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PHYSICOCHEMICAL AND TEXTURAL PROPERTIES OF PROCESSED CHEESE SPREADS MADE WITH THE ADDITION OF CHEESE BASE OBTAINED FROM UF MILK RETENTATES

Katarzyna Kycia, Antoni Pluta, Stanisław Zmarlicki

Division of Milk Biotechnology, Faculty of Food Technology, Warsaw University of Agriculture, Warsaw

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The influence of the addition of cheese base on some physicochemical and textural properties of processed cheese spread was investigated. Cheese base was obtained from whole milk (3.2% fat) concentrated by UF (*CF*=4–5), inoculated with yoghurt starter culture and fermented at 44±1°C until its pH dropped down to 5.1–5.2. Cheese base was used for the production of processed cheese spread standardised to 55% of moisture and 55% of fat in dry solids. Five experimental processed cheeses were obtained containing 0 (control sample), 10, 30, 50 and 70% of cheese base in relation to the total cheese ingredients. The best processed cheese spreads were obtained when the addition of cheese base to the processed cheese was 30%. With such an addition of the cheese base the physicochemical, sensory and textural properties of the final product were similar to those of the control cheese. The results indicated that the addition of cheese base at the level of at least 50% tended to lower pH and protein content of spreads as well as unfavourably increase the hardness of the cheeses. It has been shown that the developed cheese base can successfully replace the young rennet cheese in processed cheese spread production.

INTRODUCTION

Processed cheese is produced by blending shredded natural cheeses of different types and degrees of maturity with melting salts, followed by heating the blend under a partial vacuum with a constant agitation until homogenous mass is obtained. In addition to natural cheeses other ingredients of both dairy and non-dairy origin may be included in the blend [Carić & Kaláb, 1987; Chambere & Daurelles, 2000].

In the recent years, the application of ultrafiltration in processed cheese production has received considerable attention. Concentration of milk components by UF enables recovery of all milk proteins, which in traditional methods of cheese production are generally lost with the whey. There are numerous advantages of using milk concentrated by UF for the production of raw materials suitable for processing. Products obtained from UF retentates are characterised by a higher recovery of milk proteins, a higher biological value of protein and lower cost of production compared to cheeses obtained with traditional methods. The application of UF retentate as a raw material for processing is therefore beneficial both for food processors as well as consumers.

A number of studies have been reported on the subject of using ultrafiltration to processed cheese production. Some of them envisage evaporation of water from highly concentrated retentates to obtain products with composition similar to that of natural hard cheeses (most commonly Cheddar cheese) used for processing [Ernstrom *et al.*, 1980; Rubin & Bjerre, 1983; Trecker *et al.*, 1991; Jameson & Sutherland, 1994]. Other studies deal with methods in which milk is concentrated only by UF to different levels and the concentrate is used for processing directly or after ripening [Tamime & Younis, 1991; Aly *et al.*, 1995; Simbuerger *et al.*, 1997; Acharya & Mistry, 2005; Gigante *et al.*, 2001]. Also protein preparations obtained by drying milk or whey UF retentates (MPC or WPC) were successfully used for processed cheese production [Gupta & Reuter, 1992; Moran *et al.*, 2001; Hyde *et al.*, 2002].

Processed cheese represents an extremely delicate and complex system as its properties are affected by many variables, such as the composition and nature of the cheeses used as ingredients, type and amount of melting salts, pH and processing parameters [Marchesseau *et al.*, 1997]. Therefore using new ingredients in processed cheese production it is indispensable to study the influence of these variables on its quality.

The objective of this investigation was to study the effect of a newly elaborated cheese base addition on physicochemical and textural properties of processed cheese spreads.

MATERIALS AND METHODS

Cheese base production. Pasteurised milk (3.2% fat) was heated to 50°C and submitted to ultrafiltration at

Author's address for correspondence: Katarzyna Kycia, Division of Milk Biotechnology, Faculty of Food Technology, Warsaw University of Agriculture, ul. Nowoursynowska 159C, 02-776 Warszawa, Poland; tel.: (48 22) 59 37 671; e-mail: kkycia@gmail.com

52±1°C to a volume concentration factor (VCF) equal to 5.3, 4.6, 4.4 and 4.2 using a membrane with an average molecular weight cutoff equivalent to 50 000 Da. The retentate was pasteurised (72°C/15 s), and after cooling down to 46±1°C it was inoculated with yoghurt culture (YC-X11 or YC-180 Chr. Hansen) in the amount of 0.3 g/dm^3 retentate. Inoculated retentate was packed under slight vacuum into plastic bags and incubated at 44±1°C until its pH reached the value of 5.1–5.2. The obtained cheese base was cooled down in ice water and stored at 6°C until processing.

Processed cheese spread production. Five different experimental batches of processed cheese spreads containing 0 (control), 10, 30, 50 and 70% of the cheese base in relation to total cheese ingredients were produced. The formulations of processed cheese blends are presented in Table 1. The control sample (0% of cheese base addition) was made only from natural cheeses: young Gouda cheese (30%) and mature Gouda cheese (70%). In experimental cheeses the young Gouda cheese was replaced by cheese base. In further experiments mature Gouda cheese was also partially replaced by cheese base. All experimental products were formulated to result in 55% of moisture and 55% of fat content in dry solids. Other ingredients used in the formulation were as follows: butter Extra grade, water, melting salts Joha PL new (3% in relation to the weight of all cheese ingredients) and salt (1% of the added cheese base). Processed cheese spreads were produced using Stephan UMC 5 electronic cooker, in which all ingredients were melted during mixing at a constant rate of 300 rpm for 15 min at 80°C. The weight of the processed cheese spreads obtained was about 500 g. Control and experimental processed cheese spreads were produced in four replicates in which cheese base obtained form different experiments were used.

Texture analysis. Texture profile analysis (TPA) was performed using a TA-XT2 texture analyser (Stable Micro Systems) equipped with a flat plate probe type P/75. Experimental processed cheese spreads were equilibrated at 6°C (the measuring temperature) for 72 h before further preparation of the test samples. The measurements on the experimental samples were conducted 72 h after production. From each experimental cheese (just before measurements), 5 to 7 cylindrical portions (20 mm in diameter and 25 mm in height) were cut using a cork-borer (lubricated with a thin layer of edible oil). After transfer of each portion to the platform of the texture analyser, a very thin layer of oil was also applied on the top of the portion and the plate probe. During the TPA test the following settings were used: test and post-test speed 0.5 mm/s, time between the strokes 10 s. Each sample was subjected to 50% compression and compressed twice to give a "two-bite" force-time compression curve. Textural parameters: hardness, springiness, cohesiveness, gumminess and elasticity, were read from the resulting deformation and force responses recorded by the software analysis program of the texture analyser.

Penetration tests were performed with TA-TX2 texture analyser using a conical probe P/45C. The force required to penetrate the processed cheese sample to a depth of 10 mm at a speed of 1 mm/s was recorded as the hardness [N]. Penetration was carried out after 72-h equilibration at 6°C on the experimental processed cheese spreads poured just after the production into cylindrical shape beakers (50 mm in diameter and 55 mm in height). The results from 5 to 7 individual penetration measurements were used to calculate a mean penetration force representing cheese hardness.

TABLE 1. Share (%) of different cheeses in processed cheese blends.

Samples	Cheese base	Mature Gouda cheese	Young Gouda cheese
Control	-	70	30
Experimental I	10	70	20
Experimental II	30	70	-
Experimental III	50	50	-
Experimental IV	70	30	-

Physicochemical analysis. Cheese base and processed cheese spreads were examined for pH, titratable acidity, fat, water, total protein (N*6.38) and ash content [PN-73/A--86232].

Sensory analysis. Processed cheese samples were evaluated on 5-score scale basis (5 – excellent, 1 – unacceptable) according the following sensory attributes: taste, flavour, colour and texture, by the panel of at least 9 assessors.

Statistical analysis. Using Statgraphics Plus program (version 4.1) simple regression was performed to examine the correlation between the two methods of measurement of cheese hardness: by TPA and penetration test. An analysis of variance was used for checking the influence of cheese base addition on the physicochemical, sensorial and textural properties of processed cheese spreads.

TABLE 2. Physicochemical composition of cheese bases used for processed cheese production.

Specification	Cheese base obtained in experiment number:				$\bar{X}$ (I–IV)
	I	II	III	IV	
Dry matter (%)	38.18	33.49	32.35	31.28	33.83
Water (%)	61.82	66.51	67.65	68.72	66.18
Fat (%)	16.75	14.50	14.00	13.50	14.69
Fat in dry matter (%)	44.53	43.30	43.28	43.16	43.57
Protein (N·6.38) (%)	16.90	13.69	13.31	13.14	14.26
Ash (%)	2.08	1.69	1.66	1.60	1.76
pH	5.20	5.11	5.12	5.09	5.13
Titratable acidity (°SH)	56.00	59.80	57.00	54.60	56.85

RESULTS AND DISCUSSION

Cheese base

The average chemical composition of the cheese bases manufactured from milk retentate was as follows: 33.83% total solids, 14.69% fat, 14.26% total protein and 1.76% ash (Table 2). Compositional differences between cheese bases were caused by different levels of milk concentration by UF. It is obvious that the content of protein and fat in the retentate is proportional to the VCF of milk which differed from 4.2 to 5.3 in all experiments. During UF fat and proteins are concentrated in total. This applies, to a great extent, also to calcium content as colloidal calcium present in casein micelles is also retained in the concentrate [Vyas & Tong, 2003]. It is reflected in the ash content of the retentate. The pH values and titratable acidities of the four experimental cheese bases were rather similar (from 5.20 to 5.09 and from 59.80 to 54.60°SH, respectively). The pH was intentionally kept at the level of 5.1–5.2 at the end of the fermentation in order to match the pH of young rennet cheese used as an ingredient in control processed cheese.

Processed cheese spreads

Cheese base proved to have similar properties for processing as young rennet cheese. As compared to rennet cheese it had smooth texture similar to the texture of processed cheese spreads. Good and easily formed emulsions were obtained during the production control and experimental processed cheese spreads. Furthermore, there were no syneresis or phase separation after cooling or during storage in all samples.

The results presented in Table 3 show the average physicochemical composition of control (0%) and experimental (with 10, 30, 50 and 70% addition of cheese base) processed cheese spreads. All processed cheeses did not differ in respect of the contents of dry matter (46.09–46.23%), fat (25.00%) and fat in dry matter (54.08–54.24%) due to good standardisation of cheese blends before processing. Replacing young rennet cheese with cheese base resulted in processed cheese exhibiting comparable protein content to control cheese provided the share of the base was not higher than 50%. The same observation was encountered in the previous study, where up to 30% of young rennet cheese was successfully replaced with cheese base without any significant drop in protein content as compared to control cheese [Kycia, 2005]. In this work it was also observed that the pH of the experimental cheeses with the addition of 30% of cheese base was appreciably lower than the pH of control cheese. Incorporation of cheese base at the level of at least 70% caused farther pH decrease and significantly higher titratable acidity values in comparison to the control cheese.

Results of the sensory evaluation showed that the processed cheese spreads with up to 30% of cheese base addition had taste, flavour and colour similar to those of the control cheese (Table 4). Yet, they it possessed slightly inferior texture. Higher addition of cheese base caused a higher increase in hardness, which had a negative effect on spreadability of the final product. The addition of cheese base at the highest level (70%) gave a product with slightly weaker intensity of cheese flavour in contrast to the control cheese. This was probably due to the use of small amounts of extra-mature cheese in the blend. This observation was in agreement with the results obtained by other researchers who used immature raw materials for processing [Piska & Štetina, 2004; Acharya & Mistry, 2005; Kycia, 2005].

The TPA test simulates the human chewing action by subjecting the sample to a compressive deformation (first bite), followed by a relaxation and a second deformation (second bite), while the penetration test simulates cheese

TABLE 3. Physicochemical composition of processed cheeses made with addition of cheese base.

Specification	Samples				
	Control	Experimental I	Experimental II	Experimental III	Experimental IV
Dry matter (%)	46.14^{a}	46.13^{a}	46.11^{a}	46.09^{a}	46.23^{a}
Water (%)	53.86^{a}	53.87^{a}	53.89^{a}	53.91^{a}	53.77^{a}
Fat (%)	25.00^{a}	25.00^{a}	25.00^{a}	25.00^{a}	25.00^{a}
Fat in dry matter (%)	54.19^{a}	54.20^{a}	54.22^{a}	54.24^{a}	54.08^{a}
Protein (N*6.38) (%)	16.28^{a}	15.90^{ab}	15.56^{ab}	15.15^{bc}	14.35^{c}
Protein in dry matter (%)	35.29^{a}	34.48^{ab}	33.74^{ab}	32.87^{bc}	31.05^{c}
pH	5.83^{a}	5.80^{ab}	5.78^{bc}	5.76^{c}	5.70d
Titratable acidity (°SH)	39.39^{a}	39.58^{a}	40.50^{a}	41.75^{ab}	44.50^{b}

The mean values denoted by the same letters in each row (within investigated constituent) are not significantly different (α=0.05; n=4)

TABLE 4. Results of the sensory evaluation of processed cheese spreads.

Specification	Samples				
	Control	Experimental I	Experimental II	Experimental III	Experimental IV
Taste	4.75^{a}	4.73^{a}	4.74^{a}	4.71^{a}	4.63^{b}
Flavour	4.61^{a}	4.60^{a}	4.65^{a}	4.59^{a}	4.63^{a}
Colour	4.75^{ab}	4.76^{a}	4.68^{bc}	4.74^{ab}	4.62^{c}
Texture	4.88^{a}	4.82^{a}	4.69^{b}	4.42^{c}	3.68^{d}

Scale: 5 to 1. where: 5 – excellent; 1– very poor. unacceptable; the mean values denoted by the same letters in each row (within investigated attribute) in the table 3 are not significantly different (α=0.05; n=4)

TABLE 5. Textural parameters obtained for processed cheese spreads with different levels of cheese base.

Specification	Samples				
	Control	Experimental I	Experimental II	Experimental III	Experimental IV
Hardness# (N)	3.18[a]	3.17[a]	3.41[a]	4.72[b]	5.84[c]
Springiness	0.37[a]	0.37[a]	0.35[a]	0.45[b]	0.50[c]
Cohesiveness	0.27[a]	0.28[a]	0.26[a]	0.31[b]	0.33[b]
Gumminess (N)	0.86[a]	0.90[a]	0.89[a]	1.47[b]	1.92[c]
Elasticity	0.07[a]	0.07[a]	0.07[a]	0.12[b]	0.13[b]
Firmness* (N)	2.02[a]	2.02[a]	2.10[a]	2.71[b]	3.01[c]

* measured in penetration test; # measured in TPA test; the mean values denoted by the same letters in each row (within investigated parameter) are not significantly different (α=0.05; n=4)

biting. In this study both tests were useful to characterise differences between the cheeses examined. By comparing the results obtained for hardness values from penetration and TPA tests a very good agreement between both methods of measurements was observed as indicated by a very high coefficient of correlation ($r=0.98$, $p<0.01$).

The results of the TPA and penetration tests presented in Table 5 indicated that the incorporation of cheese base to processed cheese spreads led to significant changes in their textural parameters. Generally, it was observed that increasing cheese base addition tended to increase the measured textural parameters compared with those obtained for control cheese. However, it was found out that the experimental cheeses obtained with up to 30% addition of cheese base did not differ from the control cheese in respect of hardness, springiness, cohesiveness, gumminess and elasticity. The fact that replacing young natural cheese with cheese base does not change the texture of the processed cheese affords real possibility of using cheese base as a substitute of the young rennet cheese used in processed cheese manufacture. When the addition of cheese base in the formulation was at least 50% the values of hardness, springiness, cohesiveness, gumminess and elasticity differed significantly from those of the control cheese and cheeses with lower cheese base addition. Processed cheeses with the highest addition of cheese bases showed the highest values in all textural parameters measured.

The increase in hardness accompanied by an increasing share of the cheese base in the formulation can be mainly explained by a decrease in pH caused by cheese base addition. It is well established that the texture of processed cheeses varies with pH. Published studies on the effect of pH on processed cheese texture report that low pH cheeses are firm whereas high pH products are moist and spreadable [Shimp, 1985; Marchesseau *et al.*, 1997; Lee & Klostermeyer, 2001]. For this reason, partial replacement of mature cheese (possessing higher pH values) with cheese base caused an increase in hardness of the experimental cheeses. It should be mentioned that cheese base would probably be a satisfactory raw material for block type processed cheeses production. The second reason of increasing hardness with increasing cheese base addition to processed cheese could be attributed to a low degree of proteolysis in cheese base. Consequently, the substitution of mature cheese with not ripen cheese base resulted in processed cheese with higher hardness values. It is well known that mature rennet cheese posses hydrolysed proteins and that intensified proteolysis decreases firmness and elasticity but increases spreadability in processed cheese [Shimp, 1985; Piska & Štìtina, 2004]. The third reason of increasing processed cheese hardness could be attributed to the increase in the whey protein content of cheese bases made from ultrafiltered retentates. Many authors reported that the increase in whey protein content of processed cheese gave a firmer product [Gupta & Reuter, 1992; Abou El-Nour, 1998; Gigante *et al.*, 2001].

CONCLUSIONS

1. Cheese base obtained from milk retentates (VCF 4–5) fermented by a yoghurt culture to pH 5.1–5.2 proved to be an excellent substitute for young rennet cheese traditionally used for processing provided the substitution is not higher than 30%.

2. The results of physicochemical and sensory analysis showed that processed cheese spreads obtained with such an addition of cheese base did not differ significantly from the control cheese in respect of titratable acidity, protein content, taste, flavour and colour, but slightly differed in pH and texture examined during the sensory analysis.

3. The results of the texture measurements showed that replacing the whole young rennet cheese with cheese base did not change the values of hardness, springiness, cohesiveness, gumminess and elasticity of the processed cheese compared to the control cheese obtained from rennet cheeses.

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WŁAŚCIWOŚCI FIZYKO-CHEMICZNE I CECHY TEKSTURY SERÓW TOPIONYCH DO SMAROWANIA WYPRODUKOWANYCH Z DODATKIEM MASY SEROWEJ OTRZYMANEJ Z RETENTATÓW UF MLEKA

Katarzyna Kycia, Antoni Pluta, Stanisław Zmarlicki

Wydział Technologii Żywności, Zakład Biotechnologii Mleka, SGGW, Warszawa

Badano wpływ dodatku nowego surowca przeznaczonego do topienia na właściwości fizyko-chemiczne oraz wybrane cechy tekstury serów topionych do smarowania. Surowiec ten, nazwany umownie masę serową, otrzymywano z mleka (3,2% tłuszczu) zagęszczonego metodą ultrafiltracji (współczynnik zagęszczenia mleka 4-5), a następnie ukwaszonego dodatkiem kultury jogurtowej do pH 5,1–5,2. Masę serową stosowano do produkcji serów topionych razem z serem podpuszczkowym (młodym i dojrzałym) w takich ilościach, by jej udział w stosunku do użytych surowców serowych wynosił w mieszance do topienia 0 (wariant kontrolny), 10, 30, 50 i 70% (tab. 1). Stwierdzono, że masa serowa może stanowić doskonały zamiennik sera młodego podpuszczkowego w produkcji serów topionych do smarowania pod warunkiem, że jej udział w mieszance nie przekracza 30%. Taki dodatek masy serowej pozwalał na otrzymanie sera topionego o właściwościach fizyko-chemicznych (tab. 3), sensorycznych (tab. 4) i cechach tekstury (tab. 5) zbliżonych do wariantu kontrolnego otrzymanego wyłącznie z serów podpuszczkowych. Wyższy dodatek masy serowej powodował spadek zawartości białka, obniżenie pH oraz pogorszenie się cech tekstury serów topionych badanych w teście TPA oraz w teście penetracji w stosunku do wariantu kontrolnego.