Research Report

The Science Behind Patisserie

A Chemical, Physical, and Biological Science

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Abstract

Many techniques in the world of Patisserie are completely unknown to most of the people; and even more so, a great science hides behind each and every aspect of the delicious pastries prepared in this field of work. It has a biological science, which concerns the moment a person tastes the pastry, and there is also a great part of physicochemical science in the making of those pastries. The first two hypotheses center upon how the organoleptic properties of the dessert change when different physical and/or chemical processes are applied in the making of the pastry. The third hypothesis concerns the various biological reactions humans have while tasting the pastries and how it varies when a change is made from the original product.

To have a better understanding upon the chemistry and physics behind some of the most often used ingredients, research had to be done, such as reading books, consulting nutritionists, or conducting various experiments to make conclusions. (The most common ingredients would include eggs, sugar, gelifiers, dairy products, and chocolates.) After some research, I postulated that if a chemical manipulation was done to the proteins found in the egg whites, it would affect the organoleptic results of a dessert called macarons. Therefore, an experiment had to be conducted to see if the hypothesis was correct; and to a good surprise, the results showed a drastic change in the macarons' organoleptic properties when the manipulation was omitted in difference to when it was sought through. Additionally, research of various chemical procedures and some more experiments were conducted to prove and support the current hypothesis. I could conclude from it that each time that a chemical change was made to an ingredient it would ultimately alter the organoleptic properties of the result.

I also hypothesized that physical changes play a very important part in the organoleptic properties of the desert. Therefore, I conducted an experiment regarding the physical changes that could be done to whipping cream, such as changing its temperature to see if it would alter the final product, (making sure that only physical manipulations would be involved.) The results showed in an obvious way that the organoleptic properties changed when the temperature varied, especially in the texture and density of the whipping cream.

Apart from this, I also did some research regarding chocolate and crystal formation, the changing of temperature, and some more different physical manipulations. All this pointed out that the physical manipulations done towards an ingredient is clue to obtaining many different textures, aspects, and more, therefore bringing changes in the organoleptic properties of those ingredients and desserts.

Finally, I got interested in the science concerning the body's (or more specifically the nervous system's) biological reaction when eating a pastry. As it turned out to be, I found out that the factors responsible for the perception of a food's organoleptic properties are the neurons. Furthermore, after learning that there are 5 basic sense reception systems, I hypothesized that each one influences and is connected to the other systems. In order to verify this, I conducted an experiment consisting in changing one of the perceptions, (the visual one,) by 'blindfolding' the test subjects and surveyed if they'd had a different organoleptic experience when tasting a brownie in comparison to when they had their eyes open. After the survey, I discovered that 92% of the people found a difference in either the taste, the texture, both, or even the temperature! I therefore concluded that the perception of the pastries' features varied upon the different stimuli the environment offered to the person tasting them.

It is safe to say that all this research, experimentations, analysis, and observations permitted me to learn all about the science behind "patisserie."

Acknowledgement

Throughout this report, I have been very privileged to get help from some extremely unique and kind people. Firstly, I would like to give my thanks to my wonderful tutor, Geni Duch, who has followed my report, supported my decisions, given me the right advice at the right moment, and most of all, given me a huge motivation to continue making my report as best as I could.

Secondly, I just *need* to mention how helpful and selfless my father (Didier Masson) was when I had to format and arrange the esthetic appeal of the report. He helped me even though he was tired and didn't have the time himself. Without him, it would not have turned out as eye-catching as it did and I really appreciate that teamwork.

I should also mention: my mom, Consuelo Sangabriel, my sister Claire Masson, my friend Monica Sanz, and my brothers, David, François and Yannick Masson… who have supported me throughout the year, thus, supported me throughout the report.

Finally, as the help that a certain person has brought to me throughout this *'adventure'* is surely indescribable by words, I would simply like to add: *thank you, Hilmi.*

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Introduction

Figure 1: ***Fraisier***

In this research report I have focused on three aspects of the science behind patisserie; the physical manipulations of pastries, the chemical processes applied to the desert, and the different human responses towards the final product. I developed my research by creating experiments based upon theoretical ideas and information, in order to help me validate my hypotheses. The research report has been organized in the following way: it is divided in various topics, each having its own hypothesis and a verification of it, using both the theoretic as well as the practical information I obtained throughout my investigations. Furthermore, it is arranged in order of importance: putting the most important in the end (the biological response) but the most interesting at the beginning (the science of the chemical and physical manipulations in pastries.) I find the physicochemical science behind pastries as most interesting because it catches the very fundament in which pastries are created, explaining each change in a molecular and logical level. This will intrigue the reader to read further and to discover what kind of science truly lies behind patisserie. Furthermore, I think that the biological response to pastries is the most important as the desserts' purpose is completely based on the reaction of the person who is going to taste it.

Before anything, I would like to state that I already had much experience on this subject and used this to my advantage on my research. I did some research on the side, using professional sources, (such as interviewing scientists, reading published articles, or learning from pastry books) in order to get ideas to make the experiments I needed and to clarify any doubts I had on the subject. Most of all, I centered my probe upon the experimental part of the research as it was the most efficient and clear way to truly prove my hypotheses. In short, I questioned myself about something, thought of a logical answer to that question, then I looked for information so as to know how to prove my answer, and finally, I conducted an experiment to validate if what I hypothesized was true.

Some of the experiments consisted in changing a certain aspect or procedure of a pastry and either having people taste both to see if there was a difference in the organoleptic, properties when comparing them or by simply observing the different results. If it was the prior, the people had to fill in a questionnaire about the changes noticed in the pastry. For example I did an experiment that consisted in changing the temperature at which a certain ingredient was prepared… After the survey was completed, I consulted physicists, chemists, biologists, or chefs in order to interpret the results and see if it matched with the hypotheses.

After thinking for some time, I came up with a hypothesis that needed to be proven and foremost, to be explored: "**the *physical* and *chemical* manipulations of the ingredients affect the organoleptic properties of the dessert.**" This made me question many things about what would happen if a change was made in the pastry and why. For example, what would happen if a change was made in the physical processes, or appearance, and how would that affect our perception of the new pastry?

Another doubt I had was about the chemical processes chefs used in order to change the ingredients and the importance of those procedures, etc. Every single one of those changes affected the taste, texture, temperature, or any of the organoleptic aspects of the dessert. Yet, all these doubts put together lead to what I found to be the most important question: "**how does the perception of those modified pastries affect our bodies and particularly, our nervous system?**"

The things I intended to achieve by doing this research report were to be able to prove my hypotheses and discover new information about the procedures made to make such incredible pastries. Additionally, I wanted to share the fascinating complexity behind the making of a dessert with the public. Furthermore, I wished to know more about the human's response when eating sweets. However, most importantly, I planned to carry out this assignment as a valuable experience in the field of patisserie, my favorite hobby.

Throughout my research, I have had the luck to encounter very few problems; nevertheless, those few problems helped me find out interesting things and deepen my knowledge in the matter.

The first problem I had faced was that I found it hard to interpret the results of my experiments and to make logical conclusions to them, as I have always had difficulty doing so. However, with the help of people who knew how to interpret such results, I managed to come to many conclusions that happened to very fascinating.

Figure 2: ***Éclairs au chocolat***

The other problem I had was when I tried to achieve spherification$_{8}$; as I didn't have the specific ingredients, I had to order them. This ended up taking longer than expected and I had to freeze my research on the subject for a while. Other than that, I cannot say I have encountered any other problems.

Finally, I would like to say that my intention upon making this report was not only to learn about pastries, but also in order to spread the knowledge of this delicious science to other people and hope that they will see it as fascinating as I see it.

Note: sub-index numbers stand for the word's corresponding glossary number. (Ex: organoleptic$_{7}$)

Chemical Manipulations

Processes, results and importance

Important chemical changes in Patisserie

In the following, I will explain the various and most popular chemical changes there are in patisserie. Each and every one of the manipulations is vital for the result and acts in a different way to the ingredient (I will explain the reasons of why they are so important later). First, there will be the different ways of baking ingredients and batters. Then, I shall introduce the most important manipulations made with and to eggs, as it is the most important ingredient in most of the recipes. Afterwards, I will explain the various ways one can obtain gelification[4] as it is a very important process in creams, cold desserts, tarts, custards and so on… Finally there will be an explanation of the most recent and popular chemical manipulation in modern gastronomy: spherification.

Cooking

Caramelizing, baking, frying, steaming and many other processes are essential, if not obligatory in patisserie. In the following, the science behind all processes will be explained.

- *Baking*

The most picturesque one is obviously baking, as when one smells the chocolate cake being baked in the oven, he can immediately picture "patisserie." However, appearances are tricky, baking things in the oven can actually be very difficult! Some recipes require that one does not open the oven until the cake/pastry is finished cooking, otherwise it will deflate.

Figure 3: ***Oven***

Baking at the oven usually dries the product, so one has to be careful about this too. In spite of all these inconveniences, it is the most often used method for cooking pastries because of it being so practical. It is very useful as one can control the temperature, and even cook bain-marie recipes with it nowadays!

Figure 4: ***Burned Cakes***

Depending on how one uses the oven, the results will vary; one can get a very moist and yet crunchy result while maybe some other time a person will forget about the oven and completely burn the pastry!

The oven is also very tricky as the pressure plays a very important role on cakes. Something that happens very often is that a cake or batter has grown and been baked perfectly, and when the oven is opened, it suddenly collapses.

This deflation is caused by the change of pressure so one should be careful. As the oven heats up the pressure changes, therefore, when we have the baked pastry we have to slowly let out the air come out and be very careful that the temperature drops slowly. It will always deflate a bit, but not even comparably as much as when one does *not* take precaution.

Because of the dryness of the oven, it usually makes the pastry develop a crust even if its just a slight soft layer. Also, due to the air bubbles expanding because of the heat, it makes pastries very fluffy, light, and sponge-like. Due to the special way in which the pastry cooks completely in the oven it usually gives off a product that can be conserved for longer periods of time too. However, it really all actually comes down to what one is baking, as a person can also make creams, mousses, puddings, and other various desserts with different textures...

In addition, one can bake the ingredients in order to dry, soften, cook them or bring out their flavors. An example for roasting (or drying) an ingredient through the oven is pistachios or pistachio powder. Because sometimes they have too much water if they are very fresh and are not suitable for a certain recipe one needs to dry them first.

Roasting is directly related to bringing out the flavor, as when one dries something in the oven, it makes the essential oils come out more and also brings out new flavors! Such an example would be when one roasts almonds, or any kind of nuts, in order to obtain their oil and their new flavor.

Figure 5: ***Roasted Almonds***

What actually happens during the roasting is something called the Maillard Reaction. Put simply, the Maillard reaction occurs when part of the sugar molecules (the aldehyde groups) react with the nitrogen parts of the protein molecules (in the amino groups). (Fig 6) The resulting series of reactions is not well understood even by food scientists, but it leads to the brown color and many flavorful compounds that are yet to be identified. The Maillard reaction also applies to most sugar and protein containing foods such as brioches, breads, coffee beans, etc.

To conclude I would like to say that the thing which is most sought for when baking something in the oven is the characteristic crust that all the products will obtain after that process and the new flavors it will bring.

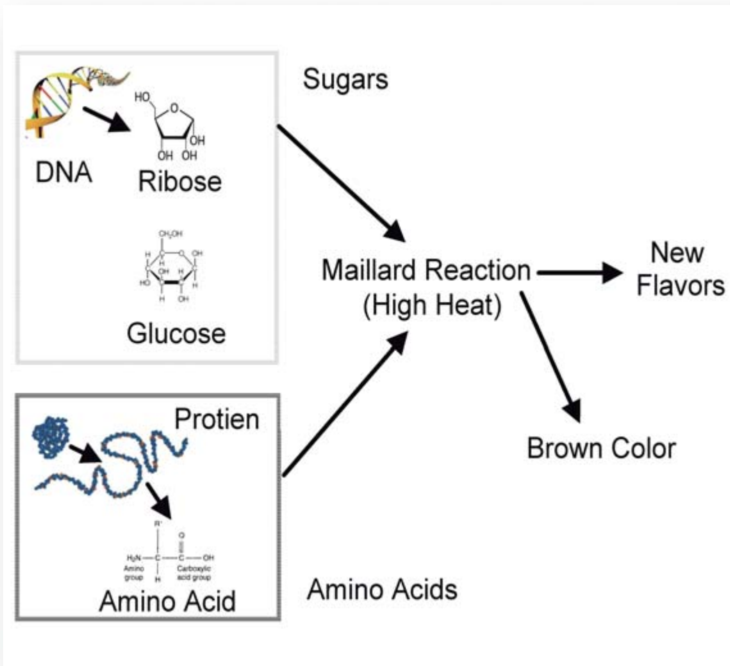


Figure 6: ***Maillard Reaction***

Steaming

Moving on to another kind of cooking: I would dare say that one of the most digestible and healthy way of cooking food, more specifically pastries, is through *steaming.* It is most popular in Japan, China, Korea, Vietnam and some other countries where steamed foods are very common on their diet. However, it can be used in two ways for pastries: one is steaming the ingredients before using them. Usually they will be fruits or vegetables- (yes, vegetables can also be used in pastries; an example would be sweet potatoes.) The other use would be for cooking a mixed batter, such as for the Chinese steamed cake where instead of cooking a cake through the oven it is steamed!

Figure 7: ***Steamer***

In the pastry business, steaming has been introduced as a modern and healthier way of cooking after being inspired by most of the countries in Eastern Asia. (As a matter of fact, many French chefs have learned steaming techniques by going to Japan and discovering the science behind it…) By baking something through vapor water, it makes the product much more moist, and it affects the texture in a very special way. Steaming any kind of batter which contains some kind of starch will lead to a naturally gel-like, soft, and mild product.

One must not forget that steaming can be quite tricky, especially when dealing with bread or something containing any kind of starch or flour in it. Why? Well, because if one over steams these kinds of mixtures, by, for example, having the fire too high or making the water evaporate too quickly, it is highly probable that the product will get a very firm and unpleasant texture.

This is actually caused because it has overheated the product and hydrated it so much, that when one takes it away from the steamer, most of the water of the product will actually evaporate completely, giving off this dry and hard like texture. It therefore becomes the opposite of what one wants to obtain through this process! That is why, when steaming one must be careful to let the water boil gently and at the end, take off the heat but leave the ingredient or dough for a little while before taking it out off the steamer and serving.

Steamed Rice Muffin Pastries
Figure 8

Apart from flour or starch containing doughs, one can also obviously over-steam simple ingredients too, (such as apples, pears, or other kinds of fruits) and turn them too "mushy" for what was intended. Also, because some flavors and essential oils will evaporate this might lead to mildness in the product. Usually mildness is the last thing one wants to have in an ingredient. Nevertheless, after knowing the things one must avoid in steaming, it is actually quite an easy task to do and it still stays as the healthiest way of cooking something.

Bain-Marie

Another form of cooking, similar to steaming but not quite, is Bain-Marie, which can be literally translated from the French to "Bath-Mary." It *is actually* like a bath, as one must take a big steaming pot or something of the kind and fill it with boiling water. On top of the water, one will place another recipient; such as a bowl or casserole containing what needs to be cooked.

This is a very complicated task to do for just wanting to cook something but it is virtually *essential* in some recipes.

*(This boiling water should actually be barely boiling or even still, and in a uniform way to make sure that all the surface of the water has the same temperature.)

Bain Marie is mostly used for cooking fragile ingredients or things that burn easily as it prevents the mixture from escalating in high temperatures. Even so, the temperature is sufficient to lightly cook proteins and such; therefore, it is useful for cooking eggs safely. This is used to the Chef's advantage mostly in egg creams, flans, and cheesecakes or even for melting chocolate so as not to burn it.

Chocolate being melted through Bain-Marie
Figure 9

Entremets prepared in Bain-Marie
Figure 10

Caramelizing

Caramelizing has been used for far longer than most people think, as it is a very good way to conserve food. In Japan, people cooked red beans with sugar for a long time so that it caramelized in order to conserve the beans, even if it was a “salty” food. Throughout the years, because of this way of conserving the red beans, japan has used them for making sweets rather than for salty dishes. Actually making marmalade is just another way of caramelizing as the sugar used to make it goes through the process of oxidation.

Figure 11: **Caramelized walnuts**

Be it with pectin, sucrose, glucose, fructose or other similar glucids, true caramelization can work as long as the reaction ends up forming caramelan, caramelen, or caramelin. What are those compounds? They are the products that come from heating up sugars to a certain degree. (Fig 12)

$2C_{12}H_{22}O_{11} = 4H_20\ C_{24}H_{36}O_{18}$ Caramelan

$3C_{12}H_{22}O_{11} = 8H_20\ C_{36}H_{50}O_{25}$ Caramelen

Continued heating yields caramelin $C_{125}H_{188}O_{80}$

Figure 12 : **Caramelan Caramelen and Caramelin**

First, the individual sugars dimerize (two sugars come together to form one molecule) into a new form that contains two rings attached by a third central ring (see compound **a** at Fig 13 in the next page). In the case of fructose, this structure is called a di-D-fructose Dianhydride. From this point, the chemistry gets a little hand-wavy. The difructose dianhydride molecules can further react on three different pathways that are the caramelan, caramelen, and caramelin mentioned before. Let’s not forget that apart from those compounds many other flavor molecules are released together with dehydration products.

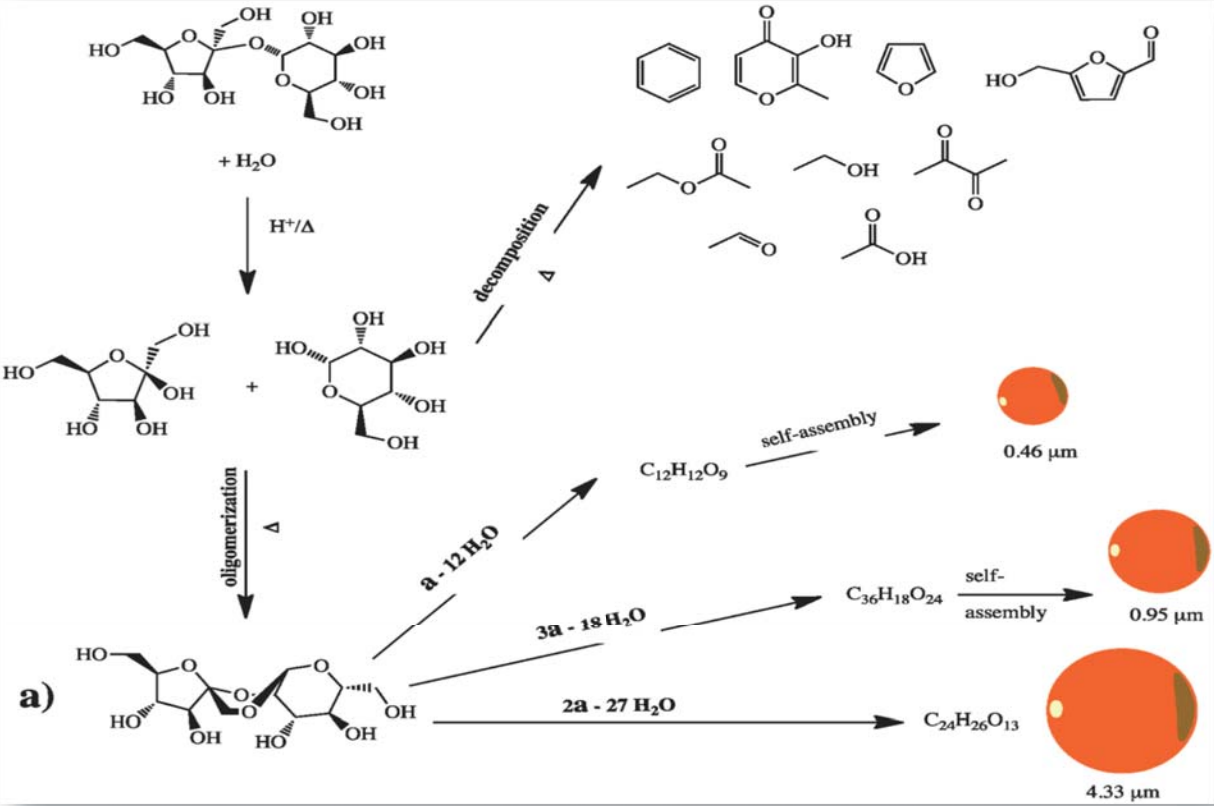


Figure 13: ***Chemical Process of Caramelization***

I've thought for many years, along with most cooks, confectioners, and carbohydrate chemists that heat melts sugar, and then begins to break it apart and create the delicious mixture we call caramel. This concept has actually been wrong all along!

It turns out that sugar *doesn't actually need to melt before caramelizing*. It can actually caramelize while it's still solid! So proved chemist Shelly Schmidt and her colleagues at the University of Illinois in studies published a few years ago.

After careful analysis, Professor Schmidt found that whenever sugar gets hot enough to turn from a solid into a liquid, some of its molecules are also breaking apart at the same time. Sucrose, for example, has a range of temperatures in which its molecules are energetic enough to shake loose from their neighbors, and a range in which the molecules break themselves apart and form new ones. What is very interesting about it is that these two ranges overlap! Whenever sugar gets hot enough to liquefy, it's also breaking down and turning into caramel, but it can start to break down even before it starts to liquefy. And the more that sugar breaks down while it's still solid, the lower the temperature at which it will liquefy.

Figure 14 : ***Tarte-Tatin***

Professor Schmidt's group discovered that when they ramped up the heat slowly, over the course of an hour, so that significant chemical breakdown takes place before the solid structure gives way, the sugar liquefied at a lower temperature. Sugar breakdown can even occur at ambient storage temperatures, though it will take months for the discoloration and flavor change to become noticeable.

In other words, caramelizing occurs when that chemical break down takes place. In order for it to actually work best, it is necessary to heat the sugar at a temperature a little lower as well as a little longer than what people usually think. For, it is not the melting that caramelizes but rather the oxidation.

Caramelizing usually gives off a crunchy, sweet, and sometimes bitter product. Some important molecules that are produced during caramelization are the furans (have a nutty aroma), diacetyl (smells like butter), maltol (toasty), and ethyl acetate (fruity).

Chemical changes in Eggs

Eggs are known to have high protein content; thanks to those proteins, we are able to manipulate the eggs in order to achieve various creams, mousses, tarts, doughs and other components for pastries. The egg whites contain 90% water and 10% proteins whilst the egg yolk contains (approximately) 17% proteins, 31% lipids, and the rest are water, vitamins, or other kinds of molecules.

- *Hydrolysis of the egg whites*

Proteins in egg whites are the best among all kinds of protein because its amino acid composition resembles human bodies. (Actually only ten percent of the egg whites' composition is protein, peptides, or amino acids as the rest of it is only water!) Furthermore, its application has been limited for its special properties such as heat instability and high viscosity. The properties of proteins in egg whites can actually be improved by enzymatic *hydrolysis* and thus its application could be widened, for example, the decline of viscosity is beneficial to process fluids and for stirring.

Figure 15:
Egg

What happens during hydrolysis is that the enzymes found in the egg start breaking down the proteins into smaller molecules, more concretely, peptides, dipeptides, or even amino acids. These smaller peptide or amino acid groups will give door for more micelles[6] to form, which is great for making meringues.

Egg-white proteins contain both hydrophilic and hydrophobic amino acids. When the protein is curled up, the hydrophobic amino acids are packed in the center away from the water and the hydrophilic ones are on the outside closer to the water. When an egg protein is up against an air bubble, part of that protein is exposed to air and part is still in water. The protein uncurls so that its 'water-loving' parts can be immersed in the water and its 'water-fearing' parts can stick into the air. Once the proteins uncurl, they bond with each other just as they do when heated, creating a network that can hold the air bubbles in place. (Fig 16)

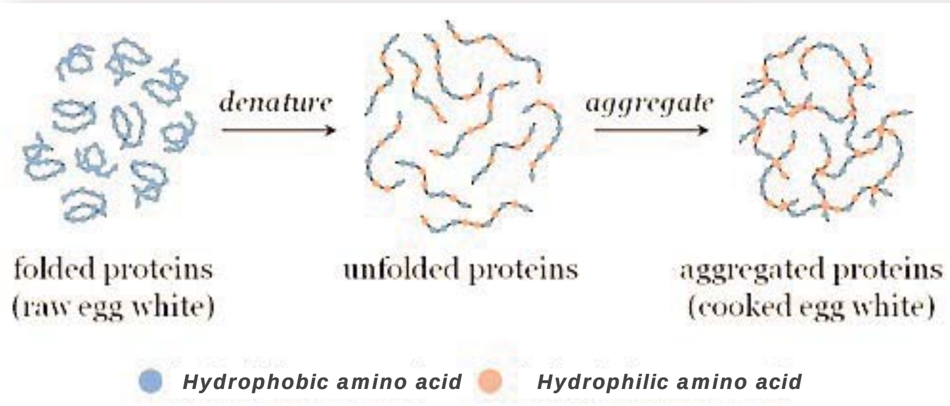


Figure 16 : ***Egg Protein Coagulation Process***

When you heat these captured air bubbles, they expand as the gas inside them heats up. Treated properly, the network surrounding bubbles solidifies in the heat, and the structure doesn't collapse when the bubbles burst. However, in comparison with original protein, the hydrolysate is more digestible due to its low molecular weight, its biological utilization rate is increased, its allergy is decreased, and it may have potential biological functions too!

In Patisserie, all those functions after hydrolysis make up for a win-win situation because the customer gets a more digestible food and the chef has a much better state of ingredient to manipulate. This breaking of the proteins interests patisserie for the making of meringues, more liquid batters or other interesting uses. It is led by natural hydrolysis of the enzymes found in the egg white. By breaking the eggshell, the enzymes are submitted to the environment that usually makes them start breaking the proteins.

Figure 17: ***Meringuettes***

Normally, one has to separate the whites from the yolk and let them in the fridge for 1-4 days depending on the freshness of the egg and the coolness of the fridge. Before using it, in order to achieve complete hydrolysis and the best result possible, one has to take it out of the fridge one hour before so it comes down to room temperature. This creates a more liquid and digestible state for the egg whites. Also, it is sometimes essential for the ingredients mixed together to be at the same temperature, or it could change the batter's consistency.

As it becomes more liquid it is a sign that the proteins have either broken down into smaller peptides or uncurled, therefore it becomes easier and faster to incorporate air due to the increase in opportunity to create micelles. However, most importantly, by hydrolyzing the egg whites through enzymatic action, smaller air bubbles can be created. The smaller the bubble is, the less likely it is to break during the mixing and cooking processes. Therefore we obtain the same air inside as if it were not hydrolyzed, but with much bigger stability and uniformity. Thanks to the size and quantity of those air bubbles, any meringue-based pastry will increase incredibly in volume when put in the oven as the air expands.

- *French, Italian, and Suisse meringue*

The making of meringue is a very tricky subject in patisserie, due to a quantity of factors that can make it go wrong. What is actually sought for when making meringue, is adding the most air possible into the mixture so it can be airy and smooth. This is achieved through the formation of air micelles by the peptides in the eggs. The temperature is a very important factor for example; on one side higher temperatures make it easier to make a French meringue because it helps coagulate, but on the other it will cause the meringue to be more fragile as the micelles become less stable. In the making of an Italian meringue one is actually playing with the temperatures in order to cook the meringue in a way that it becomes very smooth, stable, and can stay moist even after putting it in the oven. Finally, in the Suisse meringue, one searches to slowly cook the egg whites for a very long time so that it creates this very sturdy, also smooth, yet easily dried meringue! I will now attempt to explain what all those kinds of meringues mentioned before are, and how exactly they are made.

The way of making a French meringue is a very old but reliable technique. It basically consists on beating the egg whites while adding sugar from time to time until it becomes fluffy, consistent, and smooth. Nevertheless, it can still be tricky, because if too much sugar is added, it will become more liquid and much less airy then it should be. This is because, by dissolving, the sugars are taking up the hydrogen bonds in the water and consequently lowering the surface tension. A decrease in the surface tension of the water will impair the formation of the air micelles in the egg whites. The sugar will will, however, make the mixture denser and bring more consistency to it. This means that if the sugar is not added at the right moment it may cause the meringue to be either too airy or too liquid and usually not sturdy enough.

Figure 18: ***Suisse Meringue***

On the other hand, Swiss meringue is prepared by gently beating egg whites and sugar in a pan that sits above boiling water, (the before-mentioned Bain-Marie) without touching it. When the mixture reaches 50-55 ºC and the sugar is completely dissolved, the mixture is pulled off the heat and beaten vigorously to increase and attain full volume and then at a lower speed until cool and very stiff. Because of this, one can use fresh and non-hydrolyzed egg whites to make the Suisse meringue because the hydrolysis will take place during the bain-marie. This meringue tends to be drier as the bain-marie makes the mixture more concentrated and rich; also the air bubbles end up being much smaller then the ones created with French meringue due to the temperature at which it is worked with... Swiss meringue is smoother, silkier, and somewhat denser than French meringue and is often used as a base for buttercream frostings or cookie-like pastries.

The last one, Italian meringue, is the most difficult one to prepare but probably the best in texture among all the meringues as it is very airy, smooth, moist, and resistant! Most patissiers use the Italian meringue, as it is the most reliable one to work with after it is made. It is very tricky to prepare because it is cooked by adding very hot sugar syrup to the half beaten egg whites very carefully while continuing to beat the mixture. (Fig 19) Usually it is done with an electronic metal beater because otherwise one could easily burn their hands with the bowl if done by hand. (It is important that the bowl is made out of metal so that it keeps the heat in order to cook the egg whites.)

Sugar syrup being added to half beaten egg whites
Figure 19

The hot sugar syrup at around 110 to 115 degrees Celsius will add the sweetness and the heat necessary in order for the meringue to result in a smooth, creamy, and airy consistency. The heat will very quickly hydrolyze the egg whites' proteins and will also cook the eggs; therefore, it will create a much more digestible meringue then that of the French one and a much more airy one then that of the Swiss. This type of meringue is used for applying directly to some tarts, decoration, full-proof airy cakes or macarons, creams, and mousses. Unlike the French meringue, the Italian one is very sturdy, will be more easily manipulated and will be very pleasant to work with. All three meringues actually hydrolyze the egg white proteins in one way or another in order to create air micelles, which are what makes a meringue's texture and form possible!

- *Egg Yolks*

The egg yolks have many different types of molecules in them such as vitamins, proteins, lipoproteins, fats, and many more that help in various processes. They are usually used in creams since they serve as a natural gelling agent that helps with the mixture's sturdiness and texture. They also help form emulsions, as they contain proteins with both hydrophilic and hydrophobic amino acids. The amino acids in the proteins as well as the loose ones will facilitate the formation of micelles. When mixing egg proteins thoroughly with oil and water one part of the protein will stick to the water and another part will adhere to the lipids.

Lecithin is another important emulsifier found in egg yolks. Being a phospholipid, it is a fatlike molecule with a 'water-loving head' (as can be seen at the right in Fig 20 below) and a long, 'water-fearing tail' (as can be seen at the left.) The tail gets buried in the fat droplets, and its head sticks out of the droplet surface into the surrounding water. This establishes a barrier that prevents the surface of the fat droplet from coming into contact with the surface of another fat droplet.

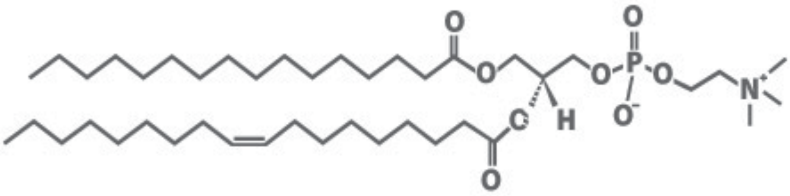


Figure 20 : **Lecithin**

Egg yolks are also used for coloring creams as they give off these golden-orange hues that are perfect for improving the aspect of many deserts, such as for the curd in lemon tarts. This color actually comes from the β-Carotene (a pro-vitamin) found in the yolk. Furthermore, they are used as enhancers for lifting cakes or doughs during the baking process because they too can form tiny air micelles, which expand with the heat.

Gelatinization

A gel is a mixture of solid particles suspended in a liquid. The solid particles in the gel can absorb water, causing the gel to swell and increase in volume. Gelatinization[4] is one of the most important processes when making pastries. That is why, I will now explain the basics of Gelatinization and with what kind of ingredients it can be achieved.

Figure 21: **Egg Flan**

- *Eggs in gelatinization*

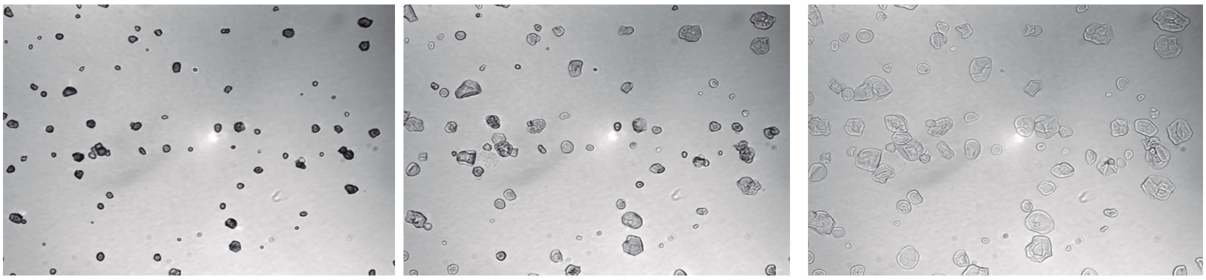
Talking about eggs, as mentioned before, they can serve as natural gelling agents when heated in creams, but how does this work exactly? When one applies heat, one agitates the placidly drifting egg proteins, bouncing them around. They slam into the surrounding water molecules. All this bashing about breaks the weak bonds that kept the protein curled up.

The egg proteins uncurl and bump into other proteins that have also uncurled. New chemical bonds form—but rather than binding the protein to itself, these bonds connect one protein to another. After enough of this bashing and bonding, the solitary egg proteins form a network of interconnected proteins. The water in which the proteins once floated is captured and held in the protein web. If one leaves the eggs at a high temperature for too long, many bonds will form and the eggs will become rubbery, or better said, jellified. This is why many recipes such as creams, flans, or similar pastries use eggs as one of the main ingredients.

- *Starches in gelatinization*

Most people use cornstarch, wheat flour or other kinds of flours to densify creams or to bake cakes, because: it is quick, mostly tasteless, and it brings consistency to the mix. All those different grinds have some things in common: they derive from plants and they all have a form of starch. For example, cornstarch is made up of many molecules of glucose, specifically amylopectin and amylase that the corn plants produce in granules so they can store up energy. When starch is heated with water, the granules swell and burst, causing them to break down and release the glucose molecules into the water. (Fig 22) This process is known as gelatinization.

When the heated water solution and cornstarch cools down, the amylase molecules can bind to each other again and create a molecular mesh. The more amylase molecules present, the firmer, or more viscous, the mesh will become. After heating, a solution with more starch will turn out to be firmer as well as stickier. Because it is more viscous, a solution with a higher percentage of starch will spread out much less than one with a lower percentage, once cooled. This is why, cooling down any cream or gel is important after baking the starch, as it will finalize the process. Different gels can be made using different starches because their consistencies vary with the proportions of amylase and amylopectin that comprise them.



Cornstarch granules being heated
(before, during and after heating from left to right)
Figure 22

Spherification

What is "Basic Spherification?" What is "Reverse Spherification?" Well, as the word may imply, it is a process that turns something into a sphere through a certain gelatinization. However, it is much more complicated then it may look like, especially when that particular sphere has to be delicious, sweet and literally bursting in flavor!

Basically, in order to make spherification, one needs a 'bath' made mostly out of water, and an ingredient or fluid that has to be put into that bath. The thing is, either one of the two components needs to have a 5% sodium alginate content while the other needs to have its equal reactant, in which calcium chloride is usually used. As the ingredient is put directly into the bath, the sodium alginate reacts with the calcium chloride (or any similar reactant containing calcium) and forms a special network of calcium alginate strings, which will actually form the gel layer. (Fig 23) The longer the ingredient is put into the bath, the thicker the gel layer will be.

Figure 23: ***Sodium alginate and Calcium chloride reaction***

Basic spherification implies the formation of very tiny gel-like spheres that have a similar texture to that of caviar, which is why it is sometimes called "caviar" itself. (Fig 23) It is normally served together with another dish or as a decoration in a desert, (if the "caviar" is sweet). In basic spherification, the sodium alginate is mixed together with the liquid that one desires to spherify and the calcium chloride is added into a bath of water. This will allow the previously mentioned liquid to form a gel when it will come in contact with the calcium chloride bath. Finally, one must pour

Basic Spherification
Figure 23

the liquid with a syringe (droplet by droplet) into the bath so it creates mini liquid spheres that will form a thin gel layer after reacting with the solution. After the spheres are formed, they will be strained and rinsed so they can be ready to serve.

Reverse spherification consists of a greater amount of fluid inside of a bigger sphere, and it is usually served as a unit or as the dish itself. (Fig 24) It is called reverse because, instead of having the sodium alginate in the edible liquid, it has the calcium reactant. Also, instead of having the calcium reactant in a water bath it has the sodium alginate in a distilled water bath. The bath has to have distilled water because the small calcium ions found in mineral water might react with the sodium alginate causing the bath itself to jellify and thus interfering with the other reaction.

Reverse Spherification
Figure 24

■ *Gelatin*

Using gelatin is the quickest and easiest way to jellify something, however it is not the most recommended one because the texture of the jellified mix tends to become too dense or wobbly to work with, if used in excess. Nevertheless, it is one of the most reliable methods to keep creams, mousses, or such components sturdy enough for making complicated desserts. Gelatin is actually a form of partially hydrolyzed collagen molecules, or more concretely, a mixture of peptides or proteins that will dissolve at warm temperatures. It can come from animal by-products or from plants. When these collagen by-products are dissolved into a solution, they will tend to create a web-like structure together with the molecules found in the mix when cooled down. (Similar to how the jellifying of the eggs work.) There is one thing that people need to be aware of when using gelatin: sometimes, hydrolytic enzymes can be found in various ingredients and more commonly in fresh fruit. Those enzymes will stop the proteins and peptides from forming a structure by breaking them, preventing the jellification[4] to take place. This will ruin the whole purpose of the gelatin's use.

*Figure 25**: Jelly Fruit Dessert***

Macaron experiment part 1: A chemical change in the ingredient

For this experiment I centered on a chemical process and a physical process that had to be made to two ingredients in the general macaron recipe. A macaron is a very popular French pastry characterized by its "crown," it contains all the textures of a cake in a "simple," coin sized meringue delicacy. Apparently, there are two steps that are vital if one wishes to achieve the pastry successfully; making a physical and a chemical change in two of the main ingredients. In order to test out the "old sayings" and "grandmother tips" given for this recipe and truly understand their importance, I decided to ignore them, and see if it would turn out wrong! I later on compared the results with the original macarons who indeed had undergone those two procedures and observe the organoleptic differences that appeared.

Figure 26: ***Successful macarons***

For the part concerning the chemical manipulation of an ingredient, I decided to try out what would happen if I did not hydrolyze the egg whites before making the meringue as the recipe informed to do. The first thing I noticed was that it was much, much, MUCH harder to obtain the meringue! I had to beat the egg whites for 20 minutes, compared to when they are hydrolyzed and it only lasts 10 minutes maximum… I noticed that the bubbles were larger and it had more of a sea foam texture than that of a creamy one. The lack of hydrolysis makes the creation of the air bubbles be affected in a certain way (which I previously explained in *Chemical Manipulations).* So in difference to the other normal meringue procedure, the only thing I did not do was to let the egg whites sit for 24 hours or so before using them. Amazingly, the result was already starting to be different in barely the first step.

Afterwards, I had to add the tant-pour-tant[9] and start the macaronage[5], at this state, I could see that the meringue was much more fragile, less stable, and less dense. Because of this, I was obliged to mix it less; otherwise the batter would be too runny if I kept on. However, I succeeded in having an almost perfect texture for the macarons batter in the end, so then I became to wonder if it was truly going to affect the result… I piped the little pastries and let them sit for 25 minutes as the recipe indicated. I finally put them in the oven and waited for the twelve minutes to pass.

Difference between successful and cracked macarons
Figure 27

I was immediately baffled by the complexity of baking macarons as I saw that they had all cracked, and none had the special "crown" they should have around the bottom. Instead, after I took them out of the oven and let them cool, I found out they were completely hollow inside. Just as if one had mixed water with soap, created bubbles, and with time all the bubbles disappeared. (Fig 28)

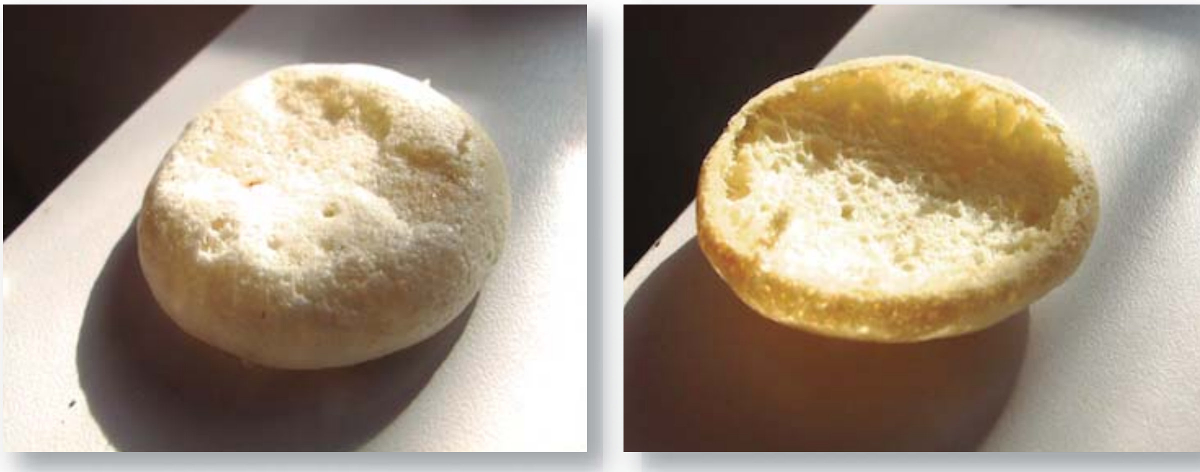


Figure 28: ***Macarons made without having the egg white hydrolyzed***

As for the organoleptic properties… the taste was the same as normal macarons, but the texture was too crisp, and it actually felt more like a butter cookie then an actual macaron. I could not feel any of the softness inside the macarons, as it was hollow, of course. Also, physically, the appearance was different and did not look like a macaron.

I have then confirmed that by changing only a slight chemical procedure in one of the ingredients, the final result will change considerably.

Finally, I made the normal recipe, following the instructions, including the hydrolysis of the egg white and the pulverization of the sugar. To my expectations, everything was all right, the aspect, texture, consistency, etc. of the batter seemed ok, the sugar had dissolved, and the meringue was perfect. I piped those too, waited 25 minutes, and let them cook in the oven for 12 minutes just like the others. The result was as I expected: normal, beautiful-looking French macarons.

After doing this experiment, I have proved that by changing the chemical procedures in certain ingredients, it directly affects the final result. Also I have demonstrated, that those chemical procedures are essential for the success of the recipe and have also explained why they are necessary.

Figure 29: ***Successful macarons, at last***

Spherification: Basic and reverse

To research more upon the before mentioned spherification, I decided to make an experiment and try to spherify certain liquids myself; for this, I needed particular ingredients and utensils (which will be listed below) in order for it to be successful.

Spherification Ingredients

There are a few ingredients necessary for Basic Spherification and Reverse Spherification but there are only two that are essential and absolutely required to start the spherification process: sodium alginate and some calcium element. The calcium element can be found naturally in dairy products or other similar foods, so depending on what is it that one is spherifying and if it is reverse or basic, one may or may not need to add some extra calcium chloride.

Figure 30: ***Sodium Alginate, from seeds to powder***

Sodium Alginate: It is a natural product extracted from brown seaweed that grows in cold-water regions. (Fig 30) It is soluble in cold and hot water with strong agitation and can thicken and bind. In presence of calcium it forms a gel without the need of heat. Sodium Alginate is used in the food industry to increase viscosity and as an emulsifier. What is great about this product is that it has no discernable flavor; therefore it can easily be used when making desserts that need this particular gelification process.

Calcium Chloride: (Fig 31) It is used to make the calcium bath for Basic Spherification. This is used mostly with Basic Spherification because its saltiness does not affect the main ingredient taste as it is only used for the bath. Calcium chloride is a calcium salt traditionally used in the food industry to make cheese and it is also used in many other applications as pickling agent, firming agent, flavor enhancer, stabilizer, etc. It is very soluble in water and it must be kept in tightly sealed containers.

Figure 31: ***Calcium Chloride***

Calcium Lactate: It is used to increase the calcium content of the main ingredient in Reverse Spherification. It provides a less bitter taste than calcium chloride when added to the main ingredient and it can also dissolve in fats as it is a amphipathic[1] product. It is often added to sugar-free foods to prevent tooth decay and to fresh cut fruit to keep it firm and extend shelf life.

Calcium Lactate Gluconate: It is an ideal product for increasing the calcium content of the main ingredient in Reverse Spherification. The main ingredient consistency and flavor is not altered by the addition of calcium lactate gluconate as it has no discernable flavor and dissolves in cold liquid without altering its density. It is versatile as it can be used in liquids with high acid, alcohol or fat contents. To avoid difficulties in dissolving, one must add the calcium lactate gluconate before any other powder product.

Sodium Citrate: It can be used to reduce the acidity of the main ingredient when doing Basic Spherification. The Basic Spherification process does not work if the main ingredient is too acidic (pH<3.6). Sodium citrate has a sour taste as well as having a salty taste so one should use it in moderation when adding it to the main ingredient in order not to alter its taste too much.

Xanthan: It is used to thicken the main ingredient in Reverse Spherification. When the main ingredient density is too liquid to form spheres in the alginate bath, a thickener like Xanthan is used. It is obtained from the fermentation of cornstarch with Xanthomonas campestris bacteria (found in cabbage). It is gluten free and can be used as a substitute for gluten in baking (used along with non-gluten containing flours). It is soluble in hot or cold water, stable over a range of pH or temperatures, it can thicken items with high alcohol content, and it is compatible with systems containing high concentrations of salt.

Spherification Utensils

There are several utensils that are almost if not vital to make a proper and well-done spherification. Here are the most vital tools known in spherification.

Dosing spoons: It is used to pour the main ingredient into the bath to form the sphere. A set of measuring spoons with spherical shape is recommended since they conveniently come in different sizes and one can manipulate the type of sphere that is wished. This is essential mostly in order to obtain the shape of the sphere. (Fig 32)

Figure 32: ***Dosing Spoons***

Scale with 0.1g precision: Most of the recipes require very low amounts of "molecular" ingredients, usually fractions of a gram. To be successful with spherification it is important to be precise and use a scale with such precision. This is probably the most essential piece of equipment you need even though there are charts out there to convert the molecular gastronomy chemicals' weight to volume so you can use a measuring spoon instead but this is not very precise. The density of the ingredient is very sensitive to packing of the powders and it can also vary by brand. Unfortunately for me, as I do not own such a scale, I will have to use the latter method.

Immersion blender: It is used in order to dissolve the sodium alginate that only dissolves with strong agitation. It is also used in several recipes to prepare the main ingredient and mix the xanthan gum.

Figure 33: ***Caviar Maker***

pH Indicator Paper: It is used for measuring the acidity (pH) level of the main ingredient when doing Basic Spherification; (as it doesn't work if the pH level is below 3.6.)

A Syringe or a caviar maker: It is used for creating "caviar;" that is to say, very tiny spheres which are produced in large quantities and are used as "toppings" (in the case of them being sweet) on various desserts. Just a regular syringe without the needle is needed; otherwise there are special caviar makers to go faster. (Fig 33)

Appetizer spoons: Some of the spheres are very delicate to be handled by hand or with spoons by the diners so they have to be placed carefully on appetizer spoons to be served. This is particularly necessary with basic spherification spheres due to their more delicate membrane. (Fig 34)

Figure 34: ***Appetizer Spoons***

Spherification Experiment

The main goal of the experiment consisted on directly observing the chemical reactions that take place during basic and reverse spherification. First of all, I made sure to have all the material necessary in order to make a successful spherification. As the sodium alginate, calcium chloride and distilled water were not in my possession, I had to order them at a pharmacy… Unfortunately, the sodium alginate was out of stock, causing my research on spherification to be delayed for a month! Once I had all the ingredients in hand I could finally carry on with the spherification.

- *Basic Spherification*

I started by making basic spherification by preparing a mineral water bath with a 5% concentration of calcium chloride mixing it thoroughly with a blender and pouring it into a bowl. Then I made a strawberry juice with a 5% concentration of sodium alginate and also used the blender so it would be well combined. After that, I took a syringe, gathering some of the strawberry mixture with it, and poured it droplet by droplet into the calcium chloride bath. As I poured the strawberry droplets into the bath, right after submerging them, I noticed some bubbles starting forming around the mini spheres. After five minutes, I took the “caviar” out of the bath and rinsed them with water. To my good surprise, everything went all right and the gel had formed just as I had planned. However, I found out that the small spheres were very fragile as they could break upon contact if not handled with care.

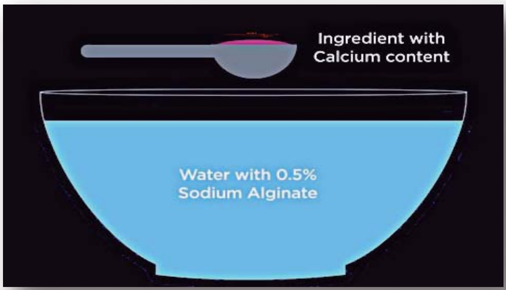
Figure 35: ***Basic Spherification Process***

This was probably due to the fact that I hadn't let them so much time to gelatinize in the bath, so I tried to make a second batch with a longer duration. After 10 minutes, I took the mini spheres out and noticed that they were much less fragile but they still had liquid in them so they could "pop" when tasted. (Fig 36) With this, I confirmed that the chemical reaction occurred only when the spheres were in contact with the calcium chloride bath and stopped when they were taken off of it.

Strawberry juice "caviar"
Figure 36

Reverse Spherification

For the reverse spherification, I used a passion fruit juice in which I added cream in order to add some calcium content into the mix. After preparing the juice, I made a 5% sodium alginate bath, specifically with distilled water so the sodium alginate wouldn't react with any minerals found in everyday water. Once the bath was ready and the material was in place, I used a dosing spoon to carry the juice in a spheric fashion, carefully placing it into the bath.



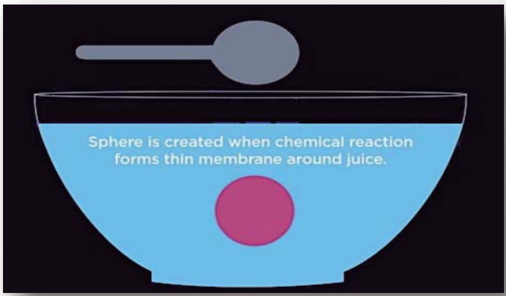


Figure 37: ***Basic Spherification Process***

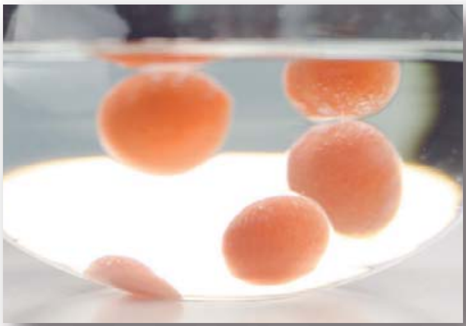


Figure 38: ***Reverse Spherification taking place***

As the medium sized spheres started to form I noticed tiny air bubbles gather around it, showing that a chemical reaction was indeed taking place. After 10 minutes, I took the spheres out very carefully and placed them in plate, ready to be inspected. Fortunately as I had planned, the sphere's outermost layer had now turned into a gel, which permitted to enclose the liquid inside quite well. The appearance of the spheres was almost exactly the same as an egg yolk; indeed, it is a truly modern and curious way of serving food.

Physical Manipulations

Processes, results and importance

Important physical changes in Patisserie

The physical manipulations applied to ingredients, pastries, and mixes end up being responsible for the texture, aspect, and some of the organoleptic properties of the finished product. In this section, the science behind the most important and common physical procedures or changes will be explained.

Changes in the Aspect

A very common physical change in pastries is the change in aspect; be it through the color, shine, texture, or even arrangement of the pastry itself. In restaurants, chefs pay close attention to how the desserts are arranged. Sometimes the pastry is rearranged in a way that the cream is on one side of the plate whilst the chocolate is in the other. The dessert might even actually be scattered around, changing the organoleptic properties of it, as everything is tasted separately instead of together as found in the traditional pastries. The chefs might also play with the colors, making the desserts more, let's say, "appeasing" or "passionate" depending on the intensity of their hues.

Macarons of different colors and flavors
Figure 39

- *Change in Color*

Color actually may even enhance the taste or at least, the person's perception of it through visual stimulation. For example, if a dessert is red or pink, one might expect strawberry, rose, or similar colored ingredients. The anticipation of the taste through the aspect can be either used as a taste intensifier, or, as found in modern gastronomy, as a great element of surprise. For instance, a chef could decide to taint a pastry green, making one think of green tea, mint or pistachios, when actually the real flavor might be vanilla, white chocolate, lemon or any other taste that has not much to do with green. This will cause a great element of surprise and therefore add intensity to the taste when first eaten. In addition, there are many natural pigments that can literally enhance the taste itself, such as the green colorant extracted from the pandan leaf. (Pandan is a plant that contains natural aromatic enhancers for ingredients such as vanilla or rice.) This is why the physical change of manipulating the colors of a dessert is so important and common when making pastries.

Change in Gleam

Apart from the changes in color, the shimmer also plays a very important part in influencing the organoleptic experience of the taster. Something that shines more will give off an impression of freshness and richness; while something dull might make the viewer think of the dessert as plain or less attractive. Shimmer can be achieved in various ways depending on the ingredients; for ingredients containing or forming crystals, the chefs will try to manipulate the structure to make them shinier. (For other products, because the shine is so important, one might even use sugar or egg coating that consists in adding luster by adding thin layers of homogeneously spread shiny ingredients. Glazing is very commonly used in fruits, nuts or any parts used in pastry surfaces and decoration, as it is what will first attract the viewer.) Most of the times, chefs will aim to manipulate the ingredients physically by pulverizing, heating or mixing to change the size and arrangement of the polymorphs found in such mixes. It is one of the most important physical processes as the appearance of a pastry plays a very important role in enhancing or decreasing the perception of the organoleptic properties in a dessert.

Figure 40: ***Shiny strawberry cheesecake***

Changes in the Temperature

Strawberry mousse at solid state
Figure 41

Another very important change that affects the pastries physically is the variation in temperature. The organoleptic qualities concerning the texture, taste, and of course, the temperature of the dessert will vary immensely weather the dessert itself is hot, warm, cold, freezing or at the ambient heat. For example, ice cream at a warm temperature is actually a crème anglaise[2]; even though the composition stays the same, the texture varies and so does the taste with it. Warmer conditions favor an enhancement in the taste, aroma, and silkiness while coolness promotes texture, freshness and dimness in the taste.

Chefs tend to mix cool creams or mixes along with warm one so that there is a greater contrast in the organoleptic features of the whole dessert when tasted. The temperature will also play a great part in the formation of micelles, as mentioned earlier, so by applying one physical change, it will open room for many more.

Vapor sweet strawberry and vanilla dessert
Figure 42

In modern gastronomy, there are various ways to affect the temperature physically without affecting the chemical composition of the dessert. Some chefs use liquid nitrogen to cool down desserts immediately for a short amount of time so that a usually liquid mixture will turn out solid just before being tasted. Modern gastronomy has gone so far that now, it is even possible to prepare a dessert in a vapor state! (Fig 42) What chefs do is that they extract the aroma and aromatic compounds of the said dessert and concentrate them in a liquid. This liquid can either be vaporized or served as such. Another way to do it is by drying the concentrated solution carefully so it does not lose any of its aromas and pulverize it so thinly that it becomes volatile. These volatile compounds will be able to be mixed with either liquid nitrogen to be served as cool or with water vapor to be served as warm and moist. The state of the dessert will therefore play a very important role in the organoleptic properties of the dessert.

Manipulation of crystals

The most difficult but important physical manipulation there in in pastry is to control the amount and size of crystals that certain ingredients or mixes may form in order to influence the aspect and texture directly. The following will be about the most commonly used ingredients or desserts in which crystal manipulation is made.

■ *Ice-Cream*

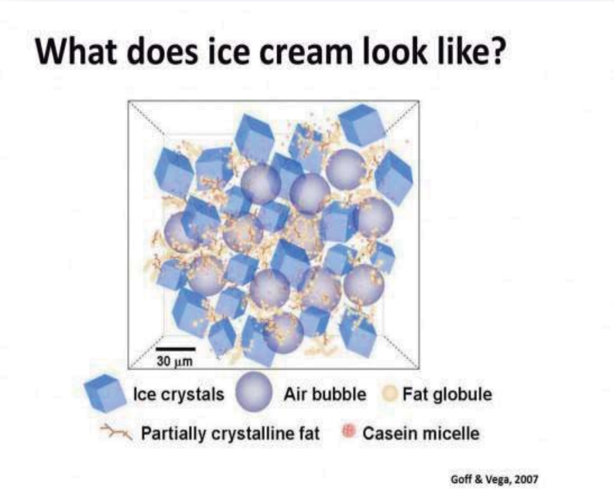
Icecream is one of the most requested desserts known in pastry as it has an incredible taste, texture, temperature and aspect. Although many factors influence the texture of ice cream, it is generally understood that smooth ice cream requires the majority of ice crystals to be smaller than about 50 μm in size. Ice crystals larger than 40 μm to 55 μm result in coarse or grainy texture if present in sufficient number.

Figure 43: ***Ice-cream***

So, how is ice cream with many small ice crystals made? Total solids content, fat content, sugar content, air bubbles, residence time, and hardening time all play and important role in forming small ice crystals and, in turn, a smooth and creamy texture. (See Fig 44 in the next page) An increase in the total solids (TS) (the percentage of milk fat, non-fat milk solids, sugar and egg solids) level will decrease the amount of water in the mix, thereby reducing the total amount of ice that can form. However, a total solid percentage over about 47% will result in a heavy, chewy ice cream.

The fat content can also influence the size of the ice crystals as fat globules could mechanically impede the ice crystal growth. It is important to keep the milkfat percentage high in ice cream in order to develop a smooth and creamy texture. Sugar also influences the size of the crystals, because in ice cream, higher sucrose content produces smaller ice crystals and an increase in sugar content from 12 to 18% decreases ice crystal size by about 25%.

Air bubbles also play a major roll in ice cream… When an ice cream mix is frozen in an ice cream maker, air bubbles are whipped into the mix. A low overrun (a small amount of air whipped into the ice cream mix in the ice cream maker) induces the formation of coarser ice crystals in ice cream compared with the same formulation made at higher overrun. This is because air cells may provide a physical impediment to ice crystallization during freezing. So, whipping more air into an ice cream mix appears to result in the formation of smaller ice crystals.



Ice-cream's general composition
Figure 44

Above all, residence time (the amount of time an ice cream mix spends in the ice cream maker) was found to have the most pronounced effect on mean ice crystal. As C. Clarke, 2004, proved through his experiments: the total number of ice crystals depends mostly on the residence time. Short residence times produce many crystals with a small mean size, whereas long residence times and high rotation speeds result in fewer, larger crystals. To obtain small ice crystals, it is necessary to have the shortest residence time possible so as to minimize the amount of ripening that occurs within the freezer barrel itself.

As for the temperature, in order to achieve small initial ice crystals, the ice cream mix must be rapidly frozen in a freezer, after it has been churned in the ice cream maker, to promote nuclei formation and minimize ice crystal growth. Temperatures as low as -30°C are used in order to promote rapid nucleation in the freezer! Several ideas involving liquid nitrogen have also been developed to promote rapid nuclei formation. When ice cream is removed from the ice cream maker, it must be immediately hardened in a freezer. The longer the ice cream spends at room temperature once it has been churned in the ice cream maker, the more ice will melt and the larger the ice crystals will be. The temperature and rate of hardening determine the final ice crystal size and the physical sensory properties of the product. Time to accomplish hardening has been assumed to be the time for the temperature at the center of the package to drop to -18°C or lower, preferably -25 to -30°C.

All these things are the reasons why one has to keep in mind so many things while trying to manipulate the crystal formations in ice cream and why it is so difficult to achieve the right consistency when making that particular dessert.

Sugar

Making sugar crystals is one of the best ways to observe crystallization because it is relatively easy to do and there are fast results. There are several different parts to the crystal-making process, and there are also two different ways that the crystals can be formed, as there is a faster way and a slower way. Though they are the same, the faster way simulates what happens in the slow way in a much quicker manner.

The basic principle behind growing sugar crystals is to saturate the water with sugar to the point where the water can no longer contain all of the sugar molecules. When this happens, if given the right conditions, the sugar will creep out of the water, forming crystals. This can either happen through over-saturation or through evaporation.

Figure 45: ***Sugar crystals on a string***

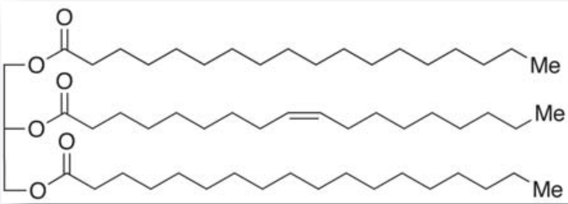
When a liquid is hot, it can contain more molecules than when it is cold. This is because when the molecules are heated, they move around more, making room for more molecules. When the molecules freeze, they slow down and expand, making less room inside a solution for foreign materials. When making a sugar solution designed to make crystals, completely saturate hot water with sugar until no more can dissolve. This makes it possible for the crystals to grow when the water cools.

Even when a water solution has been saturated with sugar, it still takes time for crystals to form. Usually it takes about three weeks to get a good number of crystals. When using the evaporation method of making crystals, it can take even longer than that. The evaporation method of making crystals is the same way that mineral crystals are formed in nature. The water slowly evaporates over time and the mineral, or in this case sugar, deposits are left in a crystal formation. Usually when growing sugar crystals one needs to give the crystals something on which to form. This is generally a string suspended above and through the sugar solution. The reason that it is necessary to have the string is so that the crystals form faster and in a way that makes them easier to view. The string acts like a guide for where the crystals should form.

Chocolate

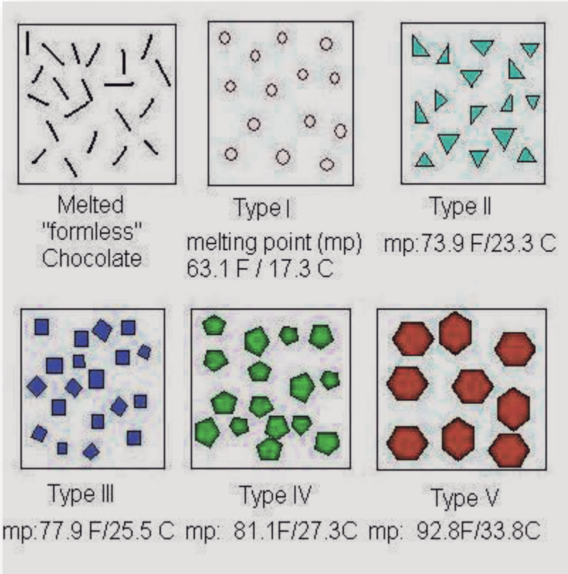
"Life is like a box of chocolates, you never know what you're gonna get." Or so said Winston Groom, the author of the famous novel, Forest Gump… Actually, you really never know what you're going to get with chocolate, as it comes in many forms and sizes, even at the molecular level; but what *is* chocolate exactly? Many know it as a delicious, crispy, shiny, sweet, yet sometimes bitter treat that can bring happiness at times of grief. As it turns out, chocolate's structure is similar to a very complicated yet well-made network of molecules that can form into tiny crystals when correctly manipulated.

Difference between non-tempered chocolate (left) and tempered chocolate (right)
Figure 46



1,3-Distearoyl-2-oleoylglycerol
Figure 47

Chocolate gets its shimmer and crunchy texture from the crystalized form of a triglyceride[11] called 1,3-Distearoyl-2-oleoylglycerol. (Fig 47) These triglycerides can actually arrange themselves in many forms depending on the temperature and the way they are cooled down. There are currently six different types of structures known to food chemists in which those polymorphs can arrange themselves. (Fig 49)



Types of chocolate crystal formations
Figure 49

What most chocolatiers look for when working with chocolate is the β (V) crystalized structure due to the fact that it is a much more solid organization of the triglycerides. (Fig 48) It will give a great shine to the chocolate, and its melting point (34 ºC) almost exactly coincides to that of a human's body temperature. The other structures will either make the chocolate melt even before one tries to eat it and will lose its shine or be a bit too resistant to the heat, which will not be quite pleasing to the client.

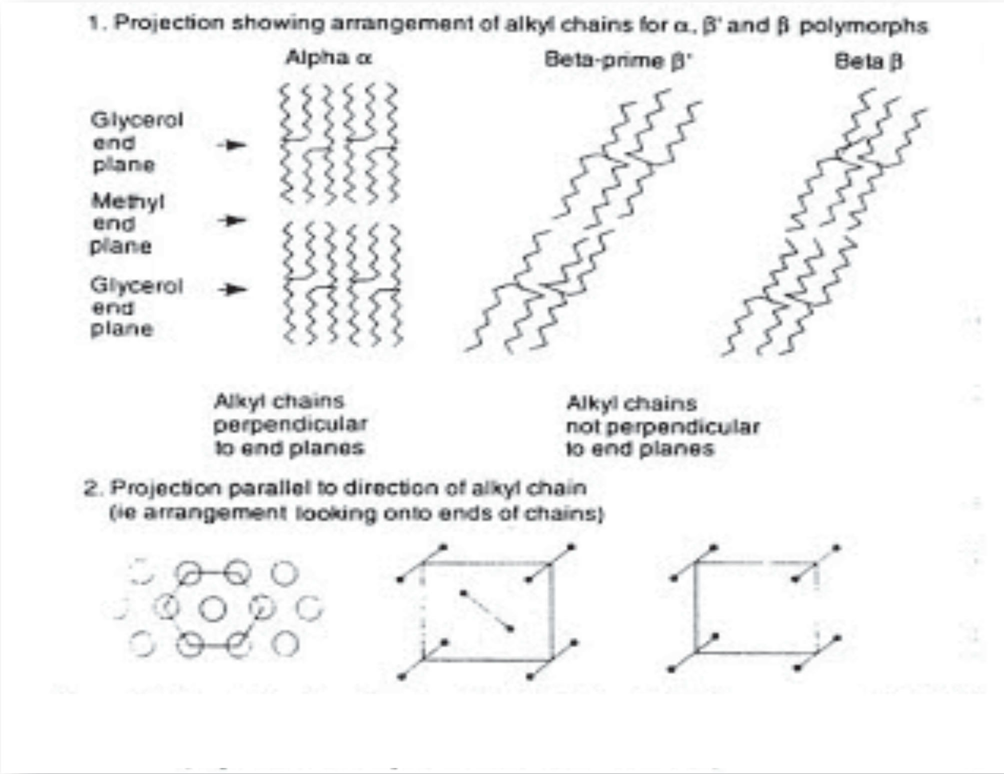
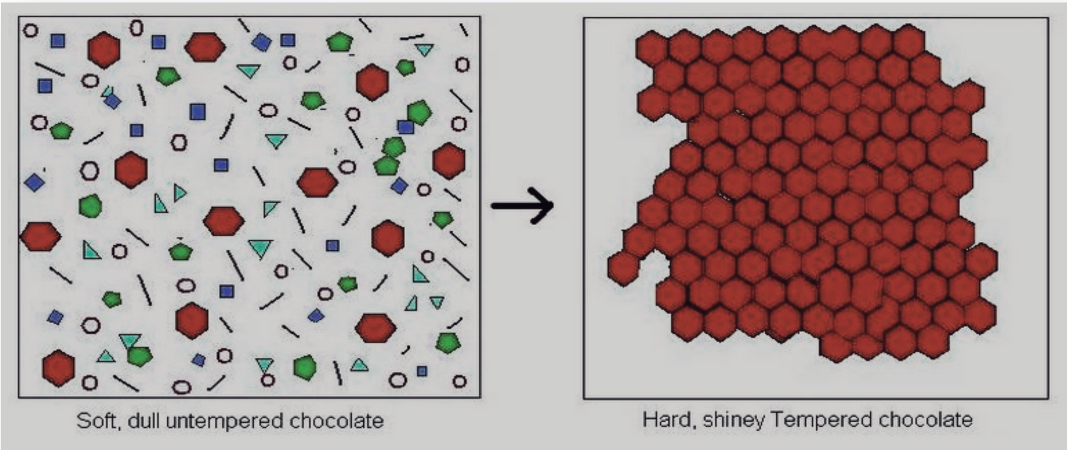


Figure 48: ***Formation of the β (V) structure with triglycerides***

If one heats and cools chocolate without controlling the temperature, the crystallization of cocoa butter will result in crystals of different sizes (bad crystals) forming, and the chocolate will bloom – that is to say it will appear matt and covered with white patches. So in order to achieve the right uniform crystalline structure, a chocolatier has to temper the chocolate, that is to say, manipulate the melting and cooling of the chocolate in a slow fashion so that it gives it time for the triglycerides to form the right crystalized pattern. The easiest but priciest way of tempering[10] chocolate is to buy a tempering machine. This heats up the chocolate very, very slowly then cools it down equally slowly, leaving the finished chocolate silky smooth.

If one does not have such a machine, the chocolate needs to be melted by bain-marie, allowing it to melt very slowly. Afterwards, there can be two options: either one adds chopped pieces of an already tempered chocolate so as if to create a crystal “seed,” or, actually cause the crystallization by manipulating the heat oneself. The “seed” concept relies on mixing the right crystalized form of the chocolate (the seed) into the other un- tempered chocolate, in order for the right crystal pattern to expand and convert all the structures to the Beta V one. (Fig 49)



Difference in structure between an un-tempered chocolate and a tempered one
Figure 49

The other option is more complicated, as one has to bring the (dark) chocolate to 46ºC with the bain-marie, then cool it to 27ºC with the help of a marble board and a metal spatula, and then reheating it again with the bain-marie to 32 ºC in order for the right crystals to form. Depending on weather it is dark, milk, white, or other kinds of chocolates the temperatures will vary. This technique actually takes years to perfect even with the help of the thermometer; this is why making chocolate is the most difficult thing to do in patisserie.

Tempered Shiny Chocolates
Figure 50

Cream experiment: A change in temperature

In this experiment I tested out different physical manipulations on an ingredient and observed if the results would be different for each change made. The modifications I made were in the temperature; (not to an excess because otherwise it would alter the chemical properties of the ingredient). The ingredient I used was (as one may guess by the image) whipping cream. The experiment consisted in taking three equal portions of the exact same whipping cream, and having each of them reach a different temperature before whipping it. As I mentioned before, if the change in temperature was too extreme, it would affect the ingredient chemically, therefore I used a special thermometer to be sure nothing went wrong. The first bowl had a cold whipped cream (A) at 6ºC, the second bowl had a room temperature whipped cream (B) at 26ºC, and the third had a warm whipped cream at 40ºC.

Whipping cream, apart from making this fabulous, smooth, airy, and soft cream we all know so well, has actually many secrets; and one of them is that it has to have a 30%-40% fat in order to be turned into a successful whipped cream. After reading an article about whipping cream from *ASHLAND*, a book called the *Chemistry of Food*, and a website about *Milk Chemistry* I was able to understand fully well what was going on in the cream. I learned about the factors that made it transform to this stiff smooth product after whipping it for three minutes or so.

Cream is actually made out of the higher butterfat layer skimmed from the top of the milk before homogenization and it obviously contains a relatively high percentage of milk fat. The percentage comes around naturally and as I mentioned before, it is crucial for the making of whipped cream; however, because of the present low-fat diets, many companies are prone to make “low-fat” or “only 7% fat” creams by taking out some of the fat. These sort of low fat creams are useless for making whipped cream.

What could this fat that has been mentioned so many times be made out of? Actually 98% of milk or cream fat is made out of **triacylglycerides.** As shown in the picture below, a triacylglycerol consists on a glycerol (at the left) and three fatty acids (in the middle) that unite through esterification (at the right). However, many people now may wonder, fat and water don’t mix, how can it be that they mix in the cream?

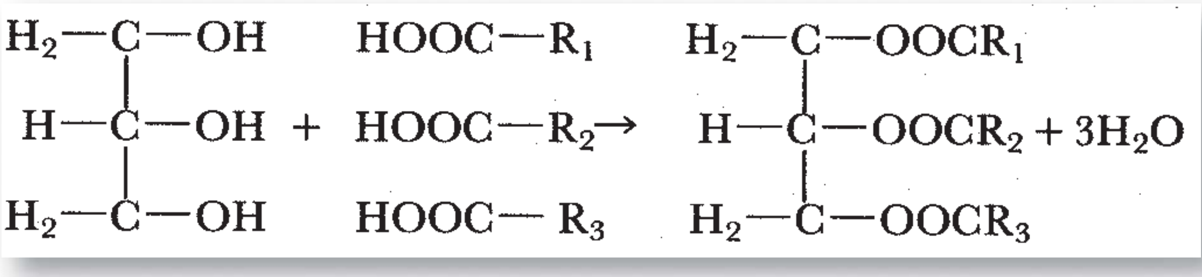


Figure 53: ***Making of a triacylglyceride (esterification)***

Well, triacylglycerides have a polar part and a non-polar part. The polar part actually mixes with water, while the non-polar part does not mix well with water. So what happens is that these triacylglycerides accumulate on the surface of the cream, having the polar part exposed to the water, and the non-polar part exposed to the air. This is very important for the formation of micelles, a crucial factor for the whipping cream.

The micelles are formed when the triacylglycerides in the surface are agitated and mixed in with the water. What will happen is that those triacylglycerides will now be immersed in the water and its polarity will force them to create a bubble, usually with air inside. The non-polar part will be pointing towards the interior, and the polar part will point towards the water. So this is how micelles are made and as a consequence, whipped cream!

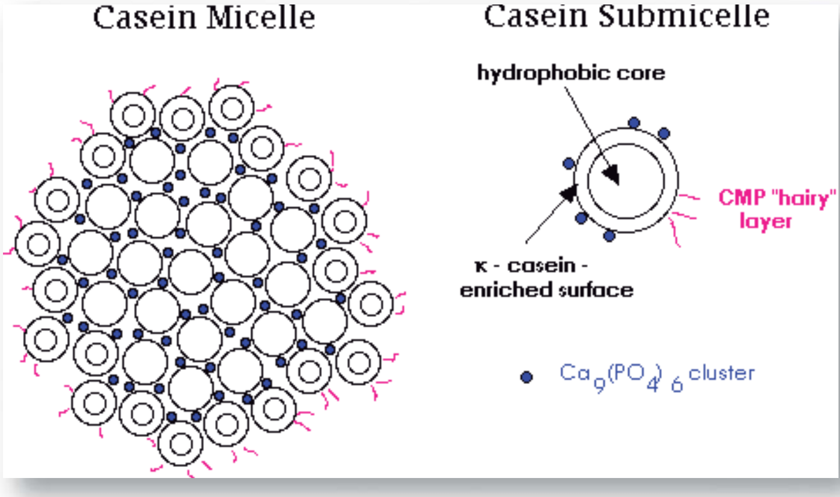


Figure 54: ***Casein Micelles***

Cream is not only made out of water and triacylglycerides, as one may know, it has many other biomolecules which collaborate in the making of whipped cream. It has galactose, proteins, calcium, calcium phosphates, etc. One of the proteins, called casein, and a small molecule called calcium phosphate, are actually another very important factor for creating those micelles. They act like bridges and chains that surround the fatty bubbles and join them together to make a more solid structure.

When one boils milk or cream, a coat of something white on top of it is usually created; that coat is actually an accumulation at the top of the casein proteins that have been denaturalized by the heat.

Curiously, what is actually happening in whipped cream or in milk is that the casein proteins are able to create complicated "micelles" of their own, (with the help of calcium phosphates) as seen in the image below. Those complicated micelles have the casein proteins and the calcium phosphates acting up as a barrier in order to imprison the sub micelles made out of triacylglycerides. It is therefore important for the making of macro micelles and it is consequently vital for the stiffness of whipped cream.

As one may know now, these micelles stabilize the cream, make it more solid, and add air to it. Now, the thing is, depending on the temperature, micelles are less or more likely to form; and this is where the experiment comes in.

Whipped cream A: I took 200 ml of a cream with 36% fat, covered it with plastic and put it on the fridge so that the temperature would go down to 6ºC. Once the temperature was the one desired, I took the whipping whisk machine and whipped it for three minutes exactly (no sugar, vanilla, or other ingredients were added in the process.)

Figure 55: ***Whipped cream A***

The result was one of a very nice whipped cream, with soft peaks and a solid form. (Fig 55) This is because the fatty acids in the triacylglycerides were fluid and yet viscous enough to create micelles with the help of casein proteins.

Whipped cream B: For the second one, I measured the same amount of cream as before, covered it with plastic too, and let it settle to room temperature, 26ºC. Once the temperature was set, I started whisking it with the same whipping machine and speed… After one minute and a half of whipping the cream, I started noticing it wasn't working so well and it was still quite liquid. (Fig 51)

Figure 51: ***Whipped cream B***

Once the three minutes were up, the result was not so good; nevertheless, it had a certain stiffness but not as great as the first one. This must have been due to the fatty acids of the triacylglycerides being more liquid and because of their loss in viscosity. Also, the intermolecular bonds with the casein must have become more fragile which caused it to have a less solid texture.

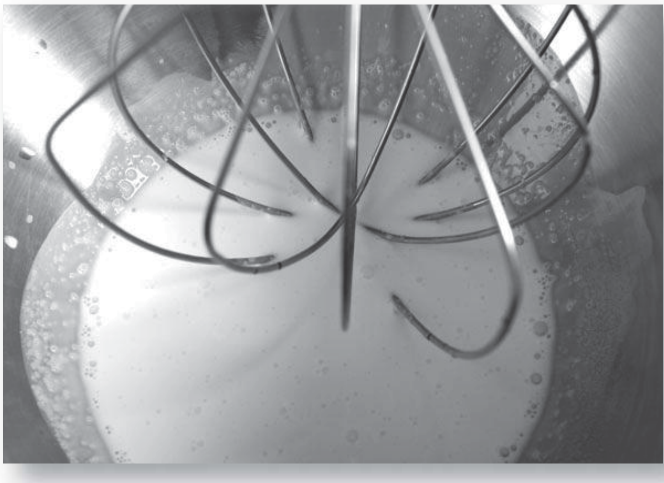


Figure 57: ***Whipped cream C***

Whipped cream C: In the last one, once again I measured the 200 ml of cream and covered it with plastic, however this time I put it in the microwave for a very short amount of time, checking constantly as the temperature went up to 40º.

Needless to say, as I put the cream in the whipping machine, after three minutes of whipping, there was no result. There were only the occasional bubbles and a liquid heterogeneous mixture. (Fig 57) This was surely caused because the fatty acids in the triacylglycerides were now too liquid to form micelles. Also, it was because the casein proteins had lost a lot of stability due to the heat and were unable to create “the bridges” between fatty acids.

This experiment proves that by changing the physical state of an ingredient, such as the temperature, it will ultimately affect the final results’ organoleptic properties. Whipped cream A turned out to be stiff, smooth, and homogeneous. Whipped Cream B turned out to be less airy, more liquid, and less homogeneous. Finally, Whipped cream C was completely liquid and couldn't even be considered whipped cream!

Macarons experiments part 2

A physical change in the ingredient

For the second part of the experiment, I centered on a physical process that had to be made to an ingredient in the general macaron recipe. The most important physical procedure for the making of macarons is to change the size of a very well known ingredient: simple sugar. In order for the recipe to be successful it is said that one has to use pulverised (or powdered) sugar and NOT normal sized sugar crystals. (See Fig 58 and 59)

This pulverised sugar will be later mixed with almond to make what's called a tant pour tant Therefore, the only thing I changed from the original recipe was that I did not pulverize the sugar. I could already tell that the tant pour tant was different, it was lumpy and we could distinguish the sugar grain from the almond. In difference to this, the usual tant-pour-tant is very dry, powdery, and smooth; also we cannot distinguish what is sugar and what is almond anymore. This is surely due to the size of the sugar crystals, by being smaller, it becomes easier to homogenize, and therefore it becomes difficult to distinguish what is sugar and what is almond.

Figure 58: ***Normal sugar***

Figure 59: ***Powdered sugar***

The next step is making a meringue, for the meringue I made it as authentic to the usual meringue as there could be: taking hydrolyzed egg whites, adding sugar bit by bit, and mixing it until it becomes white and fluffy. It turned out perfect! Then, I had to mix the meringue with the tant pour tant. After what is called “macaronage” all the lumps found earlier in the tant pour tant were gone. However, I immediately noticed that some sugar crystals had not dissolved in the meringue, surely, due to their size. If It would have been powdered sugar, it would have dissolved much more easily.

I finally piped the macarons with a piping bag into the oven paper sheet and let them sit for 25 minutes (an essential procedure for the macaron to form a slight crust.) The aspect before putting them in the oven was very normal and usual, so I started being skeptic as to whether using normal sugar would be so dramatic. Then, as I usually did, I finally put them in the oven and let them bake for 12 minutes exactly. After 5 minutes I already knew my macarons were not macarons, they did not form the 'crown[3].' Normally, at five minutes exactly my macarons always lift up and create the macaron collarette[3].

After it was done, I took them out of the oven and waited for them to cool; they had most definitely not made the typical macaron crown. Their aspect was therefore different. The color stayed the same, if not a bit too colored, and it actually looking like a butter cookie more than a macaron. (Fig 52) The texture was a bit dry upon tasting it and very crunchy, but it was soft in the interior. So, it was dryer than the usual but not too much, however the crunchiness was too pronounced. As for the taste, it was basically the same familiar sweet subtle roasted-like almond taste any unflavored normal macaron has.

Figure 52: ***Macaron made without powdered sugar***

As one can see, using normal sugar just can't work, but why? The big reason is because of the dissolution problem, it just cannot dissolve as easily as powdered sugar can without the need of excessive mixing. Since powdered sugar has such small crystals, it dissolves almost instantly. Now, why would the fact that it has not dissolved cause a problem? Because the undissolved sugar forms a crust around the macarons when they are put in the oven; as some of the crystals accumulate and dry on the top layer with the heat, a hardened cover is created.

That crust, which is too hard, makes it very difficult or even impossible for the meringue to lift, which explains the lack of collarette and the inflated aspect in the result. Actually, some people add sugar on top of brownies to create a characteristic crunchy sweet crust, but this is not useful in macarons! So this is why one must not used normal un-pulverized sugar when making the tant pour tant of the macarons.

Figure 61: ***Successful macarons***

I have then confirmed that by changing only a slight physical procedure in one of the ingredients, the final result will change considerably.

After doing this whole experiment, I have proved that by changing the physical or chemical procedures in certain ingredients, it directly affects the final result. Also I have demonstrated, that those chemical and physical procedures are essential for the success of the recipe and have also explained why they are necessary.

Figure 62: ***Successful macarons***

Biological Responses

The nervous and metabolic system

Introduction to the biological response

When tasting a treat or dessert, we react in a certain way because the body and nervous system get stimulated through chemical messages that those sweet pastries send when they reach the mouth and even the digestive system. There are always variations to how one will react to a certain food because of the genetic factor affecting the experience of one's perception when tasting it. The taste, texture, crunch, appearance, sound and aroma of the dish will all be very important in sending different messages to the brain. (The environment actually plays a significant role in influencing the sensitivity of the organoleptic features in a certain pastry.) In the following, the science behind those biological reactions will be explained in further detail.

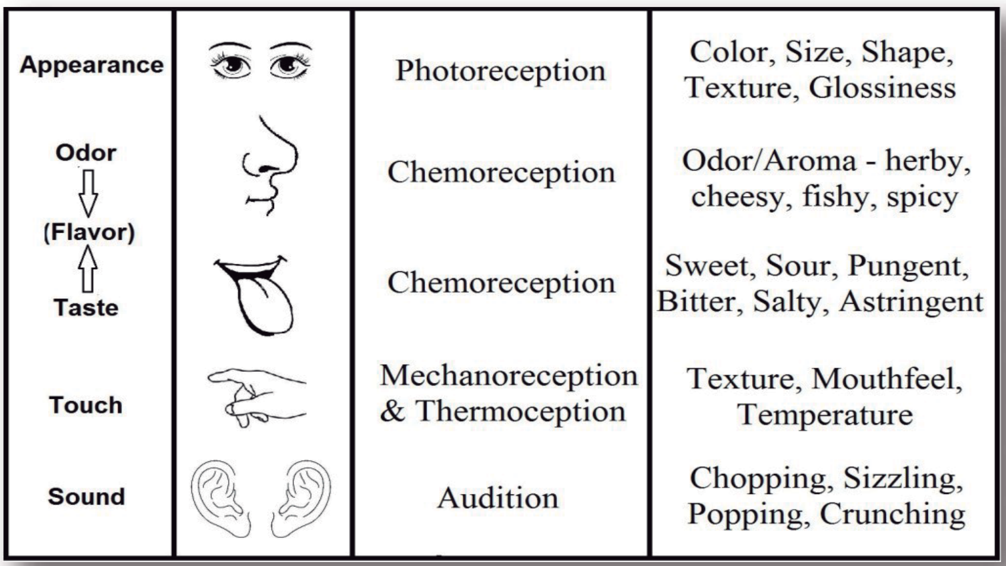


Figure 63: ***Organoleptic Senses***

Figure 53: ***Various visually appealing Pastries***

Response of the Nervous system to the Organoleptic properties

What is meant by "Organoleptic properties" is the aspects of food ingredients/products as experienced by the 5 senses – sight, smell, taste, touch and sound. These aspects are considered into account when food safety is concerned. To identify whether a product is stale or fresh, faded or rotten, the body conducts organoleptic tests automatically upon encounter with a food. What is incredible when eating is that the food will activate the mechanoreceptors, photoreceptors, chemoreceptors, auditory system and thermo-receptors, which will directly and indirectly associate with or activate the limbic system primarily and even maybe other parts of the brain as a consequence.

- *Chemoreception (Odor)*

In humans, olfaction occurs when odorant molecules bind to specific sites on the olfactory receptors. These receptors are used to detect the presence of smell. They come together at the glomerulus, a structure which transmits signals to the olfactory bulb (a brain structure directly above the nasal cavity and below the frontal lobe). Humans have two distinct olfactory systems—the main olfactory system, and the accessory olfactory system (used mainly to detect pheromones). The main olfactory system detects volatile chemicals, and the accessory olfactory system detects fluid-phase chemicals. Olfaction, along with taste, is a form of chemoreception. The chemicals themselves that activate the olfactory system, in general at very low concentrations, are called odorants. Although taste and smell are separate sensory systems in land animals, water-dwelling organisms often have one chemical sense.

The binding of the ligand (odor molecule or odorant) to the receptor leads to an action potential, a short-lasting event in which the electrical membrane potential of a cell rapidly rises and falls. Sensory neurons will then project axons to the brain within the olfactory nerve that will ultimately pass the message to the olfactory bulb of the brain through perforations in the cribriform plate. This will in turn project olfactory information to the olfactory cortex and other areas including the limbic system, causing yet again an emotional stimulation.

Smells are very powerful triggers of specific memories, and this can actually influence the experience of the taster upon smelling and trying out a new or habitual taste. This is partly due to the fact that the part of the brain that processes smell has direct links with parts that are involved in emotion and memory. Sweet or similar aromatic odors tend to create a sense of well-being or peacefulness in the brain and reduce stress, such as vanillin, the ligand compound found in vanilla.

Figure 54: ***Tasting***

Chemoreception (Taste)

Taste begins in the mouth, where each of us has between 5,000 and 10,000 taste buds. Most taste buds are located within the tongue's small, visible bumps (or papillae) but some can be found in other areas of the mouth and throat. Each taste bud contains 50 to 100 taste receptor cells that transmit taste information. When we eat a strawberry, for example, saliva dissolves the fruit's chemicals, which then enter into the central pores of the taste buds and bind to the taste cells. The cells quickly send "sweet" and "sour" taste messages from these chemicals through nerve fibers to the brain, where they eventually reach the sensory cortex. However, the whole complex flavor of "strawberry" requires the addition of information gained through the smell.

Figure 55 ***: 'Fondant au Chocolat'***

How sensitive we are to sweetness, bitterness, or any other taste depends on our genetic makeup. For example, variants of one gene, TAS2R38, help determine how strongly an individual will be able to detect some bitter tastes, and may explain why some people find particular nuts or foods bitter while others won't. Research also has shown that certain individuals, dubbed "supertasters," inherit more taste buds and receptor cells than other people. Because tastes are more intense for them, they tend to avoid powerfully flavored foods, including sugary desserts. Genetics isn't the only factor behind taste preferences, though, age and epigenetics also plays a role. We begin to lose some of our taste buds permanently as we pass through middle age, a development that can make food taste bland and eating less enjoyable. Illness and infection also can dull and deaden taste buds or the nerve pathways that send taste messages to the brain. As for epigenetics, a person's pallete might have been « educated » to notice certain tastes in a different fashion through time depending on the culture and environment.

Mecanoreception and Thermoreception (Touch)

The sence of touch, or somatic system, is very important as it will let a person know if a pastry is dry, moist, hot, cold, or more, be it through the hands, the mouth or any other way… The neurons will be in charge of percieveing the texture and temperature of the dessert and send the message to the brain. Processing will primarily occure in the primary somatosensory area in the parietal lobe of the cerebral cortex: information is sent from the receptors via sensory nerves, through tracts in the spinal cord and finally into the brain. This will also activate the limbic system and cause a surge of different emotions.

Figure 56: ***Girl eating ice cream***

Sometimes, temperature might even cause a direct physiological reaction. A curious reaction is when one tastes something that is too cold, as oftenly experienced when eating ice-cream, one may get what is refered to as a « brain freeze. » What actually happens is that when something cold touches the roof of a person's mouth, the sudden temperature change of the tissue stimulates nerves to cause rapid dilation and swelling of blood vessels. This is an attempt to direct blood to the area and warm it back up. The dilation of the blood vessels triggers pain receptors, which release pain-causing prostaglandins, increase sensitivity to further pain, and produce inflammation while sending signals through the trigeminal nerve to alert the brain to the problem. Because the trigeminal nerve also senses facial pain, the brain interprets the pain signal as coming from the forehead.

Audition

Similarly to the other systems, the neurons of the auditory system will recieve an exterior stimulation and send signals to the brain, also consequently influencing the limbic system. During eating, many sounds are produced, which will help the brain determine if the food in question is crunchy, sizzling, popping, resistant, or many more. The sound waves produced will then enter the auditory canal, into the inner ear, unto the Organ of Corti where the receptor cells will translate the information into nerve signals. These nerves signals will finally reach the brain's auditory cortex and the sound will finally be percieved.

Photoreception (Sight)

The first things the brain perceives is the appearance and not the odor, as one can see the food from long distance but the smell of a product may or may not be detected from long distances. Pungent or sharp flavored products may give out odor/aroma spreading to far distances whereas lighter products may not spread the odor; therefore, it has been decided that the appearance comes first. Through the visual system or photoreception, one can already guess the texture, be it powdery, soft, tender, gritty, rubbery or waxy. It is one of the first properties examined during the visual (sensory) analysis of a food product and unlike others, texture will contribute to vision as well as touch. Apart from the texture there is also the color, size, shape, glossiness and many more properties, which will ultimately influence the visual and therefore emotional experience of the costumer.

Figure 57: ***Shiny looking pastries***

The great biological importance of photoreceptors is that they convert light (visible electromagnetic radiation) into signals that can stimulate biological processes. To be more specific, photoreceptor proteins in the cell absorb photons, triggering a change in the cell's membrane potential. They will later on send those signals through the optic nerve unto the brain, more concretely, unto the visual cortex. The visual cortex will then send signals to the limbic system, causing an emotional output or reaction caused by that visual stimulation. Depending on the organoleptic features of the pastry, one might react in surprise, enthusiasm, pleasure, or in many more different ways when tasting the pastry...

Brownie experiment: How the brain can trick our perception

For the first experiment, I intended to challenge the brains of the test subjects in order to find out if they would distinguish a difference between two brownies, when there was actually none! The basic idea was to give a certain pastry to the test subjects when their eyes were closed, and afterwards make them taste the exact same pastry but with their eyes open and see if they would note a difference. However; first of all I had to prepare the brownies, make the survey, and find the test subjects; which I will later on explain. Afterwards I had to draw conclusions from my results and interpret them in order to start proving one of my hypotheses: *"our perceptions of the organoleptic properties change depending on the "environment" we are submitted to when tasting those pastries."* So I finally started doing this delicious and incredibly interesting experiment...

Before even starting the experiment, I had to get the idea and have a general view of how it would turn out. I actually thought of this experiment as I watched a video of a gastronomical scientist, (a person who specializes in the molecular science of cooking), who made an experiment which consisted on changing the aspect of the food and see the reaction of the people who ate it in contrast to when it had a normal aspect. This made me think that our eyes could easily deceive our brain and therefore influence our perceptions. Furthermore, I started doubting what would happen to our nervous system when we *completely closed* our eyes, and if that would that vary our perceptions of the pastry...

Afterwards, I made a short test to my family with dark chocolate, making them try it with eyes closed and then with their eyes open, to see if there would be any significant results in order for me to make the test on a large scale. To my surprise, they all noted a difference and thought I gave them a different chocolate! That concludes to why I decided to do the experiment and from where I got the idea.

Figure 58: ***Chocolate Brain***

The next day, I decided I would bake a chocolate pastry for the experiment, as I originally tested with the dark chocolate I felt it was the most suitable flavor as it has a clear and familiar taste to everyone. So, I made up my mind to bake chocolate brownies. I actually already had my brownie recipe since a long time ago, and every single time I had tried it, they would turn out with the same taste and texture, which was another advantage for me.

After I had my hypothesis, my recipe, and my questions in mind, I wrote down a survey asking carefully about the "differences" people would maybe notice (or not) when comparing the two pastries. The following list shows the questions I asked and why I have asked them:

1. Did you find a difference in texture between brownie A (eyes open) and brownie B (eyes closed)? If so, what was the difference?

   I asked this in order to find out if their perception of the texture would be affected upon inspecting the aspect of the pastry; which seemed dry. In difference to this, if my hypothesis of the nervous system being affected by the surroundings and situations were correct, the aspect of the brownie would not influence their perception since they would be closing their eyes.

Figure 59: ***Brownies from experiment***

2. Did you find a difference in taste? If so, please specify.

   I tried asking this question because I was curious to know if the taste would also be affected by the situation, meaning that either, 1) *Since they are closing their eyes, their senses become more dull as people "shut down" and therefore will sense less taste...*Or 2) *Since people cannot see, they will be more alert and therefore concentrate more upon the perception of "dangerous" tastes, such as the sour taste the dark chocolate might have...*

3. Was there an overall obvious difference between the two pastries or were they the same?

   This question was the most important question, as the answer was a direct "yes" or "no" it would tell me whether my hypothesis was correct or not. If the people noted a difference, that would mean that when changing the situation, the person's nervous system's perception of the same exact pastry would be different.

4. Have you noted a difference in the temperature?

   This question was actually far-fetched because I doubted that they would note a difference as the brain fools the perception of temperature much less easily than the ones of texture and taste. However, something (which I will later on explain) very unexpected happened.

5. What were your feelings at the time you put brownie A in your mouth?

6. In difference to brownie A, did you have a different feeling when tasting brownie B?

   I addressed those last two questions in order to know if the difference in perception (if there was one) could be caused by the feelings of the person when tasting it, or (vise versa:) if the feelings of the person would be subject to how they perceived the pastry.

After I set up the survey I prepared the brownies; the process of baking the brownies was very simple, as it only required for the ingredients to be put in a bowl, mixed, and then baked at 180 degrees Celsius for 10 minutes. Finally, I cut the brownie into equal pieces in order for the people to have equal portions when tasting them. I found the test subjects quite easily as all my classmates were very eager to taste those brownies during our class break the next day.

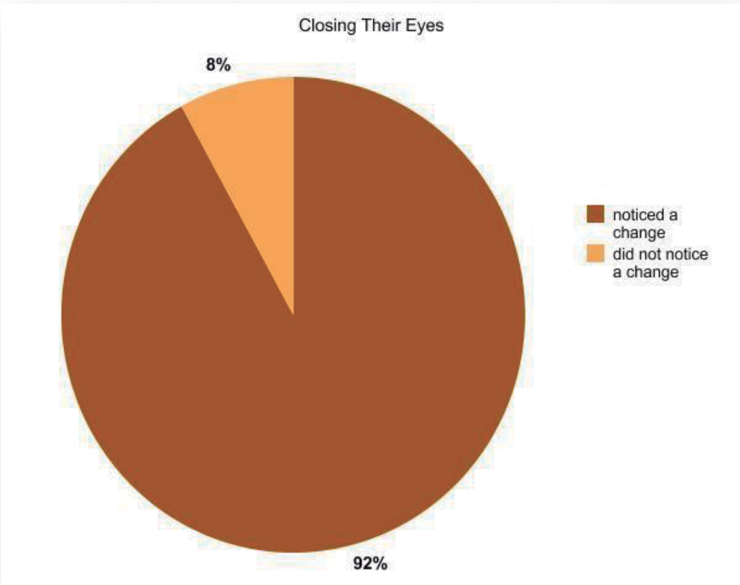


Figure 60: ***Chart 1: Closing their eyes***

The day of the survey, the test subjects had to close their eyes, and while keeping them close, they had to taste the brownie. Next, I made them open their eyes, asked them to look carefully at the chocolate delicacies, and finally let them taste the brownies once again. Afterwards, they had to complete the survey I previously prepared. All the multiple choice answers included a "there is no difference whatsoever."

Finally, I had to bring back the completed surveys home and draw my conclusions. Since it was a multiple answer survey, it was easy for me to make a percentage of the most frequent answers. The first relevant information was that 92% out of the 25 test subjects had noticed a change when closing their eyes in comparison to when they could observe the food they were about to eat. (Fig 60 on previous page) This clearly shows that when we change our impression of the food with our sight, we are also changing how we will perceive the organoleptic properties of that food. Furthermore, upon that 92%, approximately one fourth of them found a difference in texture, another fourth of them found a difference in taste, and the rest (half of them) found a variation in both the taste as well as for the texture. (Fig 61)

These percentages fit perfectly with my hypothesis, however; as I had stated before, while looking at the results, I noticed something very particular in the question concerning the differences in temperature. It seemed that some people found a variation! Only 10% had noticed this change, but what is very intriguing is that 100% of those who found that difference wrote that they felt the brownie A (with eyes closed) was cooler. Therefore, I made further research on this peculiarity by looking through articles about neuroscience or psychology and asking people who specialized on the subject, and came to a possible explanation.

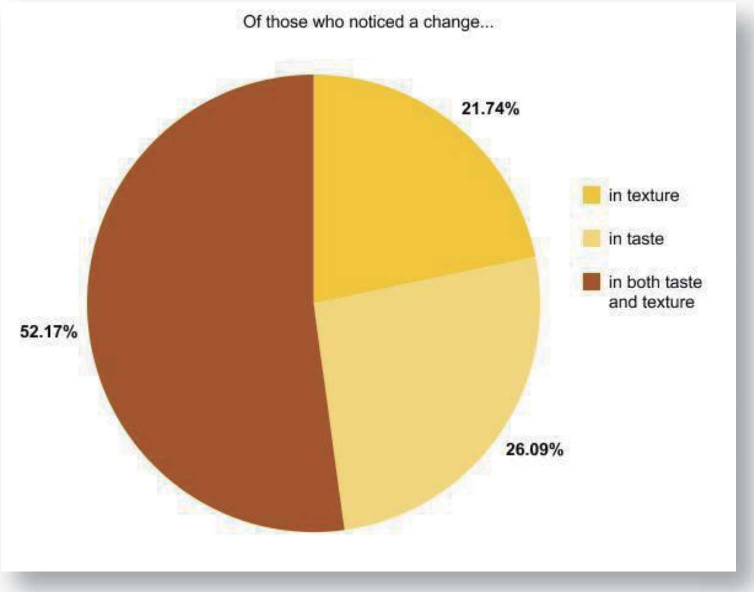


Chart 2: Of those who noticed a change
Figure 61

The color of something influences our brain in a very particular way. As it seems, when something has “warm colors” that is to say, red, yellow, brown, orange, etc. we perceive it as warmer. Therefore, that means that as they closed their eyes, the subjects could not be influenced by the color of the pastry, so they perceived it “cooler” than when they actually saw it. More appropriately said, the second one “was warmer” to them, as the brown color influenced their perception by tricking the brain into thinking that brown means warm.

Conclusion

Figure 62: ***Lemon Tart***

Throughout this report, I have learned many things concerning the science behind the making of pastries and the possible chemical as well as physical changes that can be used.

The more I researched upon the chemical changes applied to pastry creams, cakes, and other very important bases in "patisserie," the more I realized that changing one of these procedures would directly affect the organoleptic properties of the final product. However, I had to verify it through experimentation; therefore, I decided to conduct a test, (the macaron experiment part 1,) which consisted on changing a chemical procedure in one of the main ingredients and observe weather or not it would affect the organoleptic properties of the dessert. As the experiment went on I became skeptical and thought that the chemical change applied, more specifically the hydrolysis, would not actually affect the result whatsoever. However, to my good surprise, the macarons in question turned out to be completely different in aspect and texture while not changing in taste. This meant that, through a small chemical change in one of the ingredients, I had managed to influence two of the organoleptic properties of the final dessert.

After conducting the experiment, I researched more upon the possibilities of making chemical manipulation to ingredients, such as different ways of cooking them, jellification, and different ways of achieving hydrolysis. Through this, I learned about the science behind caramelization, the maillard reaction, the formation of micelles, and even about spherification.

As I became more interested in this new way of presenting food commonly found in modern gastronomy, I decided to try it out for myself, (the spherification experiment.) This was done in order to observe the chemical reaction directly and to conclude weather the organoleptic properties of a cream would differ through spherification or not. Logically enough, I had the chance to observe how the organoleptic properties from a liquid changed when it became a sphere. The changes were in texture, as a gel had formed in the outermost layer, and in aspect, as a 3D sphere of strawberry juice did not look the same as a "puddle" of the same juice.

Throughout this investigation concerning the chemical manipulations applied to desserts, ***I have established and demonstrated that some of the organoleptic features of the pastry will greatly vary from applying a different chemical process to one of its ingredient or mixes.***

Figure 63: ***Ombre Cake***

Once I had made my conclusion upon the chemical changes, I moved on to the possible physical manipulations that could be used in an ingredient or mix and how it could change the features of the final result. I explored the different and most common physical procedures and learned about the importance in aspect of the pastries. Most physical changes were done in order for the pastry to become more appetizing, such as manipulating the physical composition of the ingredients through heat, mixing or emulsion in order to produce more texture, shine, and other organoleptic qualities to the pastry. I found out that crystallization played a very important part in the hardness and luster of an ingredient and that it could be manipulated through the heat, such as with tempering chocolate.

To be sure, I conducted the second part of the macarons experiment, which consisted upon changing the size of the sugar crystals into smaller ones, or more commonly said, by pulverizing the sugar. The sugar's chemical structure did not change whatsoever, so by only changing its physical structure, I deduced it would not affect the mixture enough to cause a difference in the organoleptic properties of the dessert. Nevertheless, half way through the experiment, as mentioned before, I already started to notice a change in the texture, and in the end, the result compared to normally prepared macarons was quite different! I observed that the aspect and texture had completely change paralleled to normal macarons. This induced that by applying a physical change in one of the ingredients or not, it would directly affect the final features of the dessert itself.

Figure 64: ***Birthday Cake***

Afterwards, I decided to carry out another test concerning the physical manipulations, (the cream experiment,) but this time it would be a change in temperature so it would not be as easy to carry out. For this, I had to use a thermometer in order to be sure that I would not influence the ingredient, (whipping cream,) chemically when warming it up as I was just trying to alter its physical state. I therefore carefully changed the temperature of the whipping cream to see if the change in temperature would affect the emulsion, indirectly affecting the organoleptic properties of the final result. Once the experiment was over, it had been proven that the aspect and texture of the whipped cream varied completely depending on the temperature of the initial ingredient.

Thanks to this research and experimentation upon the physical changes applied in pastries, ***I concluded and proved that some of the organoleptic features of the pastry will greatly vary from applying a different physical process.***

Finally, I studied how the response of the nervous system worked upon eating sweets on the whole sensory system. This allowed me to learn the complex mechanism of how the neurons received a “message” from the outside and transformed it into nerve signals, which would ultimately affect the limbic system and other important parts of the brain. I learned that depending on which organoleptic features a dessert has, the brain will receive and generate different signals upon sensing it. The reaction and response of these signals may be altered depending on the brain’s current activity, on the environment in which a person is submitted, and on the state of mind in which one receives them.

In order to better understand how the perception of the organoleptic properties of a dessert varied when a person's environment or state of mind differed, yet another experiment was needed, (the brownie experiment.) Throughout the test, the visual experience was being changed in order to see if it would alter other organoleptic perceptions. If this was true, it would mean that the by changing one sensory system, it would influence the others, making the organoleptic experience differ. To my good surprise, the results showed that when 92% of the people closed their eyes, in difference to when they did not, their perception of the other organoleptic features in the brownie changed.

I therefore concluded that the perception of the pastries' features varied upon the different stimuli the environment offered to the person tasting them.

This research in the science behind pastries helped me understand how vital chemical and physical procedures are for affecting the organoleptic features of the desserts. Furthermore, it made me learn valuable information about how the sensory system works and made me realize that the perception of pastries in the brain is linked to all those factors. Definitively, it made me realize that in "patisserie" there is an immense complexity behind achieving successful, delicious, attractive and beautiful pastries for the costumers' sensory experience.

Figure 65: ***Little girl with ice-cream***

Annex

List of some of the pastries prepared

Brownies

Main Processes

- Baking

- Melting

Gateau d'Anniversaire

Main Processes

- Baking

- Starch Gelatinization

-Melting

-Emulsion

Éclairs aux Chocolats

Main Processes

- Baking

-Starch Gelatinization

-Temperage

Macarons à la Cannelle

Main Processes

- Hydrolysis

-Baking

- Egg Gelatinization

Gateau Ombre

Main Processes

- Baking

-Starch Gelatinization

- Melting

Tarte au Citron

Main Processes

- Baking

- Hydrolysis

-Egg gelatinization

List of some of the pastries prepared

Macarons à la Pistache

Main Processes
- Hydrolysis
- Baking
- Egg Gelatinization
- Melting

Gateau des Cent-trois Ans

Main Processes
- Emulsion
- Baking
- Egg Gelatinization

Cheesecake Decoré

Main Processes
- Baking
- Egg and Starch Gelatinization

Pavlova au Fruits

Main Processes
- Baking
- Hydrolysis
- Emulsion

Macarons aux caramel

Main Processes
- Hydrolysis
- Baking
- Egg Gelatinization

Muffins aux Mirtilles

Main Processes
- Baking

List of some of the pastries prepared

Macarons à la fraise

Main Processes
-Hydrolysis
- Baking
- Melting

Gateau Totoro

Main Processes
- Baking
- Starch and egg Gelatinization
-Melting
-Emulsion
-Temperage

Fraisier

Main Processes
- Baking
-Emulsion

Fondant au Chocolat

Main Processes
- Baking
-Melting
-Emulsion

Millefeuilles

Main Processes
- Baking
-Egg Gelatinization

Paris Brest

Main Processes
- Baking
- Hydrolysis
-Egg and starch gelatinization
-Caramelization

List of some of the pastries prepared

Gateau au Chocolat

Main Processes

- Baking

- Melting

-Emulsion

Macarons aux Pralinés

Main Processes

- Hydrolysis

- Baking

-Caramelizing

-Emulsion

Macaron au Chocolat

Main Processes

-Hydrolysis

- Baking

-Emulsion

-Temperage

Donuts aux chocolat

Main Processes

- Frying

- Temperage

Madeleines

Main Processes

- Baking

Macarons à la Vanille

Main Processes

- Baking

- Hydrolysis

-Egg gelatinization

List of Figures

Glossary

1. Amphipathic: A compound having both a polar and a non-polar end. This makes it soluble in both polar and in nonpolar dissolvents. This property can usually lead to creating micelles.

2. Crème anglaise: A light pouring custard used as a dessert cream or sauce; it is a mix of sugar, egg yolks and hot milk or cream, often flavored with vanilla.

3. Crown or collarette: The identity that defines the macaron, without it one cannot name it “macaron.” It is a lifted area of the meringue that forms uniformly around the border of the pastry.

4. Gelatinization, Gelification, or Jellification: The process of making something have the nature of or resemble jelly, especially in consistency.

5. Macaronage: The process of mixing meringue with tant pour tant with a spatula, slowly folding and mixing the batter at the same time so that most of the air bubbles stay. Strangely, in this process, we purposely take out some air bubbles because otherwise the macarons will grow too much and crack. However, we also avoid mixing the batter too much because the destruction of too many air bubbles would cause the macarons not to lift at all.

6. Micelles: A charged aggregate of molecules of colloidal size in a solution

7. Organoleptic: That has to do with the senses: texture, taste, touch, sight, smell, temperature, etc.

8. Spherification: The culinary process of shaping a liquid into spheres, which visually and texturally resemble caviar.

9. Tant pour tant: A mixture of a certain quantity of pulverized white almonds with equal quantity of pulverized sugar, mixed and sifted. This concept is only used for macarons.

10. Tempering: To bring to a proper, suitable, or desirable state by heating up or cooling down a certain mixture.

11. Triglyceride: An ester obtained from glycerol by the esterification of three hydroxyl groups with fatty acids, naturally occurring in animal and vegetable tissues: an important energy source forming much of the fat stored by the body.

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