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**STEADY SHEAR AND OSCILLATORY RHEOLOGICAL
MEASUREMENTS ON SOLUTIONS OF COMMERCIALY
AVAILABLE WHEY PROTEIN CONCENTRATES**

A THESIS PRESENTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
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ABSTRACT

Three commercially available whey protein concentrates (WPC), Alacen 312, Alacen 392, and Alacen 475 were studied by steady shear and oscillatory rheological methods using a Bohlin rheometer at concentrations of 5-40% and temperatures of 5-90°C. The WPC solutions showed Newtonian behaviour up to a concentration of 15%, were slightly shear thinning at 20 and 25%, and exhibited time dependent or thixotropic behaviour at concentrations of 30% and above.

The apparent viscosity of Alacen 475 solutions of concentration less than 10 percent by weight could be calculated by $\eta_s = \eta_w(1+28C)$ where η_s , η_w and C are the viscosity of the solution, the viscosity of water and the fractional weight concentration. For Alacen 475 solutions of 40% concentration the structure broken down by shearing at a high shear rate of 734 s⁻¹ recovered slowly when the shear rate was suddenly dropped to 147 s⁻¹ or zero.

The apparent viscosity of WPC solutions was temperature dependent. It decreased at first as temperature increased until a minimum viscosity was attained and then increased rapidly with further increase in temperature. Temperature also had a marked effect on the time dependency of 20% and 30% WPC solutions - causing time dependent shear thinning at 40 and 50°C and time dependent thickening at 60 and 70°C.

The continuous changes in structure of WPC solutions during heat-induced gelation were followed using oscillatory rheological measurements. The effects of temperature, concentration and heating time on the formation and dynamic rheological properties of WPC gels were determined and are discussed in terms of current theories on the rheology of protein solutions and gels. A gelling model for the gelation of globular protein solutions was proposed to interpret the

development in protein gel structure during the gelling process as reflected by the continuous changes in dynamic rheological properties.

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CHAPTER 1

INTRODUCTION

Whey protein concentrate (WPC) solutions are of commercial interest because of their high nutritional value and excellent functionality in applications such as water binding, gelation, emulsification and foaming. The flow properties of WPC solutions are of practical significance in the manufacture of WPC; for example, rheological properties of dilute solutions are important in the ultrafiltration process and rheological properties of concentrated solutions are important in the evaporation and drying stages. The flow behaviour and gelling properties of WPC solutions are also very important functional properties of the product and may control the texture of commercial protein-containing foods.

Flow properties of WPC solutions are governed by molecular composition, size, shape, flexibility and degree of hydration, and by intermolecular interactions (Tung, 1978; Kinsella, 1979). These in turn are influenced by environmental conditions such as temperature, concentration, pH, ionic strength, shear rate, shear time and previous processing or treatment history (Tung, 1978). The formation and rheological properties of WPC gels may depend on composition, temperature, concentration, pH, ionic strength and the time of heating since whey protein gelation characteristics are drastically altered by these factors (Hermansson, 1979; Hillier et al., 1980; Schmidt and Morris, 1984). Information on the relationships between environmental conditions and rheological properties of WPC may be used to modify rheological behaviour of protein-containing foods so as to impart desired product textures (Tung, 1978).

A number of workers have reported steady shear and oscillatory rheological data for whey protein systems (McDonough et al., 1974; Hermansson, 1975, 1979; Pradipasena and Rha, 1977a, 1977b; Richardson and Ross-Murphy, 1981; Beveridge et al., 1984; Paulsson et al., 1986, 1989). However, more work is needed to investigate the flow properties of WPC solutions, the gelation mechanism and the rheological properties of whey protein gels.