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Effects of starches on the mechanical properties and microstructure of processed cheeses with different types of casein network structures

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We investigated the effects of tapioca starch (TS) and potato starch (PS) on the viscosity, mechanical properties and the microstructure of processed cheese with different casein network structures and discussed the casein network structure relating to the firmness and viscosity. Different casein network structures of processed cheese were produced using two types of pre-cooked cheeses (PCs): PC1 and PC2. In the PC1 group, the casein network structure represented a random type. The addition of TS caused the casein network structure to become dispersed, leading to increased firmness, and the addition of PS caused the casein network structure to become fine-stranded and brought the most firmness. In the PC2 group, the casein network structure was a fine-strand type. Both TS and PS had no obvious impact on the casein network structure and the firmness. The results of this study will help us to understand the roles of different textural starches contributing to the viscosity and mechanical properties in processed cheese with different types of casein network structures.

1. Introduction

Processed cheese is a popular and traditional gel-like dairy product consumed in many countries. The gel-like food initially starts as a mixture of ingredients in dispersion that solidifies because of processing and somehow associates in a way that gives the network its mechanical properties (John, 2014). It is generally known that hydrophobic bonding of casein micelles mainly decides the formation of cheese. Acidification or enzymatic hydrolysis can coagulate the concentrated casein to form a continuous protein network (Saitou, Dousako, & Igoshi, 2010).

Processed cheese is mainly prepared by mixing the raw cheeses, emulsifying salts, water and limited amounts of additional ingredients, heating to melt the mixture, and stirring the mixture in a reaction container (Bennett, Trivedi, Hemar, & Reid, 2006). The most important part of the process is heating for an appropriate time with continuous stirring (emulsifying process) until a homogeneous mass is formed. The emulsifying process enhances the qualities of the processed cheese, especially its viscosity and mechanical properties. The continuous increase in viscosity during cooking is called the *creaming effect*, and the continuous cooking itself is called *creaming*. The creaming effect can also be induced by cooling and storage, which essentially change the casein network (Kawasaki, 2008). In processed-cheese manufacturing, creaming affects the sizes of the milk fat globules and the casein network structure, thereby influencing the viscosity of the melted cheese or the firmness of the final product (Saitou et al., 2010).

The functional properties of processed cheese are affected by several factors, including the types and characters of natural cheeses, additional ingredients, emulsifying conditions, fat and moisture content, pH, cooling and ripening (Hennelly, Dunne, O'Sullivan, & O'Riordan, 2005; Bunka et al., 2012; Mizuno & Lucey, 2005; Guinee, 2004; Guinee & O'Callaghan, 2013; Banks, 2004; Kiziloz, Cumhur, & Kilic, 2009; Ong, Dagastine, Kentish, & Gras, 2012; Everard et al., 2007; El-Bakry, Duggan, O'Riordan, & O'Sullivan, 2010). Recently, the addition of pre-cooked cheese (PC) has been also used to improve the functional properties of processed cheese during factory manufacturing. PC is essentially processed cheese because after the production is complete, the processed cheese that remains in the pipeline is often used as PC in

Abbreviations: TS, tapioca starch; PS, potato starch; PC1, pre-cooked cheese produced at 1000 rpm, 10 min; PC2, pre-cooked cheese produced at 1000 rpm, 30 min; NPC1, processed cheese added PC1; TPC1, processed cheese added PC1 and TS; PPC1, processed cheese added PC1 and PS; NPC2, processed cheese added PC2; TPC2, processed cheese added PC2 and TS; PPC2, processed cheese added PC2 and PS.

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the following production (Kawasaki, 2008). PC can affect the creaming effect and is often used to adjust the viscosity or firmness based on the purpose. The potency of PC is influenced by emulsifying salts, emulsifying conditions, and storage period. In general, in the cases of using long-chain phosphates (e.g. polyphosphate), more stirring strength, or longer storage period, the potency of PC becomes stronger (Saitou et al., 2010; Lee, Buwalda, & Euston, 2003; Shirashoji & Jaeggi, 2006; Noronha et al., 2008a).

Earlier, it has been found that PC used in different emulsifying conditions brought the changes in the functional properties of processed cheese, especially the casein network structure. Casein network structures are influenced by the cheese-making process, and any changes in the casein network structures impinge on the final properties of cheeses (Lee, Buwalda, Euston, Foegeding, & Mckenna, 2003; Kawasaki, 2008). Based on the creaming effect, PC primarily has two types of casein network structures: a random type structure found before the creaming effect and a fine-stranded type obtained from the start of the creaming effect. If these two types of PCs are respectively added as additional ingredients, then the processed cheese will have different viscosities, mechanical properties and casein network structures depending on the casein structure in the PC used.

Polysaccharides are also widely used to improve the functional properties of processed cheese through their ability to bind water, improve viscosity and aid in gelling (Bennett et al., 2006). As popular food ingredients, starches and modified starches have been widely used to control the functional properties and viscosities of food products and certainly in the production of processed cheese (Noronha et al., 2008a,b; Ye, Hewitt, & Taylor, 2009; Ye & Hewitt, 2009; Trivedi et al., 2008; Gampala & Brennan, 2008; Benaouadj, Ziane-zafour, & Rebiha, 2017). Different types of starches have different food textures and functions. Tapioca starch (TS) and potato starch (PS) represent two typical starches used. For example, addition of TS to wheat noodles creates a chewy texture because the fibrous structure inside TS extends when it is fractured. Moreover, it is widely accepted that PS makes food brittle because it does not easily break when compressed (Eguchi, Yoshimura, & Kohyama, 2012; Fu & Nakamura, 2017).

Previous studies (Fu et al., 2018) have demonstrated that longer stirring times affect the casein network structure of processed cheese, converting them from a random type to a fine-stranded type. In this study, we focused on two types of casein network structures and investigated the effects of different textural starches on processed cheese with different casein network structures. However, because different stirring times were used to produce different casein network structures, it was unclear whether the changes in the functional properties were due to the addition of starches or due to varied stirring times used, which also had a large influence on starches. Therefore, in this study, we produced the two casein network structures by adding PCs with different degrees of shear-induced emulsification or creaming and then added the starches, thereby investigating the effects of the starches on casein network structures.

The objective of this study was to investigate the effects of different textural starches on the functional properties of processed cheese with different casein network structures and to explain the changes from their microstructures. With a better understanding of these, it will be possible to effectively use starches and to optimise the functional quality attributes of processed cheese.

2. Materials and methods

2.1. Materials

The raw cheeses of Gouda and Cheddar (ripened for 9 months) were obtained from Megmilk Snow Brand Company, Ltd. (Tokyo, Japan). Sodium polyphosphate, disodium phosphate and sodium bicarbonate were of food additive grade. TS and PS were kindly provided by J-OIL MILLS, Inc. (Tokyo, Japan) and α-amylase was obtained from Wako Pure Chemical Ind. (Tokyo, Japan). 50% Glutaraldehyde (TAAB) and 2% osmium tetraoxide (Chiyoda Pure Chemical Ind., Ltd., Japan) were used. The other chemicals were of a special grade. Distilled water was used in all processed cheese preparations.

2.2. PC preparation

The PCs were manufactured in Rapid Viscosity Analyzer (RVA-4, Newport Scientific Ltd., Australia). As the manufacturing process, we followed Metzger, Kapoor, Rosenberg, and Upreti (2002) with the following changes.

The stirring speeds and times of the emulsifying conditions of PCs were varied as follows: 1000 rpm for 10 min (PC1); 1000 rpm for 30 min (PC2). For the short stirring time, the temperature was increased from 50 to 90 °C in 3 min, then held at 90 °C for 7 min. For the long stirring time, it was raised from 50 to 90 °C in 3 min, then held at 90 °C for 27 min. A binary mixture of polyphosphate with disodium phosphate was added as the emulsifying salt. The formulation of the PC preparation is given in Table 1. After cooking, the melted PCs were transferred to zipped bags and placed in ice-cold water for cooling. The PCs were stored at 5 °C.

2.3. Processed cheese preparation

Gouda cheese, Cheddar cheese and PCs were mixed using a paddle with emulsifying salts, sodium bicarbonate, starches and distilled water in an aluminium container Distilled water was added to ensure that the moisture content of the processed cheese was controlled at approximately 48%–50% w/w. The total of sample was 26 g. The formulation of the processed cheese preparation is given in Table 2. Emulsifying condition of 1000 rpm, 15 min was set to produce the processed cheese using RVA, which the temperature was increased from 50 to 90 °C in 3 min, then held at 90 °C for 12 min. A binary mixture of polyphosphate with disodium phosphate was added as the emulsifying salt. The amount of sodium bicarbonate was adjusted to meet the target pH (5.8–5.9). After cooking, the melted cheese was filled in a 70 × 100 mm zipped bag, and shaped to a height of 5 mm. The bag was placed in ice-cold water for cooling. The samples were stored at 5 °C. The samples were of six varieties, including processed cheese with added PC1 (NPC1), that with added PC1 and TS (TPC1), that with added PC1 and PS (PPC1), that with added PC2 (NPC2), that with added PC2 and TS (TPC2) and that with added PC2 and PS (PPC2).

Table 1
Formulation of the precooked cheese (PCs) preparation.

Mixture	Ingredient composition % (w/w)	
	PC1	PC2
Gouda cheese	40	40
Cheddar cheese	40	40
Sodium polyphosphate	1.6	1.6
Disodium polyphosphate	0.4	0.4
Target		
Moisture content (%)	45–46	45–46
pH	5.8–5.9	5.8–5.9
RVA conditions		
Stirring speed (rpm)	1000	1000
Stirring time (min)	10	30
Temperature (°C)	90	90

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