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Effect of Wheat Starch on Imitation Cheese Texture

John S. Mounsey
Teagasc, Moorepark Food Research Center, Moorepark, Fermoy, Co. Cork, Ireland

Abstract: This study was undertaken to determine if partial replacement of the rennet casein protein with native wheat starch (at 0-20% levels) in the formulation of imitation cheese would affect the textural properties of the final product. Increasing levels of starch to 5% levels significantly increased the hardness of the imitation cheese from 128N-146N. The peak stress values of imitation were significantly increased from 425 kPa for the control to ~510 kPa at the higher levels of starch addition (5-9%). The stress relaxation times increased significantly from 35.3 sec control to 140 sec with increasing levels of wheat starch to 9%, possibly indicating reinforcement of the product through amylose and amylopectin association. Cohesiveness was significantly reduced with increasing levels of wheat starch from 0.151 for the control to 0.113 at 9% starch levels. The reduction in the cohesiveness of imitation cheese by starch was due to reductions in the protein content and possibly by stress localisation at the starch-protein matrix interface. Results are indicative that the starch functioned as a filler allowing the casein to dominate the products textural properties.

Key words: Imitation cheese, wheat starch, texture, cohesiveness, partial replacement, protein

INTRODUCTION

Imitation cheese has the potential to overcome problems associated with natural cheeses such as high production and storage costs, functional variability and compositional and nutritional inflexibility (Taranto and Yang, 1981; Kiely *et al*., 1991). Imitation cheese is generally manufactured from casein or its derivatives, vegetable fats or oils, salts, acids and flavourings (Mounsey and O'Riordan, 1999). These ingredients are blended and cooked, while agitating continuously, until a smooth homogeneous plastic mass is obtained. The protein acts as both a gelling and emulsifying agent. In the case of rennet casein (i.e., calcium para-casein), which is insoluble in water, solubility is achieved primarily by the addition of emulsifying salts but also by heat and agitation. The salts such as trisodium citrate or disodium phosphate combine with calcium attached to the caseins and in doing so sequester the calcium, which otherwise interlocks the protein strands together and thus prevents hydration and solubilisation. The solubilised protein not only emulsifies the free oil but also binds the added water, increases the viscosity of the aqueous phase and stabilises the dispersed oil droplets, which contributes greatly to the structure of the finished imitation cheese (Aimutis, 1995; Ennis *et al*., 1998). Cooking is normally performed by the injection of live steam until the cheese mass reaches a temperature of 77°C (Galal *et al*., 1983). The hot molten mass is then packaged and cooled rapidly by blast freezing (-10 to -30°C) to retard excessive body development), which would influence the final texture and rheology of the imitation cheese.

Previous research has shown that various types of added starch have modified the rheological and melting properties of imitation cheese (Mounsey and O'Riordan, 1999, 2001, 2008; Guinee *et al*., 2004; Herrero *et al*., 2006).

The aim of this study was to determine, if partial replacement of the casein with native wheat starch in the formulation of imitation cheese would affect the textural properties of the imitation cheese.

MATERIALS AND METHODS

Manufacture of imitation cheeses: A control imitation cheese was manufactured with the following formulation: 48.8% water, 24.5% rennet casein (82% protein) (Kerry Ingredients, Listowel, Ireland), 26% vegetable fat (Trilby Trading Ltd., Liverpool, England), 2.18% emulsifying salts (1.08% trisodium citrate, 0.62% citric acid (Jungbunzlauer, Pernhofen, Austria), 0.48% disodium phosphate (Ellis and Everard, Ireland)), 1.67% sodium chloride (Salt Union, Cheshire, England) and 0.1% sorbic acid (Hoechst Ireland Ltd., Dublin, Ireland). All ingredients (except citric acid) were blended in a twin-screw cooker (model CC-010, Blentech Corporation, CA) at 35°C and heated to 78°C using direct steam. Citric acid was added. After 5 min of mixing at 100 rpm the product was packaged, cooled to 4°C and vacuum packed (model C 10 H, Webomatic®, Bochum, Germany) 24 h later. During cooking the solid screw agitators of the cooker turned in opposite directions causing the product to be folded into the centre and moved around the cooker in a counter clockwise direction resulting in a well-emulsified homogeneous cheese mass. Using a similar manufacturing process, a series of imitation cheeses were prepared with 3, 5, 7 or 9% (w w^{-1}) native wheat starch (Roquette, Lille Cedex, France) by replacing 15, 25, 35 or 45%, respectively of the casein protein in the control and reducing the concentration of emulsifying salts used to solubilise the casein accordingly.

Texture Profile Analysis (TPA): Textural properties were measured with an Instron Universal Testing Machine (Instron Model 4301, Instron Corp., Canton, MA). Cylinders of cheese 20 mm high and 18 mm in diameter were cut with a cheese borer, wrapped in selophane to prevent dehydration and allowed to thermally equilibrate for 1.5 h. Samples were compressed by 80% of their initial height using a 35 mm diameter plate at a crosshead speed of 50 mm min^{-1}. The uniaxial compression test was performed in 2 successive cycles and the textural parameters; hardness and cohesiveness were calculated as described by Bourne (2002).

Stress relaxation: Samples for stress relaxation measurements were prepared as described for TPA measurements. Each specimen was lubricated with rapeseed oil at the parallel surfaces in contact with the cross-head and compressed to 80% of its initial height at a crosshead speed of 25 mm min^{-1} with the Instron. A 100N loadcell was used. Relaxation curves were recorded for 8 min following deformation, with a sampling rate of 5 point sec^{-1}. The peak stress (Pa) and stress relaxation time (the time (sec) required for the initial stress to relax to 1/e (i.e., 1/the exponential) of its initial value (van Vliet, 1991)) were determined.

Statistical analysis: The imitation cheeses were manufactured in triplicate. All tests were replicated 4 times. PROC GLM of SAS (SAS Institute, Cary, N.C., USA) was used to determine differences between treatment means. Treatment means were considered significantly different at $p \le 0.05$.

RESULTS AND DISCUSSION

Textural hardness (measured at 80% compression) and peak stress (measured at 20% compression) were used as indices of products strength, while stress relaxation time and cohesiveness were used to indicate the viscoelastic behaviour and strength of internal bonding of the imitation cheeses, respectively. The effects of increasing levels of wheat starch on hardness, peak stress, stress relaxation time and cohesiveness of imitation cheese are presented in Fig. 1a-d, respectively.

The control imitation cheese (0% starch) had a textural hardness of 128±10N (Fig. 1a). Increasing levels of starch to 5% levels significantly ($p \le 0.05$) increased the hardness to 146±9N. The hardness was reduced at higher levels of starch addition (125±13N). Previous research showed that increasing levels of pre-gelatinised starch had no significant effect on imitation cheese hardness (Mounsey and O'Riordan, 2008). However, Mounsey and O'Riordan (2001) showed that imitation cheeses containing 3% added high amylose (25-28% amylose) native starches had increased hardness values compared to a control. These authors suggested that the granular shape of the starch as well as hydrogen bond formation following leaching of amylose during processing of the imitation cheese contributed to the increased textural hardness. In the present study, the wheat starch at optimal levels (5-7%) increased the strength of the imitation cheese possibly with the starch granules acting as reinforcing fillers of the protein matrix.

The peak stress values (Fig. 1b) of imitation cheese containing 3% starch was not significantly ($p \le 0.05$) different from the control (425±41 kPa). However, at the higher levels of starch addition (5-9%) the peak stress values were significantly ($p \le 0.05$) increased to ~510 kPa. Previous resaerch showed that increasing addition of pre-gelatinised starch at 9% levels increased the peak stress value of imitation cheese by over 50% (Mounsey and O'Riordan, 2008). It was suggested that the pre-gelatinised starch may have formed a continuous phase in tandem with the casein, which contributed to increased structure development.

The control imitation cheese (0%, w w^{-1} starch) had a stress relaxation time of 35.3±1.6 sec (Fig. 1c). The stress relaxation times increased significantly ($p \le 0.05$) to 44.8±5.1 sec with the addition of 3% wheat starch. At higher levels of wheat starch, the stress relaxation time was reduced. Previous authors suggested that the inclusion of starch resulted in an increase in interactions such as salt linkages and hydrogen bonds due to association of amylose and amylopectin molecules (Mounsey and O'Riordan, 2001). Stress relaxation times are increased for casein gels with higher ratios of casein to water (Zhou and Mulvaney, 1998).

Mounsey and O'Riordan (2008) suggested that the exclusion effect between casein and pre-gelatinised starch generated a multi-textured gel with increased protein-protein interactions in the casein matrix. The present results indicate that the casein matrix of the imitation cheese was less hydrated in the presence of optimal levels

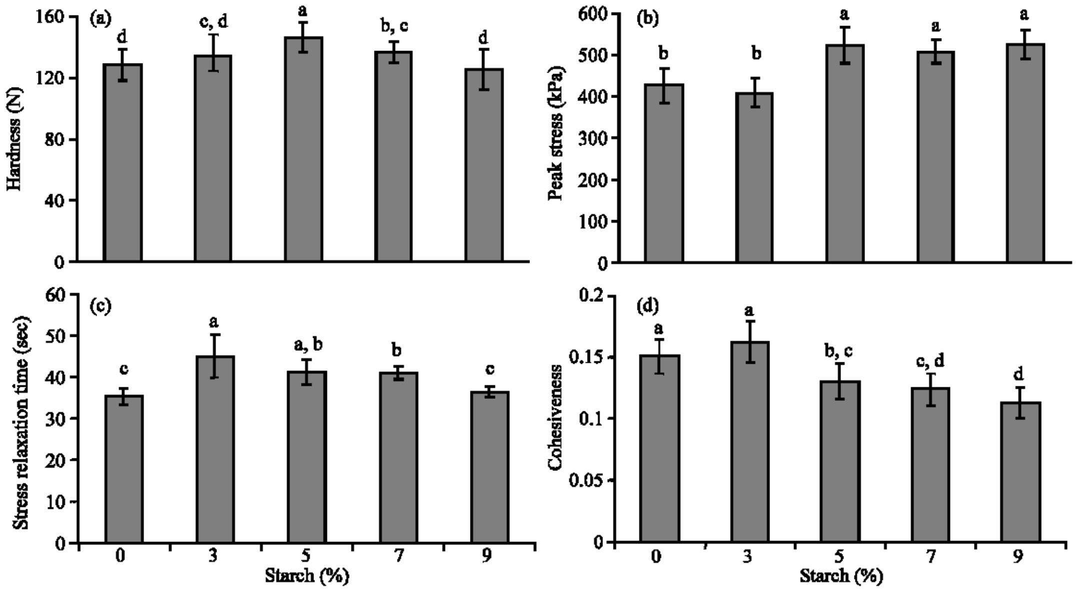

Fig. 1: Imitation cheeses containing increasing levels of wheat starch. a) Hardness (N) , b) Peak stress (Kpa), c) Stress relaxation time (sec), d) Cohesiveness. Each bar represents the mean of triplicate trials. Means with the same letter do not differ significantly at $p \leq 0.05$

of wheat starch resulting in enhanced protein-protein interactions and increased strength/elastic properties in the imitation cheese. Results indicate the wheat starch functioned as a swollen filler in the paracaseinate network in an analogous fashion to its function in surimi (Kong *et al*., 1999).

Cohesiveness of imitation cheese containing 3% wheat starch was not significantly ($p \leq 0.05$) different from the control (0.151 ± 0.014) (Fig. 1d). However, cohesiveness was significantly ($p \leq 0.05$) reduced with increasing levels of wheat starch (to 0.113 ± 0.012 at 9% starch levels). The decrease in cohesiveness at the high levels of starch may be partly attributable to reductions in the protein content and the corresponding number of bonds capable of reforming after destructive strain (Bhaskaracharya and Shah, 1999).

Additionally, relatively weak adhesion and concentration of stress between the filler (starch granules or associated molecules of amylose or amylopectin) and the protein matrix may also have contributed to failure on deformation, due to stress localisation at the starch-protein matrix interface (Noel *et al*., 1993) resulting in cohesiveness reductions.

CONCLUSION

When casein was partially replaced with native wheat starch in an imitation cheese formulation the textural properties were altered with enhanced hardness and peak stress at intermediate starch levels. The reduction in the cohesiveness of imitation cheese by starch was due to reductions in the protein content and possibly by stress localisation at the starch-protein matrix interface. Results are indicative that the starch functioned as a filler allowing the casein to dominate the textural properties of the imitation cheese products.

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