ACTA Acta Sci. Pol. Technol. Aliment. 21(2) 2022, 173–182

www.food.actapol.net pISSN 1644-0730 eISSN 1898-9594 http://dx.doi.org/10.17306/J.AFS.2022.1034

ORIGINAL PAPER

Received: 6.02.2022
Accepted: 4.04.2022

DESIGNING OF PROCESSED CHEESE PRODUCTS TAKING INTO ACCOUNT QUALITY INDICATORS AND COST OF RAW MATERIALS

Nadiia Mashta✉

Department of Management, Faculty of Documentary Communications, Management, Technology and Physics, Rivne State University of Humanities, St. Bandery Street 12, 33028 Rivne, **Ukraine**

ABSTRACT

Background. Processed cheeses and processed cheese products are products that often contain non-dairy raw materials. However, the vast majority of research is aimed exclusively at studying the effects of these raw materials on quality and nutritional value, but the cost of finished products is not taken into account. Given this, it is important to search for recipes for processed cheese products using non-dairy raw materials which will achieve the minimum cost of production considering the optimal values of rheological parameters and organoleptic characteristics.

Materials and methods. To optimize the recipe of processed cheese products, we used an experiment planning for a linear dependence model with two active factors (mass fraction of a mixture of palm oil and hemp oil and mass fraction of a mixture of oat flour and rice flour) and two output parameters (shear stress limit and organoleptic characteristics) followed by a search for the recipe of the processed cheese product of the minimum cost and acceptable quality.

Results. The linear models obtained from the results of the planning of the experiment allow the influence of the amount of oil mixture (palm oil and hemp oil in the ratio 84.1:15.9) and of the amount of flour mixture (oat flour and rice flour in the ratio 55:45) on the shear stress limit and organoleptic characteristics of processed cheese products to be predicted. The mass fraction of the oil mixture and flour mixture is predicted, from which it is possible to produce a product of a set quality. Graphical interpretation of the results made it possible to determine the points of intersection of graphs (special points), which unite the zones of shear stress limit from 650 to 700 Pa and organoleptic assessment of processed cheese products in the range from 87 to 93 points. The mass fraction of the oil mixture and flour mixture at special points, respectively, are: (1) 8 and 0.5%, (2) 8 and 1.21%, (3) 10.25 and 2.5%, (4) 11.5 and 2.5%. Further calculation of the cost of raw materials at these points showed that the minimal possible cost of raw materials for processed cheese products of a set quality (shear stress limit is 650 Pa, organoleptic evaluation is 93 points) is 3.43 EUR/kg with 2.5% flour mixture and 11.5% oil mixture. To ensure the quality of the product of the specified reliability, and considering the error of the experiment $\Delta x_1 = \pm 0.09$ and $\Delta x_2 = \pm 0.05$, the proposed recipe for the processed cheese product contains 11.32% oil mixture and 2.45% flour mixture at a cost per product of 3.48 EUR/kg. The product has an elastic, homogeneous consistency, a clean and pronounced odor with a slight aroma of roasted sunflower seeds, a moderately salty pleasant taste with a slight aftertaste of oatmeal, and a uniform cream color. The physico-chemical parameters (mass fraction of moisture, fat, salt, pH) are within the established norms.

Conclusions. It is possible to use a mixture of palm oil and hemp oil (in the ratio of 84.1:15.9) in the amount of 8 to 12% of the total number of raw components and a mixture of oat flour and rice flour (in the ratio of 55:45) in the amount of 0.5 to 2.5% in the recipe of processed cheese products. In this case, it is possible to obtain a product of different consistency (from plastic to elastic) with a high organoleptic rating, which

✉nadya.mashta@rshu.edu.ua, https://orcid.org/0000-0002-9704-9278

depends on the amount and ratio of the non-dairy raw materials used. The processed cheese product which contains 11.32% oil mixture and 2.45% flour mixture is characterized by having the minimum cost, optimal value of shear stress limit, high organoleptic properties, and physicochemical parameters within established norms. The proposed approach to the designing of the recipe, taking into account its cost, can be used in the manufacturing of processed cheese products using other non-dairy raw materials.

Keywords: processed cheese products, processed cheese, experiment planning, shear stress limit, organoleptic characteristics

INTRODUCTION

Processed cheese and processed cheese products are multi-component foods whose properties can be purposefully controlled. Scientific research confirms that cheeses, including processed ones, are most frequently fortified by nutrients (Villamil et al., 2021). As well as this, the shortage of raw milk and the negative impact of animal husbandry on the climate necessitates the use of non-dairy components in processed cheese products or the manufacturing of cheese analogues without milk proteins and fats as an alternative to processed cheeses (Guinee et al., 2022). Therefore, the use of vegetable proteins and fats in the composition of processed cheese products in order to reduce the cost of the finished product has become the norm. However, much scientific research has shown that the use of blends of vegetable fats and proteins in processed cheese products can not only reduce the cost of the product, but also affect its organoleptic characteristics and nutritional value (Villamil et al., 2021).

Recently, many scientific papers have been devoted to the possibility of introducing vegetable oils into cheese products: canola oil (Ramel et al., 2018b), rapeseed oil (Ramel et al., 2018a), soybean oil in the form of oleogel using rice bran or sunflower wax (Huang et al., 2018), and lycopene oil obtained from tomato peel waste (Zayan et al., 2021), etc.

Given the urgency of the problem of obesity and the need to produce low-calorie foods, scientists are exploring the possibility of using fat substitutes in the recipe of defatted processed cheeses. In particular, scientific work (Schädle et al., 2020) has proven the feasibility of adding inulin, polydextrose, corn dextrin, and microparticle whey protein (MWP) as fat substitutes in concentrations from 3 to 7 g/100 g, and scientific work (Ferrão et al., 2016) demonstrates the specifics of the introduction of starch and inulin with a simultaneous decrease in sodium and the addition of probiotics to processed cheeses.

Research on the use of vegetables and flour in processed cheeses and processed cheese products has caught the attention of scientists, some of whom have proven the feasibility of using mixtures of powdered mushrooms, potatoes, zucchini, carrots, green beans, green peas, celery, leeks, dill, and parsley (Farahat et al., 2021); the expediency of using oatmeal in concentrations of 1 and 2.5% in processed cheeses to increase their biological value has been substantiated (Hamdy et al., 2021); the influence of asparagus powder (in concentrations of 0.5%, 1% and 1.5%) on the qualitative properties of processed cheese has been evaluated (Solhi et al., 2019); the positive effects of wild onions *Allium odorum* (fresh and powdered) on the organoleptic characteristics and shelf life of processed cheese has been proved (Alimardanova et al., 2021); the effects of carrot pomace paste (10, 20, 30% of processed cheese base; El-Dardiry, 2021) and red sweet pepper paste (10, 20% of processed cheese base; Atwaa et al., 2020) on the physicochemical and textural properties has been analyzed; the optimal amount of sea buckthorn in a recipe of processed cheese taking into account its influence on organoleptic and rheological parameters using response surface methodology has been established (Haixiang et al., 2021); the expediency of adding 5 and 10% roasted walnut paste to the recipe of processed cheeses in order to improve their fatty acid composition has been proved (Abbas et al., 2021); the influence of cassava flour (3, 5, and 7%) on the quality of processed cheese has been analyzed (Rodríguez et al., 2020); the optimal amount (3%) of sunflower isolate in processed cheeses has been established (Bolgova et al., 2020); the possibility of partial replacement of dairy ingredients by 2–6% of black rice powder for the production of functional processed cheeses has been investigated (Khalil and Elkot, 2020).

A review of the literature has shown that the latest way to introduce non-traditional components into processed cheese is to use microcapsules. In particular, the possibility of adding functional microcapsules from mustard seed extract and *Bifidobacterium* to the composition of processed cheese has been substantiated (El-Sayed et al., 2021). It allows a product with functional properties to be obtained. The possibility of using microencapsulated chia oil (*Salvia hispanica*) and inulin for the enrichment of processed cheese with polyunsaturated fat has been proven (Cardoso et al., 2020). It has been substantiated that adding microencapsulated extract of fig leaves has a positive effect on the shelf life of processed cheese (Elsayed et al., 2021).

It is quite common to research the possibilities of using local products in processed cheeses. In particular, the possibilities of using a unique Greek phytotherapeutic product – Chios mastic gum (Salek et al., 2020) and canistel (exotic fruit) in combination with inulin in processed cheeses have been researched (Saraiva et al., 2020); the positive effects of curcumin nanoemulsion by ratios of 2.5% and 5% (El-Sayed et al., 2021), date syrup in the amount of 15, 20, 25% (El-Loly et al., 2021), and date seed powder in the amount of 0, 1, 5, 10% (Darwish et al., 2020) on the physicochemical, microstructural, organoleptic, and functional properties of processed cheese have been confirmed.

In addition, research on the possibility of adding dietary fiber to processed cheeses remains relevant. In particular, scientific work (Ferrão et al., 2018) has proved the feasibility of using galactooligosaccharides and xylooligosaccharides in the processed cheese Requeijão cremoso. The influence of oat fiber on the rheological properties of processed cheese has been researched (Ramel et al., 2018b). Scientists have also examined the effects of hydrocolloids (tapioca starch and potato starch (Fu and Nakamura, 2018), konjac glucomannan and konjac flours (da Silva et al., 2016), and basil seed gum (Hosseini-Parvar et al., 2015) on the rheological properties and microstructure of processed cheeses.

However, the vast majority of research is aimed solely at studying the impacts of additives on quality and nutritional value and does not take into account the costs of the finished product, although the production of processed cheeses and cheese products belongs to the material industry. Therefore, it is important to find a recipe for processed cheese products that uses non-dairy raw materials which will achieve the minimum possible cost of the finished product while taking into account the optimal values of rheological parameters and organoleptic evaluation.

MATERIALS AND METHODS

The control sample was a processed cheese product containing hard cheese with a mass fraction of fat in the dry matter of 50%, skimmed milk powder with a mass fraction of dry matter of 96%, acid-set cheese with a mass fraction of fat of 9%, water, refined deodorized palm oil, margarine with a mass fraction of fat of 72%, salt-melter «Carfosel 996» and stabilizer «GMP-250». Deodorized palm oil was according to DSTU 4306:2016 «Oil palm. General technical specifications», unrefined cold pressed hemp oil (TM «Korysna oliia», Kyiv), oat flour and rice flour (manufactured by «Agrosnab LLC», Kyiv) were chosen as non-dairy raw materials.

To solve the tasks set in the article, experimental planning for a linear dependence model was used (Makarichev and Ivannikov, 2016).

The active factors selected are:

- x_1 – mass fraction of the oil mixture (refined deodorized palm oil and unrefined hemp oil)
- x_2 – mass fraction of a mixture based on oat flour and rice flour.

The output parameters were:

- y_1 – shear stress limit, Pa
- y_2 – organoleptic characteristics, points.

The calculation of the composition of the first active factor (ratio of oils in the composition) was performed using a method based on linear programming (Okara et al., 2009) in a spreadsheet in MS Excel, taking into account that the palm oil in the composition contains at least 75% and a ratio of ω-6:ω-3 polyunsaturated fat is (6–7):1. The result is an oil mixture containing 15.9% hemp oil and 84.1% palm oil.

The ratio of the components of the second active factor, namely the mixture of oat flour (55%) and rice flour (45%), was determined by optimizing the composition of the mixture by the smallest modules (Babenko et al., 2009), the essence of which is to use the tool «Search solutions» (Solver) of the spreadsheet in MS Excel in order to select the ratio of components with amino acid composition as close as possible to ideal according to the Report of a Joint FAO/WHO/UNU Expert Consultation «Energy and protein requirements».

The first output parameter y_1 (shear stress limit) was determined by the method of penetration using a hand penetrometer of the LP brand by immersing a conical indenter with an angle at the apex of 60° and height of 0.016 mm in the product. The temperature of the processed cheese during research was 2 ±2°C. The shear stress limit of the processed cheese product was calculated using the formula of Rebinder:

$$y_1 = K \cdot (m/h^2)$$

where:

- K – the constant of the cone, which depends on the angle of the cone at its apex, N/kg, $K = 2.1$ N/kg
- m – the mass of the moving part of the device, kg, $m = 0.2857$ kg
- h – the maximum depth of immersion of the cone, m.

To establish the values of the second output parameter y_2 (organoleptic quality indicators), the author's 100-point evaluation system was used (Mashta, 2009), which includes quality indicators such as the condition of the surface after removing the package, view after cutting, dough color, consistency, odor, and taste. Quality assessment was performed on the processed cheese products which had been refrigerated for two days at a temperature of 2 ±2°C. Organoleptic evaluation of the processed cheese products was carried out at the meetings of three tasting commissions which involved 10 experts. Each taster was provided with samples of the processed cheese products, tasting cards, and a scale for assessing the quality of the processed cheese products.

The calculation of the recipes for the processed cheese products was carried out using standard formulas of material balance to obtain finished products of the required fat content and moisture.

Control and experimental samples of the processed cheese products were made under laboratory conditions using an automatic cheese factory "Craftstore" for 10 liters by traditional technology in accordance with the technological instructions for processed cheese TU U 15.5-30019749-007:2005 «Processed cheese. Specifications».

The adding of non-dairy raw materials to the processed cheese products required correction of the traditional technological process of production. Therefore, a mixture of oat flour and rice flour was diluted with water at 40–45°C and kept for 15–20 minutes to fully hydrate and disperse the particles of the added powders; next, it was pasteurized at 90–95°C for 15–20 seconds, after which it was added to the cheese mass. The oil mixture was added to the cheese in two stages: palm oil – after melting hard cheese and acid-set cheese, and hemp oil – 3 minutes before the end of the melting process to minimize its heat treatment.

pH measurements were performed using a pH meter-millivoltmeter pH-150M according to DSTU 8550:2015 «Milk and milk products. PH measurement by potentiometric method». The mass fraction of moisture was determined by drying the sample of the test product at a temperature of 100 ±2°C in an oven to constant weight, followed by weighing according to DSTU 8552:2015 «Milk and milk products. Methods for determining moisture and dry matter». The mass fraction of fat in the dry matter was determined using the butyrometric method according to DSTU ISO 11870:2007 «Milk and milk products. Determination of fat content. General guidance on the use of butyrometric methods». The mass fraction of salt was determined using the method using silver nitrate according to GOST 3627-81 «Milk products. Methods for determination of sodium chloride». The mass fraction of milk fat in the fat phase was calculated according to the GOST R 52685-2006 «Processed cheeses. General specifications».

RESULTS AND DISCUSSION

Given that the aim of the research was to develop a new processed cheese product of minimum cost and made using non-dairy raw materials, the active factors during the mathematical planning of the experiment were: x_1 – mass fraction of oil mixture (refined palm oil and unrefined hemp oil) and x_2 – mass fraction of flour mixture (oat flour and rice flour). The ranges of change of these factors and the intervals of their variation are given in Table 1. Acceptable values of the output parameters, which indicate the high quality of processed cheese products, are given in Table 2. The planning matrix and the results of the experiment are presented in Table 3.

According to the results of the statistical processing of the experimental data, we obtained linear models that allow the effects of the amount of oil mixture and flour mixture on the shear stress limit (1) and organoleptic quality indicators (2) of processed cheese products to be predicted.

Table 1. Terms of experiment planning

The active factors	Level			Interval of variation
	–1	0	+1	
x_1 mixture of hemp oil (15.9%) and palm oil (84.1%)	8.00	10.00	12.00	2.00
x_2 mixture of oat flour (55%) and rice flour (45%)	0.50	1.50	2.50	1.00

Table 2. Acceptable values of output parameters

The name of the output parameter	Unit of measurement	Acceptable value
Shear stress limit	pascal	650–700
Organoleptic evaluation	points	87–100

$$y_1 = 647.50 - 72.5x_1 + 62.5x_2 - 7.5x_1x_2 \quad (1)$$

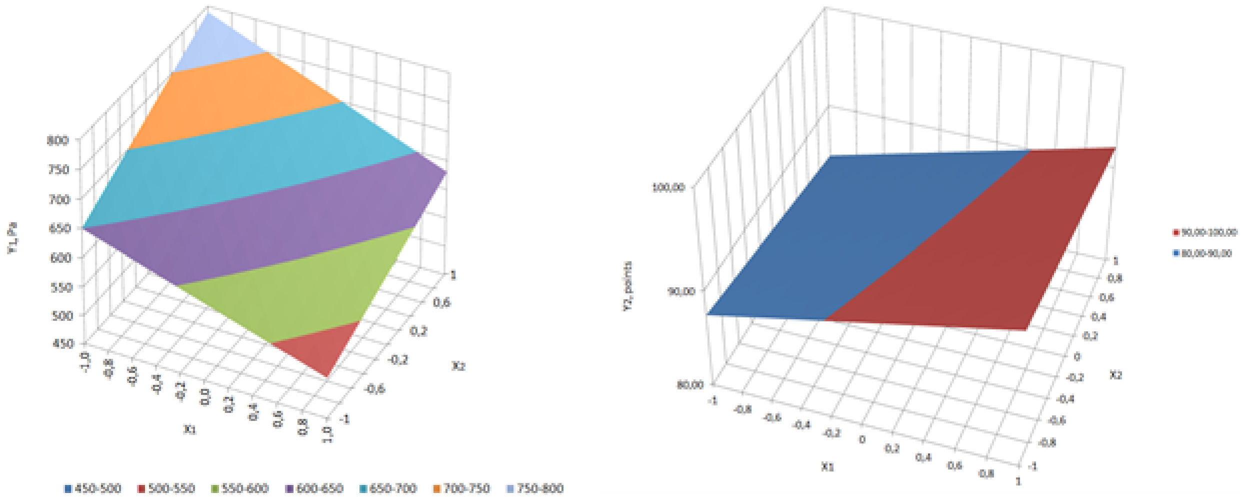
$$y_2 = 89.55 - 1.2x_1 + 3.5x_2 - 0.25x_1x_2 \quad (2)$$

Graphic interpretation of the dependence of the shear stress limit and organoleptic parameters on the number of added components of non-dairy raw materials is given in Figure 1. It is evident to obtain processed cheese products with the optimal value of shear stress (650–700 Pa) by increasing the mass fraction of the flour mixture requires the mass fraction of the oil mixture to be increased based on hemp oil and palm oil. It is possible to obtain a product with less elastic consistency by using the minimum amount of flour mixture (0.5% in the researched case) and the maximum amount of oil mixture (12% in the researched case). However, this consistency reduces the overall organoleptic evaluation of the finished product. To obtain a product with a more elastic consistency, it is necessary to increase the mass fraction of the flour mixture while reducing the mass fraction of the oil mixture.

The next stage of research was to find the optimal values of the mass fraction of the recipe components, taking into account the cost of the finished product. The optimization task was formulated as follows: it is necessary to find the following values of independent variables x_1 and x_2, at which the cost of the raw material of the processed cheese product will be the lowest possible, and organoleptic evaluation and shear stress limit will be acceptable: 87–100 points and 650–700 Pa respectively. The graphs corresponding to the optimization problem that we formulated are given in Figure 2.

Table 3. Planning matrix and experiment results

Experimental point number	Active factors				Output parameters	
	code values		natural values % of the total mass of the processed cheese product		shear stress limit Pa y_1	organoleptic indicators, points y_2
	x_1	x_2	x_1	x_2		
1	+1	+1	12.00	2.50	630	92.1
2	+1	–1	12.00	0.50	520	84.6
3	–1	+1	8.00	2.50	790	94.0
4	–1	–1	8.00	0.50	650	87.5



a **b**

Fig. 1. Graphical interpretation of the influence of the mass fraction of the oil mixture and flour mixture on shear stress limit (**a**) and organoleptic quality indicators (**b**) of the processed cheese products

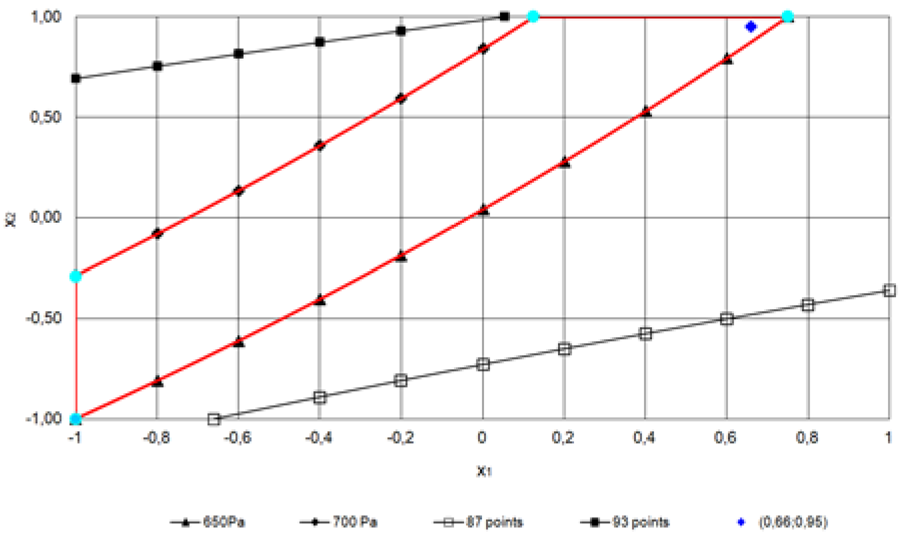


Fig. 2. Search for the minimum cost of processed cheese product (with a dry matter content of 46% and a mass fraction of fat in the dry matter of at least 55%)

Determining the cost at the intersection of the graphs will allow the values of x_1 and x_2 to be set at a level where the recipe of the processed cheese products will be minimal. Therefore, Table 4 shows the mixtures and the cost of the raw material of the processed cheese products at these points. Thus, the minimum cost of the processed cheese product is at the point $x_1 = 0.75$, $x_2 = 1$ with a mass fraction of the oil mixture of 11.5% and a mass fraction of the flour mixture of 2.5%. However, to reliably ensure the proper quality of the product, it is necessary to take into account the value of the error of the experiment, which at 95% reliability for factors x_1 and x_2, respectively, is $\Delta x_1 = \pm 0.09$ (0.66–0.84) and $\Delta x_2 = \pm 0.05$ (0.95–1.05). The cost of

Table 4. Recipe and cost of processed cheese products at the intersections of graphs

No	Prescription component	The content of components at the points of intersection of graphs kg/1020 kg of finished product			
		$x_1 = -1$ $x_2 = -1$	$x_1 = -1$ $x_2 = -0.29$	$x_1 = 0.125$ $x_2 = 1$	$x_1 = 0.75$ $x_2 = 1$
1	hard cheese with a dry matter content of 57% and a fat content of 50%	442.86	435.62	422.46	402.06
2	acid-set cheese with a mass fraction of fat of 9%	250.00	250.00	250.00	250.00
3	butter with a mass fraction of fat of 73%	37.53	39.53	11.74	2.26
4	skimmed milk powder with a mass fraction of dry matter of 96%	19.73	15.61	8.77	15.03
5	oil mixture (palm oil 84.1% and hemp oil 15.9%)	81.60	81.60	104.55	117.30
6	flour mixture (oat flour 55% and rice flour 45%)	5.10	12.34	25.50	25.50
7	salt-melter Carfosel 996	15.00	15.00	15.00	15.00
8	ascorbic acid	1.02	1.02	1.02	1.02
9	tincture of walnut leaves	1.02	1.02	1.02	1.02
10	drinking water	166.14	168.27	179.94	190.82
The cost of raw materials for the manufacture of 1 kg of product, EUR		3.72	3.68	3.54	3.43

raw materials used will be higher. Accordingly, Table 5 shows the recipe and the cost of the processed cheese product at points $x_1 = 0.66$ and $x_2 = 0.95$, which corresponds to the optimal composition (11.32% of the oil mixture and 2.45% of the flour mixture).

The results of the organoleptic studies confirmed the high quality of the developed product, which is characterized by a slightly elastic, homogeneous consistency; a pure, pronounced odor with a slight aroma of roasted sunflower seeds (due to the adding of unrefined hemp oil); a moderately salty pleasant taste with a slight aftertaste of oatmeal; a uniform cream color.

According to the shear stress limit (Table 6), the developed processed cheese product corresponds to

Table 5. Basic and developed recipe of processed cheese products with a dry matter content of 46% and a mass fraction of fat in the dry matter of at least 55%

No	Prescription component	Basic sample	Developed product
1	2	3	4
1	hard cheese with a dry matter content of 57% and a fat content of 50%	450.00	412.77
2	acid-set cheese with a mass fraction of fat of 9%	250.00	250.00
3	margarine with a mass fraction of fat of 72%	55.00	–
4	butter with a mass fraction of fat of 73%	–	0.66
5	skimmed milk powder with a mass fraction of dry matter of 96%	19.70	12.31
6	palm oil	67.78	97.10

Table 5 – cont.

1	2	3	4
7	hemp oil	–	18.36
8	oat flour	–	13.75
9	rice flour	–	11.24
10	salt-melter Carfosel 996	15.00	15.00
11	stabilizer Prodamul GMP-250	3.50	–
12	ascorbic acid	–	1.02
13	tincture of walnut leaves	–	1.02
14	drinking water	159.02	186.77
15	total	1 020.00	1 020.00
The cost of raw materials for the manufacture of 1 kg of product, EUR		3.57	3.48

Table 6. Physico-chemical and rheological parameters of basic and developed processed cheese products

No	Name of indicator	Basic sample	Developed sample
1	shear stress limit, Pa	599.30 ±26.58	655.96 ±24.40
2	mass fraction of fat, %	25.33 ±0.05	25.30 ±0.02
3	mass fraction of milk fat in the fat phase, %	58.71 ±0.05	55.26 ±0.02
4	mass fraction of moisture, %	53.88 ±0.12	53.78 ±0.06
5	mass fraction kitchen salt, %	1.28 ±0.014	1.21 ±0.023
6	active acidity, pH, units	5.70 ±0.032	5.6 ±0.038

$n = 3$, $p \leq 0.05$.

the recommended values (from 650 to 700 Pa). A more elastic consistency compared to the base sample was obtained mainly by using rice flour. The mass fraction of fat and the mass fraction of moisture in the basic and developed samples of the processed cheese products are at the same level (approximately 25.3% and 53.8%, respectively), which was laid down in the design of the recipes using material balance formulas. We also note a fairly high mass fraction of milk fat in the fat phase of the developed sample (55.26 ±0.02%) and low salt content (1.21 ±0.023%) due to the decrease in the amount of hard cheese in the developed recipe. The pH of the cheese mass of the developed product is 5.6 ±0.038 units, which is in the proposed range of 5.2–5.7.

CONCLUSION

1. To develop the recipe of a cost-optimized processed cheese product, it is advisable to use experimental planning for a linear model of dependence. The active factors may be the mass fraction of non-dairy raw materials, and the output parameters are rheological and organoleptic quality indicators.

2. The obtained experimental and statistical mathematical models of dependences of shear stress limit and organoleptic evaluation on the amount and ratio of added non-dairy supplements (mixture of palm oil and hemp oil and mixture of oat flour and rice flour) can be used to predict the quality and cost of processed cheese products.

3. It is possible to use a mixture of palm oil and hemp oil (in the ratio of 84.1:15.9) in the amount of 8 to 12% of the total number of raw components and a mixture of oat flour and rice flour (in the ratio of 55:45) in the amount of 0.5 to 2.5% in the recipe of processed cheese products. It is possible to obtain a product of different consistency (from plastic to elastic) with a high organoleptic rating which depends on the amount and ratio of the non-dairy supplements used.

4. The processed cheese product which consists of 11.32% of a mixture of palm oil and hemp oil and 2.45% of a mixture of oat flour and rice flour is characterized by a minimum cost. The product has an elastic, homogeneous consistency, a clean and pronounced odor with a slight aroma of roasted sunflower seeds, a moderately salty pleasant taste with a slight aftertaste of oatmeal, and a creamy uniform color. The physicochemical parameters (mass fraction of moisture, fat, salt, and pH) are within the established norms.

5. The proposed approach to the design of the recipe, taking into account its cost, can be used in the manufacturing of processed cheese products using other non-dairy raw materials.

REFERENCES

Abbas, K. A., Abdelmontaleb, H. S., Hamdy, S. M., Aït-Kaddour, A. (2021). Physicochemical, functional, fatty acids profile, health lipid indices, microstructure and sensory characteristics of walnut-processed cheeses. Foods, 10(10), 2274. https://doi.org/10.3390/foods10102274

Alimardanova, M., Tlevlessova, D., Bakiyeva, V., Akpanov, Z. (2021). Revealing the features of the formation of the properties of processed cheese with wild onions. East.-Eur. J. Enterpr. Technol., 4 (11(112)), 73–81. https://doi.org/10.15587/1729-4061.2021.239120

Atwaa, E. H., Mahytab, R. F., El-Sattar, E. A. (2020). Production of functional spreadable processed cheese supplemented with sweet red pepper paste. J. Food Dairy Sci., 11(5), 127–132. https://doi.org/10.21608/jfds.2020.102741

Babenko, P. P., Gruzinov, E. V., Ivanova, M. V., Kremer, A. I. (2009). Komp'yuternoe proektirovanie smesej rastitel'nyh belkov, optimizirovannyh po soderzhaniyu nezamenimyh aminokislot [Computer-aided design of plant protein blends optimized for essential amino acid content]. Storage Proc. Farm Prod., 12, 44–47 [in Russian].

Bolgova, N., Samilyk, M., Kohan, V., Lisova, N. (2020). Expanding the range of processed cheeses using sunflower isolate. Sci. Messenger LNU Vet. Med. Biotechnol. Ser. Food Technol., 22 (94), 23–26 [in Ukrainian]. https://doi.org/10.32718/nvlvet-f9405

Cardoso, L. G., Bordignon, I. J. Junior, da Silva, R. V., Mossmann, J., Reinehr, C. O., Colla, L. M. (2020). Processed cheese with inulin and microencapsulated chia oil (*Salvia hispanica*). Food Biosci., 37. https://doi.org/10.1016/j.fbio.2020.100731

da Silva, D. F, de Souza Ferreira, S. B., Bruschi, M. L., Britten, M., Matumoto-Pintro, P. T. (2016). Effect of commercial konjac glucomannan and konjac flours on textural, rheological and microstructural properties of low fat processed cheese. Food Hydrocoll., 60, 308–316. https://doi.org/10.1016/j.foodhyd.2016.03.034

Darwish, A. A., Tawfek, M. A., Baker, E. A. (2020). Texture, sensory attributes and antioxidant activity of spreadable processed cheese with adding date seed powder. J. Food Dairy Sci., 11(12), 377–383. http://doi.org/10.21608/jfds.2021.60281.1014

El-Dardiry, A. I. (2021). Impact of carrot pomace paste (*Daucus carota* L.) addition on some properties of processed cheese. Egypt. J. Appl. Sci., 36 (7–8), 16–28. http://doi.org/10.21608/EJAS.2021.195258

El-Loly, M. M., Farahat, E. S., Mohamed, A. G. (2021). Novel approach for producing processed cheese fortified with date syrup. ACS Food Sci. Technol., 1 (5), 737–744. http://doi.org/10.1021/acsfoodscitech.1c00012

El-Sayed, M. I., Shalaby, T. I. (2021). Production of processed cheese supplemented with curcumin nanoemulsion. Am. J. Food Nutr., 9, 3, 96–105. http://doi.org/10.12691/ajfn-9-3-1

El-Sayed, S. M., Elaaser, M., El-Sayed, H. S. (2021). Ameliorate the processed cheese production by functional microcapsules loaded with mustard seed extract and *Bifidobacterium bifidum*. Biocatal. Agric. Biotechnol., 38. https://doi.org/10.1016/j.bcab.2021.102221

Elsayed, S., El-Sayed, H., Salama, H. H., Abd-Rabou, N. (2021). Preparation and evaluation of microencapsulated fig leaves extract for production novel processed cheese sauce. Egypt. J. Chem., 64, 4, 1665–1678. https://doi.org/10.21608/ejchem.2020.52706.3087

Farahat, E. S., Mohamed, A. G., El-Loly, M. M., Gafour, W. A. (2021). Innovative vegetables-processed cheese: I. Physicochemical, rheological and sensory characteristics. Food Biosci., 42. https://doi.org/10.1016/j.fbio.2021.101128

Ferrão, L. L., Ferreira, M. V., Cavalcanti, R. N., Carvalho, A. F., Pimentel, T. C., Silva, H. L. A., …, Cruz, A. G. (2018). The xylooligosaccharide addition and sodium reduction in *requeijão cremoso* processed cheese. Food Res. Int., 107, 137–147. https://doi.org/10.1016/j.foodres.2018.02.018

Ferrão, L. L., Silva, E. B., Silva, H. L. A., Silva, R., Mollakhalili, N., Granato, D., …, Cruz, A. G. (2016). Strategies to develop healthier processed cheeses: Reduction of sodium and fat contents and use of prebiotics. Food Res. Int., 86, 93–102. https://doi.org/10.1016/j.foodres.2016.04.034

Fu, W., Nakamura, T. (2018). Effects of starches on the mechanical properties and microstructure of processed cheeses with different types of casein network structures. Food Hydrocoll., 79, 587–595. https://doi.org/10.1016/j.foodhyd.2017.12.001

Guinee, T. P. (2022). Cheese analogs. In P. L. H. McSweeney, J. P. McNamara (Eds.), Encyclopedia of dairy sciences (3rd ed., pp. 45–55). Academic Press. https://doi.org/10.1016/B978-0-12-818766-1.00081-7

Haixiang, X., Lingling, L., Zida, C., Jiachen, L. (2021). Optimization of processing technology of sea buckthorn processed cheese by response surface methodology. [J]. China Dairy, 0(9), 106–115. https://doi.org/10.12377/1671-4393.21.09.20

Hamdy, S. M., Hassan, M. G., Ahmed, R. B., Abdelmontaleb, H. S. (2021). Impact of oat flour on some chemical, physicochemical and microstructure of processed cheese. J. Food Proc. Preserv., 45, 9. https://doi.org/10.1111/jfpp.15761

Hosseini-Parvar, S. H., Matia-Merino, L., Golding, M. (2015). Effect of basil seed gum (BSG) on textural, rheological and microstructural properties of model processed cheese. Food Hydrocoll., 43, 557–567. https://doi.org/10.1016/j.foodhyd.2014.07.015

Huang, H., Hallinan, R., Maleky, F. (2018). Comparison of different oleogels in processed cheese products formulation. Int. J. Food Sci. Technol., 53, 11, 2525–2534. https://doi.org/10.1111/ijfs.13846

Khalil, R. A., Elkot, W. F. (2020). Functional properties and nutritional quality of processed cheese spreads enriched with black rice powder. Egypt. J. Food Sci., 48(2), 281–289. http://doi.org/10.21608/ejfs.2020.36261.1068

Makarichev, Y. A., Ivannikov, Y. N. (2016). Metody planirovaniya eksperimenta i obrabotki dannykh [Methods of planning experiment and data processing]. Samara: Samara State Technical University [in Russian].

Mashta, N. O. (2009). New scale for quality assessment of processed cheese and processed cheese products. Herald LUTE. Ser. Techn. Sci., 10, 20–27. http://journals-lute.lviv.ua/index.php/visnyk-tech/article/view/569 [in Ukrainian].

Okara, A. I., Zemlyak, K. G., Kalenik, T. K. (2009). Upravlenie zhirnokislotnym sostavom i potrebitel'skimi svojstvami rastitel'nyh masel-smesej putem optimizacii receptur [Management of the fatty acid composition and consumer properties of vegetable oil mixtures by optimizing recipes]. Oil Fat Ind., 2, 8–10 [in Russian].

Ramel, P. R., Marangoni, A. G. (2018a). Engineering the rheological and thermomechanical properties of model imitation cheese using particle fillers. J. Food Eng., 235, 9–15. https://doi.org/10.1016/j.jfoodeng.2018.03.023

Ramel, P. R., Marangoni, A. G. (2018b). Processed cheese as a polymer matrix composite: A particle toolkit for the replacement of milk fat with canola oil in processed cheese. Food Res. Int., 107, 110–118. https://doi.org/10.1016/j.foodres.2018.02.019

Rodríguez, E., Rodríguez-Herrera, T., Martínez, I., Hernández, O. (2020). Harina de yuca para la elaboración de un queso procesado: Cassava flour to make a processed cheese. Cien. Tecnol. Aliment., 30(2), 24–28 [in Spanish]. https://www.revcitecal.iiia.edu.cu/revista/index.php/RCTA/article/view/129

Salek R.N., Lorencová, E., Míšková, Z., Lazárková, Z., Pachlová, V., Adámek, R., …, Buňka, F. (2020). The impact of Chios mastic gum on textural, rheological and melting properties of spread-type processed cheese during storage. Int. Dairy J., 109. https://doi.org/10.1016/j.idairyj.2020.104755

Saraiva, B. R., Licci, N. M., Anjo, F. A., Vital, A. C., Silva, J. B., Bruschi, M. L., Matumoto-Pintro, P. T. (2020). Effects of inulin and canistel addition in the physical characteristics of fat-reduced processed cheese. Res. Soc. Develop., 9(11). http://doi.org/10.33448/rsd-v9i11.9917

Schädle, C. N., Eisner, P., Bader-Mittermaier, S. (2020). The combined effects of different fat replacers and rennet casein on the properties of reduced-fat processed cheese. J. Dairy Sci., 103, 5, 3980–3993. https://doi.org/10.3168/jds.2019-17694

Solhi, P., Azadmard-Damirchi, S., Hesari, J., Hamishehkar, H. (2019). Effect of fortification with asparagus powder on the qualitative properties of processed cheese. Int. J. Dairy Technol., 73, 1, 226–233. https://doi.org/10.1111/1471-0307.12635

Villamil, R.-A., Guzmán, M.-P., Ojeda-Arredondo, M., Cortés, L.Y., Archila, E.G. Giraldo, A., Mondragón, A.-I. (2021). Cheese fortification through the incorporation of UFA-rich sources: A review of recent (2010–2020) evidence. Heliyon, 7(1). https://doi.org/10.1016/j.heliyon.2020.e05785

Zayan, A. F., Bakry, A. M., AbdulAlim, T. S., Radwan, H. M., Safdar, W., Taha, A. (2021). Novel processed cheese production using lycopene oil obtained by green-extraction technique of tomato peels waste. J. Nutr. Food Proc., 4(1). https://doi.org/10.31579/2637-8914/035