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ANALYTICAL CHALLENGE

Solution to Hollandaise challenge

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Solution

Can one recover a failed Hollandaise sauce by adding cold water? Let us first try to understand the production of this sauce before examining how it can fail and be recovered. First, egg yolks are mainly composed of approximately 50 % water, 15 % proteins, and 35 % lipids, including phospholipids and triglycerides, Belitz and Grosch [1]. Butter is made of about 82 % triglycerides of many varieties (which explains why the melting point of butter begins at –10 °C and finishes at +55 °C), a maximum of 16 % of water, including some lactose and proteins, Bouteille et al. [2], Lopez and Ollivon [3].

The processes that occur during the first step of thermal processing of the mixture of egg and an aqueous solution depend on the temperature, as egg proteins can denature, aggregate, and even coagulate as soon as the temperature reaches 61 °C, This, 2009 [4]. At the same time, air bubbles are introduced by the whisk, which can be observed simply from the whitening of the sauce or by microscopic optical examination (Fig. 1).

When melted butter is added, the liquid fat is dispersed in the water phase, making a more complex physical system: the final sauce is a suspension (of egg proteins aggregates), an emulsion (of melted fat droplets), and a foam (of air bubbles) at the same time. The disperse system formalism of such a system can be described as (G+O+S)/W, where G stands for the gas bubbles, O for the oil droplets, S for the protein aggregates, solidus / for the random dispersion, and solid protein for the continuous water phase, This, 2012 [5].

What happens when heating is too strong or too long, particularly when the finished sauce is kept on mild heat until it is served? There are many possibilities, but the most obvious is a phase separation, Thakur et al, 2007 [6] because of an insufficient quantity of water: for an emulsion to subsist, approximately 5 % water is needed and, indeed, this limit is breached when water evaporates during the sauce preparation. It is useful to remember that the water quantity can be small in the sauce. A typical recipe would contain 20–30 % water before heating.

Is it true that water can help to recover a smooth system? Indeed, and one can easily perform the experiment. In one of

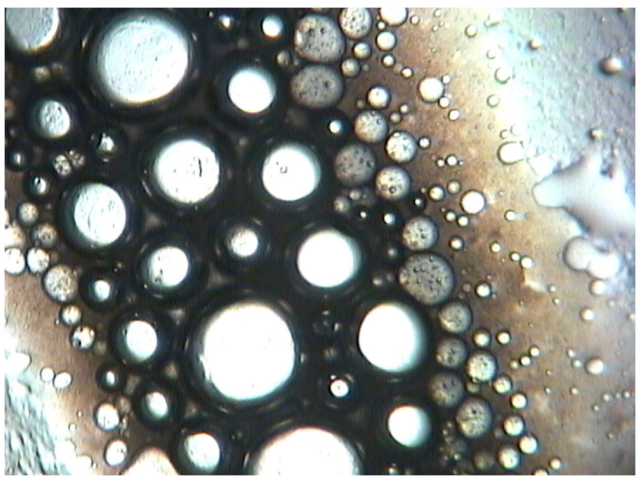

Fig. 1 Microscopic view of the Hollandaise sauce. One can see the oil droplets (smaller white disks) and the air bubbles (bigger disks, with a dark edge). The egg aggregates appear with difficulty at this magnification (the diameter of the largest air bubbles is about 0.1 mm).

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our monthly Seminars of Molecular Gastronomy, AgroParisTech, 2016 [7], we added three spoons of cold water to a (purposely) failed Hollandaise sauce, and the emulsion recovered spontaneously. We heated the 4 yolks, 2 spoons of water recovered sauce again until a second phase decomposition occurred, and the sauce recovered again by the addition of water. We repeated the phase decomposition/recovering five times, until we decided to boil the sauce so strongly that brown butter would form. After this very strong thermal processing, we added cold water again… and the sauce recovered, This, 2012 [5].

Of course, proteins coagulate during this process because the temperature is above the denaturation and coagulation points of most proteins from egg yolks, This, 1996 [8]. However, the protein aggregates can nonetheless be surface-active. This can be shown by cooking an egg white (an almost pure solution of proteins), grinding the coagulated mass into a few grams of water, and whipping oil into the system: an emulsion is obtained. One cannot overlook the role of phospholipids because these compounds are not modified during thermal processing and remain surface-active, thereby promoting the formation of emulsion, as another experiment shows: if oil is added to a boiled solution of lecithins in water, again an emulsion is obtained [9]. This, 2015 regardless of precise explanations, the experiment is clear: a failed Hollandaise sauce can be readily recovered by a simple addition of water, as some chefs have empirically discovered Carême, 1847 [10].

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