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Inclusion of starch in imitation cheese: Its influence on water mobility and cheese functionality

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Abstract

The impact of starch type and concentration on the nature of water in and the rheology of imitation cheese were investigated. Imitation cheese (55% moisture) containing four starches (native, pre-gelatinised, resistant or waxy corn) at inclusion levels of 1.9%, 3.9%, 5.8%, 7.8%, or 9.9% w/w were manufactured using a *Brabender* Farinograph-E®. The textural properties were assessed by torsion gelometry and dynamic rheology and the mobility of water by nuclear magnetic resonance (NMR) relaxation techniques. Cheese microstructure was assessed using light microscopy. Increasing the starch content changed the texture of cheeses from 'soft' to 'brittle/tough' and significantly ($p<0.05$) decreased the mobility of water. Cheese melt and hardness were influenced by the mobility of water. Matrices in which the water was more mobile produced good melting soft cheeses, while cheeses in which water was less mobile were tough and non-melting. Light micrographs showed that starch type influenced cheese microstructure. The native and pre-gelatinised starches became swollen and disrupted the continuity of the protein matrix, separating the matrix into a protein and starch phase. Resistant and waxy corn starches were present in the protein matrix as small discrete particles, appearing relatively intact, unswollen and relatively unchanged by the cheese manufacturing process. The study indicates that varying the level/type of starch alters the water mobility and thus the functionality of imitation cheeses.

Keywords: Imitation cheese; Starch; NMR relaxometry; Light microscopy; Torsion

1. Introduction

Consumer preference for tailor-made convenience products using molten cheese, i.e. pizza pie topping, sauces have necessitated the production of cheese analogues; imitation Mozzarella cheese being the product of choice (Jana & Upadhyay, 2003). The stability of imitation cheeses with respect to shredability, apparent viscosity and free oil during refrigerated storage make them appealing to food processors and food-service industries.

Native and modified starches have been used to modify the functional applications of imitation cheese (Mounsey & O'Riordan, 2001, 2008, respectively). Native starch granules are insoluble in cold water; however with continued heat these granules swell and imbibe water (Davies, 1995). Pre-gelatinised starches are modified starches that are cold water soluble, which have immediate viscosity effects (Light, 1990). Both pre-gelatinised and native starches have a tendency to retrograde on cooling, with the linear amylose molecules re-associating, forming hydrogen bonds, which results in the formation of a gel. Waxy starch develops viscosity without the gelling characteristics generally associated with native starches (Thomas & Atwell, 1999). Resistant starch is a starch that has been designed to withstand gelatinisation (granule swelling) under most heating regimes (Sajilata, Singhal, & Kulkarni, 2006).

Work conducted previously in this laboratory used native, pre-gelatinised and waxy maize starch to replace rennet casein in imitation cheese (Mounsey & O'Riordan, 2001). These authors suggested that starch type had an impact on the functionality of starch-containing imitation cheeses, with native starch reducing casein hydration to a

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lesser extent than the pre-gelatinised starch. Recently our laboratories have produced a variety of imitation cheeses in which resistant starch has been used as a fat replacer (Montesinos, Cottell, O'Riordan, & O'Sullivan, 2006; Noronha, O'Riordan, & O'Sullivan, 2007). Incorporation of relatively high levels (17.3% w/w) of resistant starch had minimum effects on cheese functionality, e.g. meltability, which was attributed to the low water binding capacity of the resistant starch used in that study (Duggan, Noronha, O'Riordan, & O'Sullivan, 2008).

Although work to date has hypothesised that starch addition influences the properties of imitation cheese by affecting casein hydration, there has been no direct evidence to support this theory. Many researchers have found that the mobility of water, as measured by nuclear magnetic resonance (NMR) relaxometry relates to the availability of water in complex systems (Chen, Long, Ruan, & Labuza, 1997; Ruan et al., 1997; Schmidt, 1990). In relaxometry, the spin-lattice and transverse relaxation times (T_1, T_2) are related to the mobility of water molecules with very mobile water molecules taking longer to reach their equilibrium state, thus having long relaxation times.

The objective of this study was to replace different levels of fat with starches (native, pre-gelatinised, resistant, or waxy corn starch)—chosen on their ability to bind water differently—on certain functional properties of imitation cheese. In addition the effect of this replacement on the hydration characteristics of cheese was examined using NMR.

2. Material and methods

2.1. Materials

Kerry Ingredients Ltd. (Listowel, Co. Kerry, Ireland) provided rennet casein (80% protein). Hydrogenated palm oil and rapeseed oil were obtained from Trilby Trading (Ireland) Ltd. (Drogheda, Co. Louth, Ireland). Native (Numould), pre-gelatinised (Instant Pure-cote), resistant (Novelose 240) and waxy (Amioca) corn starches were all obtained from National Starch Food Innovations (National Starch and Chemicals, Bridgewater, NJ, USA). All chemicals, including anhydrous disodium phosphate (Albright and Wilson Ltd., Cheshire, England), trisodium citrate and anhydrous citric acid (Jungbunzlauer GmbH, Pernhofen, Austria), sodium chloride (Salt Union, Cheshire, England) and sorbic acid (Hoechst Ireland Ltd., Dublin, Ireland) were of food grade.

2.2. Manufacture of imitation cheese

A control imitation cheese was manufactured according to the following composition (expressed as weight percentage (% w/w)): 54% water, 21.7% protein, 21.0% vegetable oil, 0.9% trisodium citrate, 0.4% disodium phosphate, 1.4% sodium chloride, 0.5% citric acid and 0.1% sorbic acid.

Batches (150 g) were manufactured by agitating the vegetable oil with water in the *Brabender* Farinograph-E® (mixer bowl type: sigma mixer S50, mixer speed: 63 rev min^{-1}) (*Brabender* Instruments, Inc., S. Hackensack, NJ, USA) at 50 °C for 2 min. The temperature of the mixer jacket was regulated by an external water bath (55 °C). Trisodium citrate, disodium phosphate, sodium chloride and sorbic acid were then added and mixed for a further 2 min. The rennet casein was subsequently added, and following 2 min of mixing the temperature was increased to 80 °C by closing the valve to the water bath at 55 °C and opening the valve to another water bath set at 95 °C. The mixture was maintained at 80 °C until a homogeneous cheese mass was produced and no pockets of water were observed on visual inspection. Citric acid was added and mixed in for 1 final minute. The product was discharged into a plastic box, covered and then placed into a refrigerator at 4 °C for 24 h, after which the cheese was vacuum packed (Model C10H, Webomatic®, Bochum, Germany) and stored at 4 °C until analysed. All samples were analysed within 1 week of manufacture.

Using a similar process, imitation cheeses, containing 1.9%, 3.9%, 5.8%, 7.8%, or 9.9% w/w native, pre-gelatinised, resistant and waxy corn starch were manufactured. The starches were added in direct replacement (on a weight basis) of hydrogenated palm oil in the control formulation. The starch was incorporated into its respective batch once the temperature of 80 °C had been reached. The rest of the procedure was the same as for the control cheese.

2.3. Compositional analysis of imitation cheese

The moisture content of imitation cheese was determined by the oven drying method (IDF, 1958) and the pH was measured by inserting a calibrated Unicam glass/Ag/AgCl combination pH electrode attached to a pH meter (model 9450, Unicam, Cambridge, UK) directly into the cheese at three randomly chosen locations after equilibration of imitation cheese to room temperature for at least an hour. The nitrogen content of imitation cheese samples was determined by combustion in a nitrogen analyzer (Leco, St. Joseph, MI) according to manufacturer's instructions. A Kjeldahl factor of 6.38 was used to calculate crude protein.

2.4. Differential scanning calorimetry (DSC)

The gelatinisation temperatures of native, resistant, waxy and pre-gelatinised corn starch were assessed. Duplicate aqueous samples (10% (w/w) of 35 mg wet weight) were prepared in sealed stainless steel differential scanning calorimetry (DSC) pans (60 μl; Perkin-Elmer Instruments, Norwalk, CT). Each sample was then heated in a DSC 7 (Perkin-Elmer Instruments, Norwalk, CT) from 10 to 180 °C at 10 °C/min.