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Use of sodium polyphosphates with different linear lengths in the production of spreadable processed cheese

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ABSTRACT

The objective of this study was to describe the dependence of textural properties (hardness, cohesiveness, and relative adhesiveness) of processed cheese spreads on the proportion of disodium phosphate (DSP), tetrasodium diphosphate (TSPP), and sodium salts of polyphosphate in ternary mixtures of emulsifying salts. Sodium salts of polyphosphate with different mean lengths (n ≈ 5, 9, 13, 20, and 28) were used. Pentasodium triphosphate (PSTP) was used instead of TSPP in the second part of the study. Products with and without pH adjustment were tested (the target pH value was 5.60–5.80). Textural properties of the processed cheese were observed after 2, 9, and 30 d of storage at 6°C. Hardness of the processed cheese with a low content of polyphosphate increased at a specific DSP:TSPP ratio (~1:1 to 3:4). This trend was the same for all the polyphosphates used; only the absolute values of texture parameters were different. The same trends were observed in the ternary mixtures with PSTP, showing lower final values of hardness compared with samples containing TSPP. Hardness and cohesiveness decreased and relative adhesiveness increased in the samples with increased pH values and vice versa; the main trend remained unchanged.
Key words: processed cheese, emulsifying salt, polyphosphate, textural property

INTRODUCTION

Processed cheese can be characterized as a viscoelastic matrix, the basic material of which consists of cheeses at different stages of maturity. It is made by using a wide range of dairy (e.g., cream, butter, anhydrous milk fat, curd, milk powder, whey powder, caseinates) and nondairy ingredients and additives (e.g., hydrocolloids, coloring, sensory active mixtures), which are applied to modify the content (e.g., DM content, fat content, protein content) or functional properties of the product (e.g., firmness, meltability). Key components for the production of processed cheeses are emulsifying salts (**ES**), usually sodium salts of phosphates, polyphosphates, or citrates. The discontinuous production of processed cheeses includes (1) determining the composition of ingredients (with respect to the desired parameters of the final product); (2) placing the determined amounts of ingredients and additives into the melting device and the actual melting process (at a usual temperature of 85 to 105°C with a dwell time of several minutes); and (3) packaging in different wrapping materials (Guinee et al., 2004; Mizuno and Lucey, 2007).

The essential role of ES is the exchange of sodium ions for calcium ions in the casein matrix (gel) of the cheese; insoluble calcium paracaseinate changes into more soluble sodium paracaseinate, whose molecules (chains) can move within the melt system and thus enhance fat emulsification and water binding (Guinee et al., 2004; Shirashoji et al., 2006; Muslow et al., 2007). The ability of individual ES to support the exchange of sodium for calcium ions can vary. Generally, the ability to support ion exchange occurs in the following order (considering sodium salts): citrates ≈ monophosphates < diphosphates < triphosphates < short polyphosphates (<10 phosphorus atoms in a molecule) < long polyphosphates (>10 phosphorus atoms in a molecule) (Guinee et al., 2004; Mizuno and Lucey, 2005a, 2007). El-Bakry et al. (2011) stated that citrates support ion exchange to a greater extent than monophosphates.

However, ES also affect the process of gel formation in the cooling matrix of the melt and thus enhance the formation of the final structure of the processed cheese. The process of forming the final matrix during cooling and subsequent storing is called creaming and it covers a wide range of different interactions: calcium bridges, disulfide bridges, hydrophobic interactions, electrostatic interactions, hydrogen bonds, calcium-phosphates complexes (bridges), and so on (Horne, 1998; Mizuno and Lucey, 2005a, 2007). Individual ES are able to influence gel formation in different ways. Diphosphates and triphosphates are considered to be substances directly supporting gel formation, and this is especially true when they are at an optimal concentration with respect to the other components in the mixture (Mizuno and

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Lucey, 2007; Buňka et al., 2013). According to Kaliappan and Lucey (2011) and Weiserová et al. (2011), specific interactions exist between monophosphates and diphosphates (at a ratio of approximately 1:1 to 3:4) that strongly support gel formation. Weiserová et al. (2011) emphasized that specific interactions also occur between monophosphates and triphosphates that influence the properties of processed cheeses. On the other hand, polyphosphates are thought to inhibit gel formation. Within the conditions of processed cheeses, polyphosphates bind to casein fractions and give them a strong multiple negative charge. More intensively charged casein fractions repel each other, which inhibits the formation of some of the above-mentioned bonds (mainly hydrophobic interactions; Mizuno and Lucey, 2007; Shirashoji et al., 2010; Buňka et al., 2013).

Processes such as the exchange of sodium ions for calcium ions and formation of the final matrix (creaming), and thus the roles of the individual phosphates in these processes, are closely related. According to Mizuno and Lucey (2005a,b) and Shirashoji et al. (2010), higher ion-exchange ability is linked to better casein dispersion in the melt. According to these authors, greater casein dispersion also leads to a more intensive formation of mutual bonds during the creaming process. On the other hand, longer polyphosphates make the negative charge of caseins more intensive and thus weaken the gel (Shirashoji et al., 2010; Buňka et al., 2013). A balance exists between these 2 processes in the melt that seem to be contrary to each other, which is reflected in the final quality of the gel. However, the above-mentioned processes are much more complex because ternary and quaternary mixtures of ES are often used in practice and therefore the mutual interactions between ES must also be taken into consideration (Awad et al., 2002; Weiserová et al., 2011; Buňka et al., 2012).

Over the past few years, several studies (e.g., Awad et al., 2002; Weiserová et al., 2011; Buňka et al., 2012, 2013) have shown the dependence of texture parameters of processed cheeses on the composition of binary and ternary mixtures of phosphate ES (consisting mainly of disodium phosphate, tetrasodium diphosphate, and sodium salt of polyphosphate). In these studies, a specific ratio of disodium phosphate to tetrasodium diphosphate was determined (approximately 1:1 to 3:4), at which hardness of the processed cheeses increased rapidly but cohesiveness and adhesiveness decreased. The influence of this specific ratio decreased with an increasing relative amount of sodium salt of polyphosphate. When the amount of sodium salt of polyphosphate exceeded 60%, the influence of this specific ratio became insignificant. The phenomena were not affected by the maturity stage of the raw material (Dutch-type cheese; maturity stage within the range of 2 to 8 wk) or the concentration of the ES (2–3% wt/wt; Kapoor et al., 2007; Weiserová et al., 2011; Buňka et al., 2012, 2013).

However, existing studies are limited to linear-chain polyphosphates with mean length (n; the number of phosphorus atoms bound in a linear molecule of polyphosphate) of about 20 (Sádlíková et al., 2010; Weiserová et al., 2011; Buňka et al., 2012, 2013). On the other hand, sodium salts of polyphosphate with different mean lengths of chain are often used in practice. Chains of different length could affect the intensity of the exchange of sodium ions for calcium ions and thus casein dispersion (Mizuno and Lucey, 2007; Lu et al., 2008; Sádlíková et al., 2010). On the basis of the available literature, this hypothesis has not yet been proved experimentally. The role of polyphosphates with different chain lengths in mixtures with triphosphates, diphosphates, and monophosphates during the process of casein dispersion has not been described either. A different number of phosphorus atoms in a linear chain could also affect the creaming process; for example, by means of interactions with casein fractions of varying intensity. Moreover, the use of polyphosphates with different chain lengths can also affect the pH of the product (Lu et al., 2008). Finally, no studies have dealt with the influence of different compositions of ternary mixtures of ES containing triphosphate on the texture parameters of processed cheeses.

The first aim of this study was to compare selected texture parameters (hardness, cohesiveness, and relative adhesiveness) of model processed cheeses made with ternary mixtures of phosphate ES with the addition of sodium salts of polyphosphate with different mean lengths. The second aim was to observe the influence of the replacement of pentasodium triphosphate with tetrasodium diphosphate in ternary mixtures of ES on the textural properties of model processed cheeses. The above-mentioned parameters were observed (1) with nonadjusted pH of the processed cheeses arising from the interactions of the ES mixtures, and (2) with adjusted pH values of the samples (target pH values in the range from 5.60 to 5.80), which correspond to standard pH values of processed cheese spreads. The third aim was to study the link between the development of selected texture parameters of model processed cheeses related to different composition of ternary mixtures of phosphate ES and the effect of these mixtures on dispersion of casein micelles in the model milk system.

MATERIALS AND METHODS

Processed Cheese Manufacturing

Composition of the ingredients (Dutch-type cheese blocks, ~50% wt/wt DM content; ~30% wt/wt fat in