



## Food Formulation and Processing

### Lesson 1: Functional Properties of Food

#### Introduction

1. Hello and welcome to the lesson on the functional properties of food.

In this lesson we will learn about:

- The main organoleptic properties of food: colour, flavour, odour and appearance
- The kinaesthetic properties of food: texture, mouthfeel and grittiness
- How water interacts with food in determining its hydration properties: solubility, wettability, viscosity
- How chemical bonds confer food stability properties and some practical examples in emulsions and foams.

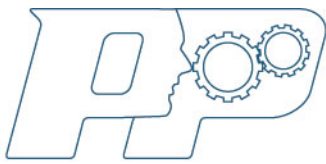
#### Organoleptic properties of food

The organoleptic properties usually include flavour, odour, colour and appearance and are described by the sensory response from both a qualitative and a quantitative point of view.

#### 2.1 Colour

The wide array of bright colours that give fruits and vegetables their visual appeal come from three main types of pigment: carotenoids, which give orange and yellow vegetables their colours; flavonoids, which provide blue, red and cream colours; and chlorophyll, which makes greens green.

But colour is an important organoleptic property of food not because of how fresh produce appear; it is also one of the main properties to be affected by heating, as cooked foods often change colour.



The browning in food following Maillard reaction is one type of colour change, but many others are also quite evident.

Meat, for instance, contains myoglobin, a red pigment that gives meat its colour even when the red blood has been removed. When myoglobin is heated, it reacts with oxygen and turns brown, giving cooked meat the colour we see in a well-done steak. Chlorophyll contains a central atom of magnesium that is lost during cooking and replaced by a hydrogen atom, resulting in a colour change into a more greyish pale or yellow green.

Another factor that highly affect the colour in food is the pH: among flavonoids we find anthocyanins, pigments able to reflect red light in acid solutions and blue light in basic solutions, and therefore colouring fruits, leaves and flowers according to the levels of acid in the plant.

A common chemistry demonstration is making a broth from red cabbage and then showing how it turns red in the presence of vinegar and blue in the presence of baking soda. The same effect can be seen when washing a glass that has had red wine or grape juice in it: since most tap water is neutral or slightly alkaline, the red wine will turn blue as its acids are diluted or neutralised.

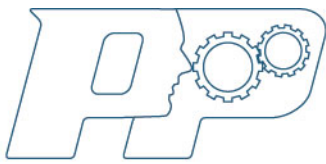
## 2.2 Flavour

There are five universally accepted basic tastes that stimulate and are perceived by our taste buds: sweet, salty, sour, bitter and umami. As the buds on our tongue are stimulated, a nervous response is triggered and a message is delivered to the receptors for that specific taste in the brain.

The tongue can also feel other sensations not generally included in the basic tastes, as these particular sensations are not detected by the taste buds and are also delivered to the brain through a different set of nerves:

- Pungency, also spiciness or hotness, a particular sensation triggered by spicy food
- Coldness, caused by the activation of the same mechanism that signals cold
- Numbness, a tingling sensation caused by spices such as Sichuan pepper
- Astringency, a puckering sensation of the mucous membrane of the mouth caused by unripe fruits and tannins
- Metallicness, an off-flavour taste sometimes caused by food and drink, some artificial sweeteners, certain medicines, dental fillings and blood.

Recent researches have revealed a potential new taste receptor, considered as a possible receptor for lipids, which has triggered the proposal of introducing oleogustus, the taste of fat, as the sixth basic taste.



## 2.3 Odour

Of the three chemical senses, smell is the main determinant of a food item's flavour. While the taste of food is limited to sweet, sour, bitter, salty, umami, and other tastes, the smells of a food are potentially limitless.

That's why a food's flavour can be easily altered by changing its smell while keeping its taste similar. Think as an example of artificially flavoured jellies, soft drinks and candies, which, while made of bases with a similar taste, have dramatically different flavours due to the use of different scents or fragrances.

But food odour is not always a nice, appealing smell: when food goes bad and starts to become pungent, it is most often due to the growth of spoilage microbes such as bacteria, yeasts and mould.

Odours can come from two sources: chemicals that are released from the food as the microbes decompose it, or chemicals produced directly by the microbes themselves.

Spoilage odours come in many flavours, depending on the type of spoilage microbe and the food being spoiled.

These bad smells are sometimes a by-product of other essential processes that the microbes need to engage in for survival, but in other cases they can be a way microbial species interact with each other and with larger organisms, such as humans. It's like by making food unappealing to us, the microbes are stealing our resources for their own survival.

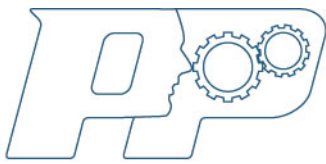
## 2.4 Appearance

The appearance of a food includes its size, shape, colour, structure, transparency or turbidity, dullness or gloss, and degree of wholeness or damage. While selecting a food and judging its quality, a consumer takes these factors into account, as they are indeed an index of quality.

For example, the colour can be an indication of ripeness, as in fruit, strength, as in tea or coffee, degree of cooking, freshness, or spoilage.

Consumers expect foods to be of a certain colour, and if they are not, it is judged to be a quality defect.

The same is true for size, and one may choose large eggs over small ones, or large peaches over small ones for example.



Structure is important in many foods, but it is especially in baked goods. For example, bread should have many small holes uniformly spread throughout and not one large hole close to the top.

Turbidity is important in beverages; for example, orange juice is supposed to be cloudy because it contains pulp, but white grape juice should be clear and without any sediment, which would instead indicate a quality defect.

### 3. Kinaesthetic properties of food

Let's have a look now at the kinaesthetic factors that affect food, such as texture, mouthfeel and grittiness.

#### 3.1 Texture

Food texture is defined as those properties of a food that are sensed by touch in the mouth and with the hands, in other words that can be felt by fingers, tongue, palate, or teeth.

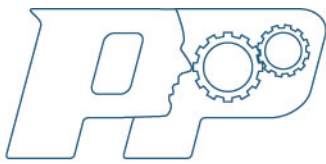
We use many words to describe food texture—foods can be soft or hard, mushy or crunchy, or smooth or lumpy. Texture is important to the enjoyment and acceptability of foods.

Texture is also an index of quality. The texture of a food can change as it is stored, for various reasons. If fruits or vegetables lose water during storage they wilt or lose their turgor pressure, and a crisp apple becomes unacceptably leathery on the outside; bread can become hard and stale on storage; products like ice cream can become gritty due to the precipitation of lactose and the growth of ice crystal if the temperature is allowed to fluctuate, allowing thawing and refreezing.

The evaluation of texture involves measuring the response of a food when it is subjected to forces such as cutting, shearing, chewing, compressing or stretching.

Food texture may be divided into two components: texture as we perceive it and rheology, the branch of physics which deals with the science of deformation in response to a force.

In this instance, the texture of a food is evaluated on how easily it breaks or flows in the mouth when it is chewed: as teeth, tongue and jaw exert a force on the food it is determined whether it is perceived as hard, brittle, thick, runny, and so on. Similarly, estimate fruit firmness on the basis of the deformation resulting from physical pressure applied by hand and fingers.



Foods are compositionally and structurally complex systems that can exhibit a wide range of different rheological behaviours, ranging from low viscosity fluids, like milk or orange juice, to hard solids, like hard candy. But things can be a bit more complicated: since most foods are extremely complex and they do not fit easily into one category

### 3.2 Mouthfeel

Mouthfeel is a product's physical and chemical interaction in the mouth, an aspect of food rheology, and it is used in many areas related to the testing and evaluating of foodstuffs, such as wine-tasting. Mouthfeel starts with the initial perception on the palate, proceeds with biting and mastication and ends with swallowing and aftertaste.

Many parameters are perceived through mouthfeel: cohesiveness, density, dryness, fracturability, graininess, gumminess, hardness, heaviness, moisture, mouth coating, roughness, slipperiness, smoothness, uniformity, wetness, just to list a few.

### 3.3 Grittiness

Grittiness is quite often used as a synonym of texture, but specifically it refers to the presence of granules in the food.

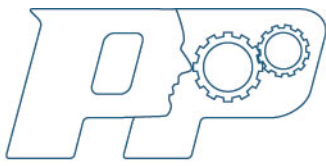
The grittiness of a food product is quantified mainly by sensory evaluation, since it is difficult to use a measuring instrument for perceived texture.

Nonetheless, grittiness is often regarded as an unwanted characteristic in foodstuff, for example lumps in soups, yoghurts or sauces, or bits of soil and debris in vegetables that haven't been thoroughly washed.

## 4. Hydration properties in food

Water is abundant in all living things and consequently is in almost all foods, unless steps have been taken to remove it. Water plays a major role in determining the texture of foods, as can be seen when comparing grapes and raisins, or fresh and wilted lettuce. It gives crisp texture or turgor to fruits and vegetables and also affects perception of the tenderness of meat. For some food products, such as potato chips, salt, or sugar, lack of water is an important aspect of their quality and keeping water out of such foods is important to maintain quality.





As we've already seen in a previous lesson, most of the food processing techniques involve the use of water or the modification of food water content in some form: freezing, drying, emulsification, baking, thickening are a few examples. Moreover, because bacteria cannot grow without water, the water content has a significant effect on maintaining the quality and affecting the shelf life of foods.

Water is also an important solvent, it can be the medium where acids and bases turns into ions, it is necessary for many chemical reactions, it is a heating or cooling medium and it can be used as a cleansing agent.

Because water has so many functions that are applied to Food Science, it is important to be familiar with some of its unique properties, so let's have a look at the main hydration properties in food.

## 4.1 Solubility

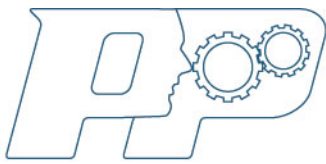
Substances are either dissolved, dispersed, or suspended in water depending on their particle size and solubility.

Small molecules such as salts, sugars, or water-soluble vitamins form what's called a true solution. These can be either ionic, if the dissolving substances ionize (or turn into ions), such as salts, or they can be molecular, if molecules create hydrogen bonds with the molecules of water.

Sugar crystals in water from molecular solutions. When the crystals dissolve, the hydrogen bonds within the sugar molecule breaks and re-form as hydrogen bonds between the water and the sugar molecules. As each sugar molecule gets surrounded by water molecules, the sugar crystal is gradually hydrated.

When this type of hydrogen-bond interchange is involved, solubility increases with increasing temperature, because heat disrupts hydrogen bonds and reduces water–water and sucrose–sucrose attraction and therefore it facilitates the formation of hydrogen bonds between water and sucrose and hydration of sucrose molecules. That's why sucrose is much more soluble in hot water than in cold water

Gases also dissolve in liquids. Carbon dioxide, for instance, dissolves in water to make carbonated water. With gases temperature has the opposite effect than with particles. Gases don't have hydrogen bonds in their molecules that need to first be broken before it can dissolve, but the bonds between the gas and the water molecule do break more easily as temperatures increase. That's why carbon dioxide will dissolve more in cold water than in warm or hot water.



Examples of solutions in food are numerous: broth is a solution of salt, proteins, sugars, and other small molecules, sodas are solutions of sugar, flavourings, and carbon dioxide, vinegar is a solution of acetic acid and small flavour molecules in water, just to cite a few.

Solutions are not always liquid: honey is a supersaturated solution of fructose, glucose, maltose, and sucrose and many hard candies are solid solutions of sugar, water, and flavourings.

Molecules that are too big to form true solutions may be dispersed in water. Those with a particle size range 1–100nm are dispersed to form a colloidal dispersion. Examples of such molecules include cellulose, cooked starch, pectin, gums and some food proteins. Colloidal dispersions are often unstable, especially to factors such as heating, freezing, or pH change. Changing the conditions in a stable dispersion can cause precipitation or gelation; which is desirable in some instances, like when making jellies.

Particles that are larger than 100 nm are too large to form a colloidal dispersion, but form a suspension when mixed with water. The particles in a suspension separate out over a period, whereas no such separation is observed with colloidal dispersions. An example of a suspension would be uncooked starch grains in water: they remain suspended throughout the liquid by stirring, but they do not “dissolve.” If left undisturbed, they settle downward, and a sediment is observed at the bottom of the container.

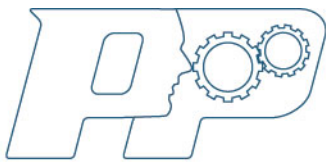
#### 4.2 Wettability

Wettability refers to the interaction between fluid and solid phases and it is described as the ability of a liquid to maintain contact with a solid surface, resulting from intermolecular interactions when the two are brought together.

This property becomes extremely important in food applications especially in powders that need to be hydrated to be reconstituted. Since the presence of fat or oil may decrease the wettability of a powder, food powder manufacturers aim at improving the properties of such products, for instance by agglomerating the powder or adding wetting agents to their recipes.

#### 4.3 Viscosity

Viscosity is a measure of the resistance to flow of a liquid when subjected to shearing forces, those unaligned forces pushing one part of a body in one specific direction, and another part of the body in the opposite direction.



For liquids, it corresponds to the informal concept of "thickness": the thicker the liquid, the greater its resistance to flow and therefore the greater its viscosity. For example, water has low viscosity and flows readily, whereas ketchup, as an example, has a higher viscosity and flows relatively slowly.

Viscosity is another property affected by temperature. Higher temperatures decrease viscosity, causing liquids to flow more readily, whereas lower temperatures increase the viscosity.

Liquids can be separated into Newtonian and non-Newtonian fluids.

In the case of a Newtonian liquid, the flowing of the fluid, and therefore its viscosity, does not depend on the shear force applied. Examples of Newtonian liquids in food include water, sugar syrups, and wine.

However, most liquid foods are non-Newtonian, in which case the viscosity depends on the amount of shear force applied. This can be seen with ketchup, which appears fairly solid and is hard to get out of the bottle if it has been standing for a while. However, after applying a shear stress like shaking the bottle, ketchup becomes almost runny and will flow out of the bottle much more easily.

Shaking the bottle causes the molecules to align so that they flow over each other more easily and the apparent viscosity decreases.

Other non-Newtonian liquids appear to get thicker when a shear stress is applied. In this case, the particles in the liquid tend to aggregate and trap pockets of liquid, thus making it harder for the molecules to flow over each other. Examples of such liquids include starch slurries and dilute solutions of some gums.

## 5. Stability properties in food

Stability refers to the quality, state, or degree of materials being stable: such as strength and firmness. In food, this particularly applies to emulsions and foams.





## 5.1 Emulsions

Many convenience foods, such as frozen desserts, meat products and margarine, and some natural foods, such as milk and butter, are emulsions. That is, they contain either water dispersed in oil or oil dispersed in water. These liquids do not normally mix, and so when present together they exist as two separate layers. However, when an emulsion is formed, the liquids are mixed in such a way that a single layer is formed with droplets of one liquid dispersed within the other. Food emulsions need to be stable; if they are not, the oil and water will separate out again. Stability is usually achieved by adding a suitable emulsifier and, in some cases, also a stabilising agent may be required.

Emulsions can be temporary or permanent, depending on their stability, or tendency not to separate back into their two original liquid layers.

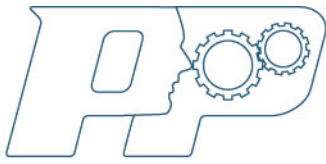
French dressing is an example of a temporary emulsion, as it tends to separate fairly soon after formation. The role of emulsifier here is exerted by mustard and paprika, which facilitate the dispersion of oil droplets in vinegar upon shaking, but do not interact to form a stable film. Therefore, when shaking is stopped, the oil droplets soon start to coalesce again and the oil and vinegar layers separate.

Mayonnaise, on the other hand, is an example of a permanent emulsion, since it is stable and does not separate under normal handling conditions. The egg yolk proteins, being excellent emulsifiers, protect the oil droplets against coalescence and separation from the vinegar.

Obviously, the main factor affecting emulsion stability is the emulsifier itself, which also have to be present in sufficient quantities to form a stable bond between oil and water. Droplet size also is an important parameter, as larger droplets are more likely to coalesce. Changing the pH by adding acid or changing the ionic strength by adding salts may also reduce the stability of the water-oil interaction, especially if the emulsifier is a protein, which can easily be denatured by such changes.

Another factor affecting emulsion stability is the viscosity of the emulsion. The thicker the emulsion, the lesser the movement of the molecules within the system and the longer it will take for the two phases to separate. Emulsions are therefore made thicker by adding ingredients such as gums, pectin, or gelatine.

Storage and handling also affect emulsion stability. Although some emulsions are termed permanent, it should be noted that all emulsions are delicate systems, inherently unstable, since they contain two immiscible liquids, so the wrong handling conditions can cause emulsion breakage.



Temperature is another factor in emulsion stability: as temperature increases, the oil droplets become more fluid and coalescence is more likely; while upon refrigeration the oil droplets might solidify and enhance the stability, but not at freezing conditions, where the proteins become denatured or the emulsion gets physically disrupted by the formation of ice crystals.

## 5.2 Foams

Foams make a vital contribution to the volume and texture of many common food products. They give volume and a distinctive mouthfeel to products such as whipped cream and ice cream and they give a light, airy texture to baked goods. Improperly formed or unstable foams result in dense products with a low volume, which are unacceptable to consumers.

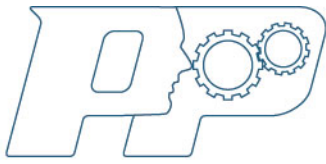
Foams are inherently unstable and it is imperative that food scientists increase their knowledge of the factors affecting foam stability, in order to enhance the quality and shelf life of these products.

A foam contains gas bubbles dispersed in a liquid continuous phase. The liquid phase may be a simple dispersion, as in egg white, which is a dilute protein dispersion, or it may be complex, containing emulsified fat droplets, ice crystals, and/or solid matter. Examples of complex food foams include ice cream, cakes, meringues, marshmallows and breads. Foams such as meringue and baked goods are heat set, which denatures the protein and converts the liquid phase to a solid phase, making the foam structure more permanent.

In order to produce a foam, energy must be supplied by whipping to incorporate gas into the liquid, break up large bubbles into smaller ones and spread the liquid phase around the gas bubbles as they form, while the foaming agent in the liquid phase forms a film around the gas bubbles.

Foam stability may be reduced due to the following factors: the tendency of the liquid film to drain due to gravity, the tendency for the film to rupture and allow coalescence or escape of gas bubbles, the diffusion of gas from small bubbles to larger ones, the evaporation of the liquid phase and consequent burst of gas bubbles.

Many food foams have additional ingredients added to enhance stability. For example, sugar is added to egg white-based foams to increase the viscosity of the liquid and protect the proteins from excessive denaturation.



## **Summary**

In this lesson we learnt:

- The main organoleptic properties of food: colour, flavour, odour and appearance
- The kinaesthetic properties of food: texture, mouthfeel and grittiness
- How water interacts with food in determining its hydration properties: solubility, wettability, viscosity
- How chemical bonds confer food stability properties and some practical examples in emulsions and foams.