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The effect of concentration and composition of ternary emulsifying salts on the textural properties of processed cheese spreads

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ABSTRACT

We used regression analysis to model the influence of varying ratios of disodium hydrogenphosphate (DSP), tetrasodium diphosphate (TSPP) and sodium polyphosphate (POLY) upon the hardness, cohesiveness, and relative adhesiveness of processed cheese spread (dry matter – 40 g/100 g; fat in dry matter – 50 g/100 g) at total emulsifying salt levels of 2.0, 2.5 and 3.0 g/100 g. Specific ratios of DSP to TSPP that rapidly increased hardness and decreased cohesiveness (1:1–3:4) and relative adhesiveness (1:1–1:2) were identified. The effect of the specific ratio of DSP:TSPP on textural parameters of samples was weakening with the rising amount of POLY in the ternary mixture. With the amount of POLY above 60%, the effect of the specific ratio of DSP:TSPP on textural parameters of samples was insignificant. With an increasing concentration of emulsifying salts, the values of hardness and cohesiveness were rising while the values of relative adhesiveness of the processed cheeses were falling. However, neither the concentration of emulsifying salts nor the adjustment of pH of the samples reaching the optimal range (5.69–5.84) affected the general trend of dependence of the observed textural parameters of model processed cheeses on the changing proportion of DSP, TSPP and POLY ($P \geq 0.05$).

1. Introduction

Sodium salts of phosphates are used in many spheres of the food industry, including dairy industry. In dairy technology, these compounds are mainly used during the production of processed cheeses and also to stabilise some liquid dairy products (UHT-treated milk, UHT-treated cream, coffee cream, concentrated milk etc.) (Chavan, Chavan, Khedkar, & Jana, 2011; Datta & Deeth, 2001; Molins, 1991).

Processed cheeses are made by heating a mixture of ingredients under partial vacuum and with constant stirring, until a smooth and homogeneous mass of desired textural properties is formed. The mixture of ingredients usually includes cheese, butter (or anhydrous milk fat and/or cream), water, stabilisers (hydrocolloids) and/or flavours. Emulsifying salts (usually within the amount of 2–3 g/100 g) are a key component – salts of polyvalent anions (phosphates, polyphosphates and/or citrates) and monovalent cations (sodium, potassium) (Guinee, Carić, & Kaláb, 2004; Gupta, Karahadian, & Lindsay, 1984).

The absence of emulsifying salts while heating the mixture of ingredients, would lead to the formation of an inhomogeneous mass (Guinee et al., 2004). Emulsifying salts ensure the ion-exchange of calcium salts for sodium salts when insoluble

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calcium paracaseinate (in the cheese) changes into sodium paracaseinate, which can easily be dispersed and thus enhances sufficient fat emulsification and water stabilisation in the matrix. During the heating process and subsequent cooling of the melt, a "creaming" process – i.e. formation of the final structure of processed cheese – occurs. The formation of a three-dimensional network of the matrix, the basis of which is formed by dispersed casein proteins, is enhanced by calcium bridges, hydrophobic interactions, disulphide bridges, hydrogen bridges and last but not least calcium–phosphate complexes. The use of different combinations of emulsifying salts (mono-, di- and polyphosphates) results in the production of processed cheeses with various consistency (from easy to spread to tough) or different functional properties (e.g. various meltability) (Guinee et al., 2004; Kawasaki, 2008; Lee, Buwalda, Euston, Foegeding, & McKenna, 2003). In practice, the individual phosphates are rarely used independently. Ternary or even more multi-component mixtures are more common (Buňka et al., 2012; Guinee et al., 2004; Kapoor & Metzger, 2008).

A different effect of the emulsifying salts on the final properties of processed cheeses lies mainly in a different ability to exchange calcium ions for sodium ions (and thus the ability to disperse casein) and in influencing and stabilising pH values (buffer ability). The ion-exchange ability increases with the extending length of the polyphosphate chain; it results in better casein dispersion and better fat emulsification and water stabilisation, which leads to better crosslinking of the matrix network in the final product (Chen & Liu, 2012; Kaliappan & Lucey, 2011; Molins, 1991; Shirashoji, Jaeggi, & Lucey, 2010). Phosphates with good buffer abilities include mono- and diphosphates.

The above-mentioned rules lead to a "simple" conclusion that toughness (crosslinking of the casein matrix) of the processed cheese increases with the amount of mixture which has a greater effect on ion-exchange and thus on casein dispersion. However, this rule has some limitations. Recent studies show that the above-mentioned rules (relationships) do not give a sufficient explanation of all the phenomena related to the intensity of crosslinking of the casein matrix in processed cheeses. According to Weiserová et al. (2011) and Buňka et al. (2012, 2013), there are specific ratios of monophosphate to diphosphate or triphosphate (usually ranging in the instance of 1:1–3:4) which rapidly increase hardness and decrease adhesiveness of the samples. As it follows from the studies by Brickley et al. (2008), El-Bakry, Duggan, O'Riordan, and O'Sullivan (2010, 2011), Chen and Liu (2012), Hoffmann, Gärtner, Lück, Johannsen, and Maurer (2012) and Chen and Liu (2012), textural properties of processed cheeses are also significantly influenced by the concentration of emulsifying salts.

Another key feature of processed cheeses influencing their consistency is pH of the melt. Optimal pH values of processed cheese spreads usually range within the interval of 5.60–6.10. Very low pH values (pH <5.40) lead to harder products; on the other hand, high pH values (pH >6.10) usually result in soft cheeses and microbiological problems could occur (Lee & Klostermeyer, 2001; Marchesseau, Gastaldi, Lagaude, & Cuq, 1997). According to Mizuno and Lucey (2007), pH value of the environment also affects the intensity of ion-exchange in phosphates and thus the degree of casein dispersion. However, to date, textural parameters of processed cheeses depending on the changing proportion of emulsifying salts have been studied mainly without the adjustment of pH values reaching the optimal range.

The aim of this study is to model, by means of methods of regression analysis, the influence of a changing proportion of disodium hydrogenphosphate (DSP), tetrasodium diphosphate (TSPP) and sodium salt of polyphosphate (POLY) in ternary mixtures of emulsifying salts on selected textural parameters (hardness, cohesiveness and relative adhesiveness) in relation to a different total concentration of the ternary mixture of emulsifying salts (2.0; 2.5; and 3.0 g/100 g). Another goal is to compare the trends observed in products where pH of the processed cheeses was not adjusted with those in which pH values were adjusted to reach the optimal range (the target values of 5.70–5.80). By means of regression models, the proportions of DSP, TSPP and POLY, corresponding to the maximum value of hardness in processed cheeses are also compared.

2. Material and methods

2.1. Production of samples

The composition of raw materials (including Edam cheese blocks: dry matter ≈ 50 g/100 g and fat in dry matter ≈ 30 g/100 g, 7-week maturity; butter: dry matter ≈ 82 g/100 g and fat content ≈ 80 g/100 g; and water) for the production of model processed cheese spreads was adjusted in order to get the target values of dry matter and fat in dry matter content reaching 40 and 50 g/100 g, respectively. The following emulsifying salts were applied: ternary mixtures of DSP, TSPP and POLY in 66 percentage proportions with a step of 10% (0:0:100, 0:90:10, 0:80:20,..., 50:50:0,..., 90:10:0, 100:0:0). The pH values of aqueous solutions (1 g/100 g) of DSP, TSPP and POLY were 9.38 ± 0.02, 10.02 ± 0.03 and 6.45 ± 0.02, respectively. Three total concentrations of emulsifying salts were used (2.0; 2.5; and 3.0 g/100 g; calculated for the total weight of the model samples). The addition of emulsifying salts was adjusted by means of water and butter in order to maintain constant values of dry matter content and fat in dry matter content. The model samples were produced using a Vorwerk Thermomix TM 31 (Vorwerk & Co., GmbH, Wuppertal, Germany); the melting temperature of 90 °C was kept for 1 min (the temperature was controlled using a thermometer inserted in the melt). The manufacturing process was described in Weiserová et al. (2011). The hot melt was poured into polypropylene cups of cylindrical shape (52 mm in diameter; 50 mm high; volume of the melt 50–55 ml) and sealed with aluminium lids. Samples with each variant of the ternary mixtures (66 variants) were produced twice at each of the three total concentrations of emulsifying salts – 396 lots in total (66 variants of emulsifying salts × 3 concentrations × 2 productions of each variant and each concentration). The pH values of these model samples were not adjusted.

Subsequently, model samples in which pH values were adjusted to reach the optimal range of pH for processed cheese spreads were manufactured – the target values of 5.70–5.80. The pH values were adjusted by means of NaOH or HCl ($c = 1$ mol l^{-1}). The manufacturing process of the model samples was the same as that of the products without any pH adjustment. The calculated amount of acid or alkali (the amount based on a calibration model made in the pilot study – unpublished data) was added to the equipment at 85–86 °C (approx. 30–50 s before reaching the melting temperature). The total addition of water was decreased by the calculated amount of NaOH or HCl (in order to reach a constant dry matter content and fat in dry matter content). Another 396 lots were made in this way.

Within 2 h, all manufactured and sealed samples were cooled to 6 ± 1 °C and stored at the same temperature for 28 days. Dry matter content of the model samples was determined (according to ISO 5534 (2005)) and pH was measured (by direct insertion of a spear electrode (pHSpear, Eutech Instruments, Oakton, Malaysia) into the model samples). Each variant of the sample was measured eight times.