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Original article

Firmness and melting quality of processed cheese foods with added whey protein concentrates

VK Gupta *, H Reuter

Institut für Verfahrenstechnik der Bundesanstalt für Milchforschung, Kiel, Germany

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Summary — Processed cheese foods were prepared by replacing young Cheddar cheese solids with those of whey protein concentrates (WPC) obtained by ultrafiltration of Tilsit cheese whey. Firmness of processed cheese foods decreased in a highly significant manner ($P < 0.01$), while melting quality increased in a highly significant manner ($P < 0.01$) with the increase in moisture over a wide range. An increased amount of whey protein concentrates and trisodium citrate improved the firmness in a highly significant manner ($P < 0.01$), but had a highly significant deleterious effect ($P < 0.01$) on the melting quality of processed cheese foods.

processed cheese food / firmness / melting quality / whey protein concentrate addition

Résumé — Fermeté et aptitude à la fusion de fromages fondus avec ajout de concentrés de protéines de lactosérum. *Le fromage fondu était préparé en remplaçant la matière sèche du cheddar jeune avec celle de concentrés de protéines de lactosérum obtenus par ultrafiltration de lactosérum de fromage de tilsit. La fermeté du fromage fondu diminuait tandis que l'aptitude à la fusion augmentait avec l'augmentation de l'humidité sur une grande échelle. L'addition d'une quantité croissante de concentrés de protéines de lactosérum et de citrate trisodique augmentait considérablement la fermeté, mais avait un effet néfaste sur l'aptitude à la fusion des fromages fondus.*

fromage fondu / fermeté / aptitude à la fusion / concentré de protéines de lactosérum

* *Present address* : Dairy Technology Division, National Dairy Research Institute, Karnal - 132 001, India.

INTRODUCTION

Processed cheese foods are manufactured by adding a portion of highly varied non-cheese dairy ingredients to the cheese system. However, there is little information available on processed cheese foods with added whey protein concentrates (WPC) (Georgakis, 1975; Kairyukshtene *et al*, 1978; Gupta and Reuter, 1992). The introduction of various ultrafiltration processes over the last 2 decades has increased the production of good quality WPC at a relatively economical cost. WPC is reported to provide excellent nutritional value to those foods in which it is used as an ingredient (Morr, 1979). In a previous paper, we experimented with a few emulsifiers and observed that only trisodium citrate imparted a smooth texture to processed cheese foods prepared with added WPC (Gupta and Reuter, 1992).

In processed cheese foods firmness and melting quality are 2 important parameters for assessment of overall quality. Firmness is the measure of the degree of product hardness, while the term melting quality is used to denote the ease with which the cheese melts when subjected to heat (Weik *et al*, 1958). Among a number of factors, the degree of emulsification affects these parameters to a great extent in processed cheeses (Templeton and Sommer, 1936; Rayan *et al*, 1980).

This paper reports an investigation on the firmness and melting quality of processed cheese foods as influenced by varying amounts of moisture, WPC and trisodium citrate emulsifier.

MATERIALS AND METHODS

Manufacture of WPC

WPC with high ultrafiltration (UF) concentration (total solids (TS) > 25%) and low calcium/TS content (< 0.8%) were prepared by UF of Tilsit cheese whey on a UF module with a hollow fiber membrane (Romicon, polysulfone membrane type pM 50, fiber inside diameter 1.1 mm, effective membrane area 2.5 m^2 and molecular weight cut-off point 50 000). Fresh whey was collected from the Ascheberg cheese factory situated at a distance of 30 km and brought to the Institute within 1 h of its production. The whey was immediately filtered, clarified by centrifugation at 25–28°C and pasteurized at 72°C for 15 s followed by cooling to 45°C. The entire processing took ≈ 1 h. After holding the whey for 30–40 min, ultrafiltration was carried out at 45°C. The inlet and outlet pressures employed were 1.8 and 0.5 kg/cm^2, respectively. After proper concentration was achieved WPC was collected filled in polythene bags and kept at –20°C until used.

Manufacture of processed cheese/ processed cheese foods

Processed cheese/processed cheese foods were prepared and stored according to the procedure described earlier (Gupta and Reuter, 1992).

Moisture analysis

WPC and processed cheese/processed cheese foods were analyzed for moisture content by a gravimetric procedure (Kosikowski, 1982).

Firmness of processed cheese/ processed cheese foods

Sample firmness was measured *via* a SUR penetrometer type PNR 6 (Sommer and Runge KG, Berlin) equipped with a large base-plate fitted with levelling screws and a spirit level, a dial indicator capable of reading up to 1/10th of a mm, coarse and fine adjustments, digital timer for presetting the desired penetration time, electronically-controlled plunger movement and an electronic detector for precise placing of the penetrometer tip on the test material.

Product samples were maintained at 18°C for ≈ 24 h prior to firmness measurement. To take a reading the sample in original pack was placed at the base-plate of the penetrometer. The 47.5-g plunger with an additional weight of 50 g and a penetration cone of 3 g (cat No 18.222) was allowed to penetrate the sample for a present time of 5 s. Penetration depths were recorded in duplicate at 3 different points in each sample. The average of these penetration dephts (in mm) was recorded as the penetration value (inverse firmness).

Melting quality of processed cheese/processed cheese foods

The melting quality of product samples was evaluated essentially according to the method of Arnott *et al* (1957). All samples were maintained at 6°C for ≈ 24 h prior to the test. Cylindrical pieces (diameter and height, 17 mm each) of the samples in triplicate were positioned on a glass tray, accurately measured for height and transferred to an electric oven previously heated to 110–112°C. During the transfer of cheese pieces and the lower temperature of the cheese and the glass tray, the oven temperature dropped to 100–102°C, which was then maintained. The glass tray along with the test pieces was removed from the oven after 15 min and cooled to room temperature. The height of each melted cheese piece was measured separately. The average % decrease in cheese cylinder height due to heat treatment was noted as the melting quality of cheese/cheese food.

Statistical analysis

The data were analyzed by 1-way analysis of variance without interaction according to the procedure of Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Firmness of processed cheese foods

Effect of moisture content

An accelerated and highly significant increase ($P < 0.01$) in penetration value (inverse firmness) was found with the increase in moisture content of processed cheese foods irrespective of the addition of varying amounts of WPC and trisodium citrate emulsifier as illustrated in figures 1 and 2. When the moisture was increased from 42 to 47%, the increase in penetration values amounted to 48.6% and 39.86% with 2.5 and 3.0% trisodium citrate emulsifier respectively in processed cheese foods with 20% of the cheese solids replaced by those of WPC. A relatively lower increase in penetration value with 3% trisodium citrate than with 2.5% trisodium citrate is probably due to the relatively firmer body of processed cheese foods in the former case. Fukui *et al* (1972) reported a rapid decline in hardness of processed cheese with an increase in moisture of 40–50%. Templeton and Sommer (1936) and Olson and Price (1961) also reported decreased firmness of processed cheeses with an increase in moisture in the system.

Varying penetration values of commercial processed cheeses from the NDRI Experimental and Amul Dairy (India) may be largely due to the different raw cheeses used in their manufacture. The excessive hardness of Amul cheese is probably the result of the Cheddar cheese made from buffalo milk and a high level (4%) of trisodium citrate emulsifier used in its formulation.

Effect of WPC content

A highly significant decrease ($P < 0.01$) was observed in the penetration value of processed cheese foods with the increase of WPC solids (fig 1). At a 44.0% moisture level, the penetration values of control and processed cheese foods with 10 and 20% cheese solids replaced by those of WPC were ≈ 17, 16.5 and 12.8 mm, respectively. Presumably, unfolding of the whey protein molecule during heat processeing exposes

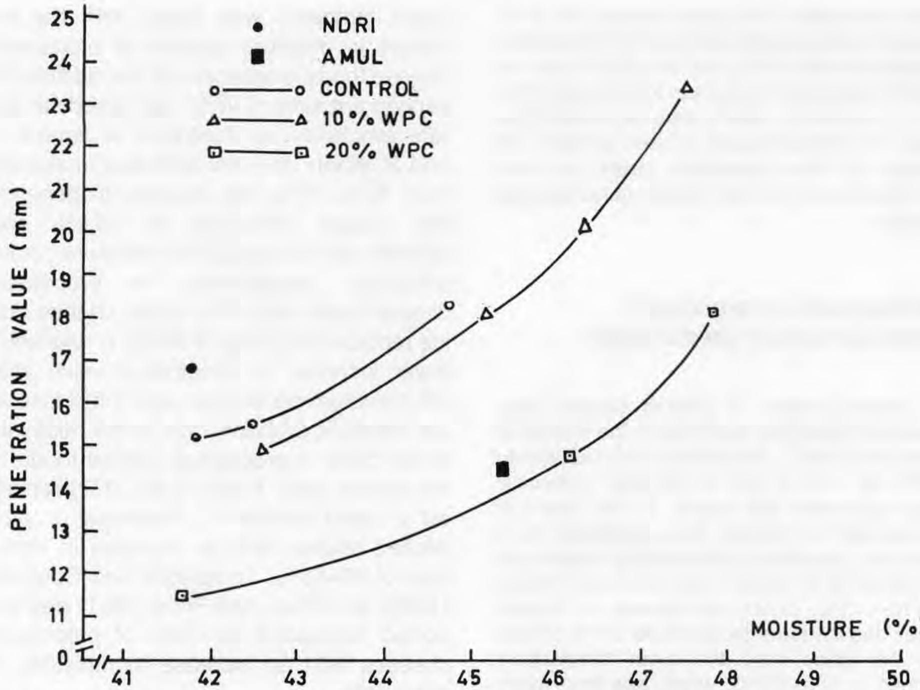

Fig 1. Effect of different levels of WPC and moisture on the penetration value of processed cheese foods (3% trisodium citrate).
Effet de différents taux de concentrés de protéines de lactosérum et d'humidité sur l'inverse de la fermeté (valeur de pénétration) du fromage fondu (3% de citrate trisodique).

hydrophobic groups that can orient at the oil and water interface and improve emulsion stability (Modler, 1985). Shimp (1985) explained that in cheeses with nearly perfect emulsification, the fat globules are very small and are almost lost in the protein network of the water phase. The proteins link up and form a structure of their own. Such cheeses tend to be hard (Templeton and Sommer, 1936; Rayan *et al*, 1980). Further, although native whey proteins have a low texture-forming capa-city (Korolczuk and Mahaut, 1991a), heat denaturation of the whey proteins improves the consistency of cheeses. By the penetrometric method Korolczuk and Mahaut (1991a, b) found that 1% denatured whey proteins have similar effects on consistency to 0.6 to 1.2% casein. It is probable that the lower penetration values of processed cheese foods with the increase in WPC solids is largely due to increased whey proteins that mostly become denatured on subsequent heat-processing at 82°C for 3–5 min. A higher consistency in terms of viscosity, module elasticity or tangential stress with the increase in protein content has been reported (Korolczuk and Mahaut, 1991a,b; Mahaut and Korolczuk, 1992).

Effect of trisodium citrate content

The penetration value of processed cheese foods with 20% cheese solids replaced by those of WPC decreased in a highly significant manner ($P < 0.01$) with an increase in trisodium citrate from 2.0 to 3.0% (fig 2). At 44% moisture content, the penetration values of processed cheese foods with 2.0, 2.5 and 3.0% trisodium citrate were ≈ 14.8, 14.1 and 12.7 mm, respectively. As it is a good emulsifier, trisodium citrate in a larger amount should emulsify processed cheese foods more intensely.

Melting quality of processed cheese foods

Effect of moisture content

The melting quality of processed cheese foods improved in a highly significant manner ($P < 0.01$) with the increase in moisture content, irrespective of the WPC and trisodium citrate levels in the product (figs 3, 4). The softer body of processed cheese foods with a higher moisture content might help in providing higher meltability as flowability improves. Park *et al* (1984) determined that meltability was related to both the heat transfer and thermal phase change characteristics of the solid cheese and to the rheological or flow properties of the melt.

Effect of WPC content

Meltability of processed cheese foods decreased in a highly significant manner ($P < 0.01$) with the addition of an increased amount of WPC (fig 3). At 44% moisture

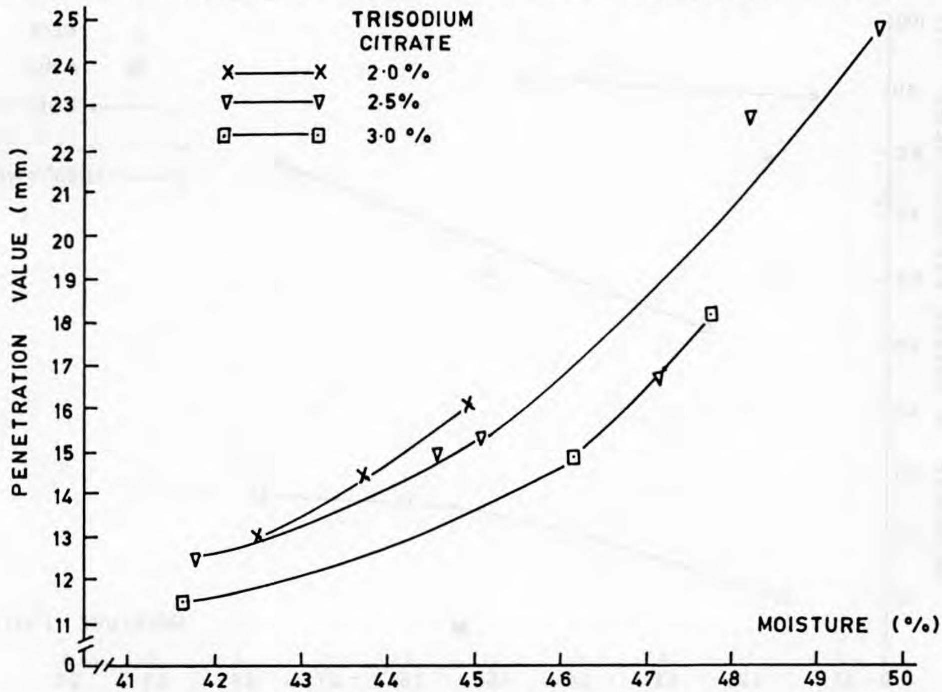

Fig 2. Effect of different levels of trisodium citrate and moisture on the penetration value of processed cheese foods (20% WPC).
Effet de différents taux de citrate trisodique et d'humidité sur l'inverse de la fermeté du fromage fondu (20% de concentrés de protéines de lactosérum).

content the controlled and processed cheese foods with 10 and 20% cheese solids replaced by those of WPC showed ≈ 90.5, 60.5 and 19% decrease in cheese cylinder height. Better emulsification of processed cheese foods with a greater amount of WPC might partly be responsible for the poor melting quality (Templeton and Sommer, 1936; Rayan *et al*, 1980). Also at higher processing temperatures whey proteins denature and bind the free water available, thus solidifying the processed cheese foods (Schulz, 1976) and increase the consistency as already mentioned. Poor flowability of the cheese melt hampers the melting quality (Park *et al*, 1984). Indian commercial processed cheese from NDRI and Amul showed 78.32 and 9.35% decrease in cheese cylinder height, respectively. The very poor melting quality of Amul cheese reflects intense emulsification in the system, which is further corroborated by its excessive hardness. Large variations in melting quality of available commercial processed cheese foods (Gupta *et al*, 1984) suggest that the products are well accepted over a large range of meltability.

Hence, the lower melting quality of processed cheese foods with added WPC should not be considered deleterious.

Effect of trisodium citrate content

An increased amount of trisodium citrate in processed cheese foods with 20% cheese solids replaced by those of WPC de-

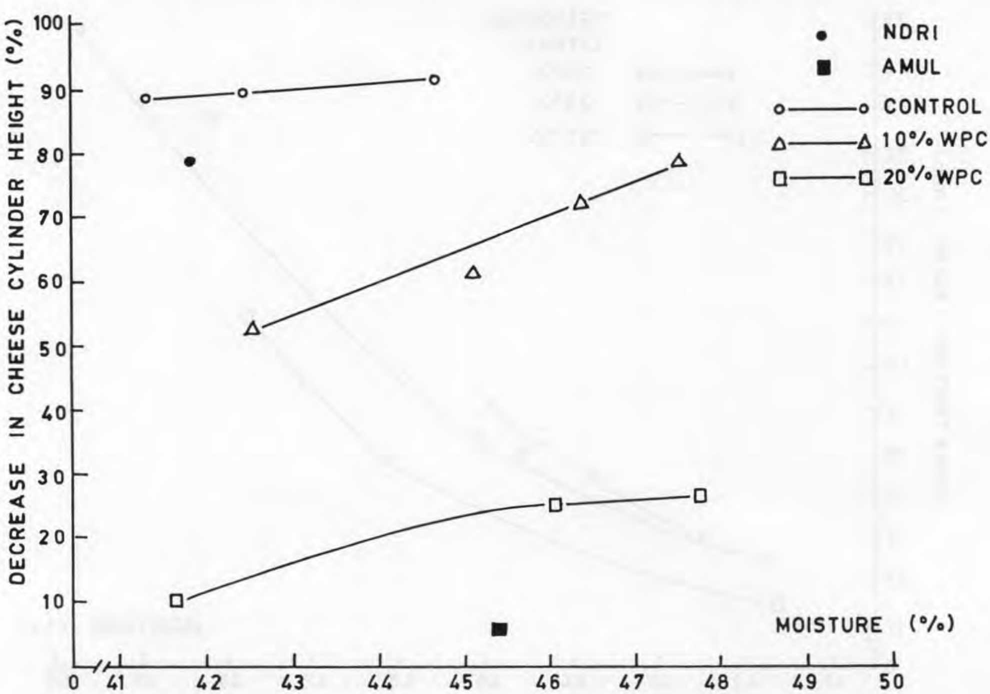

Fig 3. Effect of different levels of WPC and moisture on the melting quality of processed cheese foods (3% trisodium citrate).
Effet de différents taux de concentrés de protéines de lactosérum et d'humidité sur l'aptitude à la fusion du fromage fondu (3% de citrate trisodique).

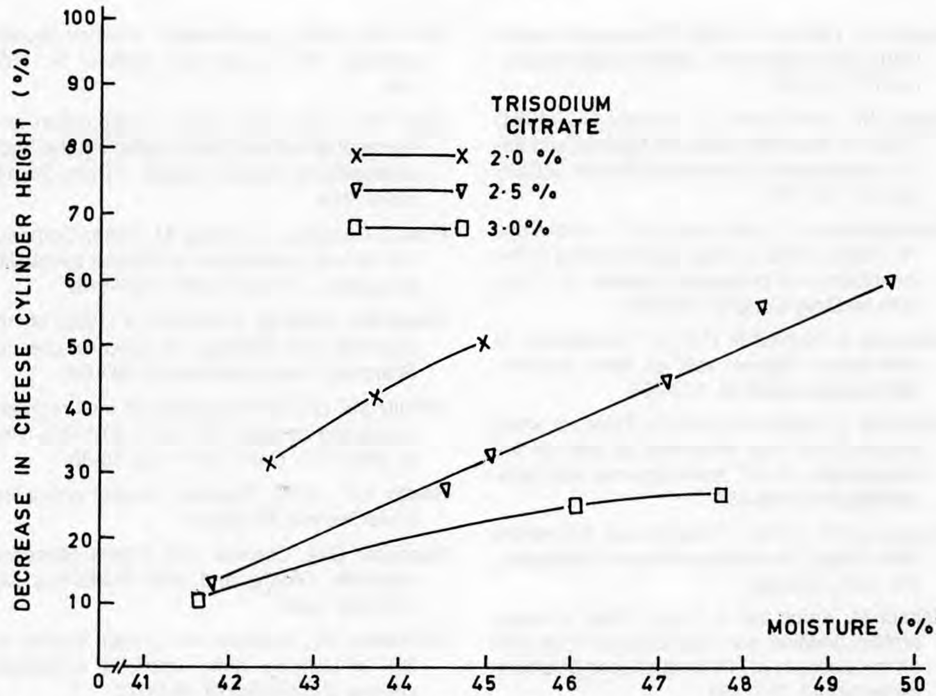

Fig 4. Effect of different levels of trisodium citrate and moisture on the melting quality of processed cheese foods (20% WPC).
Effet de différents taux de citrate trisodique et d'humidité sur l'aptitude à la fusion du fromage fondu (20% de concentrés de protéines de lactosérum).

creased the melting quality in a highly significant manner ($P < 0.01$) (fig 4). At 44% moisture content the product had ≈ 43.5, 24.5 and 18% decrease in cheese cylinder height when 2.0, 2.5 and 3.0% trisodium citrate respectively were added. A higher level of emulsification with a larger amount of trisodium citrate is considered to be the reason for such a trend.

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