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The effect of different composition of ternary mixtures of emulsifying salts on the consistency of processed cheese spreads manufactured from Swiss-type cheese with different degrees of maturity

R. N. Salek, M. Černíková, S. Maděrová, L. Lapčík, and F. Buňka[1]
Department of Food Technology, Faculty of Technology, Tomas Bata University in Zlín, T. G. Masaryka 5555, 760 01, Zlín, Czech Republic

ABSTRACT

The scope of this work was to investigate the dependence of selected textural (texture profile analysis, TPA) and viscoelastic properties of processed cheese on the composition of ternary mixtures of emulsifying salts [disodium hydrogenphosphate, DSP; tetrasodium diphosphate, TSPP; sodium salt of polyphosphate (with mean length n ≈ 20), P20; and trisodium citrate, TSC] during a 60-d storage period (6 ± 2°C). The processed cheese samples [40% wt/wt dry matter (DM) content, 50% wt/wt fat in DM content] were manufactured using Swiss-type cheese (as the main raw material) with 4 different maturity degrees (4, 8, 12, and 16 wk of ripening). Moreover, the pH of the samples was adjusted (the target values within the range of 5.60–5.80), corresponding to the standard pH values of spreadable processed cheese. With respect to the individual application of emulsifying salts (regardless of the maturity degree of the Swiss-type cheese applied), the samples prepared with P20 were the hardest, followed by those prepared with TSPP, TSC, and DSP. Furthermore, a specific ratio of DSP:TSPP (1:1) led to a significant increase in the hardness of the samples. On the whole, the hardness of all processed cheese samples increased with the prolonging storage period, whereas their hardness significantly dropped with the rising ripening stage of the raw material utilized. In all of the cases, the trends of hardness development remained analogous, and only the absolute values differed significantly. Moreover, the findings of TPA were in accordance with those of the rheological analysis. In particular, the specific ratio of DSP:TSPP (1:1) resulted in the highest gel strength and interaction factor values, followed by P20, TSPP, TSC, and DSP (used individually), reporting the same trend which was demonstrated by TPA. The monitored values of the gel strength and interaction factor decreased with the increasing maturity degree of the Swiss-type cheese used. The intensity of the rigidity of the samples showed an analogous relationship to the intensity of the gel strength; the higher the gel strength of the sample, the more inflexible product can be expected.
Key words: Swiss-type cheese, processed cheese, sodium salt of phosphates, sodium salt of citrate, rheology

INTRODUCTION

Processed cheese (**PC**) is a multicomponent dairy complex system described as stable oil-in-water emulsion (Lee et al., 2003; Chen and Liu, 2012; Hanaei et al., 2015). The multilaterism of PC derives from the fact that it contains a wide variety of interacting components and a high water content (Marchesseau et al., 1997). Therefore, its matrix is formed by blending shredded cheese (of different types and maturity degrees) in the presence of emulsifying salts (**ES**; mainly sodium salts of phosphates, polyphosphates, citrates, or a combination of these), heated under partial vacuum and constant stirring, resulting in a homogeneous and smooth mass with desired properties (Guinee et al., 2004; Lee et al., 2004; Sádlíková et al., 2010; Chen and Liu, 2012).

Cheese ripening is the term describing a technological process during which biochemical and microbiological changes occur in cheese (raw material for PC manufacturing), resulting in the development of a specific flavor and consistency in the matured product (Pachlová et al., 2012; Ochi et al., 2013). The degree of casein proteolysis in the cheese applied during PC manufacture is a parameter that significantly influences its textural and viscoelastic properties (Piška and Štetina, 2004; Brickley et al., 2007; Buňka et al., 2013).

The consistency of PC can be affected by many factors, including the type, composition, and chemical profile of the cheese used (DM, fat, protein, and calcium ion content, and maturity degree), the type and concentration of ES, the presence and concentration of ions (especially calcium, sodium, and potassium), other optional dairy and nondairy ingredients, the pH

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[1]Corresponding author: bunka@ft.utb.cz

of the mass to be melted, the processing and storage conditions (processing and storage temperature, stirring speed, time and temperature of the fusion, and cooling rate) and a possible use of some hydrocolloids (Shirashoji et al., 2006; Dimitreli and Thomareis, 2007; Gustaw and Mleko, 2007). Moreover, ES are ingredients of great importance in PC manufacture. Their ability to sequester calcium in the cheese matrix leads to the enhancement of casein emulsifying properties; the replacement of calcium from the insoluble calcium-paracaseinate (present in cheese) with sodium results in the formation of soluble sodium-paracaseinate, which can easily be dispersed and thus considerably influence the emulsification of fat (casein coats the surfaces of the dispersed free fat globules) and water stabilization within the matrix formed (Kawasaki, 2008; Chen and Liu, 2012; Buňka et al., 2014).

Furthermore, PC with diverse consistency and alternative functional properties may be manufactured as a result of the use of different types (phosphate, citrate, or both) and combinations of ES. In practice nowadays, the individual application of ES is very rare. In fact, ES are applied in ternary or even more componential mixtures (Guinee et al., 2004; Kapoor and Metzger, 2008; Salek et al., 2015). Generally, the effect of different composition of ternary mixtures of the individual sodium salts of phosphates (especially disodium hydrogenphosphate, tetrasodium diphosphate, and sodium salt of polyphosphate) has been described in the papers by Weiserová et al. (2011) and Buňka et al. (2012, 2013), but only for Dutch-type cheese as the raw material for the PC tested. Swiss-type cheese (**STC**) is a group of hard or semi-hard cheeses in texture, with desired propionic acid fermentation caused by propionic acid bacteria (especially *Propionibacterium freudenreichii* ssp. *freudenreichii* and *Propionibacterium freudenreichii* ssp. *shermanii*). Therefore, their flavor is characterized as sweet and nut-like. This is due to free fatty acids, peptides, AA, carbonyls, or their mutual interactions (Paulsen et al., 1980; Beuvier et al., 1997; Bouton et al., 2009). However, in the available literature, no existing study delineates PC manufacture using STC as the main raw ingredient. Swiss-type cheese is often used as part of the raw material for PC manufacture. On the other hand, the individual usage of STC in PC production has not been described. The influence of different maturity degrees of STC associated with different combinations of ES ternary mixtures affecting PC consistency has not been found in the literature.

The first aim of this study was to explore the dependence of selected textural properties (especially hardness, cohesiveness, and relative adhesiveness) and viscoelastic properties of PC on the composition of ternary mixtures of ES containing disodium hydrogenphosphate (Na_2HPO_4, **DSP**), tetrasodium diphosphate ($Na_2P_2O_7$, **TSPP**), sodium salt of polyphosphate with mean length n ≈ 20 (**P20**), and trisodium citrate ($C_2H_5Na_3O_7$, **TSC**) during a 60-d storage period. The above-mentioned dependence was observed in samples with adjusted pH values (target values within the interval of 5.60–5.80) corresponding to the standard pH values of PC spreads. The second aim was to investigate the effect of different maturity degrees of the STC (basic raw material) on the above-mentioned dependence.

MATERIALS AND METHODS

Manufacture of PC Samples

For the manufacture of the model PC samples with 40% (wt/wt) DM content and 50% (wt/wt) fat in DM, the following materials were used: STC block (60% wt/wt DM content, 30% wt/wt fat DM content; 4, 8, 12, and 16 wk of ripening; the same raw materials of STC were used in the whole experiment; MoraviaLacto, a.s., Jihlava, Czech Republic), butter (84% wt/wt DM content, 82% wt/wt fat content; Sachsenmilch Leppersdorf, GmbH, Wachau, Germany), water and ternary mixtures of DSP, TSPP, P20 (Fosfa PLC Company, Břeclav, Poštorna, Czech Republic), and TSC (SigmaAldrich Inc., St. Louis, MO). Moreover, the ES were applied into 4 types of ternary mixtures comprising DSP:TSC:P20, DSP:TSPP:TSC, TSC:TSPP:P20, and DSP:TSPP:P20. The total concentration of the ternary mixtures mentioned above was 3% (wt/wt) of the total weight of the melt. Each type of the ternary mixture was tested in 12 reciprocal percentage ratios (100:0:0; 50:50:0; 0:100:0; 40:40:20; 40:20:40; 20:40:40; 50:0:50; 0:50:50; 40:0:60; 20:20:60; 0:40:60; 0:0:100); the percentage of the components was estimated on the basis of the total weight of ES (total weight = 100%). Each combination of the ES formulation was made in duplicate resulting in 96 lots in total (4 types of ternary mixtures × 12 reciprocal percentage ratios × 2 repetitions). The scheme of the experiment design is shown in Figure 1. A Vorwerk Thermomix TM 31–1 blender cooker (Vorwerk & Co. Thermomix, GmbH, Wuppertal, Germany) with indirect heating was employed for the manufacture of the PC samples. The same apparatus was also used for a contiguous scope in the work by Lee et al. (2004, 2013) and Buňka et al. (2013). The manufacturing procedure was described in detail in the work by Buňka et al. (2013) and Salek et al. (2015). Briefly, a target temperature of 90°C was held for 1 min (the total melting time was 10–12 min) at approximately 2,750 × *g*. Therefore, the pH of the samples was adjusted (target values within the interval of 5.60–5.80) using acid or alkali (1 mol/L of HCl or NaOH). Accord-