Electronic Supplement for Weir et al., Simplicity in Complexity …

Effect of oil content on caramel elasticity

Caramels with a continuous phase composition of 7%P 30%W 63%S and different oil content were made in 5ml glass vials at 90 °C and cooked in an oil bath for 2 hours, as per the method described in section 5.4 of the paper. We were unable to prepare caramel at 0% fat due to excessive frothing. The G' at 1 Hz of other caramels with variable oil content is shown in Fig. S1. It is clear that increasing the oil content at invariant continuous phase composition leads to higher G' and stronger caramels. Thus, the fat droplets act as an 'active fillers' that are chemically bonded to the surrounding continuous-phase matrix.[1]

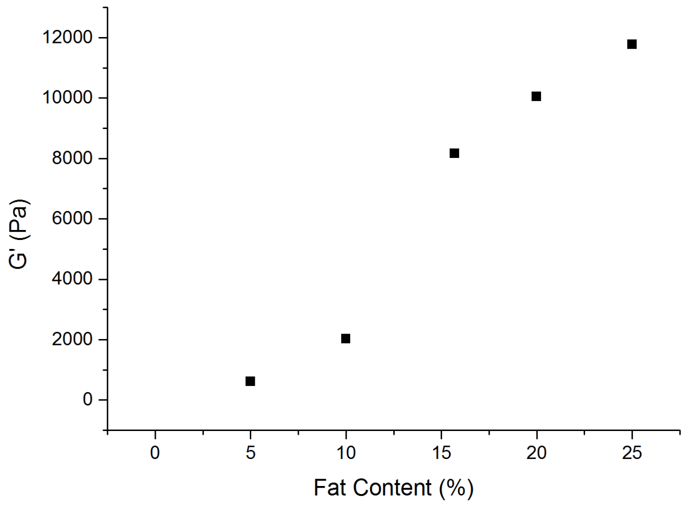

Figure S1 G' at 1 Hz of caramels with constant continuous phase P:W:S = 7:30:63 and different oil contents.

How to do rheological superposition

Rheological superposition involves collecting spectra, typically $G'(\omega)$ and $G''(\omega)$, under different conditions (temperature, composition, curing time, etc.) over a fixed frequency window, and then 'gluing' shifted copies of these spectra together to form master curves. We show schematically in Fig. S2 the simplest case where only shifts along the frequency axis is needed, applied to three spectra. The details are described in the figure caption. In general, as in the tCS and tQS performed in the main text, shifts along the modulus axis are also required.

Time-composition superposition in detail

Figure 5 of the main paper shows two sets of master curves obtained from two sequences of samples sharing a single common reference sample (green point 5%P, 20%W, 75%S). Figure S3 shows in detail

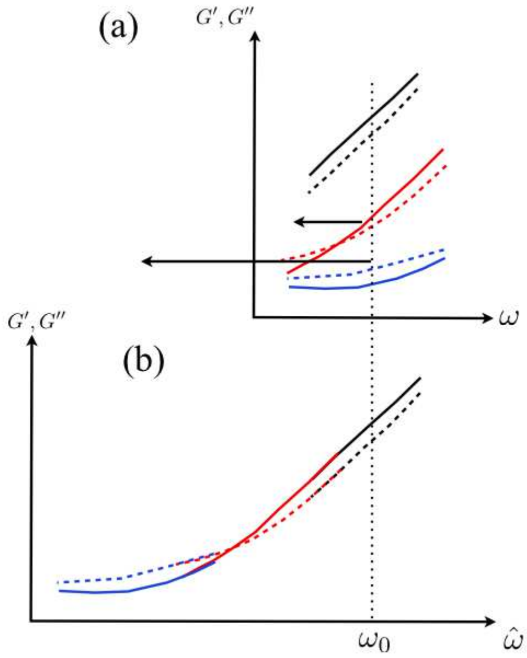

Figure S2 How to build a master curve. (a) G' and G'' as a function of frequency measured under three different conditions (temperature in tTS, composition in tCS) over a limited frequency window. To obtain the rheology of, say, the sample giving the black curves, one shifts the red and blue curves as shown to obtain a master curve. (b) The master curve for the sample giving the black curves over many orders of frequency. Note that the scaled frequency axis overlaps with the original frequency scale for the black curves. Master curves for the other two samples can be obtained similarly, and will have an identical shape, albeit with different frequency scales.

how we constructed the master curves for the green sample by shifting data taken for samples along the constant-water-content sequence, resulting in the black pair of curves plotted in Fig. 5.

This overlaying of master curves can be generalised over any collection of caramels that share a common point. Fig. S4 shows seven caramels, three sets that share a common caramel. These three sets can be superposed and then overlaid Fig. S4 (g). This supports the universality of the underlying master curve of caramel. Indeed this universality can be used to improve the superposition of caramels where data does not exist and fitting becomes harder e.g. Fig. S4 (f).

References

1 J. Chen, E. Dickinson, H. S. Lee and W. P. Lee, *Food Colloids: Fundamentals of formulation*, Royal Society of Chemistry, Cambridge, 2001.

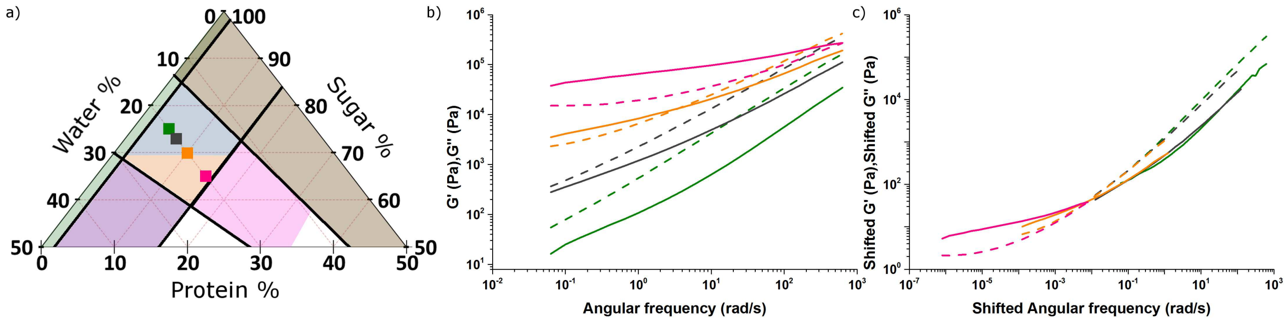

Figure S3 (a) The 15.7% oil 'cut' in our tetrahedral compositional space, showing the four samples used for tCS at 20%W content. (b) The $G'(\omega)$ and $G''(\omega)$ curves for the 4 samples shown in part (a), with matching colour scheme. (c) Time-composition superposition analysis of the rheology of the green reference sample. We shifted all of the other curves in part (b) relative to the green curves to give the master curves for the reference caramel over 10 decades in time and 6 decades in moduli. Solid lines: G' Dashed lines G''. Compositions are Red: 5%P, 20%W, 75%S; Orange: 7%P, 20%W, 73%S; Green:10%P, 20%W, 70%S; Blue: 15%P, 20%W, 65%S .

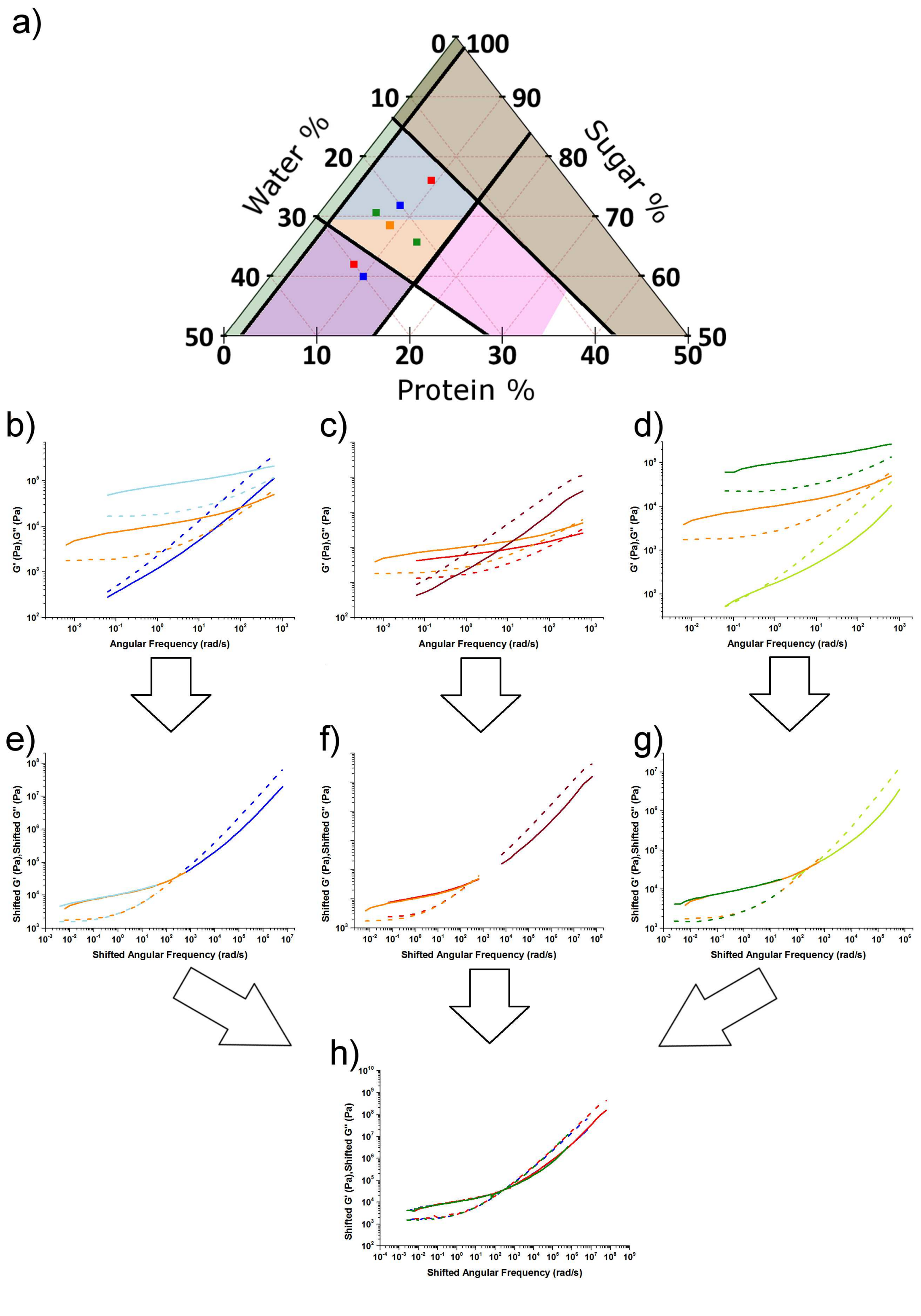

Figure S4 (a) The 15.7% oil cut of tetrahedral composition space, showing all the compositions used in tCS analysis in the other parts of this figure.(b-d) the rheology of the caramels as shown in (a), with colour scheme matching samples to rheological spectra. Orange point/curves are for the common, reference caramel. (e-g) master curves using the orange data as the reference set with respect to which we shift the others data sets. (h) overlay of the master curves obtained in (e-g). Solid lines: G' Dashed lines G''. Compositions are Orange: 8.33%P, 23.33%W, 68.33%S; Light Blue:10%P, 30%W, 60%S; Dark Blue: 7%P, 20%W, 73%S; Burgundy: 9.11%P, 15%W, 75.89%S; Red: 7%P, 30%W, 63%S; Light Green: 5%P, 24.1%W, 70.9%S; Dark Green: 15%P, 21.57%W, 63.43%S.

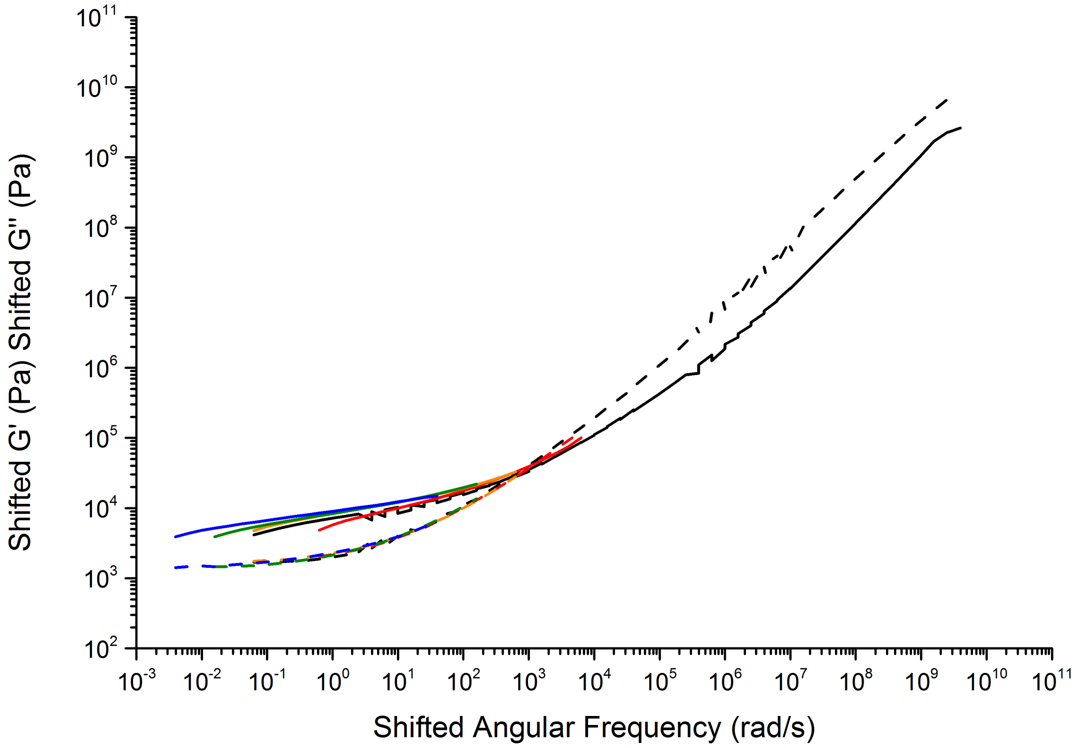

Figure S5 An overlay of the master curves produced via tQS and tCS from Fig 7 in the paper. TQS is produced as Fig 7; Composition 7%P, 30%W, 63%S. Time cooked: purple $0\,\mathrm{h}$, red $1\,\mathrm{h}$, orange $2\,\mathrm{h}$, green $3\,\mathrm{h}$, blue $7\,\mathrm{h}$. The black curve is the master curve of the following compositions, 7%P, 30%W, 63%S, 7%P, 25%W, 68%S, 7%P, 20%W, 73%S, 7%P, 15%W, 78%S , shifted relative to the 7%P, 30%W, 63%S composition. Solid lines: G', Dashed lines: G''.