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Evaluation of the synergistic effects of milk proteins in a rapid viscosity analyzer

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ABSTRACT

Protein systems (PS) are routinely used by companies from Brazil and around the globe to improve the texture, yield, and palatability of processed foods. Understanding the synergistic behavior among the different protein structures of these systems during thermal treatment under the influence of pH can help to better define optimum conditions for products and processes. The interpretation of the reactions and interactions that occur simultaneously among the protein constituents of these systems as dispersions during thermal processing is still a major challenge. Here, using a rapid viscosity analyzer, we observed the rheological changes in the startup viscosities of 5 PS obtained by combining varying proportions of milk protein concentrate and whey protein concentrate under different conditions of pH (5.0, 6.5, and 7.0) and heat processing (85°C/15 min and 95°C/5 min). The solutions were standardized to 25% of total solids and 17% of protein. Ten analytical parameters were used to characterize each of the startup-viscosity ramps for 35 experiments conducted in a 2 × 3 × 5 mixed planning matrix, using principal component analysis to interpret behavioral similarities. The study showed the clear influence of pH 5.5 in the elevation of the initial temperature of the PS startup viscosity by at least 5°C, as well as the effect of different milk protein concentrate:whey protein concentrate ratios above 15:85 at pH 7.0 on the viscographic profile curves. These results suggested that the primary agent driving the changes was the synergism among the reactions and interactions of casein with whey proteins during processing. This study reinforces the importance of the rapid viscosity analyzer as an analytical tool for the simulation of industrial processes involving PS, and the use of the startup viscosity ramp as a means of interpreting the interactions of system components with respect to changes related to the treatment temperature.
Key words: whey protein concentrate, milk protein concentrate, rapid viscosity analyzer, principal component analysis

INTRODUCTION

Milk proteins are important for human nutrition. They are responsible for a wide variety of functional dynamic properties that are widely exploited by the food industry with the objective of improving the texture, yield, and palatability of processed products. Different methods for the industrial-scale production of milk proteins have been developed in recent years. As a result, a wide variety of specifically designed products has been manufactured, with highly concentrated protein products as the most important from the industrial point of view. These include CN, caseinate, whey protein concentrate (**WPC**), whey protein isolate, milk protein concentrate (**MPC**), and milk protein isolate. The processes used in the manufacture of these products tend to modify the native structure of the milk proteins, which may lead to new protein-protein interactions and therefore have an effect on their technological functionality (Singh, 2009).

Milk proteins are commonly added as ingredients in the manufacture of formulated milk products such as processed cheeses to increase the concentration of protein, the yield of the final product, or both. Milk proteins have also been added to improve the textural characteristics of different types of fermented milk. The use of milk proteins in nutritional drinks is growing; for example, in such applications, MPC contributes to the protein fraction of the milk (i.e., CN and whey proteins) in the same proportion as the original milk, but at a much lower lactose concentration (Baldwin

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and Pearce, 2005). Whey protein concentrate has applications in meat products, beverages, baked goods, and children's products (Kinsella, 1984; De Wit, 1989). The main functional characteristics of these products are related to the whey proteins and include their strong interactions with water, as well as emulsification, aeration, and gelling capabilities. These features depend not only on the protein composition but also on the various processes to which they are subjected during manufacturing (De Wit et al., 1986). The process of converting milk or liquid whey into powder alters the nature and behavior of the milk components. Factors affecting the water absorption ability of milk proteins include composition; protein conformation and structure; surface charge and polarity; presence of carbohydrates, lipids, and salts; pH; ionic strength; temperature; degree of denaturation and aggregation; and disulfide bond formation (Damodaran, 1996; Garcia et al., 1997; Fox and McSweeney, 2003).

Understanding the synergistic interactions and evaluating the effects of milk proteins as industrial ingredients are still required to better develop suitable uses and achieve each desired technological profile in different lines of processing (e.g., processed cheese). Understanding the interactions of milk proteins will enable the food industry to obtain better cost:benefit relationships by using the most suitable protein for the desired characteristics in the final product. In this way, products can be brought to market using different protein powder systems (**PS**) as technological ingredients that better use the synergistic capacities of their components. In view of these interactions, the pH of the medium is presented as a major factor influencing the intensity and type of reactions that occur. Denaturation and protein interactions occur in different forms and intensities when the pH of the medium varies (Anema, 2008). The unfolding of the milk protein fractions can affect the rheological properties of the food system and have a positive or negative effect on consumer acceptance of a dairy product.

The rapid viscosity analyzer (**RVA**) is a rotational viscometer with a computer interface that is capable of continuously measuring the viscosity of a sample under controlled temperature conditions (Booth and Bason, 2007). The instrument is commonly used to evaluate the intrinsic viscosity properties of starches, cereals, pastas, and other foods. The ability to suspend the RVA sample in a solvent, maintain the suspension throughout the test, and apply appropriate agitation can be configured as an industrial-like process, which lends it great value in many research processes. It is particularly useful for materials that require complex tests that use variable temperature and stirring conditions, allowing the material to demonstrate its properties with respect to viscosity. This instrument has already been used in product development, as well as studies of the effects of heat treatment on milk proteins and the way proteins interact with other ingredients (Metzger et al., 2002; Kapoor et al., 2004; Prow, 2004; Kapoor and Metzger, 2005; Prow and Metzger, 2005; Onwulata et al., 2013).

We sought to characterize the viscosity changes that occur during the heating of dispersions containing various ratios of WPC and MPC under different pH and temperature conditions. The synergistic reactions and interactions from the thermal denaturation of the proteins were evaluated by interpreting 10 direct and derived parameters related to the variation in the startup viscosity during the beginning of processing. Thus, we aimed to characterize the influence of varying CN and whey protein proportions in PS powder mixtures containing WPC and MPC, especially the effects on the physical and rheological properties of these mixtures for application as dairy ingredients under different pH conditions when processing is simulated in a RVA.

MATERIALS AND METHODS

Samples and Preparation of Experiments

Commercial samples of WPC and MPC containing 70% of protein on a dry basis were selected for the RVA experiments, due to our interest in their use as dairy ingredients. The products, which are not domestically produced, were imported, acquired, and kindly provided by Tate & Lyle Gemacom Tech S/A. The MPC was chosen because of its protein composition, which is equivalent to the original milk and maintains a ratio of caseins and whey proteins of approximately 80:20 (Supplemental Figures S1 and S2; http://dx.doi.org/10.3168/jds.2015-9300). The WPC was selected because it uniquely contributes whey proteins (Supplemental Figure S3; http://dx.doi.org/10.3168/jds.2015-9300).

The total fat, moisture, total protein, ash, and pH were analyzed according to the components of most interest to the study, employing methods described by AOAC International (2000).

To evaluate the effects of different MPC:WPC ratios on the rheological behavior during thermal processing, 5 PS powder samples were prepared by dry mixing according to the proportions shown in Table 1. The MPC:WPC ratios ranged from 0:100 to 30:70 to evaluate the influence of the gradual change in the ratio of caseins and whey proteins (~80:20) to an approximate reversal of the original proportion in milk in sample