Hollandaise sauce is one of our most beloved and elegant butter sauces. It has the power to lift a piece of baked fish, asparagus or a poached egg to something luxurious. Its history is long, and it is one of the sauces chefs across the world find most precious. The reason may be its versatility, but undoubtedly it has also to do with the sauce’s velvety texture. One interesting point is that the average person normally does not make it from scratch at home. This probably has to do with the sauce’s reputation of being difficult to make. In addition, the sauce contains a high amount of butter, which may make it unattractive to modern people on a diet. However, hollandaise sauce may be the component that provides a dish with that something extra, and because of this we are devoting a chapter to it. Hollandaise sauce may have “a temper”, but by understanding its nature with some scientific insights, it is probable that you will succeed with your future butter sauces.

Hollandaise Sauce History

Hollandaise sauce is an old sauce – in fact, so old that historians do not agree on its origin, or why or where it got its name. Hollandaise is French and means Dutch or made “Dutch-style”. Some believe that the sauce was originally developed in the Netherlands and then imported to France. The first known recipe resembling hollandaise sauce is presented in a Dutch cookbook from 1593 by Carel Baten (Battus, 1593). Another account from 1651, by François Pierre La Varenne, describes a sauce made “with good fresh butter, a bit of vinegar, salt and nutmeg, and an egg yolk to bind the sauce” (La Varenne, 1651). This sauce was intended for cooked asparagus. There are also other early reports of sauces resembling hollandaise sauce and being thus named, but they also contain other ingredients than what we consider typical hollandaise sauce ingredients today. So, the question is - what sauce composition variations are acceptable in order to call a sauce a hollandaise sauce? Historians do not agree on this point either, and therefore we cannot conclude on the sauce’s origin and why it got its name, although many hypotheses have been made. The only thing we can be sure of is that hollandaise sauce has a long history.

Due to the sauce’s long history, both preparation techniques and ingredient selection have somewhat changed over time, which is the case for many types of food with a long history. For example, many of the old recipes for hollandaise sauce contain different types of spices, but spices such as nutmeg are normally not used in hollandaise sauce today. It is important to have in mind that foods are not static products. They continuously adapt to the ingredients they are made of, available preparation equipment and food trends.

There are different variations of the preparation method for hollandaise sauce. Old recipes yield sauces with denser and more custard-like textures compared with modern standards, because in these recipes the yolks are heat treated just with stirring (not whisking) together with vinegar and/or butter from the start. Today, chefs normally base the sauce on the warm and stiff foam of egg yolks, called a sabayon, which gives the sauce a much airier texture and makes the mouthfeel lighter.
We are now going to have a closer look at emulsion science, because it is an important point in order to understand the behavior of warm butter sauces. By making emulsions, we are unfortunately working against “the natural order” of things, as emulsions are “programmed” to separate, which they may do in a number of different ways. There is unfortunately never a good time for emulsion separation, especially if you are expecting guests, which is why learning how to control emulsions can lead to less stress in the kitchen.

Mixing of the Immiscible
Many emulsions, especially the warm ones, have a reputation for being difficult both to make and to keep stable. The reason lies hidden in the emulsions’ structure. Emulsions are mixes of two main ingredients – water and fat in the form of oils or melted butter. As we know, water and oils are immiscible liquids, but when we make emulsions, what we do is to mix these two phases. The way it is done is by breaking up one of the phases into small droplets, which are dispersed in the other phase. To the naked eye, the emulsion looks like a homogeneous mixture of the phases, but on a microscopic scale, the structure is heterogeneous. The mixing of the phases often results in a yellow-whitish product, such as mayonnaise, because all the small droplets in the emulsion scatter the light.

There are two main groups of emulsions: those in which oil droplets are suspended in water, which are called oil-in-water emulsions (O/W), and water-in-oil emulsions (W/O), the direct opposite; see Figure 73.1. Most food emulsions are O/W emulsions. Since oil or butter and water are immiscible liquids due to their different densities, the force in the emulsion system is towards separation into two distinct phases once more. This is where we must start to apply our knowledge about emulsions in order to encourage them to remain stable for a longer time, preferably beyond the time of consumption.

Ratios
The first thing to control when making an emulsion is the ratio between oil/butter and water. In an O/W emulsion, all oil droplets need to be suspended in water, and the amount of water compared with oil or melted butter is therefore crucial. Butter sauces and mayonnaises are made with water-containing ingredients such as egg yolks, wine reductions, vinegar, lemon juice and mustard. When a large amount of oil or butter is used, the water comprised in these ingredients may not be enough to hold all the oil droplets. If the emulsion separates as a result, many believe that they have not used enough egg yolk, but the reality is that one can produce over 20 liters of stable mayonnaise with only one egg yolk, as long as supplementary water is added (McGee, 1990). More information about the emulsifying properties of egg yolks will follow later.

It is therefore not wise to go far below 20 percent water by weight compared with oil in an O/W emulsion, although less than 10 percent is possible. The limit depends on the droplet size range. However, as water evaporates slowly from food, even at room temperature, if it is too close to the water content limit, the emulsion becomes more unstable. You should therefore have a certain idea of how much water by weight compared with oil you have in your emulsion. Unfortunately, it is not always easy to calculate water content based on recipes, as measurement units are often “spoonfuls” and “halves”, which are not standardized units.

Warm emulsions, such as butter sauces, require a higher water percentage than cold emulsions, as the evaporation rate of water is proportional to the temperature. If you are planning to prepare a hollandaise sauce a while before serving, it may be wise to whisk in some water during the holding time to keep the sauce stable. If you have questions regarding water content in foods, there are food databases available online where this kind of information is readily available (USDA, nd). Just remember that there may be variations from one product brand to another and between products from different countries.

The Art of Mixing
An important type of emulsion separation happens when the oil droplets in the O/W emulsion merge and grow larger until all droplets form one phase and the emulsion has completely separated. This type of emulsion separation is called coalescence. If few and large droplets are present in the emulsion, it will normally separate quite quickly. However, if each droplet is smaller, the process will take longer, which is why mixing an emulsion vigorously or for a longer time can drastically increase the stability. Today we have different types of kitchen machines at our disposal, like immersion blenders or stand mixers, which can relieve our arms and make the droplets in emulsions much smaller than by hand. Warm butter sauces are still normally prepared by hand, but there is also equipment today that allows whisking while heating, such as induction stand mixers or induction blenders. Unfortunately, they are often quite expensive. In Figure 73.1 you will find schematic information about emulsion structure and the different types of emulsion separation.

Stabilizers and Emulsifiers
Gravity is a major driving force in the separation of emulsions. Because water is denser than oil, it slowly moves downwards, while the oil droplets travel to the top, like the cream in unhomogenized milk. This type of emulsion separation is called creaming (see Figure 73.1). Gravitational movement in
the emulsion should therefore be limited in order to increase the stability and prolong an emulsion’s life. By limiting the movement in emulsions, the number of oil droplet interactions are also decreased. Increasing the viscosity or thickness of the water phase provides this result. Products with such abilities are called stabilizers in emulsion terminology. Everyday examples of stabilizers are thickeners such as flour, potato flour, cornstarch or gelatin, but the list of available stabilizers for the industry is long.

Although the term may not seem particularly appetizing, an emulsifier is just a name given to a group of compounds able to form emulsions.
to stabilize emulsions. Many ingredients naturally contain emulsifiers, such as egg yolks and milk. Emulsifiers are able to adsorb at the emulsion interface (see Figure 73.1), which is where the oil and water phases meet. At the interface, the emulsifier covers the droplets like a protective film and ensures that droplets coming into contact with each other do not merge and create larger ones (by electrostatic repulsion). In this way, the emulsifiers make emulsions more stable by preventing aggregation and coalescence.

Industrial emulsions normally contain both stabilizers and emulsifiers for increased protection against emulsion separation. Next time you have a jar of store-bought mayonnaise in front of you, take a glimpse at the declaration, and you will probably find that it contains both emulsifiers and stabilizers. This is also why numerous homemade emulsions contain egg yolks, in which both stabilizers and emulsifiers are naturally present. Egg yolk proteins act as emulsifiers, but they may also stabilize the water phase, especially if they are heat treated and coagulated (a result of denaturation, the scientific term for uncoiling of the egg yolk proteins). The denaturation of egg proteins results in gelling of the water phase, the same property we exploit when custards are thickened with egg yolks by heating.

The Droplets’ Life in Solitude

Many of the measures taken to increase emulsion stability are done to minimize movement and contact between oil droplets in the system, because droplets that come into contact with each other may merge as a result. This is also the reason why the temperature as a general rule should be kept low in emulsions, and temperature fluctuations should be avoided. However, there are certain exceptions, such as warm butter sauces, where it is important to keep the sauce temperature higher than the butter’s upper melting temperature, normally 35–40 °C. An explanation will be given in the section about butter.

Hollandaise Ingredients

We have now gone through why it is essential to know about emulsion properties when making hollandaise sauce. In the rest of the chapter, we will have a closer look at hollandaise sauce ingredients and preparation. Butter sauces may be prepared with a wide range of flavours. The use of different types of flavours has led to numerous different emulsion sauces. Hollandaise sauce is normally made with a white wine and vinegar reduction, egg yolks, butter, salt, pepper and lemon juice. Some purists have strict ideas of which ingredients the sauce must contain in order to be called a hollandaise sauce, but others just add what they think will make the best sauce. For most chefs, the seasoning with salt and lemon juice at the end is a necessity for a hollandaise sauce, but many also include shallots or bay leaf in the reduction.

Chefs often disagree on which white wine to use in a wine reduction. Wine type, acidity or sweetness level does not significantly influence the sauce flavor, so just choose a wine you like. The fat in the sauce will normally mask any sweetness in the wine, as long as you do not use a dessert wine. The degree of reduction has much more influence on sauce flavor than the wine choice (Rognså et al., 2017). The sauce flavor, and sometimes also the sauce texture, is influenced by the ingredients in the aqueous phase.

Some chefs add salt from the beginning of the sauce-making, whereas others just season the sauce with salt before serving it. The sauce texture is influenced by when you add the salt. Adding it towards the end may produce a thicker sauce compared with adding the salt at the start (Rognså, unpublished results). Butter sauces can easily be made thinner by adding water or lemon juice, and thicker by whisking in more butter.

The Problematic Butter

Butter is, by percentage, the most important ingredient in hollandaise sauce, and it is added to the sauce either in cold cubes, warm or clarified. The different options do not necessarily result in the same product, because if whole butter is used, water and a small portion of milk proteins are also added to the sauce, as whole butter contains up to 15–20 percent water and about 1 percent proteins. If you use cold butter, the sauce-making process will take longer, as you decrease the temperature of the sauce each time you add butter to it. These temperature fluctuations may also result in particle formation in the sauce (Rognså, 2014). Most chefs today use warm and clarified butter when preparing hollandaise sauce (Rognså et al., 2017).

Butter is, in fact, composed of many different types of fat, each of them having a specific melting point. These melting points vary from approximately –40 to 40 °C (Wright et al., 2001), and they are responsible for butter being more or less spreadable at different temperatures. Butter is said to be “semi-crystalline” in this temperature range, meaning that some of the fats are present as solid fat crystals and some of the fats are liquids at the same temperature. The composition of the fat is influenced by numerous factors, including what the cow has eaten and the cow’s breed (Kalač and Samková, 2010).

These properties of butter are, in fact, very important when it comes to the stability of the hollandaise sauce. If a hollandaise sauce is cooled to below approximately 40 °C, fat crystals start to form in the fat droplets of the emulsion, and they may even grow through the protective emulsifier film. When droplets with fat crystals on the surface come into contact, the crystals may entangle, which results in clotting of fat droplets, an effect called partial coalescence (McClements, 2005). This is not good from a stability point of view, because the aggregated droplets are susceptible to merging, especially if the sauce is reheated above 40 °C. Merging of droplets creates larger droplets of different sizes in the emulsion, which can quickly lead to separation of the hollandaise sauce.

It is therefore very important to control the temperature of hollandaise sauce if it is supposed to stay stable for some time before serving. A butter sauce is challenging to prepare long before serving for several reasons, water evaporation and temperature fluctuations among them. Butter sauces should, in any case, not
be made long before serving due to bacterial issues. Holding temperatures for butter sauces promote bacterial growth, which is why such sauces should, in any case, not be kept more than approximately 2 hours before serving (and leftovers should be discarded. Guidelines vary slightly between countries (Gisslen et al., 2006). It is also recommended to use pasteurized egg yolk in countries where Salmonella contamination in eggs is a continuous challenge.

**Hollandaise Preparation**

It is wise to prepare hollandaise sauce in a steel bowl over a pot containing hot water, as this facilitates temperature control during the preparation. If you use a pan directly on the stove, the temperature may become too high, which can result in curdling/coagulation of the egg yolks proteins, resulting in a grainy and unappealing sauce. Although elevated temperatures are necessary to make butter sauces, too high temperatures, in general over 75 °C, may lead to large structural changes in the egg yolks proteins. These temperature-induced changes may result in the yolk proteins lumping together in an uncontrolled manner by coagulation, which is like the scrambling of your eggs for breakfast. Coagulation of the egg yolk first makes the water phase thicker, which is a desired effect, but a high degree of coagulation makes the sauce grainy and lumpy, normally followed by sauce separation.

As mentioned before, there are several variations of how to prepare hollandaise sauce, but today, chefs strive to make light-textured sauces as a contrast to the high butter content, which may be achieved by building the hollandaise sauce on a sabayon. A sabayon is a light and relatively stiff foam made from a wine or vinegar reduction and egg yolks, and it is formed when the egg yolk mixture is heated while whisking with a balloon whisk. The temperature in the sabayon during preparation should, as a general rule, not exceed 70 °C. When the sabayon is made, the structure of some of the yolk proteins is changed (denatured), which is what increases the thickness of the foam. When the sabayon has stiffened, the heating is halted. Then, the butter is incorporated slowly while whisking; warm (60–65 °C is recommended), clarified butter is normally used. Seasoning with lemon juice and salt finishes the sauce. The sabayon ensures the presence of air bubbles in the hollandaise sauce (a foam). The aqueous phase of the sauce also contains coagulated egg yolk proteins, which gels the phase (a suspension). This means that a hollandaise sauce in reality has the characteristics of several types of systems: emulsion, foam and suspension.

**Summary of Success Points for Emulsions and Warm Butter Sauces**

Hollandaise sauce and its derivatives are loved because of their subtle flavor and velvety texture. It is, however, important to remember that many of the properties of hollandaise sauce are linked to it being, among other things, an emulsion, and knowing about emulsion characteristics may help you to know what to do when preparing the sauce, or rather, what not to do. By following these principles, you should be able to minimize the times emulsions separate in your kitchen. Hopefully, knowledge about these properties may encourage more people to make butter sauces and emulsions at home.

To recapitulate the highlights for stable emulsions: When making emulsions at home, you should first of all check and be sure that you are using enough water. Do not just blindly trust the recipe, as its writer may not be aware of the importance of the water ratio in O/W emulsions. If you do not want to calculate, just add a bit more water, vinegar, lemon juice or another water-based ingredient to be on the safe side. Then mix the emulsion – thoroughly. Use an immersion blender or a stand mixer if you want to keep your emulsion stable for longer. Handmade emulsions may keep together sufficiently long if you also use ingredients containing emulsifiers and/or stabilizers, such as egg yolks. Finally, maintain stable and low temperatures to keep the emulsion stable, except for butter sauces, which require higher holding temperatures. For butter sauces, such as hollandaise sauce, keep the sauce above 40 °C, but make the sauce close to serving time, as you do not want to serve your guests a food poisoning together with the dinner.

Butter sauce-making may not be an easy task, but practice makes perfect. Making delicious hollandaise sauce is considered an art by many chefs. By knowing these important points about hollandaise sauce and emulsion properties, you may avoid the most common pitfalls.

**Hollandaise Sauce Recipe**

**Base:**

- 4 egg yolks from large eggs (approximately 80 grams in total)
- 40 grams liquid (water, white wine vinegar, dry white wine, lemon juice or a reduction (see following recipe))
- 220 grams unsalted and clarified butter (from 300 grams whole unsalted butter)

**White wine and vinegar reduction:**

- 60 grams dry white wine
- 60 grams white wine vinegar
- 15 peppercorns
- 1 shallot

**Flavorings:**

- Salt and freshly ground pepper
- Lemon juice

1. If you want to use a reduction for extra flavor in the sauce, you start by making the wine reduction. If you prefer only to use water, jump to step 2. For the reduction, start by finely chopping the shallot. Put all the ingredients in a saucepan and reduce till you have approximately 40 grams of liquid. Pour the reduction...
through a sieve before use to eliminate the peppercorns and chopped shallot.

2. Put about 300 grams whole butter in a pot and melt it slowly over medium heat. When the butter has melted, the water will be at the bottom of the pan, and you can easily obtain 220 grams clarified butter. Keep the butter warm, approximately 65 °C.

3. Isolate the yolks and place them in a heat-resistant bowl. Add 40 grams of liquid (wine reduction, water and/or lemon juice) and start whisking. It is recommended to use a balloon whisk for this task.

4. Place the steel bowl over a pot containing hot water (close to the boiling point), but make sure that the bowl is not in contact with the water. Whip the sabayon forcefully until it stiffens. You should not exceed 70 °C in the foam to avoid curdling of the yolks. An average yolk contains about 50 percent water, and the total water content in this recipe is therefore about 23 percent water (before evaporation), which will ensure that the emulsion does not separate because of too little water.

5. When the sabayon is stiff, remove the bowl from the water bath, and start to incorporate warm (60–65 °C) clarified butter while whisking. Start adding the butter carefully in the beginning.

6. When all the butter is incorporated, flavor the sauce with lemon juice and salt according to your own taste, and serve.

You have now made a hollandaise sauce. The sauce may be developed further by adding ingredients such as tarragon and/or chervil to obtain a béarnaise sauce, caviar or löjrom for an exquisite sauce for baked fish, or beurre noisette for a complexly flavored sauce to serve with vegetables, fish or meat. Bon appétit!

REFERENCES

USDA. nd. Food Data Central by US Department of Agriculture, fdc. nal.usda.gov (last access 18 June 2020).