ABSTRACT

Many foodstuffs are concentrated dispersions of solid particles in a liquid medium (e.g. tomato ketchup), or liquid droplets in a liquid medium (e.g. mayonnaise). The manufacture of these products has to be very reproducible in order to satisfy customer needs. The rheological properties of these materials give an indication of this reproducibility and can be correlated with, for example, storage stability, ease of pumping and sensory perception (i.e. mouthfeel). Modern rheometers offer an opportunity to very precisely characterise the rheological properties of foodstuffs, and identify rheological differences that may not be apparent using conventional rotational viscometers.
Introduction

Mayonnaise is an emulsion of vegetable oil in water, where the oil droplets are stabilised by lipoprotein from egg yolk. A typical formulation for a mayonnaise is (weight %): egg yolk 6.00, water 12.0, acetic acid 0.20, sugar 1.55, salt 0.25 and oil 80.0. The emulsion is produced by slowly adding the oil and the water plus acetic acid (vinegar) to the egg yolks. Low calorie mayonnaise allows for an increase in the water content and since the egg yolk content remains constant, the emulsion is prevented from destabilising by the addition of artificial dispersants. The formulator has the problem of producing a low calorie mayonnaise which is not, perceptively, different in its properties from ‘normal’ mayonnaise.

Rheological Analysis

The experiments reported were performed on a Bohlin Controlled Stress rheometer at 10 deg.C.

Stress sweep analysis

In this experiment the material is subjected to a sinusoidal stress and the strain response (also sinusoidal) is measured. At low stresses the input signal is directly proportional to the output signal and the material is behaving in a LINEAR VISCOELASTIC (LVE) manner. As the stress is increased the material will become non-linear, and the extent of this linear region gives an indication of the type of structure in the material. Coagulated and strongly flocculated dispersions have relatively short linear regions; while weakly flocculated and stable dispersions have longer linear regions. Figure 1 (a) shows a stress sweep analysis on samples of a leading brand of mayonnaise - sample A is the ‘ordinary’ mayonnaise, while sample B is the ‘light (low calorie)’ mayonnaise. Sample B has a slightly longer LVE than sample A, which is probably to be expected since it contains more water and, in order to maintain stability of the emulsion, also contains added artificial dispersants/stabilisers. The onset of non-linearity is thought to result from coalescence of the emulsion droplets, or emulsion destabilisation. Figure 1 (b) shows similar curves for ‘leading brand’ (sample B) and ‘supermarket brand’ (sample A) low calorie mayonnaise. Since G* (sample A) is higher than G* (sample B) this indicates that the latter is slightly more stable than the former. This hypothesis is confirmed by the dramatic loss of linearity shown by sample A at higher stresses, which again indicates a lower degree of stability. This may manifest itself in (a) phase separation during storage (which would result in aesthetically displeasing droplets of water appearing in the jar), and (b) destabilisation of the mayonnaise during shear.

Yield stress analysis

Figure 2 shows curves produced using the unique yield stress analysis on the mayonnaise samples. In this test the stress is gradually increased over a reasonably long time scale. The viscosity is calculated assuming the relationship, viscosity = shear stress/shear rate. Materials that have structure can absorb the stress being applied until the structure starts to break down. This results in an increase in the viscosity as the structure is maintained, followed by a rapid decrease in the viscosity as the structure collapses. The stress at which this occurs is the so-called yield stress. Figure 2(a) shows a comparison of the ‘leading brand’ samples, where sample A is the ‘ordinary’ mayonnaise. It can be predicted from the curves that A would be easier to pump than sample B. However, in both samples, onset of flow of the mayonnaise causes a dramatic decrease in the viscosity, which indicates a uniformity of the microstructure. In comparison, the curves for the ‘supermarket brand’ sample behaves quite differently (Figure 2(b)). This would probably result in non-uniform flow during pumping, and probably indicates non-uniformity in the emulsion, caused by polydispersed emulsion droplets. The non-uniform flow of the mayonnaise is important since it needs to flow through pipes as a plug. If it does not have this flow profile then there is a possibility that some of the mayonnaise will remain resident in the pipeline for long periods of time.

These experiments indicate that it is possible to obtain performance-related rheological data on the materials, and also, by performing the correct rheological experiments, information on the microstructure of the materials.

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The Rheological Properties of Mayonnaise