DETERMINATION OF PROCESSING CONDITIONS FOR INDUSTRIAL MANUFACTURE OF PRE-DENATURED WPC

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ABSTRACT

The purpose of this study was to establish processing conditions for manufacturing denatured whey protein concentrate (WPC) with the ability to form self-supporting gels upon addition of water with minimal or no heating. Such product could be used as thickening and gelling agents in various food applications.

In the preliminary studies, fresh whey and ultrafiltrate (UF) retentate solutions were heated and analysed using polyacrylamide gel electrophoresis (PAGE). The results showed that heating 1% protein solution of retentate (pH 7.0) at 80°C for 20 min formed the desired "soluble" aggregates. Those aggregates were predominantly formed at lower protein concentration compared to that at higher protein concentration. Much larger aggregates were formed when acid whey was heated under similar conditions.

The same heating conditions (1% retentate solution, pH 7.0, 80°C for 20 min) were used in two different pilot plant trials (Massey University and Anchor Products) to produce denatured WPC powders. The denatured WPC powders were capable of forming viscous solutions or gels at ~ 10% protein concentration upon re-hydration and addition of GDL, $CaCl_2$ or NaCl at ambient temperatures. By contrast, the unheated WPC solutions did not gel under these conditions. The viscosity or gel strength of the denatured WPC solutions increased with protein concentration, incubation time and temperature in the presence of additives.

The heat-denatured WPC powders produced in the pilot plants had desirable functional properties. The high viscosity and the ability to form a gel upon addition of GDL or salts at 5-40°C would enhance their application in food systems, such as in comminuted meat, pressed ham/bacon, mayonnaise and yoghurt products.

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CHAPTER 1
INTRODUCTION

Whey proteins have been widely used to enhance the nutritional value and various functional properties of many food products, for example, infant formula, health foods and drinks, frozen foods. Whey protein concentrate (WPC) is a major whey protein product in dairy industry and has attracted considerable attention as a potential food ingredient during the last two decades. The New Zealand WPC products are sold at premium prices in the international markets, largely because of their highly desired functional properties, such as gelation, emulsification and foaming. However, the functional applications of WPC products are still rather limited compared to the market expectations. Being aware of competitors attempting to replace the present products, much research is needed to enhance the functionality of WPC products using innovative technologies to produce new WPC products with superior functionality.

One of the applications of WPC in food systems is where minimal or no heat treatment is required. In these applications, WPC is pre-denatured or pre-gelatinised and upon re-hydration under appropriate conditions, forms a gel. Researchers in this area have largely been using extrusion technologies, where a combination of heat and shear results in a denaturation and aggregation of whey proteins. Generally a standard WPC powder is used with addition of water to a certain concentration (30 to 39% of total solids) suitable for extrusion conditions. The extrudate is then dried and milled into a powder form. The powder can be used as a stabiliser or thickener in products such as ice cream, yoghurt and other dairy desserts. However, commercial production of WPC using the above approach has a few associated problems. Firstly, a WPC powder is used for the extrusion process, which means that the WPC powder is being further processed by extrusion and milling to get a "secondary" powder - the final product. Secondly, the extrusion process does not usually provide strict control of the rates of denaturation and aggregation that is critical in the manufacture of products with desired functionality. The final denatured or gelatinised product is usually undesirable for some intended applications because of inconsistent particle sizes in the powder. Thirdly, the cost of extrusion is very high and does not justify production in many cases. Therefore, understanding of how to control the degree of thermal

denaturation and aggregation of whey proteins is the key point in developing novel processes for WPC products with desired functionality.

Research on the thermal properties of WPC have showed that the nature of aggregates formed during heat-induced denaturation vary strongly with experimental heating conditions (McSwiney *et al.*, 1994a,b; Gezimati, *et al.*, 1997; Havea, 1998; Havea *et al.*, 1998). For example, large aggregates are formed when whey proteins are heated at low pH, high protein concentration, high ionic strength or at fast heating (high-temperature) rates. More detailed information on the effects of environmental conditions on the size of the aggregates formed is desirable to permit optimisation of heat treatments that ensure the formation of specially sized and shaped aggregates, which give the desired functional characteristics to the WPC products.

Recent studies by Professor Harjinder Singh's research group at Massey University (unpublished) have indicated that the size and type of protein aggregates formed in heated solutions of whey proteins could be manipulated by controlling the ionic strength, heat treatment, pH and protein concentration. The results could be applied to develop a novel process for producing WPC products containing pre-aggregated whey proteins, capable of formation of gels at ambient temperature.

In recent years, a technique, namely cold-set gelation, has been introduced to produce whey protein ingredients that are capable of thickening solutions or creating gels at ambient and even refrigeration temperatures (Barbut & Foegding, 1993; Kawamura *et al.*, 1993; Hongsprabhas & Barbut, 1996; Ju & Kilara, 1998a). In such cold-set gelation of WPC or WPI, preheating is an essential step required for denaturing the whey proteins, followed by incubation with additions of salts, acidulants or enzyme. The preheating is considered to be responsible for providing a significant degree of protein denaturation and aggregation, which have the effect of producing high viscosity and good gelation properties of the final WPC or WPI products. The gel properties depend on preheating conditions as well as factors affecting denaturation and aggregation of whey proteins, and subsequent gel induction methods. However, most studies on the cold-set gelation focused only on WPI and limited to a laboratory level. Knowledge on the effects of preheating on the formation and development of aggregates as well as preheating and incubation conditions on the properties of cold-set gels is still limited. There is no information available on the

production of heat-denatured WPC products and factors affecting cold-set gelation of denatured whey proteins in WPC system.

The purpose of this study was to determine the appropriate processing conditions (protein concentration, heating temperature and time, pH and ionic strength) for commercial production of a heat-denatured WPC product, capable of gel formation upon re-hydration with minimal or no further heat treatment. The processing conditions, determined in bench-scale fundamental work, were tested in pilot plant trials to produce concept of denatured WPC products. In addition, the functional properties of heat-denatured WPC powders produced were investigated.