Chapter 2: Characteristics of Food

Water

1.Water Activity (aw)

In food, water is not always fully available, as it can be bound to biochemical components, thereby reducing its chemical reactivity. Therefore, it is not the total water content that determines the stability of a food product but rather its availability. This availability is expressed by water activity (aw), a crucial parameter in the food industry, defined as the ratio between the partial vapor pressure of water in the food (Pw) and that of pure water at the same temperature (P°w). By definition, pure water has a water activity of 1, while in food, this value is always lower than 1. The higher the aw, the more accessible the water is to microorganisms and chemical reactions, directly affecting the preservation and stability of food. Thus, measuring aw is essential to determine the risk of microbial growth and the optimal storage conditions for food products.

2.Sorption Isotherm

The sorption isotherm is a tool used to assess how a food retains water based on the relative humidity of the surrounding air at a constant temperature. It is a curve that illustrates the amount of water present in a food that is in equilibrium with the environmental humidity. This relationship is particularly important for understanding how a food absorbs or loses water, which affects its texture, preservation, and microbiological stability. Studying sorption isotherms helps optimize food processing and storage processes, preventing dehydration or excessive moisture absorption that could alter food quality.

States of Water in Food

Water present in food exists in different forms depending on its degree of binding with the components of the food matrix.

- **Strongly bound water**, corresponding to a water activity between 0 and 0.2-0.3, is tightly bound to the surface of molecules, particularly proteins, carbohydrates, and salts. It forms a stable monomolecular layer, making it unavailable as a solvent or reactant. This water is non-freezable and difficult to remove, providing significant stability in food products.
- **Weakly bound water**, with a water activity greater than 0.2-0.3, is less tightly retained by the food matrix. It is bound through hydrogen bonds in the first adsorption layer and can also exist as condensed water vapor within food pores. More mobile, it plays an active role as a solvent and participates in various biochemical reactions. It is commonly found as a gel within cells and intercellular spaces. Its retention is influenced by several factors, including pH, ionic strength, and the nature of salts present in the food. This type of water is crucial for food stability and preservation, as

its availability determines microbial growth and enzymatic reactions that may alter food quality.

3.Importance of Isotherms in Food Technology

Sorption isotherms play a fundamental role in food technology as they help predict water activity in a mixture of ingredients with different moisture levels. This predictive ability is essential for understanding how a food product behaves when subjected to processing or storage in environments with varying humidity.

For example, an unprotected hygroscopic product can absorb ambient moisture, potentially altering its texture, shelf life, or sensory acceptability. Additionally, sorption isotherms are used to estimate the amount of water absorbed by packaging over time, which helps assess the shelf life of food products. They also allow for the analysis of temperature variations' impact on water activity in a product stored in airtight packaging, where water content remains constant. These analyses help optimize preservation and packaging processes to ensure better food stability and extend product longevity.

4.Water Activity and Food Modification

Water activity plays a crucial role in food stability during industrial processing and storage.

- **Low water activity** helps slow down enzymatic reactions and microbial growth.
- **Higher water activity** promotes biochemical and physicochemical transformations, which can lead to product deterioration.

The rate of food degradation based on water activity is illustrated by specific curves, which help identify critical ranges where deterioration occurs most rapidly. This knowledge is particularly important for adapting preservation techniques such as dehydration, freeze-drying, or the addition of stabilizing agents to best maintain food quality.

5. Chemical and Bacteriological Characteristics of Drinking Water

1. Drinking water must meet several criteria to be safe for human consumption. These criteria include physical, chemical, and microbiological aspects, as well as organoleptic requirements that ensure good sensory quality. Water intended for consumption should be odorless, fresh, and tasteless, with no undesirable flavors or odors.
2. From a physical perspective, drinking water must comply with certain quality limits, particularly in terms of turbidity, clogging potential, and coloration. These parameters influence not only the appearance of the water but also its potability and acceptability by consumers.
3. From a microbiological perspective, drinking water must be free from any pathogenic organisms or parasites that could pose a health risk. It should contain no indicators of

fecal contamination, such as *Escherichia coli*, which must be completely absent in a 100 mL sample. Similarly, fecal streptococci must not be detected in 50 mL of water, and sulfite-reducing *Clostridium* must be absent in a 20 mL sample. These criteria ensure that the water does not pose a risk of transmitting waterborne diseases.

4. From a chemical perspective, the quality of drinking water is defined by its mineralization and the concentration of certain trace elements. The total mineralization should not exceed 2000 mg/L to prevent an excess of dissolved salts that could alter the taste and digestibility of the water. Several metals and potentially toxic elements must be present in controlled amounts. For example, the lead concentration should not exceed 0.1 mg/L, while fluoride is limited to 1.0 mg/L to prevent adverse health effects. Other elements, such as selenium, arsenic, and hexavalent chromium, must be at very low concentrations, often below analytical detection limits. Additionally, certain metals such as copper (1.0 mg/L), iron (0.3 mg/L), manganese (0.1 mg/L), and zinc (5.0 mg/L) must be monitored to prevent any alteration of water quality and ensure its safety. Phenolic compounds must not be detectable in drinking water to avoid undesirable chemical contamination.
5. These combined criteria ensure that drinking water is safe for human consumption and does not pose any public health risks.

Vegetable Fats and Oils

1. **Roles of Lipids**
   Lipids play multiple roles in nutrition. From a nutritional standpoint, they are a significant energy source and are essential for the absorption of fat-soluble vitamins (A, E, K, D), which require lipids to be assimilated by the body. Additionally, lipids have a crucial organoleptic role, as they influence the texture and flavor of foods. They also contribute to culinary properties, such as frying and emulsification, by modifying the consistency and stability of food preparations.

2. **Characteristics of Fatty Acids (FA)**
   Fatty acids, which are the main components of lipids, have specific characteristics. In nature, they usually have an even number of carbon atoms, with double bonds mostly in the *Cis* configuration, while the *Trans* configuration is rarer. Two key concepts help to better understand their properties:
   - The longer the carbon chain, the more hydrophobic the fatty acid, reducing its solubility in water.
   - The acidity of a fatty acid, defined by the dissociation of its carboxyl group (COOH), decreases as the chain length increases. As a result, short-chain fatty acids (C4-C10) are volatile and can evaporate with water vapor, while only fatty acids with four and six carbon atoms remain soluble in water.

3. **Physicochemical Properties of Lipids and Their Impact on Foods**
Lipids possess several physicochemical properties that influence the structure and stability of foods. Their insolubility in water is essential for forming food emulsions, while their low melting point can cause certain foods to soften or liquefy at room temperature. The plasticity of lipids also plays a significant role in the texture of food products.
The melting point of a triglyceride depends on several factors, including the length of the fatty acid carbon chain, the presence or absence of double bonds, the type of isomerism (*Cis* or *Trans*), and the position of fatty acids on the glycerol molecule. Unlike a pure substance that melts at a precise temperature, a fat or oil contains multiple triglycerides, leading to a gradual melting over a range of temperatures. This characteristic explains why solid fats, like butter, retain some plasticity due to the coexistence of solid crystals suspended in a liquid phase.

4. **Factors Influencing the Texture and Melting of Lipids**
Several factors affect the texture and melting of lipids. The rate of cooling or heating influences the crystallization and melting of fats, as does agitation during food processing. Additionally, storage conditions, such as temperature, duration, and thermal fluctuations, play a crucial role in the stability of lipids and their impact on food.
The composition of fats directly influences their functional properties. For example, butter and margarine must have a suitable texture for easy spreading. Cocoa butter is known for its brittle texture at room temperature but melts smoothly in the mouth—an essential characteristic in chocolate making. Cooking oils must be clear and transparent, while in pastry and biscuit-making, lipids are indispensable for their ability to incorporate air and enhance the texture of finished products through their lubricating effect.

5. **Key Characteristics of Dietary Fats and Oils**
Dietary fats and oils come from both plant and animal sources and are used in various food applications. They are essential ingredients due to their nutritional, functional, and technological properties.
Vegetable fats are typically extracted from oilseeds and fruits. They are widely used in food applications, including the production of table oils, frying fats and oils, and in the manufacture of margarine and emulsifiable fats.
Animal fats, on the other hand, come from the adipose tissue of animals and exhibit specific characteristics depending on their source. Ruminant fats are generally more unsaturated than those from other animals. Lard, derived from pig fat, is commonly used in frying and baking. Tallow, obtained from beef and mutton fat, is primarily used in soap production. Whale and fish fats, which are rich in unsaturated fatty acids,

must undergo hydrogenation before being used in human food, particularly for margarine production, frying, and even in animal feed.
Some fats are considered special cases because they possess unique properties and are protected by strict regulations due to their texture, aroma, or specific use. This is the case for olive oil, butter, lard, and cocoa butter, which are subject to specific quality standards. In contrast, other refined fats are often interchangeable due to their neutral flavor and widespread use in various food formulations.

6. **Factors Affecting Lipid Oxidation**
Lipid oxidation is a process that leads to rancidity, resulting in a deterioration of food quality both in terms of sensory attributes and nutritional value. This process is influenced by several factors that can either accelerate or slow down lipid degradation.
Among the factors that promote oxidation, a high initial peroxide content is a key indicator of lipid degradation. The presence of pro-oxidants, such as certain metals (iron, copper), myoglobin heme, or the enzyme lipoxygenase, also accelerates oxidation by facilitating the formation of unstable compounds.
Another crucial factor is the low activity of natural antioxidants, such as tocopherols (vitamin E) and certain amino acids, which normally help slow down lipid oxidation.
Additionally, water activity plays a significant role, as it influences the catalytic action of metals that can accelerate oxidation reactions.
Lastly, the nature and dispersion of lipids in food directly affect their susceptibility to oxidation. Competitive oxidation, which involves interactions between two oxidizable substances present simultaneously, can also alter the speed and intensity of the lipid oxidation process.

7. **Prevention of Lipid Oxidation**
The preservation of foods containing lipids relies on preventing oxidation, a natural process that degrades their organoleptic and nutritional qualities. To limit this deterioration, various antioxidant methods and substances can be used, classified into three main categories based on their mode of action.
   - **Type I Antioxidants** are substances that reduce the number of free radicals by neutralizing these unstable molecules before they react with lipids. Examples include propyl gallate, BHA (butylated hydroxyanisole), and BHT (butylated hydroxytoluene), which are commonly used in the food industry. Wood smoke also has a natural antioxidant effect and is used in certain smoking processes to extend food shelf life.
   - **Type II Antioxidants** work by preventing the formation of free radicals, mainly by binding to metals that catalyze oxidation reactions. These agents include metal chelators such as EDTA (ethylenediaminetetraacetic acid), citric acid, and certain amino acids like cysteine and histidine. Their action helps stabilize lipids by reducing the effects of pro-oxidant metals.

- **Protective Methods Against Oxidation** provide an additional approach to slowing lipid oxidation. One effective method is reducing the partial pressure of oxygen in packaging, using vacuum packaging or modified atmosphere packaging. Moreover, protecting food from light is essential, as exposure to ultraviolet radiation accelerates lipid degradation.

Summary
Lipid oxidation is an inevitable but controllable phenomenon. By using appropriate antioxidants and effective packaging techniques, it is possible to extend the shelf life of foods while preserving their nutritional and sensory quality.

Milk and Dairy Products

1. Composition and Nutritional Value

1.1. Definition

The term "milk" generally refers to cow's milk. It is a product obtained from the complete and uninterrupted milking of a healthy dairy female. This milk must be properly collected and must not contain colostrum.

1.2. Composition

Milk, regardless of the animal species it comes from, is primarily composed of water, proteins, lactose, fats, and minerals. Its composition varies depending on several factors, including the animal's diet, the lactation period, the season, and the bovine breed. In addition to these major components, milk also contains enzymes, antibodies, hormones, and suspended particles such as fat globules and casein micelles. It may also contain cells, including macrophages, microorganisms, and possible traces of antibiotics and antiparasitic substances. Its structure is a complex system with multiple phases: a dispersing phase consisting of whey containing lactose and globular proteins, a particulate phase corresponding to the emulsion of fat globules, and a colloidal suspension of casein micelles.

1.3. Physical and Chemical Properties

Milk is a white, opaque, or slightly opalescent liquid with a very faint odor and a mildly sweet taste. Its density ranges from 1.022 to 1.034, with an average of 1.032. The boiling point varies between 100.15°C and 100.17°C, while the freezing point is around -0.555°C. The pH of milk ranges between 6.5 and 6.7. The acidity of milk is measured in Dornic degrees (°D), where 1°D corresponds to 0.01% lactic acid or 0.1 g/L. Fresh milk has an acidity of about 18°D. Due to its complex composition, milk is an unstable liquid.

1.4. Milk as a Secretion Product

Milk is secreted by the mammary glands of female mammals. Its synthesis occurs in the acinar cells of these glands, which extract essential components from the blood and lymph. It consists of two types of elements: on the one hand, components common to both blood and milk, such as water, mineral salts, albumin, and globulin; and on the other hand, elements specific to milk, including lactose, casein, fats, and citric acid, which are produced directly by the mammary cells.

1.5. Nutritional Value of Milk

Although it is a liquid, milk contains between 10% and 13% dry matter, comparable to some solid foods. It is an important energy source, providing approximately 700 kcal per liter. Its proteins have high nutritional value, particularly lactoglobulin and lactalbumin, which are rich in essential sulfur-containing amino acids.

Milk is also a major source of minerals such as calcium and phosphorus, which are essential for bone health. It contains riboflavin (vitamin B2), which plays a key role in energy metabolism. In terms of vitamins, milk provides vitamins A, B1 (thiamine), and B12 (cobalamin), which are essential for proper bodily functions. However, it is low in iron, copper, vitamin C (ascorbic acid), and niacin, and it has a relatively low vitamin D content.

Some individuals suffer from lactose intolerance due to a deficiency in intestinal lactase, leading to digestive disorders when consuming milk.

2. Lactose

Lactose is the main carbohydrate in cow's milk. This disaccharide, unique to milk, consists of β-D-galactopyranosyl (1-4) D-glucopyranosyl (α or β). It has specific characteristics, such as a mildly sweet taste—only one-sixth the sweetness of sucrose—a low solubility, approximately ten times lower than that of sucrose at room temperature, and the presence of a reducing group.

In dairy products, lactose plays a fundamental role as a substrate for lactic fermentation: it is hydrolyzed into glucose and galactose, which are then converted into lactic acid by lactic acid bacteria. From a nutritional perspective, lactose is essential for infants. However, it can present certain challenges, particularly nutritional issues related to lactose intolerance, and technological concerns due to its hygroscopic nature in powdered milk and its crystallization in condensed milk and ice cream.

3. Milk Lipids

The lipid content in milk varies between 2.5% and 5%, which is approximately 35 g per liter. This content depends on several factors, including milk production: high production is often associated with lower fat content and vice versa. Seasonality also plays a role, as milk production is generally lower in winter.

Milk lipids are divided into four main fractions. The first fraction consists of triglycerides, which make up about 98% of milk lipids, with a fatty acid composition that varies depending on the animal species. It contains a high proportion of saturated fatty acids (SFA), accounting for 60% to 70%, particularly high-melting-point fatty acids (C14-C16-C18), as well as short-chain fatty acids (C4-C5), which are volatile. Monounsaturated fatty acids (MUFA) represent 25% to 30% of the lipid fraction, while polyunsaturated fatty acids (PUFA) account for 2% to 5%.

The second fraction consists of phospholipids (1%), primarily lecithin and cephalin, which have amphiphilic properties that help maintain the bond between the fat and aqueous phases. The third fraction is sterols, representing about 0.3% to 0.4% of milk lipids, including cholesterol (70 mg/L) and vitamin D (0.02 mg/L). Finally, the fourth fraction includes carotenoids, with carotene (0.15 mg/L), β-carotene, and vitamin A (0.5 mg/L).

The origin of milk fatty acids is twofold: approximately 60% come from fatty acids circulating in the bloodstream, while 40% are synthesized by mammary cells from precursors with 2 or 4 carbon atoms.

4. Physicochemical State of Lipids

In milk, lipids are dispersed as spherical globules in suspension. Their number is estimated between 1.5 and 4.6 × 10^{12} globules per liter, with an average diameter ranging from 1.5 to 4 µm. These globules are surrounded by a complex membrane composed of polar lipids (mono- and diglycerides, free fatty acids, sterols, and phospholipids), glycolipids, carotenoids, lipoproteins, and other proteins.

The fat globule membrane plays a crucial role in protecting lipids from lipolysis, which can be induced by naturally occurring lipases in milk or microbial enzymes. It also helps maintain the emulsion of fat globules in the aqueous phase through lecithin. However, this membrane can be altered by various factors, including mechanical or thermal treatments, as well as enzymatic action by lipases. These alterations can destabilize the emulsion and promote lipolysis by facilitating contact between lipases and milk fat.

Milk fat globules have a lower density than the rest of the milk, causing them to naturally rise to the surface to form cream. This phenomenon is enhanced by certain conditions, such as heating at 80°C or a decrease in pH, which influence the stability of lipids in milk.

5. Milk Proteins

Milk contains approximately 35 g/L of proteins, which are divided into several categories. Some proteins consist solely of amino acids, such as α-lactalbumin and β-lactoglobulin.

Others contain phosphorus, including α- and β-caseins. Kappa-casein, on the other hand, may include a carbohydrate fraction. Milk also contains a proteose-peptone fraction, rich in carbohydrates and with intermediate properties.

5.1. Caseins (80% of cow's milk proteins)

a) Casein Structure

Caseins are phosphorylated polypeptides associated with mineral components that account for about 8% of their structure, particularly calcium (Ca), phosphorus (P), and magnesium (Mg). Several types of caseins exist: α-casein (40%), composed of αs-casein and κ-casein, β-casein (30%), as well as γ-casein and other forms (15%). Genetic variations can influence the structure of caseins.

b) Properties and Micelle Formation

The isoelectric point (pHi) of caseins is 4.7, meaning they precipitate when the milk pH reaches this value. At a pH of 7, caseins behave differently: αs-casein forms small polymers, β-casein exists as monomers, while κ-casein is a larger polymer. At pH 7 and a temperature of 37°C, the addition of calcium ions (Ca^{2+}) induces the coagulation of αs-casein and the precipitation of β-casein, whereas κ-casein remains unchanged. When αs- and β-caseins are mixed, the addition of calcium promotes their precipitation but does not affect κ-casein.

5.2. Whey Proteins (20% of milk proteins)

Whey proteins are characterized by their low molecular weight and their presence as monomers and polymers. Unlike caseins, they do not precipitate at their isoelectric point, do not contain phosphorus, and do not coagulate under enzymatic action. They have excellent nutritional value and are rich in sulfur-containing amino acids and lysine. The main whey proteins include β-lactoglobulin (10%), α-lactalbumin (2%), immunoglobulins, serum albumin, proteose-peptone, and lactoferrin.

6. Biochemical Processes of Milk Coagulation

Milk coagulation results from the destabilization of casein micelles, leading to curd formation. This process can occur through two mechanisms: acid coagulation and enzymatic coagulation.

6.1. Coagulation by Lactic Acidification

This type of coagulation is based on lowering the pH to the isoelectric point of caseins. It can be achieved either by adding a mineral acid such as hydrochloric acid (HCl) or sulfuric acid (H_2SO_4), or by inoculating milk with lactic acid bacteria. Acidification neutralizes the negative charges of caseins, causing their flocculation and the formation of a homogeneous gel. Simultaneously, progressive demineralization of micelles occurs, with colloidal calcium migrating to the whey.

6.2. Coagulation by Rennet Action

Enzymatic coagulation is mediated by different types of enzymes. Animal-origin enzymes include rennet and pepsin, while plant-based enzymes include bromelain and ficin. Fungal proteases, derived from microorganisms such as *Mucor pusillus* and *Mucor miehei*, can also be used. Rennet is a proteolytic enzyme extracted from the stomachs of young milk-fed ruminants. It mainly consists of chymosin (80%) and pepsin (20%).

7. Effects of Chemical Treatments

7.1. Non-Enzymatic Browning (NEB)

Non-enzymatic browning (NEB) includes several chemical reactions that alter the color and flavor of foods. The most notable among these reactions are the Maillard reaction and caramelization. These transformations lead to the formation of brown pigments and modifications in the aroma and taste of food.

NEB can have beneficial effects, such as the golden crust of bread, the appetizing color of roasted meat, or the formation of caramel. However, it can also be undesirable in certain products, such as condensed milk, fruit juices, or dehydrated foods (powdered milk, eggs, meat), where it may negatively impact the sensory and nutritional quality.

7.2. Substrates Involved in NEB

NEB involves several types of substrates. The primary ones include reducing sugars such as glucose, fructose, lactose, and maltose. Certain vitamins, like ascorbic acid (vitamin C) and vitamin K, can also participate in these reactions. Proteins and amino acids, due to their free amine groups, play a crucial role in the Maillard reaction.

Several factors influence the intensity and speed of non-enzymatic browning. The nature of the reducing sugars is key: pentoses (such as ribose) are more reactive than hexoses (glucose, fructose), which in turn are more reactive than disaccharides (lactose, maltose). Temperature also plays a significant role: the reaction slows down at low temperatures and accelerates at higher temperatures. Water activity affects the reaction rate, as does the pH of the medium.

In a slightly basic or neutral environment (pH between 6 and 8), such as in milk and eggs, the Maillard reaction is favored. At a more acidic pH (2.5 - 3.5), as in acidic fruit juices, the degradation of ascorbic acid and fructose predominates. In an intermediate pH range (3.6 - 6), such as in orange juice, the Maillard reaction coexists with ascorbic acid degradation.

7.3. Prevention of NEB

Several strategies can be implemented to limit the undesirable effects of non-enzymatic browning. Removing reducing sugars from food can slow down the reaction. Lowering the pH can also reduce browning, as can strict control of temperature and humidity during food storage and processing. Finally, adding inhibitors, such as sulfur dioxide, can prevent excessive formation of brown pigments.

Summary

Milk coagulation can occur through acidification or enzymatic action. Non-enzymatic browning alters the color and taste of food, influenced by factors such as temperature, pH, and sugar composition. Preventive measures can minimize its undesirable effects and improve food quality.

Meats - Fish - Eggs

1. The Muscle Protein System

Muscle is a complex structure that plays a fundamental role in meat quality. It is primarily composed of muscle fibers, which ensure contraction and rigidity, and connective tissue, which contains blood vessels and nerves essential for oxygen supply and innervation. Lipid tissue, varying in quantity depending on the species and muscle type, influences the flavor and tenderness of meat. Myoglobin, a pigment protein, is also present, giving muscles their characteristic red color while serving as an oxygen storage molecule.

Muscle proteins are classified into three main categories. Sarcoplasmic proteins, accounting for 30-45% of total proteins, include glycolytic enzymes and myoglobin, which play key roles in energy metabolism and pigmentation. Myofibrillar proteins, constituting about 50% of muscle proteins, mainly consist of myosin (64%) and actin (27%), essential for muscle contraction. Lastly, connective tissue proteins, making up 10-15%, include collagen and elastin, which influence meat texture and tenderness after cooking.

2. Biochemical Changes After Death

2.1. Rigor Mortis

After an animal's death, the muscle undergoes several biochemical modifications affecting its structure and sensory properties. Rigor mortis occurs progressively due to ATP depletion, an essential molecule for muscle relaxation. In the absence of ATP, actin and myosin filaments form irreversible bonds, leading to continuous muscle contraction and increased rigidity. This phase lasts from a few hours to several days, depending on the species, temperature, and metabolic conditions before slaughter.

This rigidity directly affects meat texture. When ATP production ceases, actin-myosin bridges remain locked, making the muscle firm and inextensible. Over time, proteolytic enzymes, such as cathepsins, begin breaking down structural proteins, initiating the aging process and softening the meat.

2.2. Muscle Tissue Acidification

Muscle acidification after slaughter is a direct consequence of glycogen conversion into lactic acid through anaerobic glycolysis. This process compensates for the loss of oxygen supply and leads to a progressive decrease in muscle pH, dropping from approximately 7.0 to a final level between 5.4 and 5.8, depending on the initial energy reserves.

Various enzymes extend ATP production post-mortem. Creatine kinase regenerates ATP from phosphocreatine, while myokinase converts two ADP molecules into ATP and AMP. Once these mechanisms become insufficient, anaerobic glycolysis becomes the primary energy source, producing lactate and lowering muscle pH.

The pH decline has multiple effects on meat quality. An excessively low pH causes protein denaturation and excessive water loss, making the meat dry and fibrous. Additionally, acidification inhibits sarcoplasmic ATPases, promoting calcium leakage from the sarcoplasmic reticulum into the cytoplasm, which further intensifies muscle rigidity.

3. Factors Influencing Rigor Mortis

Several factors influence rigor mortis, including the animal’s nutritional state and stress levels before slaughter. A stressed or malnourished animal has reduced glycogen reserves, leading to rapid ATP depletion, increased muscle rigidity, and lower water retention capacity. Moreover, a higher initial pH promotes microbial proliferation, compromising meat hygiene quality.

Carcass storage temperature also plays a crucial role. A rapid temperature drop causes a sudden pH decline, resulting in protein denaturation and excessive water loss, making the meat dry and fibrous. Conversely, a higher temperature (14-19°C) may limit excessive muscle contraction, but it is crucial not to freeze the meat before rigor mortis is fully resolved, as this could negatively impact texture and tenderness. Storing meat at around 0-1°C before the onset of rigor mortis can increase muscle contraction, making the meat tougher.

4. Resolution of Rigor Mortis (Meat Aging)

Meat aging is a natural process that improves its texture and sensory qualities. As meat matures, its toughness decreases due to the degradation of structural proteins, enhancing tenderness and water retention capacity. Additionally, aged meat is easier to cook due to improved protein extractability.

This process is mainly driven by the progressive detachment of actin filaments from the Z-line under the influence of ionic modifications and lysosomal enzymes (cathepsins), which become active as pH decreases. Various interventions can optimize this process, such as controlling pH and enzymatic activity, as well as injecting $MgSO_4$ before slaughter to reduce exudation during thawing.

Meat aging is also accompanied by biochemical reactions, including lipid oxidation and the formation of chemical compounds such as nucleotides, ammonia, hydrogen sulfide (H_2S), acetylaldehyde, and diacetylacetone. These transformations influence meat flavor and aroma, giving it optimal sensory characteristics.

Summary

Rigor mortis is a crucial process in converting muscle into meat, dependent on glycogen reserves and storage conditions. Poor temperature management can result in dry and fibrous meat, while proper aging improves tenderness and water retention capacity. Specific interventions, such as enzymatic control and pH optimization, can enhance meat aging and ensure superior final product quality.

Alterations and Preservation of Fish

1. Fish Alterations

Fish alterations are primarily caused by the combined action of endogenous enzymes and bacteria, which thrive in a favorable environment characterized by high pH and an abundance of nutrient substrates. These alterations result in the formation of foul-smelling compounds such as trimethylamine, methyl mercaptan, hydrogen sulfide (H_2S), ammonia (NH_3), and various sulfides, giving the fish an unpleasant odor. Additionally, the action of tissue and bacterial proteases leads to the rapid softening of the flesh, while the diffusion of hemoproteins alters its color. The hydrolysis and oxidation of lipids also contribute to the qualitative degradation of the fish.

2. Refrigeration

Refrigeration is an essential method for slowing down alterations, but it does not completely stop them. Certain bacteria, such as *Pseudomonas*, continue to proliferate at temperatures as low as -5°C. Furthermore, lipases remain active even when the fish is frozen, which can affect product quality over time. To optimize fish preservation, it is recommended to bleed and eviscerate it immediately after capture, then quickly cool it in seawater at a temperature between -10°C and -2°C.

3. Freezing

The timing of freezing significantly influences the texture of the fish. Freezing before rigor mortis causes rigidity during freezing, which alters the texture, especially for fillets. On the other hand, freezing after rigor mortis results in better texture, particularly for fish fillets. The speed of thawing also plays a crucial role: fillets thaw rapidly, causing sudden contraction that degrades their texture, whereas whole fish thaw more slowly, preserving muscle elasticity and maintaining better quality. In practice, freezing before rigor mortis is preferred for whole fish, such as tuna, while freezing after rigor mortis is recommended for fillet preparation. Additionally, prior soaking in a polyphosphate solution helps reduce liquid loss during thawing, thus improving the final product quality.

4. Effects of Prolonged Storage at Insufficient Temperature

Prolonged storage at an unsuitable temperature can affect lean and fatty fish differently. Lean fish, rich in proteins, undergo protein denaturation and persistent enzymatic activity of lipases, leading to flesh hardening. Fatty fish, rich in lipids, are vulnerable to lipid oxidation, and any temperature fluctuation can cause surface dissociation, reducing their quality. These alterations result in weight loss, flesh hardening, and the appearance of spots. To limit these degradations, several protective methods are recommended:

- **Glazing**, which forms a protective barrier against dehydration and oxidation.
- **Vacuum packaging** with an impermeable plastic film.
- **Brining**, which involves immersing the fish in a 23% NaCl (sodium chloride) saltwater solution before freezing, optimizing its preservation.

Summary

- Fish alterations are caused by the action of enzymes and bacteria.
- Refrigeration slows down these alterations but does not completely stop them.
- Freezing after rigor mortis improves fillet texture.
- Prolonged storage at an insufficient temperature leads to protein denaturation, lipid oxidation, and quality loss.
- Effective protection measures include glazing, vacuum packaging, and brining.

THE EGG: Composition, Properties, and Nutritional Value

1. Composition of the Egg

The egg consists of several distinct parts, each playing a specific role. The yolk, or vitellus, accounts for approximately 29% of the egg and is rich in lipids, giving it an essential emulsifying role in many food preparations. The egg white, or albumen, makes up the majority of the egg (61.5%) and is primarily composed of proteins. These two parts are protected by shell membranes, both internal and external, which act as a barrier against contamination. The entire structure is enclosed by a shell, which represents about 9.5% of the total egg weight and provides mechanical protection.

From a chemical perspective, the egg consists of 65% water, giving it a fluid texture and a high hydration capacity in culinary preparations. It also contains 23% organic substances, including 12% proteins and 11% lipids, making it a highly nutritious food. Lastly, it contains about 11% mineral matter, which is essential for the body.

2. Functional Properties of Egg Products

2.1. Coagulating Power

Egg proteins have a significant coagulating power, meaning they denature and solidify under the influence of certain agents. This coagulation can be induced by physical factors such as heat and mechanical action (beating), as well as by chemical agents like inorganic ions and heavy metals. This property is essential in the preparation of many recipes, especially in the making of creams, custards, and pastries, where the egg plays a structuring role.

2.2. Anti-Crystallizing and Foaming Power of Egg White

Egg white has specific properties that make it particularly valuable in the food industry. Its anti-crystallizing effect helps limit the formation of sucrose crystals when incorporated at a rate of 3%, which is useful in the production of ice creams and confectionery. Moreover, it plays a crucial role in foam formation due to the presence of specific proteins such as lysozyme, which contributes to foaming capacity, and ovomucin, which ensures foam stability. These characteristics make egg white an essential ingredient in the preparation of meringues, soufflés, and light mousses.

2.3. Emulsifying Power of Egg Yolk

Egg yolk has strong emulsifying power, mainly due to the presence of phospholipids such as lecithin. These compounds possess surfactant properties that help stabilize mixtures between aqueous and oily phases, enabling the emulsion of substances that are normally immiscible. The viscosity of the yolk also plays a crucial role in providing stability to emulsions, such as those found in sauces, mayonnaise, and cake batters.

3. Nutritional Value of the Egg

Nutritional Qualities

The egg is an exceptionally valuable source of high-quality proteins, as it contains all essential amino acids in optimal proportions for the human body. Additionally, it is rich in iron and vitamins, making it a nutritious and health-beneficial food. However, it is relatively low in energy, carbohydrates, calcium, and vitamin C, meaning it should be complemented with other foods to ensure a complete nutritional balance.

Egg Proteins

Egg proteins are often considered the reference standard for evaluating the quality of dietary proteins, as they contain the eight essential amino acids in ideal proportions. However, it is important to note that the distribution of nutrients is uneven between the white and the yolk. The white is primarily composed of proteins and water, whereas the yolk contains more lipids and fat-soluble vitamins.

Summary

The egg is composed of several distinct elements: yolk, white, shell membranes, and shell.

It has various functional properties, including coagulation, emulsification, and the foaming ability of the white.

Nutritionally, it is an excellent source of proteins and essential nutrients, although it is low in carbohydrates and calcium.

The Plant Seeds: Composition and Properties

1. Cereals

Cereals are plants belonging to the group of phanerogams, a subdivision of angiosperms and monocotyledons. They are part of the Gramineae family and constitute a fundamental element of human and animal nutrition. Among the main cultivated species are soft wheat (*Triticum vulgare* or *Triticum aestivum*), durum wheat (*Triticum durum*), maize (*Zea mays*), rice (*Oryza sativa*), and barley (*Hordeum vulgare*).

From a nutritional perspective, cereals represent a major source of calories and proteins, particularly in developing countries where they provide about 90% of energy and protein intake. In industrialized countries, this proportion is reduced to approximately 25%. However, the nutritional quality of cereal proteins is relatively low due to a deficiency in lysine, an essential amino acid.

Cereals are processed into various food products depending on their species. Soft wheat is mainly used in the form of flour for bread making, whereas durum wheat is transformed into semolina, used for producing pasta and couscous.

2. Composition of Wheat Grains

Wheat grains are primarily composed of water and organic matter, including carbohydrates, nitrogenous substances (proteins), and lipids, which are mostly located in the germ and husks. They also contain mineral substances, though in low proportions. These minerals are distributed at 80% in the husks and 20% in the endosperm, with essential minerals such as potassium, phosphorus, calcium, and magnesium.

The conservation of wheat grains is a key factor in maintaining their quality. Poor storage conditions can lead to an increase in free fatty acid levels, promoting lipid rancidity, which affects the quality and safety of the product.

Starch is the main component of the cereal endosperm. It is a complex polysaccharide composed of granules, themselves consisting of alternating crystalline and amorphous layers. In wheat grains, starch is enclosed in a protein network, giving it viscous and elastic properties essential for bread-making and other flour-based products.

3. Cereal Proteins

The protein content of cereals is relatively low, ranging between 10 and 12%. These proteins are mainly located in the endosperm, where they constitute about 70% of the total protein content, with a higher concentration towards the periphery of the grain.

Cereals contain several categories of proteins, classified according to their solubility. These include albumins, soluble in water, and globulins, soluble in saline solutions, each representing approximately 10% of total proteins. Prolamins, such as gliadin in wheat, are soluble in diluted alcohol and make up 45% of proteins. Finally, glutelins, soluble in diluted acid and basic solutions, account for about 35% of the total. The combination of gliadins and glutelins forms gluten proteins, which are key to wheat flour's elasticity and baking properties.

Cereal proteins are divided into two main groups based on their function. Albumins and globulins are functional proteins with a metabolic role, while gliadins and glutelins are storage proteins that store nitrogen, carbon, and sulfur for germination.

In terms of amino acid composition, cereal proteins are rich in glutamine and proline but are deficient in lysine, histidine, and arginine, which limits their nutritional value. Glutelins, however, have a higher content of lysine, glycine, alanine, and tyrosine but lower levels of glutamine, proline, and cysteine.

Glutelins are classified into different categories based on their molecular size. Those with a molecular mass greater than 200,000 resemble high-molecular-weight albumins and globulins. Those between 100,000 and 200,000 are particularly rich in glutamine and glycine. Finally, low-molecular-weight glutelins, below 50,000, are similar to gliadins.

4. Legume Seeds

Legumes include a wide variety of seeds such as fava beans, peas, beans, lentils, soybeans, and peanuts. They are distinguished by their nutritional composition, which, excluding soybeans, consists of approximately 22 to 25% proteins, 48 to 54% carbohydrates, and a low lipid content ranging between 1 and 4%.

Nutritionally, these seeds play a major role as protein sources, which is why they are often referred to as "protein crops." The main proteins present are globulins, making up between 60 and 90% of total proteins, and albumins, which range from 10 to 20%.

The structure of globulins varies depending on the type of legume. They are generally composed of 7S to 11-12S proteins and are formed from acidic and basic polypeptides linked by disulfide bonds. These bonds play a key role in protein stability and influence their functional properties.

5. Functional Properties of Legume Proteins

Legume proteins exhibit various functional properties that influence their food applications. Their solubility varies according to ionic strength and affects their water retention capacity.

The viscosity of legume proteins is minimally affected by the presence of salt but increases with temperature due to the gradual denaturation of proteins. These proteins also exhibit swelling properties, which depend on the degree of unfolding of the peptide chain.

Regarding their coagulation capacity, it begins at a temperature that varies according to the pH of the medium. Gel formation is optimal at a pH close to 7, which affects the texture properties of legume-based products.

Summary

- Cereals are an essential source of carbohydrates and proteins, though they are deficient in lysine. Their proteins include albumins, globulins, gliadins, and glutelins, with the latter responsible for gluten formation.
- Legumes, on the other hand, are rich in proteins and mainly consist of globulins and albumins. Their proteins have functional properties such as solubility, viscosity, and coagulation, which are influenced by factors like pH and temperature.

Fruits and Vegetables

1.Nutritional Importance

Fruits and vegetables are an essential source of nutrients. They are rich in calcium, vitamin C, carotene, and B vitamins. Their low caloric intake, combined with their high fiber content, promotes intestinal transit and contributes to satiety without causing weight gain.

2.Composition and Classification

Fruits are characterized by their sweet or tangy taste, distinct aroma, and are generally consumed raw. Vegetables, on the other hand, are classified according to the edible part of the plant. Some, such as cucumber, eggplant, bell pepper, and tomato, are botanically considered fruits. Others come from seeds, like peas, beans, and corn. Edible roots include beetroot and carrot, while asparagus comes from stems. Leafy vegetables include spinach, cabbage, and lettuce, whereas some consumed parts, like cauliflower and artichokes, are flowers.

3.General Properties

Fruits contain more organic acids and less starch and protein compared to vegetables. The latter generally have low acidity (pH above 5), except for tomatoes. The nutritional and organoleptic characteristics of fruits and vegetables depend on several factors, including species, variety, cultivation and storage conditions, maturity level, and post-harvest technological treatments.

4.Flavor and Aroma

The taste perception of fruits and vegetables depends on the balance between sugar and acidity, as well as the presence of tannins. Their aroma results from various volatile compounds such as esters, alcohols, ketones, and aldehydes, which develop during ripening and storage.

5.Color

Natural pigments are responsible for the different colors of fruits and vegetables. Chlorophyll, which is fat-soluble, gives a green hue. Carotenoids, also fat-soluble, produce yellow and orange shades. Anthocyanins, on the other hand, are water-soluble and create red to blue hues. The maturation process alters the concentration of these pigments, influencing the color of products over time.

6.Texture

The texture of fruits and vegetables primarily depends on their fiber composition, such as cellulose, hemicellulose, and lignin. Intracellular water, which can represent up to 96% of their weight, plays a crucial role in their firmness. Several factors affect their texture, including ripening, storage conditions, cooking methods, and freezing processes, which can alter their cellular structure and consistency.

7.Cellulose and Pectin

Cellulose is an essential structural component that provides rigidity and resistance to plants. Although indigestible for humans, it plays a significant role in intestinal transit, promoting proper digestive function. In the food industry, cellulose is used for its water-retention properties in pastries and to stabilize ice creams.

Pectin, on the other hand, is a polysaccharide found in the cell walls of fruits and vegetables. It has a unique ability to form a gel when heated in an acidic environment, a property exploited in making jams and jellies.

8.Ripening and Chemical Transformations

The ripening of fruits involves a series of biochemical changes that make them suitable for consumption, altering their texture, flavor, and color. Climacteric fruits, such as bananas, apples, and tomatoes, experience a respiratory peak before reaching full ripeness, allowing them to continue maturing after harvest. In contrast, non-climacteric fruits, such as grapes, strawberries, and citrus fruits, only ripen on the plant and do not continue to mature after being picked.

The main changes during ripening include an increase in sugar content due to the hydrolysis of starch and cell walls, as well as a decrease in acidity through the breakdown of organic acids. Fruit softening results from the transformation of insoluble protopectin into soluble pectin. Additionally, color changes occur due to chlorophyll degradation and the emergence of new pigments like carotenoids and anthocyanins. Lastly, ripening enhances the development of aromas through the production of volatile compounds responsible for the taste and smell of fruits.

9.Enzymatic Browning (EB)

Enzymatic browning is an oxidation process that leads to the formation of colored polymers, causing a brown or black tint to appear on certain fruits and vegetables after being cut or damaged. It is particularly common in apples, pears, bananas, potatoes, and mushrooms.

Various methods help limit this process. Choosing varieties low in phenolic compounds can reduce the risk of oxidation. Avoiding mechanical shocks that activate the enzymes responsible for browning is also recommended. Heat treatment effectively inactivates these enzymes, as does the addition of ascorbic acid, a natural antioxidant. Immersing foods in a saline or sugary solution, lowering the pH, removing oxygen through vacuum packaging, and using sulfur dioxide or bisulfite are other commonly employed techniques to prevent enzymatic browning.

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