Effect of whipped egg whites on soufflé volume

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THE EFFECT OF WHIPPING EGG WHITES OVER ITS LEAVENING CAPACITY IN SOUFFLES

INTRODUCTION

We may all agree with the grand statement Nicholas Kurti said over his presentation “ The Physicist in the Kitchen“:

“ It is a sad reflection on our civilization that while we can and do measure the temperature in the atmosphere of Venus, we do not know what goes on inside our soufflés” (Barham, 2001).

Soufflés, sponge cakes, meringues, and bread are some examples of baked foams. Foams “ allow [the diner] a better perception of the texture of a dense mass in the mouth and enhance the perception of odors” (This, 2009). Understanding how foams work under dynamic conditions is crucial for any chef to achieve a better end product and give the consumer a greater enjoyment.

Egg whites are commonly used as an aerating agent because of its foaming properties. Their foam assists in the leavening process, although the actual leavening agent is air. Foam simply allows air to be incorporated into baked goods (Figoni, 2011). The end goal is to capture and retain as much air inside the soufflé to achieve an airy, light and delicate end product.

Foams are a colloidal system of a gas dispersed into a liquid continuous phase (Pawel et al, 2014). In the case of soufflés, the continuous phase is water with egg white proteins, lipids and carbohydrates dissolved in it—which will strengthen the dispersing medium—, and the dispersed phase is air (McWilliams, 2012). Oxygen, nitrogen, carbon dioxide, and some of the other components of air are mostly hydrophobic. In other words, air can dissolve in water but only in tiny amounts (MyHrvold, 2011).

The mechanical action of beating pushes air bubbles into the continuous phase of the forming foam while the protein of the egg whites unfold to form a monolayer film at the surface of the air pushed inside. This stage of foam forming is called absorption (Cherry, 1981). The hydrophilic part of the egg white proteins will be attracted and bound with water and any hydrophilic component present in the solution, while the hydrophobic end will be oriented inwards surrounding the gas phase and stabilizing the bubble (MyHrvold, 2011).

When talking about foams in food products, it is of interest to know the foam's stability and volume. Any solids, such as sugar, present in the continuous phase of foam add viscosity to the liquid base. Different levels of viscosity, or resistance that a fluid poses to shear forces, changes the mouth-feel of the product and duration of the foam. In general, the more viscous a liquid is, the longer its bubbles last (Pugh, 1996). We should also keep in mind that a greater resistance to shear forces means a smaller increase of volume from air expansion. Therefore, the recipe used in this study has minimal foaming agents and foaming stabilizers to ensure that the outcome truly reflects the impact of the whipping stage on the increased volume and stability of the soufflé.

The rate and extent in which albumin unfolds to form a film at the surface of the gas, also called the absorption rate, increases as shear force is applied to the egg white when beaten (Damodaran and Song, 1988). As protein unfolds and entraps gas to form new bubbles the overall volume of the solution grows. Foam becomes opaque and can be pulled into soft peaks. While some bubbles collapse, others are surrounded with a second monolayer. The second film covers any coagulated regions, caused by over beaten proteins, from the first monolayer (Cherry, 1891). The bubbles progressively become smaller and foam gets tighter until stiff peaks are formed (McWilliams, 2012). This is usually the stage egg whites are brought to for making soufflés. It is a common belief that bringing the egg white foam to this stage will make a more stable soufflé.

The normal pH value for egg whites is from 7-8, but as they age their pH goes up. However, the rate and area to which proteins unfold and reposition at the interface is conditional to the protein’s intermolecular limitation to form new bonds. The overall egg white foam stability is optimal at or near the isoelectric pH of albumin—pH5. 5 (Cherry, 1981). This is due the convex shape bubbles take near the pI of albumin, which exhibit a slower liquid drainage rate than decay from gas diffusion and disproportionation (Damodaran, 1994). As a result of less liquid drainage the foam films remain thick enabling dry foams of high stability to be formed (Malysa and Lunkenheimer, 2007). Furthermore, the addition of an acid boosts the number of free-floating hydrogen ions in the egg white slowing down disulfide bonding and exposing hydrophobic regions that result in further adsorption sites (Murray, 2007). In order to generate the same variables for this study, all egg whites were titrated to pH 5. 5 creating a more suitable protein conformation for entrapping and holding air dispersions.

Foam will start to form when the number of new and accumulated bubbles exceeds the number of rupturing ones. The stability of foam does not only depend on the solution’s composition but also the state of the bubble’s adsorption layers (Malysa and Lunkenheimer, 2007). Most studies focus on the stability of foams under static conditions where a tight bubble network and high stability are formed. Considering that in the soufflé production process foam is subject under dynamic conditions, surface elasticity may become of significant importance when analyzing foam expansion and stability on such systems.

In addition, even though it would seem logical that a highly flexible unfolded protein would cover a greater surface area than a compact folded protein, Damodaran and Song found that one of albumin’s folded intermediates occupies a greater surface area (Damodaran and Song, 1988). Therefore, in order for a protein to entrap the maximum amount of gas in foam and exert the most favorable reduction of the surface tension, it should be processed (whipped) until an optimum degree of unfolded and folded coils are achieved (Damodaran, 1989).

The physical law that animates the phenomenon occurring in a soufflé was discovered by the French scientist and balloonist J. A. C. Charles. Charles’ law states, “…the volume occupied by a given weight of a given gas is proportional to its temperature” (McGee, 2004). Some may conclude that the greater amount of air bubbles trapped the greater the volume will raise as the soufflé is baked. Others may believe that it does not matter the stage the egg white has been whipped to because gas will always expand a fixed amount. However, bearing in mind Damodaran and Song’s discovery and the assumption that surface elasticity could play a determining roll on foams expansion and stability under dynamic conditions, there might be the possibility to believe that stiff peak is not the optimum stage at which the egg white must be whipped to achieve the maximum final volume in soufflés.

This study will focus on the effects different stages of whipped egg white foams have on the final volume of soufflés. After this study a chef will know the best possible utilization of egg whites for soufflés and other food preparations where egg whites act as a leavening agent. Learning about egg white’s surface rheology through measurements recollected over a range of timescales will help to understand how the protein structure on whipped egg whites relate to the final volume of soufflés. It may also suggest a better way to produce other backed foam products as sponge cakes, meringues and bread.

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