Characterizing the rheological behavior of sodium caseinate and casein micelles in dense suspensions

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Casein is the most abundant protein in milk and plays a key role in both the nutritional and functional properties of a wide variety of milk products. By understanding the rheological behavior of casein micelles, the most common form of casein found naturally in milk and sodium caseinate, a common isolated form of casein used as an ingredient, current products can be more precisely manipulated to improve or change the texture and new, innovative products can be more easily developed. Changes in rheological behavior of casein micelles and sodium casein due to changes in pH, temperature and concentration were explored in order to better understand the role of these variable and how they can be used to manipulate the rheological properties of casein suspensions. Additionally, the relationship between charge density (α) and pH and how changes in temperature and concentration can affect each of them were explored.

Previous work had shown that pH does not provide an adequate representation of a dynamic system, such as casein suspensions, when other parameters such as temperature or concentration are also varied. In such systems, the pH is affected by these other parameters and changes in the structure or behavior of the system are more appropriately defined by charge density (α), which is unchanged by these parameters. A series of experiments was done to establish the relationship between pH and charge density for both sodium caseinate and micellar casein as well as to demonstrate the impact of concentration and temperature on the pH for sodium caseinate and casein micelles in order to further justify the use of α as a key parameter. With this relationship established and the use of α as a key parameter justified, it was decided with our partners at FrieslandCampina to set the $\Delta\alpha=0$ reference point as the unaltered charge density of the powder for all the rheological measurements. The results of our rheological testing yielded some interesting results. Results for sodium casein were as previously reported by other authors, but our findings for casein micelles contained some previously undocumented findings. When looking at the changes in the zero shear viscosity as a function of $\Delta\alpha$, it was observed that there were two regions in which the behavior changed in response to changes in $\Delta\alpha$ above and below a concentration of 140g/l. These changes are likely due to the counteracting attractive and repulsive forces within the micelles as well as the forced close packing due to the concentration. This information could be used to better control the texture of dense dairy products like condensed milk or dulce de leche. The formation of a gel was also observed for suspensions with a concentration >100g/L and a $\Delta\alpha=-5$ (pH$\cong$8) with the gel strength being partially dependent of the concentration. This alkaline induced gelation has not been previously reported and could potentially have industrial applications. These gels could be used to create new, innovative dairy products with textures and flavors yet to be experienced!