**Tribo-rheological characteristics and physico-chemical properties of calcium-induced skim milk gels**

Olivares ML (1), Costabel LM (2), Zorrilla SE (1), de Vicente J (3)

(1) Instituto de Desarrollo Tecnológico para la Industria Química (INTEC) Universidad Nacional del Litoral – CONICET. Güemes 3450, S3000GLN, Santa Fe, Argentina.

(2) Instituto de Investigación de la Cadena Láctea (INTA - CONICET), Estación Experimental Agropecuaria Rafaela, Ruta 34 Km 227 - CC 22 - (2300) Rafaela, Santa Fe, Argentina.

(3) F2N2Lab, Magnetic Soft Matter Group and Excellence Research Unit ‘Modeling Nature’ (MNat), Department of Applied Physics, Faculty of Sciences, University of Granada, 18071, Granada, Spain

E-mail address: olivares@santafe-conicet.gov.ar

ABSTRACT

Milk gels are the base of different solid and semi-solid dairy foods. The gelation by heat treatment of calcium fortified milk leads to milk coagulation and to formation of the so called “calcium-induced skim milk gels” or “calcium milk coagulum”. In this work, the tribo-rheological and physico-chemical characteristics of calcium-induced skim milk gels were studied. Milk dispersions were prepared with different concentrations of skim milk powder (SM) (10, 20 and 30% w/w) and stored overnight at 25 °C. The next day, the samples were preheated at 90 °C for 10 min; this treatment increases conveniently the gel strength. After that, calcium chloride was added to milk samples (30, 60 and 90 mmol kg-1). Then, the pH was readjusted to the natural pH of milk of 6.66 and samples were again stored overnight al 25ºC. To induce gelation, skim milk suspensions were heated at 70 °C for 10 min. The gelation process was analyzed by rheometry (monitoring the viscoelastic moduli) throughout temperature (from 25 °C to 80 °C) and time (at 70 °C for 590 s, at 0.1% shear strain and 1 Hz frequency) sweeps. Two characteristic temperatures were determined from temperature sweeps, the initial structuring temperature (*IST*) and the critical structuring temperature(*CST*). For tribometric measurements, compliant elastomeric surfaces were used to mimic the mechanical properties of the mouth. Friction measurements were performed in a non-conforming ball-on-three-plates contact. The normal force was maintained at 1 N and the friction coefficient was measured for increasing sliding speeds from 0.0447 to 940 mm s-1. Syneresis was determined as the percentage (w/w) of whey expelled from the gel after centrifugation at 1100×g for 10 min at 10 °C. Then, the pellet was recentrifuged at 13500×g for 30 min at 10 °C (2nd centrifugation), then drained (10 min), weighed, frozen (at -20 °C) and lyophilized. The water holding capacity of the gel was calculated as the percentage (w/w) of pellet obtained after the 2nd centrifugation in the gel sample. Protein hydration was calculated as the ratio of grams of water in the pellet after 2nd centrifugation to grams of solids in the pellet after lyophilization. The results obtained by rheometry showed that gelation at temperatures lower than 70 °C was observed in samples with 10% w/w of SM and 30 mmol kg-1 of calcium chloride or similar ratio SM/calcium concentrations, when the amount of calcium remaining in the serum phase is enough to induce gel formation. Structuring parameters confirmed these results. From time sweeps, it was observed that the kinetics of gelation depended on the composition. Gels obtained using higher SM concentrations (20 and 30% w/w) showed better physical properties (low syneresis and high water holding capacity). Tribometric assays showed that higher SM and calcium concentrations improved the lubrication properties. Friction factors at 10 mm s−1 (typical speed in oral processing) decreased as the SM concentration increased. It is concluded that calcium-induced skim milk gels with different microstructure can be obtained by varying the concentration of skim milk powder and calcium salt added.

Keywords: calcium-induced milk gels, rheology, tribology, gel properties.