coefficient			22.64 ±0.85
utilisation factor			61.12 ±1.01
Amino acid scoring difference coefficient			-54.9 ±1.93
PDCAAS			96.9 ±1.1

Note: Results are expressed as mean ± standard deviation; mean values with different top indices in a row differ significantly ($p \leq 0.05$).

A comparison of the two tables shows that the protein amount of the experimental sample is maximally near to ideal, and the utilitarian coefficient is higher than that of the control sample, which speaks in favour of the filler. The amino acid index with correction on digestibility is higher in the experimental sample. It is equal to 96.9 at 39.9 at processed cheese from combined dairy raw materials without adding vegetable filler, and 18.75 in processed cheese from cow's milk. Also, the coefficient of utilitarianism 61.1 against 13.72 of the control sample shows good protein digestibility of the experimental sample.

Table 3 Analysis of the amino acid composition of control sample m without the addition of a vegetable filler.

Name of Essential Amino Acid	The perfect protein	Experimental Protein	Score
	mg/100g	mg/100g	%
isoleucine	40	40 ±0.91	100
leucine	70	110 ±0.31	157.14
lysine	55	160 ±0.52	290.91
methionine and cysteine	35	64 ±0.31	182.85
phenylalanine and tyrosine	60	119.3 ±0.25	198.83
tryptophan	10	4.2 ±0.8	42
threonine	40	81 ±0.97	202.5
valine	50	130 ±1.00	260
Index of essential amino acids	360	708.5 ±1.97	1.569143 ±1.85
rationality coefficient			8.265833 ±0.98
utilisation factor			13.72 ±0.19
Amino acid scoring difference coefficient			-43.56 ±1.78
PDCAAS			39.9 ±1.08

Note: Results are expressed as mean ± standard deviation; mean values with different top indices in a row differ significantly ($p \leq 0.05$).

Study fatty acid composition: The study of the fatty acid composition of processed cheese is an important task to determine its nutritional value, quality and compliance with regulatory requirements. The fatty acid composition of processed cheese is determined by the type and content of fats included in the cheese product. The atherogenicity and thrombogenicity indexes indicate a diet's atherogenic and thrombogenic potential better than the PUFA/UFA ratio. These indices consider the different effects that individual fatty acids may have on human health. The thrombogenicity index value indicates the propensity to form blood clots in blood vessels **[29]**.

The comparison of fatty acid composition is shown in Table 3.

Table 4 Fatty acid composition of processed cheeses.

Fatty acids	Content, g.100g^{-1}	
	Control Sample	Experimental Sample
Saturated fatty acids		
Butyric acid (C4:0)	1.70	3.50
Caproic acid (C6:0)	2.60	2.57
Caprylic acid (C8:0)	3.40	1.43
Capric acid (C10:0)	3.40	3.09
Lauric acid (C12:0)	3.20	3.46
Myristic acid (C14:0)	8.80	10.21
Palmitic acid (C16:0)	21.50	30.10
Margaric acid (C17:0)	0.15	0.61
Stearic acid (C18:0)	3.60	1.05
Arachidic acid (C20:0)	0.05	0.21
Behenic acid (C22:0)		0.09
Total	48.40	66.23
Monounsaturated fatty acids		
Palmitoleic acid (C16:1)	1.25	1.58
Oleic acid (C18:1)	11.6	25.57
Gadoleic acid (C20:1)	0.12	0.25
Docosenoic acid (C22:1)	0	0.11
Total	12.97	27.51
Polyunsaturated fatty acids		
Hexadecadienoic acid (C16:2)	0	0.02
Linoleic acid (C18:2)	0.08	2.05
Linolenic acid (C18:3)	0.25	0.93
Eicosatrienoic acid (C20:3)	0	0.11
Docosadienoic acid (C22:2)	0	0.13

As can be seen from Table 3, the fatty acid composition of the experimental sample differs in the number of polyunsaturated fatty acids 6 times higher than in the control sample, the number of monounsaturated acids in the control sample 1.3 times, the amount of saturated fatty acids in the experimental sample is lower than in the control 1.15 times Thrombogenicity index in the control sample is 3.6, while in the experimental sample 2.15.

The study proved the feasibility of adding Spirulina, a dry powder, to the formulation of processed cheese. Some of the cyanobacteria produce toxins: microcystins. Microcystins can cause gastrointestinal disorders and, in the long term, liver cancer **[30]**, which places greater demands on the choice of manufacturer of Spirulina supplements. These toxic compounds are not produced by Spirulina itself **[31]**, **[32]**, but may appear due to contamination of Spirulina batches with other toxin-producing blue-green algae species. Also in the formulation M balanced fatty acid composition, the thrombogenicity index is 2.15. In purchased processed cheeses, this index reaches 4.57 **[32]**.

CONCLUSION

Throughout this study, a processed cheese formula was meticulously developed and fine-tuned, incorporating Spirulina Maxima at a precise dosage of 1%. Notably, this formula exhibits commendable attributes, particularly regarding color parameters and sensory qualities, rendering it highly promising for subsequent production phases. The introduction of Spirulina Maxima into the processed cheese formulation substantially enhanced its nutritional profile. The processed cheese variant fortified with 1% Spirulina showcased a nearly ideal protein composition, underscored by a remarkable protein digestibility rate of 96.9%. The Spirulina Maxima-enriched formulation demonstrated a superior fatty acid composition to the control sample. Significantly augmented levels of polyunsaturated fatty acids and reduced levels of saturated fatty acids were observed. This transformation culminated in lowered atherogenicity and thrombogenicity indices, hinting at potential health advantages. The production process for these processed cheeses was streamlined through judicious adjustments, including reducing melting salt dosage and incorporating goat's milk cheese. These refinements yielded not only improved chemical characteristics but also a reduction in production costs. The findings from this study illuminate a promising pathway for integrating Spirulina Maxima into functional food production. However, it is prudent to acknowledge that further research may be necessary to commercialise this product. Aspects requiring scrutiny encompass product stability, technological intricacies, and consumer assessments. In summation, this study serves as a compelling testament to the potential utility of Spirulina Maxima in the development of processed cheeses endowed with elevated nutritional profiles and conceivable health benefits. These outcomes, therefore, lay a robust foundation for the progression of subsequent research and the evolution of functional product manufacturing.

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