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EFFECT OF pH ON RHEOLOGICAL PROPERTIES AND MELTABILITY OF PROCESSED CHEESE ANALOGS WITH WHEY PRODUCTS

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Key words: analog, meltability, processed cheese, rheology, whey

The objective of this paper was to investigate the influence of pH on rheological properties and meltability of processed cheese analogs obtained only from acid casein and partially replaced by different whey products. Hardness of processed cheese analogs obtained only on the base of acid casein was very high at pH 4.5–5.0, however decreased significantly with an increase of pH values. Addition of whey products to processed cheese analogs caused an increase of their hardness and viscosity. Meltability of cheese analogs increased in higher pH whereas decreased alongside with addition of demineralized whey powder (DWP 50) at pH 6.0-7.0. Substitution of 1% of casein with 1% whey protein produces much more solid cheeses, which can be used to reduce casein content and decrease production costs.

INTRODUCTION

Cheese analogs have gained importance in different areas. Firstly, largely because of the tremendous increase in the consumption of pizza pie and the fact that cheese is its the most costly component. In addition, the manufacture of an imitation cheese allows manufacturers greater scope in manipulating constituents toward nutritional, textural and economic ends [Bachmann, 2001]. Processed cheese is obtained by mixing natural cheeses with salts and water under the influence of heat and agitation, whereas processed cheese analogs are produced with partial or whole replacement of natural cheeses by milk or other proteins [Gustaw & Mleko, 2007]. Rennet casein is the most often used source of protein in production of processed cheese imitations [Ennis *et al.*, 1998] but recently acid casein was used too [Glibowski *et al.*, 2002]. Whey proteins and whey protein polymers were often used in the production of processed cheese and processed cheese analogs [Abd-El-Salam *et al.*, 1997; Kaminarides & Stachtiaris, 2000; Mleko & Foegeding, 2000, 2001]. Whey products generally allowed for use in processed cheeses are: sweet whey, reduced lactose whey, demineralized whey, acid whey, whey protein concentrates and whey protein isolates [Mleko & Lucey, 2003]. Substitution of casein with whey proteins produced processed cheese with the highest firmness values but worse meltability. Increase in firmness of cheese with addition of whey proteins can be caused by the formation of complexes between whey protein and casein micelles, especially between β-lactoglobulin and κ-casein [Gupta & Reuter, 1993]. The composition of cheese analogs largely determines its texture [Lobato-Calleros *et al.*, 1997]. According to Cavalier-Salou & Cheftel [1991] water content, fat content, pH range and emulsifying agents are of crucial importance. Variation of processed cheese texture with pH was firstly reported as early as 1932 [Templeton & Sommer, 1932].

The aim of this paper was to test the influence of pH on rheological properties and meltability of processed cheese analogs obtained from acid casein and partial replaced by different whey products.

MATERIALS AND METHODS

Materials. The following materials were used: demineralized whey powder (DWP 50) (12,75%) from Lacma (Nadarzyn, Poland), whey protein concentrate (WPC 35) (33.86%) from Laktopol (Warszawa, Poland), acid casein (AC) from ZPK (Murowana Goślina, Poland), anhydrous milk fat from Mlekovita (Wysokie Mazowieckie, Poland), citric acid and disodium phosphate from POCH (Gliwice, Poland).

Processed cheese analog preparation. AC (11%) or AC (10%) and DWP 50 (1%), WPC 35 (1%) were dispersed in distilled water using a magnetic stirrer Heidolph MR 3002S (Schwabach, Germany). Acid casein, whey powders and anhydrous milk fat were placed in the container of a H 500 homogenizer (Pol-Eko Aparatura, Wodzisław Śląski, Poland). After adding disodium phosphate, the pH was adjusted from 4.5 to 7.0 using 40% citric acid or sodium hydroxide. Casein, whey powders and anhydrous milk fat were mixed together for 2 min at 10,000 rpm and after that the container was immersed in 80°C water bath and the content was mixed at 10,000 rpm for 10 min. Samples were kept for 30 min at room

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temperature and stored overnight at 4°C. There were 3 replications for each treatment.

METHODS

Analytical methods. Protein content in these products was determined by analysing nitrogen and calculating protein as N x 6.38 [AOAC, 1984]. The content of water and ash was assayed with AOAC methods. Lactose content was determined with spectrophotometric analyses using DNS acid [Miller, 1959]. Fat content was indicated by producers.

Texture profile analysis (TPA). Measurements were performed with a TA-XT2i Texture Analyser (Stable Micro Systems, Godalming, UK). The processed cheese analogs samples were double compressed to 70% of deformation by a testing set (15 mm diameter). The rate of compression was 1 mm/s. Cheese samples were evaluated for hardness. There were 6 measurements for each treatment.

Puncture test. Measurements were performed with a TA-XT2i Texture Analyser (Stable Micro Systems, Godalming, UK). The cheese samples were penetrated to 20 mm by a testing set (10 mm diameter). The rate of penetration was 1 mm/s. There were 3 measurements for each treatment.

Viscosity. Viscosity of processed cheese analogs was measured using a Brookfield DV II + viscometer (Stoughton, MA, USA) with a Helipath countershaft (F). Measurements were made at constant temperature (21°C) with the spindle velocity of V=20 rpm/min. There were 3 measurements for each treatment.

Meltability. Meltability of processed cheese analogs was measured using a modified Schreiber test [Mleko & Foegeding, 2000]. Specimens (4.8 mm thick, 41 mm in diameter) were placed in a microwave oven (Samsung, South Korea) and heated for 60 s. The specimens were then removed and cooled. Their expansion was measured along 6 lines marked on a concentric set of circles as described by Kosikowski [1977]. Schreiber meltability (arbitrary scale of 0-10 units) was given as mean of 6 readings for each of 3 replications.

RESULTS AND DISCUSSION

Figures 1-2 show pH influence on hardness of different processed cheese analogs measured by texture profile analysis and puncture test. It was observed that hardness of the processed cheese analogs obtained only on the base of acid casein was very high at pH 4.5–5.0, however it decreased significantly with an increase of pH. Regarding to processed cheese analogs received from acid casein with its partial replacement by whey products, hardness was much more higher than in standard analogs with an increase in pH (5.0-7.0). It was probably caused by an interaction between casein and whey proteins. Mleko & Foegeding [2000] suggest that whey proteins interacted with casein network as a filler, or that a mixed gel network was formed. The most probably disulphide bonds between κ-casein and β-lactoglobulin were formed but also α-lactalbumin could participate in the reaction with casein [Law *et al.*, 1994]. All processed cheeses are made within a narrow pH range of 5.2-6.0. Low pH processed cheeses were hard and crumbly whereas high pH processed cheeses were less solid and elastic [Templeton & Sommer, 1932; Gupta *et al.*, 1984; Caric *et al.*, 1985; Shimp, 1985; Marchesseau *et al.*, 1997; Lee & Klostermeyer, 2001]. Stampanoni & Noble [1991] reported that decreasing the pH from 6.2 to 5.0 resulted in increased hardness and elasticity in cheese analogs. Marchesseau *et al.* [1997] suggested that the increase in the net negative charge of proteins (with increasing pH above the isoelectric point of caseins) resulted in increased hydration of casein due to the reduced electrostatic interactions. The higher sorption of water by the proteins was thought to result in a softer processed cheese at high pH. Marchesseau *et al.* [1997] also showed that water in processed cheeses made from cheese, milk powder, butter and polyphosphate melting salt yielded different protein structures at different pH values (pH 5.2-6.7). Processed cheese at pH 5.2 was granular with large protein aggregates and fat was not well emulsified. As the pH increased, compactness of the protein microstructure decreased, indicating decreasing protein-protein interactions.

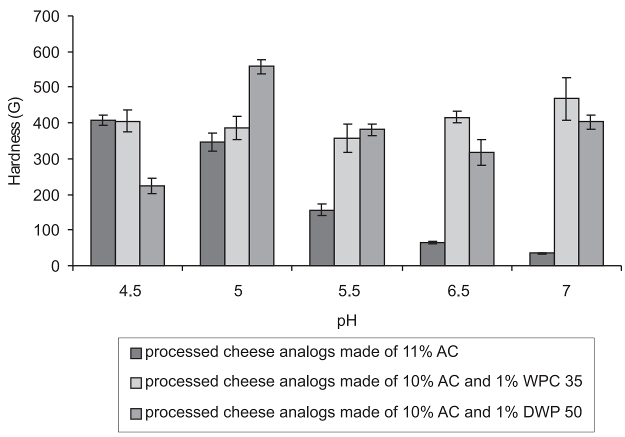

FIGURE 1. pH influence on hardness of different processed cheese analogs (TPA).

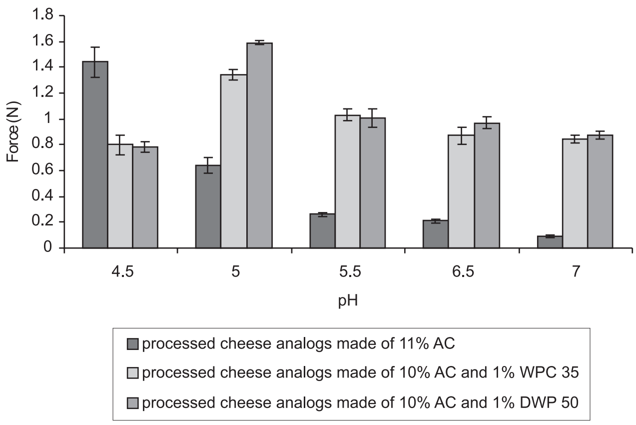

FIGURE 2. pH influence on hardness of different processed cheese analogs (puncture test).

Processed cheeses made in the pH range from 5.7 to 6.1 were firm, and showed a uniform distribution of protein in the network structure.

Many workers have determined the viscosity, in general meaning, of processed cheeses, cheese analogs and natural cheeses using various techniques of viscometry [Dimitreli & Thomareis, 2004]. Figure 3 shows the effect of whey products addition on viscosity in the range of pH 4.5-7.0. Addition of whey products to processed cheese analogs caused an increase in viscosity. Processed cheese analogs with DWP 50 exhibited the highest viscosity in the whole pH range (4.5-7.0). Also the cheese analogs with addition of WPC 35 were more viscous than cheese analogs obtained only on the base of acid casein but pH variations did not influence in their viscosity. The increase in viscosity reflects intermolecular interactions between adjacent protein molecules with the formation of weak transient networks [Boye *et al.*, 1997]. Damodaran [1997] reported that the viscosity of protein solutions generally increases exponentially with protein concentration, which can be attributed to increased interactions between the hydrated protein molecules. Dimitreli & Thomareis [2004] affirmed that viscosity of processed cheese emulsion during processing is affected by the continuous phase (water and proteins) and not by the dispersed phase (liquid fat). Incorporation of whey proteins to casein causes the growth of the molar mass of formed aggregates, and an increase in viscosity [Glibowski *et al.*, 2002]. The addition of whey proteins caused also an increase of viscosity in traditional processed cheeses [Abd-El-Salam *et al.*, 1997].

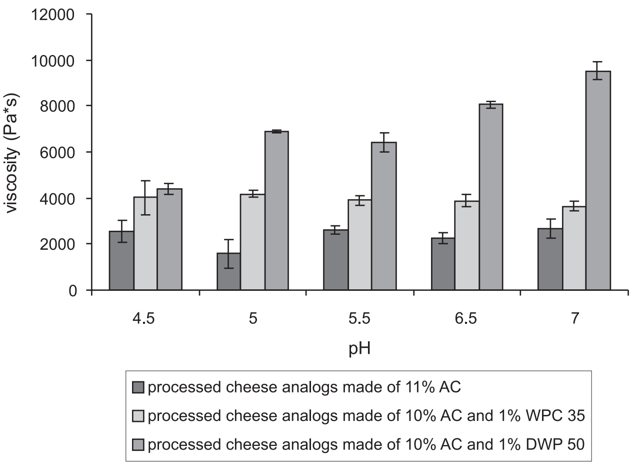

FIGURE 3. pH influence on viscosity of different processed cheese analogs.

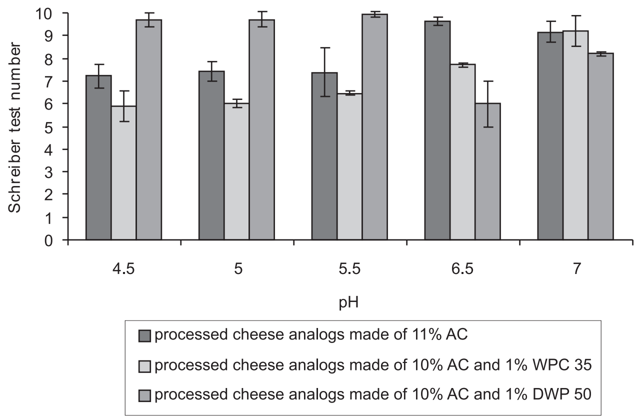

FIGURE 4. pH influence on meltability of different processed cheese analogs.

Processed cheese in the context of meltability can be considered as a two-component system, consisting of a melting casein network and unmelting whey protein network. Probably at some temperature aggregation of whey proteins or possible interaction between whey proteins and casein caused increase in elasticity of the cheeses. Processed cheese analogs containing DWP 50 exhibited the highest meltability in the range of pH 4.5-5.5 (Figure 4). In higher pH values (6.5-7.0) cheese analogs revealed lower meltability but still acceptable. Meltability of processed cheese analogs produced only on the base of acid casein and cheese analogs containing WPC 35 increased with increasing pH values. Swenson *et al.* [2000] found that increased cooking time produced softer, more meltable cheeses, while increases in cook temperature decreased firmness and increased meltability and spreadability. According to Cavalier-Salou & Cheftel [1991] melting ability of cheese analogs from calcium caseinate correlated with high pH, soft texture, high degree of casein dissociation and low degree of fat emulsification. Addition of whey protein isolate and whey protein polymers caused a significant decrease of meltability [Mleko & Foegeding, 2000]. Gupta & Reuter [1993] also found that meltability of processed cheese decreased with an increase of WPC concentration.

Substitution of 1% of casein with 1% whey protein produces much more solid cheeses, which can be used to reduce casein content and decrease production costs.

CONCLUSIONS

1. Hardness of the processed cheese analogs obtained only on the base of acid casein was very high at pH 4.5–5.0, however it significantly with an increase of pH values.

2. Addition of DWP 50 and WPC 35 to processed cheese analogs caused an increase in their hardness in range of pH values 5.0-7.0.

3. Addition of whey products to the processed cheese analogs caused an increase of their viscosity.

4. Processed cheese analogs containing DWP 50 exhibited the highest meltability in the range of pH 4.5-5.5, but meltability of processed cheese analogs produced only on the base of acid casein and cheese analogs containing WPC 35 increased with increasing pH values.

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WPŁYW pH NA WŁAŚCIWOŚCI REOLOGICZNE I TOPLIWOŚĆ ANALOGÓW SERÓW TOPIONYCH Z DODATKIEM PREPARATÓW SERWATKOWYCH

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Celem pracy było określenie wpływu pH na właściwości reologiczne i topliwość analogów serów topionych otrzymanych wyłącznie na bazie kazeiny kwasowej, jak również analogów serów topionych, w których częściowo zastąpiono kazeinę preparatami serwatkowymi. Twardość analogów serów topionych otrzymanych wyłącznie z kazeiny była najwyższa jedynie w zakresie pH 4,5-5,0, natomiast w miarę wzrostu pH obniżała się znacząco. Dodatek preparatów serwatkowych do analogów serów topionych spowodował wzrost ich twardości i lepkości. Topliwość analogów zwiększała się wraz ze wzrostem pH, jednakże dodatek sproszkowanej serwatki zdemineralizowanej (DWP 50) powodował spadek twardości analogów w pH 6,0-7,0. Zastąpienie 1% kazeiny kwasowej 1% preparatów serwatkowych pozwala otrzymać sery o większej twardości. W przypadku analogów serów topionych otrzymywanych na bazie kazeiny kwasowej, badane preparaty serwatkowe mogą spowodować znaczne oszczędności poprzez zmniejszenie ilości kazeiny w produkcie, jak również umożliwia redukcję kosztów wytworzenia sera.