FUNDAMENTALS OF MODEL PROTEIN GEL DISSOLUTION: THE PATH TO ELUCIDATING INDUSTRIAL DAIRY CLEANING

R. Mercadé-Prieto[1,2,3,*], S. Gunasekaran[2], W.R. Paterson[1], D.I. Wilson[1],

[1] *Department of Chemical Engineering & Biotechnology, New Museums Site, Pembroke Street, Cambridge, CB2 3RA, UK*

[2] *Biological Systems Engineering, University of Wisconsin-Madison, 460 Henry Mall, Madison, WI 53706, USA*

[3] *School of Chemical Engineering, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK*

ABSTRACT

The complexity of heat-induced dairy fouling has historically inhibited industry and academia from understanding the fundamentals of cleaning. Cleaning is performed daily in many processing plants around the world, successfully, yet relatively little detail of the underlying science are known. For example, which, if any, chemical reactions are important, and are they always the same for different kind of fouling deposits? Which mass transfer step is the slower one, and is it more rate-limiting than the chemical reactions? and under which cleaning conditions, *etc*. The abundance of questions and the shortage of answers has prompted fundamental research on simpler systems than industrial dairy foulants. In this work, gels formed from β-lactoglobulin (βLg) are used to study whey protein-rich (Burton Type A) fouling are this material is found in large amounts in Type A deposits.

One of the basic questions that has been addressed using this model system is when and why a gel starts to dissolve under alkaline conditions. Chemical dissolution – to be distinguished from mechanical erosion – seems only to occur when two criteria are satisfied. The first condition is that the pH of the solution has to be higher than a threshold value, found to lie at ~11.6 for typical βLg gels. This pH threshold is related to the breakdown reactions that destroy large protein aggregates. The key breakdown reactions depend on the nature of the gels (*i.e.,* covalent and/or non-covalent crosslinking), which depends on the gelation conditions (*e.g.,* gelation temperature and/or time).

The second condition for dissolution is thought to involve the following: the free volume of the gel in contact with the alkaline solution has to be greater than a critical value. High free volumes are commonly achieved by allowing the gel to swell in the presence of alkali. Swelling can be diminished greatly by increasing the ionic strength of the solution, *e.g.,* by adding salts or excess alkali, which in turn reduces the dissolution rate significantly. High concentrations of salts, however, can induce structural changes in protein gels and aggregates, which makes it difficult to prove the existence of a free volume threshold. Evidence supporting this hypothesis has been obtained by studying an apparently unrelated phenomenon, namely the cold gelation of whey proteins under alkaline pHs. This gelation process presents some unique characteristics, the most relevant to dissolution being that it quickly forms gel-like structures which are subsequently destroyed over longer time scales. A recent rheological study of this gelation/degelation process at pHs between 11-13 provides novel data to elucidate the behavior of whey protein aggregates at these pHs. Over a narrow protein concentration range, of only ~1.2 wt%, the system changes from gel-like to liquid. The observed concentration range agrees with that observed in dissolution experiments.

New evidence shows that there are many similarities between the dissolution of pure βLg gels and that of more complex whey mixture gels, such as the existence of a double threshold, although the actual values can differ significantly. We will discuss how understanding a simple model protein gel can help elucidate what happens in more elaborate systems, and by identifying key areas where further research is needed.