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Effect of increasing the protein-to-fat ratio and reducing fat content on the chemical and physical properties of processed cheese product

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ABSTRACT

Scientific studies indicate that the intake of dietary fat and saturated fats in the modern Western diet is excessive and contributes adversely to health, lifestyle, and longevity. In response, manufacturers of cheese and processed cheese products (PCP) are pursuing the development of products with reduced fat contents. The present study investigated the effect of altering the fat level (13.8, 18.2, 22.7, 27.9, and 32.5 g/100 g) in PCP on their chemical and physical properties. The PCP were formulated in triplicate to different fat levels using Cheddar cheese, skim milk cheese, anhydrous milk fat, emulsifying salt (ES), NaCl, and water. The formulations were designed to give fixed moisture (~53 g/100 g) and ES:protein ratio (0.105). The resultant PCP, and their water-soluble extracts (WSE), prepared from a macerated blend of PCP and water at a weight ratio of 1:2, were analyzed at 4 d. Reducing the fat content significantly increased the firmness of the unheated PCP and reduced the flowability and maximum loss tangent (fluidity) of the melted PCP. These changes coincided with increases in the levels of total protein, water-soluble protein, water-insoluble protein, and water-soluble Ca, and a decrease in the molar ratio of water-soluble Ca to soluble P. However, both water-soluble Ca and water-soluble protein decreased when expressed as percentages of total protein and total Ca, respectively, in the PCP. The high level of protein was a major factor contributing to the deterioration in physical properties as the fat content of PCP was reduced. Diluting the protein content or reducing the potential of the protein to aggregate, and thereby form structures that contribute to rigidity, may provide a means for improving quality of reduced-fat PCP by using natural cheese with lower intact casein content and lower calcium:casein ratio, for example, or by decreasing the ratio of sodium phosphate to sodium citrate-based ES.
Key words: processed cheese, fat, rheology

INTRODUCTION

Processed cheese products (**PCP**) are widely consumed as retail products (as spreads or slices) or as an ingredient in cheese-based dishes, including sandwiches, hamburgers, pizza, and lasagne. Their popularity as products may be attributed to several factors including, *inter alia*, the diversity they offer in flavor, texture, and cooking properties; easy customization to cheese ingredient applications; adaptability to fast food trade; and their attractive packaging into convenient formats and shapes. Such diversity is controlled by changes in formulation, processing conditions, and composition.

It is generally accepted that the intakes of dietary fat, saturated fats, and sodium in the modern Western diet are excessive and impair health, lifestyle, and longevity (Campbell et al., 1998; Simopoulos, 2002; Carrera-Bastos et al., 2011). Consequently, manufacturers of cheese and PCP, in an attempt to acquire greater market share, are pursuing the development of products with lower fat content. However, reduced-fat PCP are generally perceived as being tougher, harder, less creamy and spreadable, grainier, and more bitter than their full-fat equivalents (Muir et al., 1997). Consequently, much recent research in the area of PCP has focused on improvement of quality of reduced-fat products. Various parameters have been investigated, including addition of hydrocolloids (Brummel and Lee, 1990; Swenson et al., 2000), addition of lecithin (Drake et al., 1999), addition of various milk ingredients such as buttermilk (Raval and Mistry, 1999) and whey protein concentrates (Lee et al., 2006; Shenana et al., 2007), natural cheese characteristics (e.g., degree of maturity: Raval and Mistry, 1999; cheese made with or without exopolysaccharide-producing cultures: Hassan et al., 2007; pH and calcium content: Brickley et al., 2008), type and level of emulsifying salts (**ES**; Swenson et al., 2000; Raval and Mistry, 1999; Brickley et al., 2008), and product pH (Lee and Klostermeyer, 2001). These studies have indicated varying degrees of product improvement, depending on fat content, composition, and the product attribute(s) being assessed. In contrast, surprisingly few studies have considered the incremental effects of fat reduction on PCP. Solowiej (2012)

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reported that the hardness of cheese analogs, formed by blending acid casein dispersions and anhydrous milk fat (**AMF**), decreased as the protein content of the casein dispersion was increased from 12 to 20% and the level of AMF reduced from 30 to 10 g/100 g, despite an estimated increase in moisture content from approximately 62 to 74 g/100 g. Similarly, in other studies where data for control-fat and reduced-fat PCP are available (Brummel and Lee, 1990; Drake et al., 1999), it is difficult to infer the effects of fat reduction because of the confounding effect of moisture differences, which can sometimes be quite large (e.g., 10 to 20 g/100 g) between the treatments.

The objective of the current study was to investigate the effects of altering the fat content from approximately 33 to 14 g/100 g on the physical properties of a PCP in which the moisture content was held constant and the protein-to-fat ratio was varied.

MATERIALS AND METHODS

Raw Materials

Cheddar cheese and skim milk cheese were manufactured as described below. The following ingredients were used: disodium phosphate anhydrous (**DSP**; Albright and Wilson Ltd., Cheshire, UK), trisodium citrate dihydrate (**TSC**; Jungbunzlauer GmbH, Pernhofen, Austria), sodium chloride (Irish International Trading Corp. PLC, Cork, Ireland), potassium sorbate (Sigma-Aldrich Chemie GmbH, Buchs, Switzerland), and butteroil (Corman Miloko Ireland Ltd., Carrick on Suir, Co. Tipperary, Ireland).

Manufacture of Cheddar Cheeses of Varying Calcium Levels

Cheddar cheese and skim milk cheese were manufactured on site at the Moorepark Technology Ltd. pilot plant using a standardized Cheddar cheesemaking procedure (Guinee and O'Kennedy, 2012). The cheese milks were standardized to protein and fat contents (g/100 g), respectively, of 3.33 and 3.27 for Cheddar and 3.34 and 0.16 for skim milk cheese. The cheeses were stored at 8°C and monitored periodically for level of primary proteolysis using levels of water-soluble N (**WSN**) and pH 4.6-soluble N (**pH4.6SN**). When the level of pH4.6SN (as g/100 g of total N) of individual cheeses reached ~9.05 (~37 d for Cheddar, and 90 d for skim cheese), they were cut into cubes (~64 cm^3), frozen at –18°C, and stored until required. The cheeses were thawed at 4 to 8°C for 2 d before processing. Their compositions are given in Table 1.

Table 1. Composition of Cheddar and skim milk cheeses used in the manufacture of pasteurized processed cheese

Cheese composition	Cheddar	Skim milk cheese
Moisture (g/100 g)	37.1	50.6
Fat (g/100 g)	33.9	0.7
Protein (g/100 g)	23.2	39.4
Salt (g/100 g)	1.7	1.8
pH	5.08	5.48
Calcium (mg/100 g)	675	1,229
Calcium (mg/g of protein)	28.6	31.2
Phosphorous (mg/100 g)	511	837
Phosphorous (mg/g of protein)	22.1	21.3
WSN (% of total N)[1]	7.9	9.2
pH4.6SN[1] (% of total N)	7.5	8.7

[1]WSN = water-soluble N; pH4.6SN = pH 4.6-soluble N.

Formulation Design and Manufacture of PCP

A range of 5 formulations was designed with target fat levels in the range of 13.8 to 32.5 g/100 g and protein-to-fat ratios varying from ~0.38 to ~1.84 using cheese, butteroil, water, and ES as ingredients in all treatments (Table 2). The target DM content was fixed at 54 g/100 g, whereas the fat content was varied by altering the protein-to-fat ratio of the DM portion (Figure 1). The weight ratio of ES to cheese protein was kept constant at 0.105 to avoid the confounding effects of potential variations in protein hydration and physical properties associated with altering the level of ES (Shirashoji et al., 2006, 2010; Guinee and O'Kennedy, 2012). Similarly, the level of pH4.6SN (and hence intact casein content) in the natural cheese was kept in a narrow range (~7.5 to 8.5% of total N; Table 1) to minimize its potential effects (Garimella Purna et al., 2006; Brickley et al., 2007). To minimize the level of noncheese ingredients, skim cheese was used as the sole protein source in formulations with the 2 lowest fat levels, Cheddar cheese for the 2 highest fat levels, and a blend of skim and Cheddar cheese for the intermediate fat level. Butteroil was used with cheese to attain the desired fat levels. The formulation recipes were generated as a mixture design with target levels for fat, moisture, and ES:casein ratio using least squares optimization by means of the Excel Solver tool (Microsoft Excel 2003; Microsoft Corp., Redmond, WA). Ingredient quantities were based on analysis of all ingredients for moisture, fat, protein, ash, and lactate.

The processed cheeses were made in a Stephan UMM-SK5 processing kettle (A. Stephan u. Söhne GmbH & Co., Hameln, Germany) as described previously (Guinee and O'Kennedy, 2012). All treatment PCP were made on a given day, and triplicate trials were undertaken on 3 separate days over 3 wk. The PCP with target fat levels of 13.8, 18.2, 22.7, 27.9, and