Solution to the whipped egg white challenge

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Solution

Since 2001 children in French primary schools have learnt how to make litres of whipped egg white from a single egg, one culinary hand whisk... and their brains [1]. Obviously, the readers of this journal cannot make less! Such a large volume of foam is not too surprising if one considers the content of the whipped egg whites. In short, they are made of water, proteins and air. If the volume stops increasing after some whipping, this means that 'something' is missing. Since the air is always in excess, one has to conclude that either water or proteins are limiting the volume. In schools, children are invited to conduct the easiest experiments first, i.e. adding water. Increase of the whipped egg white volume can be readily observed, which demonstrates that the limiting factor was initially water and not proteins. Clearly, after the addition of a large amount of water, proteins can become the limiting factor.

Such 'light' egg white foam is less stable than ordinary whipped egg white because the stability of foams arises from both the interfacial forces (increasing with smaller air bubbles) and the viscosity of the liquid phase (less draining). Adding sugar, for example, can increase the viscosity of the aqueous

solution while reducing the size of the air bubbles, thereby enhancing the stability of the whipped egg white foam.

How much foam can we get? Let us perform a sketch calculation where only the orders of magnitude will be considered. The useful data for the calculation are the mass of an egg white (approximately 30 g with 10 % of the mass from proteins) and the molecular mass of egg white proteins, with a mean value of approximately 50 kDa [2]. This leads to approximately 400 amino acid residues per protein if a molecular mass of 120 Da is assumed for the average amino acid. Chemical bonds have a length of approximately 1.5×10^{-10} m and unfolded proteins can be viewed as 'rods' of length 3×10^{-7} m (five covalent bonds per amino acid) and width 10^{-9} m (five covalent bonds).

During the whipping process, air enters the solution to form bubbles and proteins stabilize the trapped air bubbles owing to their mild soaplike properties. Each protein would cover an area of 10^{-17} m² and the total area covered by all proteins is of the order of 100 m². Assuming we have bubbles of radius 10^{-4} m with a surface area of 10^{-7} m², the proteins could cover the surface of one billion (10^9) such bubbles. With close packing of bubbles in the egg white, the total volume of such protein-glazed air bubbles should be of the order of 15 L. It is clear from here that water is the limiting factor for the volume of the whipped egg white. With chefs of Montreal (Canada), we obtained some 25 L of ultralight whipped egg whites this way from a single egg. Can you match this record?

This article is the solution to the Analytical Challenge to be found at <http://dx.doi.org/10.1007/s00216-010-3767-8>

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