Tutorial 2 : Characteristics of Food

1. The Importance of Water in Food and Its Role in Preservation (Presentation 1)

Introduction

Water is a fundamental component of food, influencing its texture, stability, and preservation. Its role in food safety is crucial, as it directly affects microbial growth and biochemical reactions responsible for product deterioration. One of the key parameters for assessing water availability in food is water activity (aw), which determines how easily microorganisms can grow and cause food spoilage.

1. Definition of Water Activity (aw)

Water activity (aw) is a measure of the free water available in a food product to participate in biochemical reactions and support microbial growth. It is expressed as the ratio between the vapor pressure of the food and that of pure water at the same temperature, ranging from 0 to 1.

Unlike total water content, aw reflects water availability rather than its absolute quantity. For example, foods such as bread and raw ham have similar water content, but their aw values differ due to the nature of the bonds between water and food components. A low aw (<0.6) limits enzymatic and microbial activities, contributing to longer food shelf life.

2. Relationship Between aw and Food Stability

Water activity directly influences the physical, chemical, and biological stability of food. A high aw promotes microbial proliferation and certain spoilage reactions, whereas a low aw slows these processes.

- **Effect on Microbiological Preservation:**
  - An aw above 0.91 allows the growth of most pathogenic bacteria, such as *Salmonella* and *Clostridium botulinum*.
  - Molds and certain yeasts can survive at lower aw values (0.7-0.8), explaining the spoilage of dried fruits and bread.
  - An aw below 0.6 inhibits almost all microbial activity, ensuring the long-term preservation of foods like biscuits and powdered milk.
- **Effect on Chemical and Enzymatic Reactions:**
  - A high aw accelerates lipid oxidation, leading to rancidity in oils and fats.
  - It also promotes non-enzymatic browning (Maillard reaction), altering the color and taste of food products.
  - A moderate aw (0.2-0.6) can lead to sugar crystallization in certain products, modifying their texture.

3. Impact on Microbial Growth and Food Quality

Water activity is a key factor in controlling food contamination and spoilage. By adjusting aw, it is possible to extend shelf life and ensure food safety.

Food industries use various techniques to control aw:

- **Drying and Freeze-Drying:** Reducing free water to prolong shelf life (dried fruits, powdered milk).
- **Addition of Hygroscopic Solutes (Sugar, Salt, Glycerol):** Binding water to limit microbial growth (jams, cured meats).
- **Modified Atmosphere Packaging:** Maintaining low humidity to preserve texture and prevent microbial growth.

However, excessive modification of aw can alter the organoleptic properties of food. For instance, a significant decrease can make a product hard and brittle (biscuits), while excessive moisture can cause softening and mold formation.

Conclusion

Water plays a fundamental role in the stability and preservation of food. Water activity is a key parameter for controlling microbial growth, optimizing preservation processes, and ensuring product quality. By adjusting aw through appropriate techniques, it is possible to enhance food safety while maintaining the sensory characteristics of food.

2. Lipid Oxidation: Mechanisms, Factors, and Prevention (Presentation 2)

Introduction

Lipid oxidation is a chemical reaction that occurs in many fat-containing foods. This phenomenon alters the organoleptic quality of products and can lead to the formation of toxic compounds. Lipid oxidation is a major challenge for the food industry, as it affects the shelf life and safety of food products. This process is influenced by several factors and can be controlled through various prevention strategies.

1. Factors Promoting Lipid Oxidation

Lipid oxidation primarily follows a free radical chain reaction consisting of three stages: initiation, propagation, and termination. Several factors can accelerate this process, including:

- **Presence of oxygen:** Atmospheric oxygen is essential for the oxidation process. The more a food product is exposed to air, the more vulnerable it is to rancidity.
- **Light exposure:** UV rays and visible light promote the formation of free radicals and accelerate lipid degradation, particularly in oils and products rich in unsaturated fatty acids.
- **Temperature:** High temperatures speed up chemical reactions and encourage the breakdown of lipids into undesirable secondary compounds.
- **Lipid composition:** Polyunsaturated fatty acids, such as omega-3 and omega-6, are more sensitive to oxidation than saturated fatty acids due to the presence of double bonds in their structure.
- **Transition metals (iron, copper):** These metals catalyze free radical formation and accelerate lipid degradation. They are often present in food as trace elements or impurities.
- **Humidity:** Excessive moisture can promote lipid hydrolysis and increase their susceptibility to oxidation.

2. Consequences on Food Quality

Lipid oxidation has a significant impact on food quality, affecting taste, odor, and safety:

- **Alteration of organoleptic properties:**
  - The formation of volatile compounds, such as aldehydes and ketones, is responsible for the appearance of unpleasant odors and flavors, often described as rancid.
  - The texture of products can also be affected, particularly in bakery products and margarines.
- **Reduction of nutritional value:**
  - Oxidation leads to the degradation of essential fatty acids (omega-3, omega-6), reducing the nutritional quality of food.
  - It can also destroy certain fat-soluble vitamins, such as vitamin E, which plays a key role in cellular protection.
- **Toxicity and health risks:**
  - The formation of lipid peroxides and secondary oxidation compounds can have toxic effects, promoting oxidative stress in the body.

- Some oxidation products, such as oxidized aldehydes, are suspected of being carcinogenic and are linked to cardiovascular and neurodegenerative diseases.

3. Prevention and Inhibition Techniques for Oxidation

To minimize the harmful effects of lipid oxidation, the food industry implements several strategies:

- **Use of antioxidants:**
  - **Natural antioxidants:** Vitamin E (tocopherols), vitamin C, polyphenols, and flavonoids are used to slow free radical formation.
  - **Synthetic antioxidants:** Compounds such as BHT (butylated hydroxytoluene) and BHA (butylated hydroxyanisole) are commonly added to oils and margarines to stabilize lipids.
- **Control of storage conditions:**
  - **Reduction of oxygen exposure:** Modified atmosphere packaging (using nitrogen or carbon dioxide) limits oxygen access to lipids.
  - **Protection from light:** Opaque or colored packaging prevents photo-oxidative degradation.
  - **Low-temperature storage:** Cold temperatures slow down chemical reactions and extend the shelf life of lipid-rich foods.
- **Selection of raw materials:**
  - Using more stable oils, such as coconut oil and olive oil, which are rich in saturated and monounsaturated fatty acids, reduces oxidation susceptibility.
  - Hydrogenation or esterification processes modify lipid structures to improve their resistance to oxidation.

Conclusion

Lipid oxidation is a complex phenomenon that affects food quality and can have negative health effects. This process is influenced by various environmental and intrinsic factors related to lipids. Through the addition of antioxidants, appropriate packaging, and controlled storage, it is possible to slow down oxidation and preserve the freshness of lipid-containing foods. A better understanding of oxidation mechanisms helps improve the stability and safety of food products.

3. Milk Coagulation: Principles and Industrial Applications (Presentation 3)

Introduction

Milk coagulation is an essential phenomenon in dairy processing, particularly in the production of cheese and yogurt. This process is based on chemical and physical modifications of milk proteins, mainly caseins. Coagulation can be achieved through different mechanisms, including lactic acidification and rennet action. Heat treatments also influence coagulation, determining the texture and quality of the final products.

1. Different Types of Coagulation

Milk coagulation involves the destabilization of casein micelles, leading to their aggregation and the formation of a gel. Two main types of coagulation are used in the dairy industry:

- **Coagulation by lactic acidification:**
  - This results from a decrease in pH due to the fermentation of lactose into lactic acid by lactic acid bacteria (Lactobacillus, Streptococcus, etc.).
  - When the pH reaches approximately 4.6, casein micelles lose their stability and aggregate to form a gel.
  - This type of coagulation is used for making yogurt and certain fresh cheeses such as cottage cheese.
- **Coagulation by rennet action:**
  - Rennet is an enzyme extracted from the stomach lining of young ruminants (primarily chymosin), which hydrolyzes kappa-casein, a protein essential for the stability of casein micelles.
  - This hydrolysis leads to the precipitation of caseins in the form of a firmer gel than that obtained through lactic acidification.
  - Enzymatic coagulation is widely used in the production of ripened cheeses (Camembert, Emmental, Parmesan, etc.).

These two mechanisms can sometimes be combined, as in certain cheeses where lactic acidification precedes or accompanies rennet action to refine the texture and flavor of the product.

2. Role in Cheese and Yogurt Production

Milk coagulation is a key step in dairy processing, influencing texture, flavor, and shelf life:

- **Yogurt production:**
  - After inoculation with specific lactic acid bacteria (*Lactobacillus bulgaricus* and *Streptococcus thermophilus*), milk is incubated at around 42°C to promote lactic acid production and gel thickening.
  - The resulting yogurt has a smooth texture and a slight acidity due to fermentation.
- **Cheese production:**
  - Coagulation is the first step in cheese-making. After gel formation, it is cut into curds to facilitate whey drainage.

- Depending on the type of cheese, different stages of draining, pressing, and ripening are carried out to obtain varied textures, from fresh cheese to hard cheese.
- Enzymatic coagulation results in firmer structures, whereas lactic acidification produces more crumbly cheeses.

The choice of coagulation type and processing parameters (pH, temperature, fermentation time) allows for the production of a wide range of dairy products.

3. Impact of Heat Treatments on Coagulation

Heat treatments applied to milk for sanitary and technological reasons influence coagulation and dairy product quality:

- **Effect on enzymatic coagulation:**
  - Excessive pasteurization (above 75°C) can alter milk protein structure, making enzymatic coagulation more difficult.
  - The denaturation of whey proteins can interact with caseins, modifying curd texture.
- **Effect on lactic acid coagulation:**
  - Heat promotes protein solubilization and can accelerate the activity of lactic acid bacteria, affecting the acidification rate and gel firmness.
  - However, excessive heat treatments can inactivate certain bacteria essential for fermentation.
- **Specific treatments and alternatives:**
  - Ultra-pasteurization and sterilization significantly alter proteins, making coagulation more difficult, limiting their use in cheese and yogurt production.
  - Some industrial processes use microbial or plant-based coagulants to meet consumer demands (e.g., vegetarian cheeses).

Conclusion

Milk coagulation is a fundamental process in dairy product manufacturing. It primarily relies on lactic acidification or rennet action, each impacting the texture and structure of the final product differently. This phenomenon is widely exploited in the food industry, especially for yogurt and cheese production. Heat treatments influence coagulation quality, requiring technological adjustments to ensure process success and high-quality final products.

4. Biochemical Changes in Meat After Slaughter (Presentation 4)

Introduction

After slaughter, meat undergoes a series of biochemical changes that influence its sensory and technological characteristics. These transformations include the rigor mortis and aging processes, as well as the impact of preservation methods such as refrigeration and freezing. Understanding these mechanisms is essential for optimizing meat quality in terms of tenderness, texture, and flavor.

1. Rigor Mortis and Meat Aging Process

As soon as slaughter occurs, blood circulation stops, triggering a series of biochemical reactions that affect the muscles:

- **Rigor mortis:**
  - After death, ATP (adenosine triphosphate) production, which is necessary for muscle relaxation, ceases.
  - The absence of ATP prevents the release of actin-myosin bonds, leading to irreversible muscle contraction and increased meat hardness.
  - This process begins a few hours after slaughter and typically lasts between 6 and 24 hours, depending on the animal species and storage temperature.
- **Meat aging:**
  - After rigor mortis, meat enters an aging phase during which endogenous enzymes (cathepsins, calpains) gradually break down certain muscle proteins.
  - This process enhances meat tenderness and flavor.
  - Aging is crucial for red meats (beef, lamb) and takes place under refrigeration for several days or even weeks, depending on the type of meat and storage conditions.

The final quality of meat thus depends on the proper execution of these steps, which directly influence its organoleptic properties.

2. Effects of Preservation Methods (Refrigeration, Freezing)

Preservation methods play a key role in maintaining meat quality and controlling its biochemical changes:

- **Refrigeration:**
  - Meat is stored between 0 and 4°C to slow down enzymatic and microbial activity.
  - It allows for controlled aging, improving tenderness and flavor development.
  - However, prolonged refrigeration may lead to water loss and color deterioration.
- **Freezing:**
  - Meat is frozen at temperatures below -18°C to completely halt enzymatic and microbial activity.
  - Rapid freezing helps prevent the formation of large ice crystals that can damage muscle fibers, thus minimizing juice loss after thawing.

- Poorly managed freezing can alter texture and make meat drier after thawing.

The choice between refrigeration and freezing depends on the desired storage duration and the type of meat.

3. Impact on Meat Texture and Tenderness

Post-mortem biochemical changes directly affect the sensory properties of meat:

- **Effects of rigor mortis:**
  - If meat is consumed before rigor mortis is complete, it is very tough and unpleasant to eat.
  - A post-mortem resting period is necessary to achieve more tender meat.
- **Effects of aging:**
  - The breakdown of muscle proteins by enzymes improves tenderness.
  - Chemical reactions also contribute to the development of the characteristic flavors of aged meats.
- **Influence of preservation methods:**
  - Prolonged refrigeration can enhance tenderness but may also cause excessive water loss.
  - Freezing followed by slow thawing helps preserve meat texture, whereas rapid thawing can make it more fibrous and dry.

Conclusion

The biochemical changes in meat after slaughter play a crucial role in its final quality. The transition through rigor mortis and aging affects meat texture and flavor. Preservation methods, particularly refrigeration and freezing, must be carefully controlled to maintain these qualities. A thorough understanding of these processes is essential to ensure high-quality meat products that meet consumer expectations in terms of flavor, tenderness, and food safety.

5. Enzymatic Reactions in Fruits and Vegetables: Enzymatic Browning and Ripening (Presentation 5)

Introduction

Fruits and vegetables undergo enzymatic transformations that influence their quality, appearance, and preservation. Among these transformations, enzymatic browning and ripening play a key role in determining their market value and consumer acceptance. Understanding these phenomena allows for optimized storage and processing while preserving their nutritional and sensory qualities.

1. Mechanisms of Enzymatic Browning and Ways to Limit It

Enzymatic browning is a chemical reaction that affects the appearance of fruits and vegetables, particularly after they are cut or damaged. It is caused by the oxidation of phenolic compounds under the action of the enzyme polyphenol oxidase (PPO) in the presence of oxygen.

Mechanism of Enzymatic Browning:

1. When a fruit or vegetable is cut or injured, the cells break, releasing polyphenols and enzymes.
2. In the presence of oxygen, polyphenol oxidase transforms these phenolic compounds into quinones, which polymerize to form brown pigments (melanins).
3. This phenomenon is responsible for the darkening of apples, bananas, avocados, and potatoes, reducing their visual appeal.

Ways to Limit Enzymatic Browning:

Several techniques can be used to prevent this undesirable reaction:

- **Reducing oxygen exposure:** By vacuum packaging or using protective films.
- **Inactivating polyphenol oxidase:** Through heat treatment (blanching) or the addition of enzymatic inhibitors (citric acid, ascorbic acid).
- **Controlling pH:** PPO is less active in acidic environments (adding lemon juice or vinegar).
- **Using antioxidants:** Such as sulfites or ascorbic acid, which reduce polyphenol oxidation.

Controlling enzymatic browning is essential in the food industry to extend the shelf life of fresh or processed fruits and vegetables.

2. Factors Influencing Fruit Ripening

Ripening is a biological process that transforms fruits, giving them their final sensory characteristics (taste, texture, aroma, color). It is influenced by several internal and external factors.

Internal Factors:

- **Type of fruit:**
  - **Climacteric fruits** (banana, apple, tomato, pear) continue to ripen after harvest due to ethylene production.
  - **Non-climacteric fruits** (orange, grape, strawberry) must be harvested at maturity, as their development stops after picking.
- **Hormonal regulation:**
  - **Ethylene**, a gaseous hormone, plays a central role in accelerating ripening by activating enzymes responsible for softening and aroma development.

External Factors:

- **Temperature:** High temperatures accelerate ripening, while low temperatures slow it down (cold storage).
- **Humidity:** Optimal humidity prevents fruit dehydration while avoiding mold growth.
- **Oxygen and CO_2:** An atmosphere enriched with CO_2 slows ripening by inhibiting ethylene action (used in controlled fruit storage).

3. Chemical Changes and Impact on Sensory Quality

During ripening, fruits undergo chemical modifications that improve their edibility and attractiveness.

Main Chemical Modifications:

- **Carbohydrate transformation:**
  - Starch is hydrolyzed into simple sugars (glucose, fructose, sucrose), making fruits sweeter.
- **Pigment modification:**
  - **Chlorophyll degradation** (loss of green color).
  - **Synthesis of carotenoids** (orange/yellow) and **anthocyanins** (red/blue), enhancing visual appeal.
- **Aroma development:**
  - Release of volatile compounds characteristic of ripe fruit.
- **Texture modification:**
  - Breakdown of pectin and cell fibers by **pectinases** and **cellulases**, making the fruit softer.

Impact on Sensory Quality:

- **Taste improvement:** Increased sweetness and reduced acidity.
- **Texture modification:** Fruits become softer and juicier.
- **Aroma change:** More pronounced fruity fragrances appear.

However, excessive ripening leads to loss of firmness and rapid deterioration, reducing the fruit’s commercial value.

Conclusion

Enzymatic reactions in fruits and vegetables, particularly enzymatic browning and ripening, significantly influence their quality and shelf life. Controlling these phenomena is crucial for ensuring better product preservation and optimizing industrial processing. By mastering ripening factors and applying strategies to limit browning, it is possible to enhance the visual appeal, texture, and flavor of fruits and vegetables, ensuring their consumer acceptance and market value.