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Characterization of the polymorphism of milk fat within processed cheese products

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ABSTRACT

Differential scanning calorimetry (DSC) and X-ray diffraction (XRD) were used to characterize the polymorphism of milk fat within commercial processed cheese products. Using anhydrous milk fat (AMF) as control, we show that the dispersion of milk fat as cream and the embedding of milk fat globules into the casein matrix results in the formation of a higher proportion of the β polymorph of milk fat. Furthermore, the effects of other cheese ingredients on the polymorphic stability of milk fat were determined. By storing and determining the polymorphism of the cheese samples at the final melting temperature of AMF, we found similar amorphous XRD diffraction patterns which confirmed that the characteristic diffraction peaks observed at refrigeration temperatures are from milk fat crystals. Upon fast cooling of molten cheese sample, milk fat crystallized into the β′ polymorph. No correlations were found between the polymorphism of fat and small deformation dynamic shear rheological parameters of processed cheese products. Characterization of the polymorphism of milk fat within processed cheese provides better understanding of the crystallization behavior of fats as affected by the food matrix. Furthermore, the results of the study could provide insights into the functionality of milk fat within food at the nano- or molecular scale.

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1. Introduction

Milk fat (MF) is widely used in food applications due to its unique texture and flavor. Upon crystallization, MF forms a crystal network that is important in the development of structure of different dairy products such as butter and ice cream (Gliguem et al., 2009; Goff & Hartel, 2013; Walstra, Wouters, & Geurts, 2006; Wright, Scanlon, Hartel, & Marangoni, 2001). Furthermore, MF crystals perform different functions in confectionary and bakery products such as prevention of bloom in chocolate and enhancement of flakiness in puff pastry (Ghotra, Dyal, & Narine, 2002; Sonwai & Rousseau, 2010). Due to the advantages that MF provides, its crystallization behavior and structure formation from the melt has been extensively studied (Grotenhuis, Aken, Malssen, & Schenk, 1999; Herrera, De León Gatti, & Hartel, 1999; Ramel, Peyronel, & Marangoni, 2016; Sangwal & Sato, 2012; Truong, Morgan, Bansal, Palmer, & Bhandari, 2015; Woodrow & deMan, 1968). Factors such as composition (*e.g.*, blending with other fats and oils) and various processing conditions such as cooling rate and crystallization temperature, and mixing or shear have been shown to affect greatly its crystallization behavior (Campos, Narine, & Marangoni, 2002; Lopez, Lavigne, Lesieur, Keller, & Ollivon, 2001a; Mazzanti, Guthrie, Sirota, Marangoni, & Idziak, 2004; Mazzanti, Marangoni, & Idziak, 2009; Wright, Batte, & Marangoni, 2005; Wright, Hartel, Narine, & Marangoni, 2000). These research studies, however, were carried out on bulk MF rather than in the state it is found in food products, *i.e.*, dispersed in a solid food matrix and in contact with other food materials. A knowledge gap, therefore, exists because MF crystallization also takes place after processing of the food product (*e.g.*, before packaging or during storage), and the conditions previously studied do not fully match those of MF within the food matrix.

In processed cheese, MF (in emulsified or bulk form) can be observed in the spaces or pockets throughout the cheese matrix formed mainly by proteins (*i.e.*, casein and whey proteins) (Martini & Marangoni, 2007; Tamime, Muir, Shenana, Kalab, & Dawood, 1999). The stability of fat within the polymer matrix is one of the

Abbreviations: MF, milk fat; PCL, processed cheese loaf; PCSS, processed cheese single slices; CRC, cream cheese.

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most important considerations during the manufacture of processed cheese, as the texture and other properties (*e.g.*, meltability, firmness and integrity) of this product are also affected by MF properties. Through homogenization, fat globule size distribution is made more uniform which is followed by emulsifier addition to keep a stable dispersion of fat throughout the product (Martini & Marangoni, 2007; Tamime, Kalab, Davies, & Younis, 1990; Tamime et al., 1999). Initial work by Gliguem et al. (2009) and Gliguem, Lopez, Michon, Lesieur, and Ollivon (2011) showed that the thermal behavior and polymorphism of MF within cheese, as determined by XRD and DSC, also affect the viscoelastic properties of processed cheese. However, further characterization is necessary to comprehensively explain the importance of MF in processed cheese.

In this study therefore, the polymorphism of MF is studied within finished processed cheese products using differential scanning calorimetry (DSC), X-ray diffraction (XRD), and microscopy techniques. Rheological properties of the products are also investigated. Results of this study could have wider applications as MF is also present in many food products such as pastries.

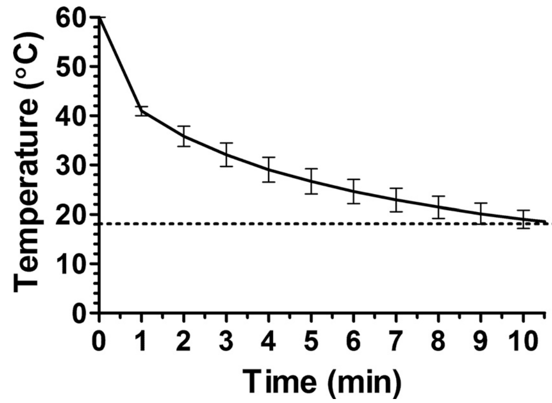

Fig. 1. Temperature profile (60–18 °C) of processed cheese samples upon cooling when placed directly into a walk-in refrigerator. Dotted line indicates temperature after 10 min.

2. Materials and methods

2.1. Processed cheese products and milk fat

Processed cheese products were obtained from the supermarket. Three different products were investigated namely Velveeta processed cheese loaf (PCL), processed cheese single slices – Kraft (PCSS 1), Black Diamond (PCSS 2), Compliments (PCSS 3), No Name brands (PCSS 4), and Philadelphia cream cheese original brick (CRC). Lactose (β-D-Lactose, ACROS Organics, Fisher Scientific, Leicestershire, UK), which is usually present in these products, was also investigated. Geographical difference was also investigated by testing samples produced in USA and Canada (CAD). The composition obtained from the labels on the products are shown in Table S1. As control, anhydrous milk fat (AMF) and cream (~40% fat), provided by The Kraft-Heinz Company, USA, were analyzed (Ramel et al., 2016). These products were stored and stabilized at refrigeration temperatures (0–7 °C) before analysis (*i.e.*, one week

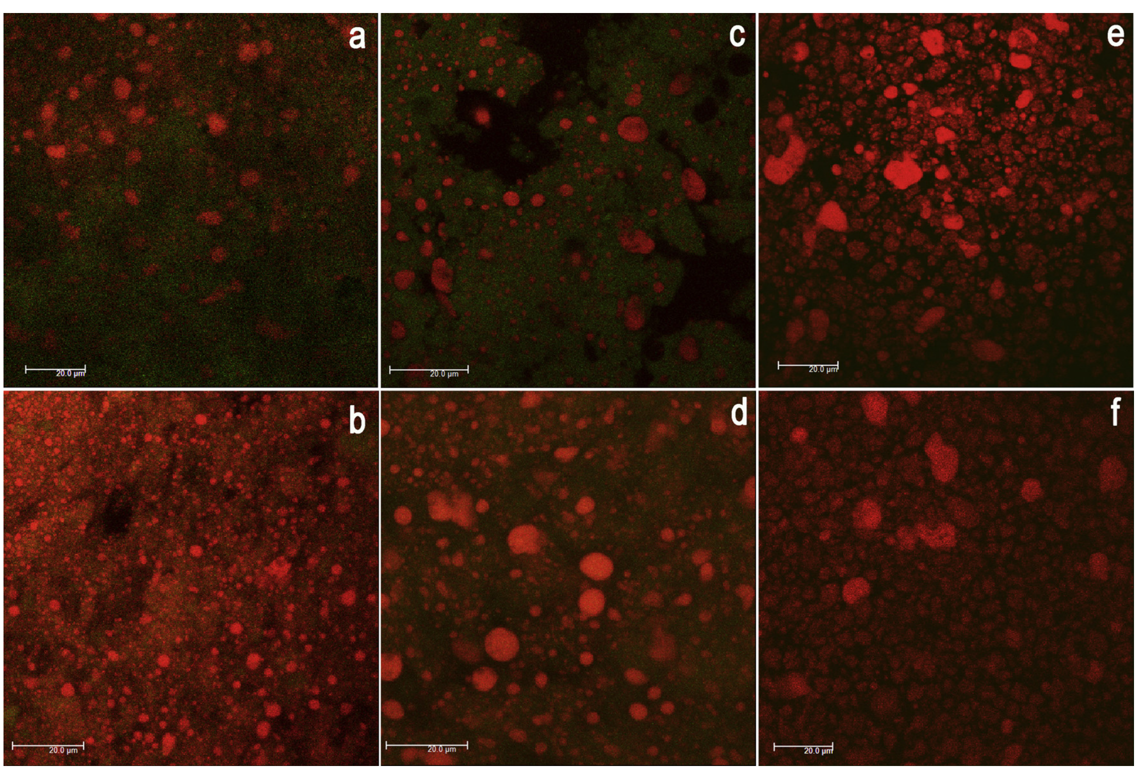

Fig. 2. Confocal laser scanning (CLSM) micrographs of various processed cheese products – (a) USA processed cheese single slices (PCSS); (b) CAD processed cheese single slices – Kraft brand (PCSS 1); (c) USA processed cheese loaf (PCL); (d) CAD processed cheese loaf (PCL); (e) USA cream cheese (CRC); and (f) CAD cream cheese (CRC). Fat globules can be distinguished as red globular or irregular structures while the protein matrix is stained green. Scale bars correspond to 20 μm. The depth of optical sectioning from the surface of the sample were varied depending on the optical density of the samples. (For interpretation of the references to color in this legend, the reader is referred to the web version of the article.)

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