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Microstructure and textural and viscoelastic properties of model processed cheese with different dry matter and fat in dry matter content

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ABSTRACT

The aim of this work was to examine the effect of a different dry matter (DM) contents (35 and 45% wt/wt) and fat in DM contents (40 and 50% wt/wt) on the textural and viscoelastic properties and microstructure of model processed cheeses made from real ingredients regularly used in the dairy industry. A constant DM content and constant fat in DM content were kept throughout the whole study. Apart from the basic chemical parameters, textural and viscoelastic properties of the model samples were measured and scanning electron microscopy was carried out. With increasing DM content, the rigidity of the products increased and the size of the fat globules in the model samples of the processed cheeses decreased. With increasing fat in DM content, the rigidity of the processed cheeses decreased and the size of the fat globules increased.
Key words: processed cheese, texture, rheology, scanning electron microscopy

INTRODUCTION

Spreadable processed cheese is defined by Codex Alimentarius (1978) as a product made by grinding, mixing, melting, and emulsifying with the aid of heat and emulsifying salts, one or more varieties of cheese with or without the addition of milk components or other foodstuffs in accordance with this standard. The rules for the relationship between the DM content and the fat in DM (**FDM**) content are also presented (Codex Alimentarius, 1978). In the region of Middle Europe, we could also find products in which the DM content is lower than the amount stated in the standard but that is still named "processed cheese."

Processed cheeses are traditionally manufactured from a mixture of natural cheeses and many other dairy (e.g., anhydrous butterfat, butter, cream, milk powder, whey, buttermilk) and nondairy (e.g., stabilizers, preservatives, flavor enhancers) ingredients. Important food additives during the production of processed cheeses are emulsifying salts (usually the sodium salts of phosphates, polyphosphates, and citrates or their mixtures), which help the casein proteins emulsify the fat present, hydrate the free water, and participate in developing the final matrix of the product. Processed cheeses are directly consumed and are used as raw material for further processing in the industry and catering (Lee et al., 2003; Kapoor and Metzger, 2008; Nagyová et al., 2014).

One of the most important and very critically evaluated parameters of processed cheeses is their consistency, which can be, according to the actual parameters, in the form of blocks, slices, spreads, or sauces (Kapoor and Metzger, 2008). The particular consistency of the product is affected by many factors, which can be divided into 4 main groups: (1) the final parameters of the processed cheese (especially DM, protein, fat and fat-free DM content, and pH value); (2) the composition of the raw material mixture (e.g., the type and degree of maturity of the natural cheese, the concentration and composition of the emulsifying salts, and the concentration and composition of the stabilizers), which to some extent determines the final parameters of the product quoted in (1); (3) processing parameters during production (especially the agitation speed, melting temperature, stirring time, and rate of cooling the melt); and (4) the storage conditions of processed cheeses (e.g., impermeability of the packaging, storage temperature, and length of the storage period; Lee and Klostermeyer, 2001; Dimitreli and Thomareis, 2004, 2007, 2008; Kapoor and Metzger, 2008; Bayarri et al., 2012; Buňka et al., 2013, 2014; Nagyová et al., 2014; Shirashoji et al., 2016). During the storage period, especially within the first 14 d of cold storage, a further change in consistency, along with an increase in

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the rigidity of the processed cheeses, is to be expected (Buňka et al., 2013; Nagyová et al., 2014).

In the industry, the consistency of processed cheeses regularly is assessed sensorially. However, the instrumental evaluation using small (e.g., dynamic oscillation rheometry) or large (e.g., texture profile analysis) deformations or their combinations is increasing (Lee et al., 2003; Kapoor and Metzger, 2008; Buňka et al., 2013, 2014; Nagyová et al., 2014). Rheological parameters measured in the area of small or large deformations are given mainly by the microstructure of processed cheeses and mutual bonds between the individual components (especially the properties of the protein network and its interactions with other components; Hosseini-Parvar et al., 2015; da Silva et al., 2016). To explain the nature of the current state of consistency, it is therefore useful to have the data about the mechanical properties of the processed cheese and also its microstructure. The microstructure of processed cheeses may be studied by several methods, the most common of which are optical microscopy (Hladká et al., 2014; da Silva et al., 2016), scanning electron microscopy (Kaláb and Modler, 1985; Noronha et al., 2008; Cunha et al., 2010), transmission electron microscopy (Lee et al., 2003; Zhang et al., 2011; Hoffmann and Schrader, 2015), and confocal laser scanning microscopy (Hosseini-Parvar et al., 2015; Lee et al., 2015).

Although the final parameters of processed cheeses (especially DM, FDM, and fat-free DM content) affect their consistency to a large extent, they have not been given sufficient attention in the literature over the past 10 yr. One of the few studies, by Lee et al. (2015), dealt with the effect of protein content (10–20% wt/wt) and fat content (0–40% wt/wt) on the viscoelastic properties of model samples of processed cheeses made from rennet casein (melting temperature = 85°C) and stored for 24 h. With the increasing protein content and decreasing fat content (constant protein-to-water content, variable DM content), the rigidity of the processed cheeses increased. A more significant effect of the protein content was observed compared with the fat content. The conclusions of the study were supported by the results of confocal laser scanning microscopy.

Guinee and O'Callaghan (2013) used processed cheeses made from cheddar and skim milk cheese (melting temperature = 80°C) with a fat content of 14 to 33% (wt/wt), protein content of 12 to 25% (wt/wt), and constant DM content of 46 to 47% (wt/wt) stored for a maximum of 4 d. With the increasing fat content (and decreasing protein-to-fat ratio), the rigidity of the samples declined. Dimitreli and Thomareis (2004, 2007, 2008) studied the viscosity and the textural and viscoelastic properties of processed cheeses made from Gouda (melting temperature = 80°C) with a different DM (38–62% wt/wt), protein (11–30% wt/wt), and fat (12–23% wt/wt) content stored for 24 h. With the decreasing DM and protein content and the increasing fat content, the rigidity of the model samples declined. Some of the other few studies dealing with the effect of the content components on the consistency of processed cheeses were published by Bayarri et al. (2012) and Chatziantoniou et al. (2015). In both of the studies (specific processed cheeses made from whey Myzithra-type cheese and the samples obtained from the retail network), the rigidity of the samples increased with the decreasing FDM content. None of the studies mentioned in this paragraph used any of the microscopic methods to explain the changes in consistency.

The aim of this work was to examine the effect of a different DM content (35 and 45% wt/wt) and FDM content (40 and 50% wt/wt) on the textural and viscoelastic properties and microstructure of model processed cheeses made from real ingredients regularly used in the dairy industry. A similar objective was already fulfilled in some of the previously mentioned studies. However, none of the published works took advantage of the rheological methods, using both large and small deformations in combination with scanning electron microscopy (which helps to explain the processes going on during the manufacture and storage of processed cheese), to describe the properties of the samples. A constant DM content and constant FDM content were kept throughout the whole study. These 2 parameters were variable in most previously published works. Most of the studies published in this area used model samples stored for only 24 h or for a maximum of 4 d at a cold storage temperature. This work uses processed cheeses stored for 14 d at 6 ± 2°C. Within this time, the most intensive changes in consistency occur during the storage period. In most producers, processed cheeses are dispatched after 10 to 14 d when the almost-final consistency of the product is already known. The samples with 40 and 50% (wt/wt) FDM content and 45% (wt/wt) DM content are "spreadable processed cheese" according to the standards of Codex Alimentarius (1978). The samples with lower DM content (35% wt/wt) and both FDM contents (40 and 50% wt/wt) correspond to products that are available in the region of Middle Europe.

MATERIALS AND METHODS

Preparation of the Samples

Dutch-type cheese (50% wt/wt DM content and 30% wt/wt FDM content), butter (84% wt/wt DM content and 82% wt/wt fat content), water, and emulsifying salts (the total concentration was 2.9% wt/wt of the