1. Food preservation and microbiology

a. Food Spoilage
b. Food microbiology
c. Food preservation technology
d. Food additives

Food Spoilage

Food spoilage refers to the deterioration of food products, leading to changes in their sensory properties that render them unacceptable or unsafe for consumption.

- Appearance,
- Texture,
- Consistency
- Taste,
- Odor

Food Safety:

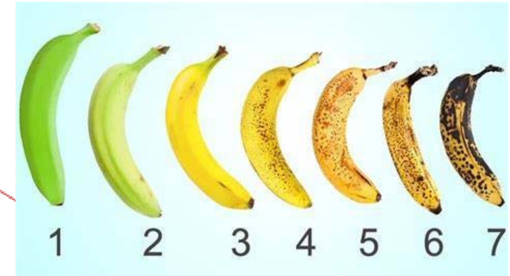
Economic Loss

Food Preservation

South-East Asia Region, nearly 150 million people fell ill with foodborne diseases in 2010, which led to 175 000 deaths.

Does fresh food also smells bad?

Change in colour (long storage of banana)



Change in smell (rancid smell of spoiled oils)

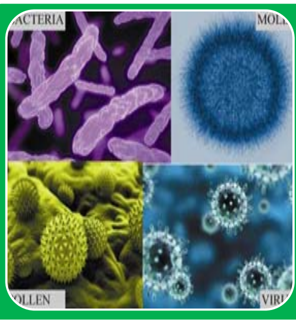
Change in consistency (splitting of milk)

Change in texture (rotting of carrot)

Change due to mechanical damage (eggs with broken shell)

Undesirable Changes in Food due to Spoilage

Factors in Food Spoilage



Biological Factors

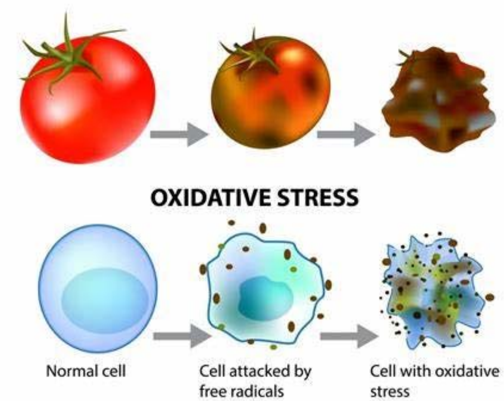
- Microbial Spoilage
- Insect,
- Rodents, Birds

Chemical Factors

- Enzymatic and non enzymatic reactions
- Rancidity
- Chemical intereactions

Physical Factors

- Light, pH, Temperature
- Transport
- Mechanical damage



Food Spoilage

Microbial Spoilage: Microorganisms such as bacteria, molds, and yeast can proliferate on food surfaces, leading to spoilage. Common signs of microbial spoilage include:

1. Foul odors, off-flavors, or unusual tastes.
2. Visible mold growth on the surface of the food.
3. Slimy or mushy texture.
4. Gas production, causing swelling or bloating of packaging.

Enzymatic Spoilage: Enzymes naturally present in food can catalyze chemical reactions that degrade its quality. Enzymatic spoilage is often accelerated by factors such as temperature, pH, and oxygen exposure. Signs of enzymatic spoilage include:

1. Browning or discoloration of fruits, vegetables, and meats.
2. Texture changes, such as softening or mushiness.
3. Off-flavors or odors caused by enzymatic breakdown of proteins, lipids, or carbohydrates.

Chemical Spoilage: Exposure to certain chemicals, such as oxygen, light, or reactive metals, can cause food spoilage. Common signs of chemical spoilage include:

1. Rancid or off-flavors resulting from lipid oxidation.
2. Discoloration or fading caused by exposure to light.
3. Metallic or off-odors from contact with reactive metals.

Physical Spoilage: Physical damage to food can accelerate spoilage by providing entry points for microorganisms or facilitating enzymatic reactions. Signs of physical spoilage include:

1. Bruising or bruise-like discoloration.
2. Crushing, bruising, or puncturing of fruits and vegetables.
3. Mechanical damage to packaging, leading to exposure to air or moisture.

Biological Factors

Spoilage due to Insects, Pests and Rodents

1. Insects and pest attack fruits, vegetables, grains and their processed products. Warm humid environment promote insect growth, although most insects will not breed above 35°C or falls below 10°C.
2. Presence of insects and pests render consumable loss in the nutritional quality, production of off-flavours and acceleration of decay processes.
3. Rats and mice carry disease-producing microorganisms on their feet, feces and urine and contaminate food.

What are the importance of microorganisms in food?

Good (desirable)	Bad (undesirable)
Food bioprocessing	Foodborne disease
Food biopreservation	Food spoilage
Probiotics	

Biological Factors: Microbial spoilage

Microbial spoilage refers to the deterioration of food products caused by the growth and activity of microorganisms such as bacteria, molds, and yeasts.

These microorganisms can thrive in various food environments, leading to changes in texture, flavor, appearance, and overall quality of the food.

Food poisoning: The highest number of victims between 2009 and 2022 were in Karnataka (1,524), Odisha (1,327), Telangana (1,092), Bihar (950) and Andhra Pradesh (794). – CAG report

Bacteria:

•Bacteria are single-celled microorganisms that can spoil food through various mechanisms such as enzymatic degradation, production of toxins, and alteration of food pH.

•They can be classified into different groups based on their shape (e.g., cocci, bacilli, spirilla) and their oxygen requirements (aerobic, anaerobic, facultative anaerobic).

•Examples of spoilage bacteria include:

- Lactic acid bacteria: Contribute to the souring of dairy products like milk and yogurt.

- Pseudomonas spp.: Associated with spoilage of meat, poultry, and seafood, causing off-odors and slimy textures.

- Clostridium spp.: Responsible for spoilage of canned foods, producing gas and off-flavors.

Molds:

•Molds are multicellular fungi that grow as visible colonies on the surface of food products. They can thrive in acidic or alkaline environments and tolerate low moisture levels.

•Molds produce enzymes that degrade food components such as carbohydrates, proteins, and lipids, leading to changes in texture and flavor.

•Examples of spoilage molds include:

- Aspergillus spp.: Commonly found in grains, nuts, and dried fruits, producing musty odors and visible mold growth.

- Penicillium spp.: Associated with spoilage of cheese and bread, producing blue or green mold growth and off-flavors.

Yeasts:

•Yeasts are single-celled fungi that can ferment sugars to produce alcohol and carbon dioxide. They can grow in acidic or sugary environments and tolerate low moisture levels.

•Yeasts can cause spoilage in food products such as fruits, vegetables, and bakery goods, leading to fermentation, gas production, and off-flavors.

•Examples of spoilage yeasts include:

- Saccharomyces spp.: Commonly found in fruit juices and alcoholic beverages, causing fermentation and off-flavors.

- Candida spp.: Associated with spoilage of acidic foods like fruit preserves and pickles, producing gas and off-odors.

Microbial Growth in Food

- Intrinsic factors
  - Nutrients
  - Water activity
  - pH
  - Redox potential and oxygen
  - Antimicrobials

- Extrinsic factors
  - Temperature
  - Relative humidity
  - Gaseous Environment
  - Packaging conditions
  - Added preservatives

Microbial Growth in Food

- Nutrient availability
- Moisture
- Temperature
- pH
- Osmotic pressure
- Oxygen levels

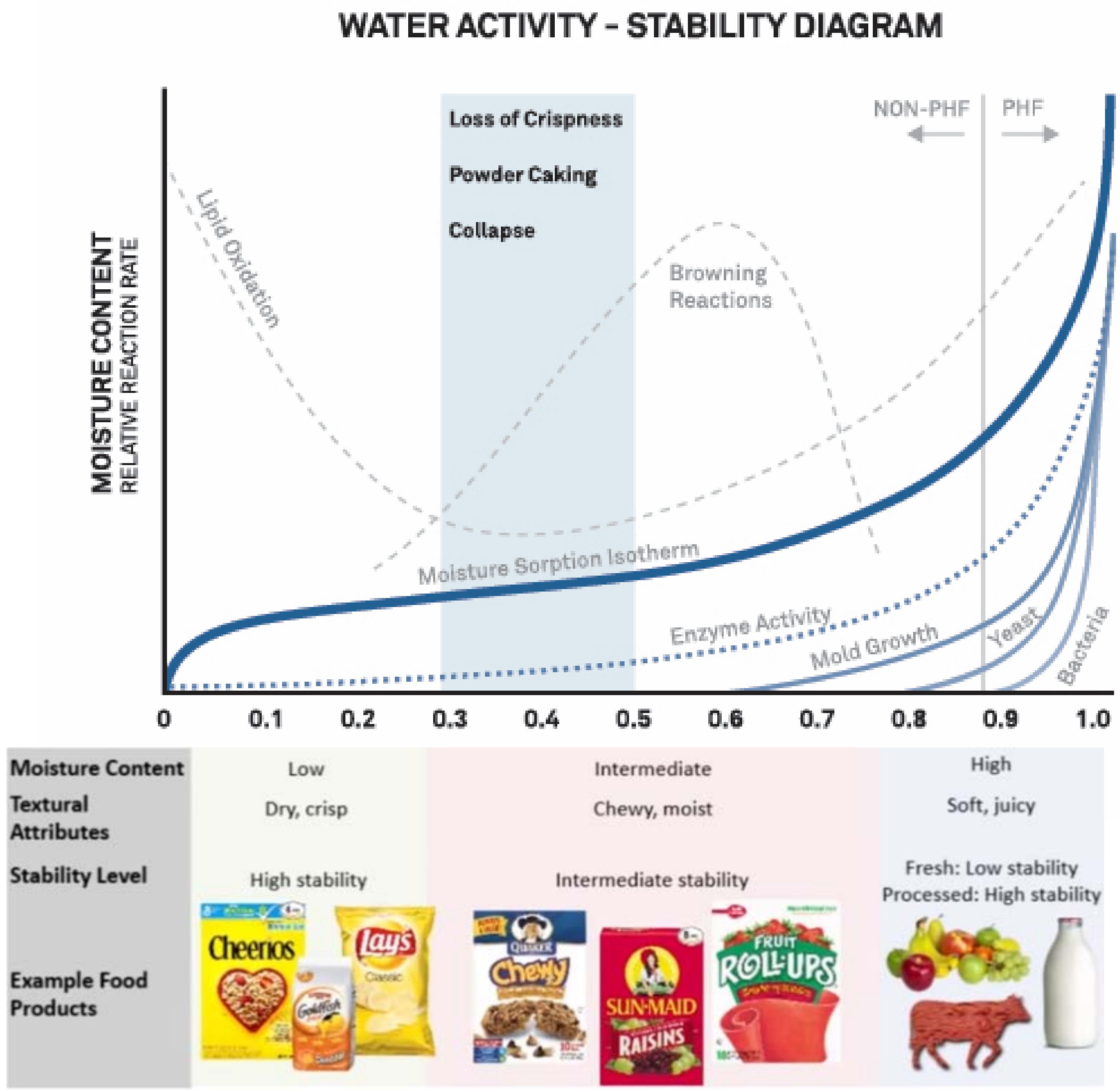
Microbial Growth in Food – Nutrient

- Microbial nutrition need
  - Carbon
  - Nitrogen
  - Sulphur
  - Phosphorus
  - Vitamins
  - Certain trace elements - copper, iron, zinc, sodium, chloride, potassium, calcium, etc.

1. **High Sugar Content:** spoilage by molds, such as Aspergillus and Penicillium.
2. **Protein-Rich Foods:** spoilage by bacteria, including *Salmonella, Escherichia coli*, and *Listeria monocytogenes*.
3. **High Fat Content:** spoilage by bacteria like Clostridium botulinum and molds.

Food	Water Content (%)
Meat	
Pork, raw, composite of lean cuts	53–60
Beef, raw, retail cuts	50–70
Chicken, all classes, raw meat without skin	74
Fish, muscle proteins	65–81
Fruit	
Berries, cherries, pears	80–85
Apples, peaches, oranges, grapefruit	90–90
Rhubarb, strawberries, tomatoes	90–95
Vegetables	
Avocado, bananas, peas (green)	74–80
Beets, broccoli, carrots, potatoes	85–90
Asparagus, beans (green), cabbage, cauliflower, lettuce	90–95

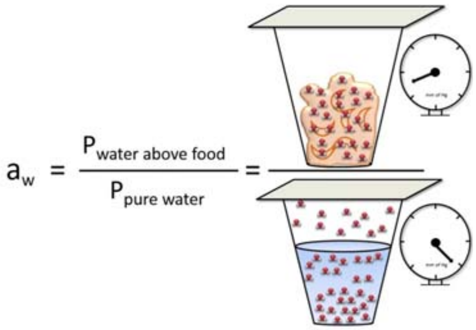
Source: Fennema, O.R. in *Food Chemistry*, Marcel Dekker, New York, 1996, 17–94.



Bound water

Free water

Microbial Growth in Food – Water



$a_w = P_{above\ food}/P_{pure\ water}$

water at a given T, (a_w = 0 to 1)

Table 1.

Microbial Group	Example	a_w	Products Affected
Normal bacteria	*Salmonella species* *Clostridium botulinum*	**0.91**	Fresh meat, milk
Normal yeast	*Torulopsis species*	**0.88**	Fruit juice concentrate
Normal molds	*Aspergillus flavus*	**0.80**	Jams, Jellies
Halophilic bacteria	*Wallemia sebi*	**0.75**	Honey
Xerophilic molds	*Aspergillus echinulatas*	**0.65**	Flour
Osmophilic yeast	*Saccharomyces bisporus*	**0.60**	Dried fruits

		a_w
Moulds	***Aspergillus chevalieri***	**0.71**
	Aspergillus ochraceus	**0.78**
	Aspergillus flavus	**0.80**
	Penicillium verrucosum	**0.79**
	Fusarium moniliforme	**0.87**
Yeasts	***Saccharomyces rouxii***	**0.62**
	Saccharomyces cerevisiae	**0.90**
Bacteria	***Bacillus cereus***	**0.92**
	***Clostridium botulinum* (proteolytic)**	**0.93**
	***Clostridium botulinum* (non-proteolytic)**	**0.97**
	Escherichia coli	**0.93**
	Salmonella	**0.95**
	Staphylococcus aureus	**0.83**

Canned foods: Classes based on Acidity

	Low	Medium	Acid	High
pH	>5.2	5.2-4.6	4.6-4.0	<4
Microbes	Thermophilic flat sour (*B. Stearothermophilus & B. Coagulans)* Sulphide producing anaerobic bacteria (*C nigrificans, C bifermentans*) mesophilic putrefactive anaerobic bacteria (*C botulinum types A and B*)	Thermophilic anaerobic bacteria (*Thermoanaerobacterium thermosaccharolyticum*) Putrefactive anaerobic bacteria (*Clostridium sporogenes*)	Mesophilic spore-forming (*B. polymyxa & B. macerans*) Butyric anaerobic bacteria (*C. butyricum and C. tertium)* *Aciduric bacteria* (*G. stearothermophilus and B. coagulans)*	Yeasts, molds, and lactic acid bacteria (*Lactobacillus brevis, Leuconostoc mesenteroides)*
Food	Meat, Milk, Seafood, Corn and Pears	Meat and Vegetable mixtures	Tomatoes, Pears, Figs, Olive, Pineapple	Pickle, Grapefrutis, Citrus juices, Ketchup, Peaches

Microbial Growth in Food – Redox Potential

Microbes	Redox value
Aerobes	+500 to +300 mV
Anaerobes	+100 to -250 mV
Facultative anaerobes	+300 to -100mv

Microbial Growth in Food – Antimicrobials and competitive microbes

- Eugenol – Clove
- Lysozyme – Egg
- Lactoferrin, lactenin, Lactoperoxidase - Milk
- Cinnamon aldehyde – Cinnamon
- allyl-isothiocyanate – mustard
- Lactic acid bacteria – Lactic acid and H_2O_2
- Yeast by producing alcohol
- Citric acid producing bacteria (corynebacterium)
- Bacteriocins

Chemical Factors:
Chemical factors play a significant role in food spoilage, contributing to changes in flavor, texture, and nutritional value. These factors include enzymatic and non-enzymatic reactions, rancidity, and chemical interactions between food components.

Enzymatic and Non-Enzymatic Reactions:

1.Enzymatic Browning: Enzymatic browning occurs when enzymes like polyphenol oxidase (PPO) catalyze the oxidation of phenolic compounds in fruits and vegetables upon exposure to oxygen. Examples include:

1. Browning of sliced apples or potatoes.
2. Browning of lettuce leaves.

2.Non-Enzymatic Browning (Maillard Reaction): Non-enzymatic browning involves the reaction between reducing sugars and amino acids at high temperatures, resulting in the formation of brown pigments and flavors. Examples include:

1. Browning of bread crust during baking.
2. Browning of meat during grilling or roasting.

Rancidity:
Rancidity refers to the development of off-flavors and odors in fats and oils due to their oxidation. There are two main types:

1.Hydrolytic Rancidity: Occurs when lipids undergo hydrolysis in the presence of water and lipase enzymes, leading to the release of free fatty acids. Examples include:

1. Rancidity in butter or margarine due to hydrolysis of triglycerides.
2. Rancidity in fried foods due to the hydrolysis of frying fats.

2.Oxidative Rancidity: Results from the oxidation of unsaturated fatty acids in fats and oils, leading to the formation of volatile compounds responsible for off-flavors and odors. Examples include:

1. Rancidity in nuts and seeds due to the oxidation of their natural oils.
2. Rancidity in cooking oils exposed to air and light over time.

Food Browning

Foods may develop a variety of brown colors, from yellow-brown to red-brown to black-brown, during handling, processing, and storage

Numerous reactions lead to browning in foods. Some of these may also generate **flavors** and/or alter the **nutritional properties** of foods

TYPES

DESIRABLE

Tea, Coffee, Dried fruits eg: Raisins, Figs etc

UNDESIRABLE

Fruits, Vegetables, Sea foods etc

Desirable (coffee, beer, bread, etc) and Detrimental (Frutis, vegetables, dried milk, dried egg, etc)

Even when desirable, browning should not be **excessive**, as in potato chips, French fries, and apple juice

Food Browning

Enzymatic

Acid Oxidase enzyme

Non-enzymatic

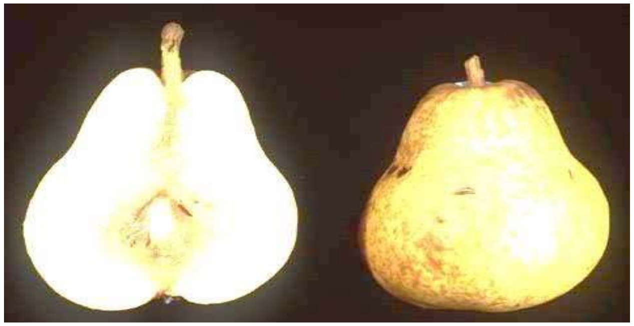
Caramelization

Maillard Reaction

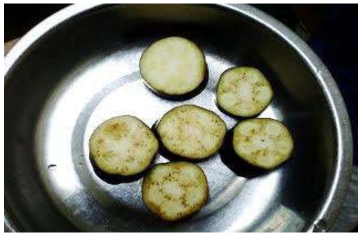
Ascorbic acid browning

Enzymatic Browning

- Enzymatic browning is a chemical process that occurs in fruits and vegetables when certain enzymes catalyze the oxidation of phenolic compounds in the presence of oxygen.
- This reaction leads to the formation of brown pigments known as melanins.
- Enzymatic browning is a natural process that can affect the color, flavor, and nutritional quality of foods.



Fruits like Apple, Pear, Banana



Potato, Mushroom, Brinjal

Dea food: Lobsters, Shrimps, Crabs

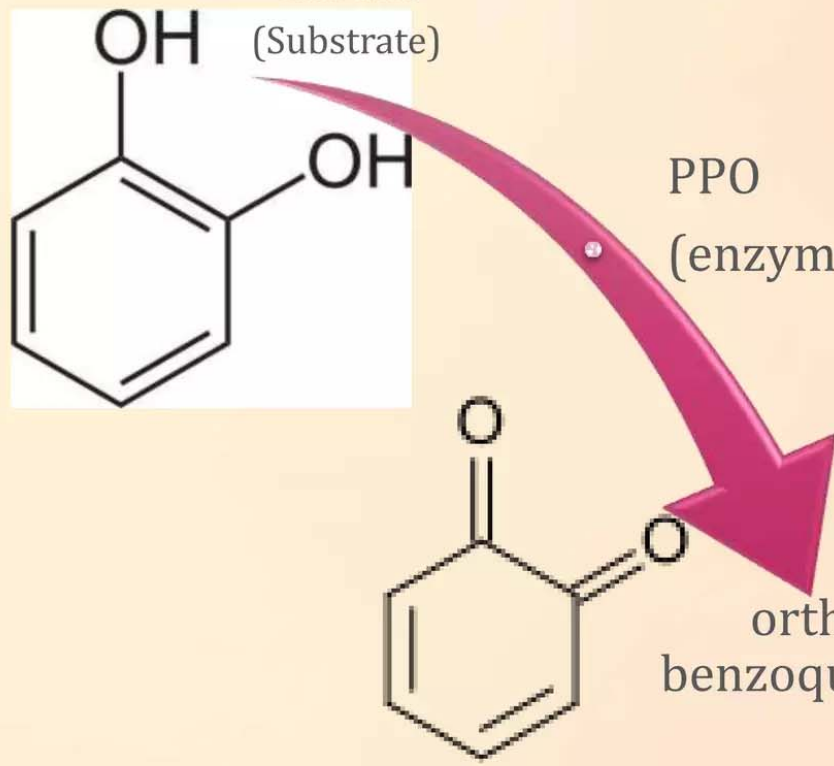
Polyphenol Oxidase (PPO)

- PPO are enzymes located at the plastids and the mitochondria
- Catalyze the reaction between phenols and oxygen to create colored compounds called quinones which gradually turn to melanins
- Responsible for the browning reaction of cut vegetables and fruits

Phenols

Example: Catechol

(Substrate)



PPO

(enzyme)

ortho-benzoquinone

Conditions required:

Exposure to air/oxygen, warm temperature, pH : 5-7

Enzymatic Browning

- Phenolic compounds, including phenols and catechols, serve as substrates for polyphenol oxidase.
- Phenolic substrate acted upon by the enzyme is converted to quinones, which in turn polymerise to form dark brown-black, insoluble polymers called melanins
- Involves a series of bio-chemical reactions

factors influencing enzymatic browning:

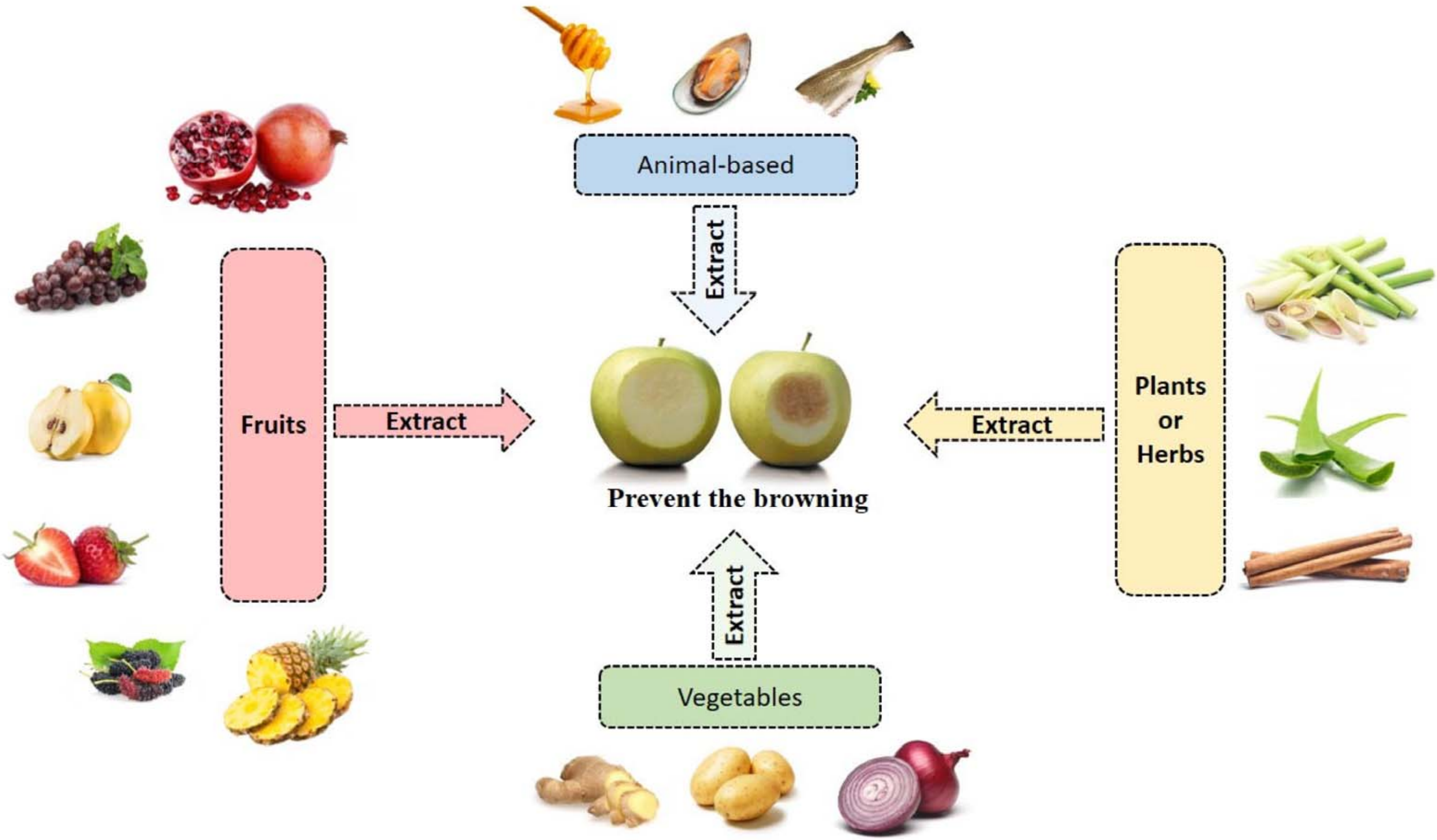
1. **Enzyme Activity:** Activity of polyphenol oxidase (PPO).
2. **Substrate Availability**: Presence of phenolic compounds.
3. **Oxygen Availability:** Access to atmospheric oxygen.
4. **Temperature:** Influence on enzyme kinetics.
5. **pH Level**: Effect on enzyme activity.
6. **Presence of Inhibitors or Activators**: Compounds modulating PPO activity.
7. **Tissue Integrity:** Condition of fruit or vegetable tissue.

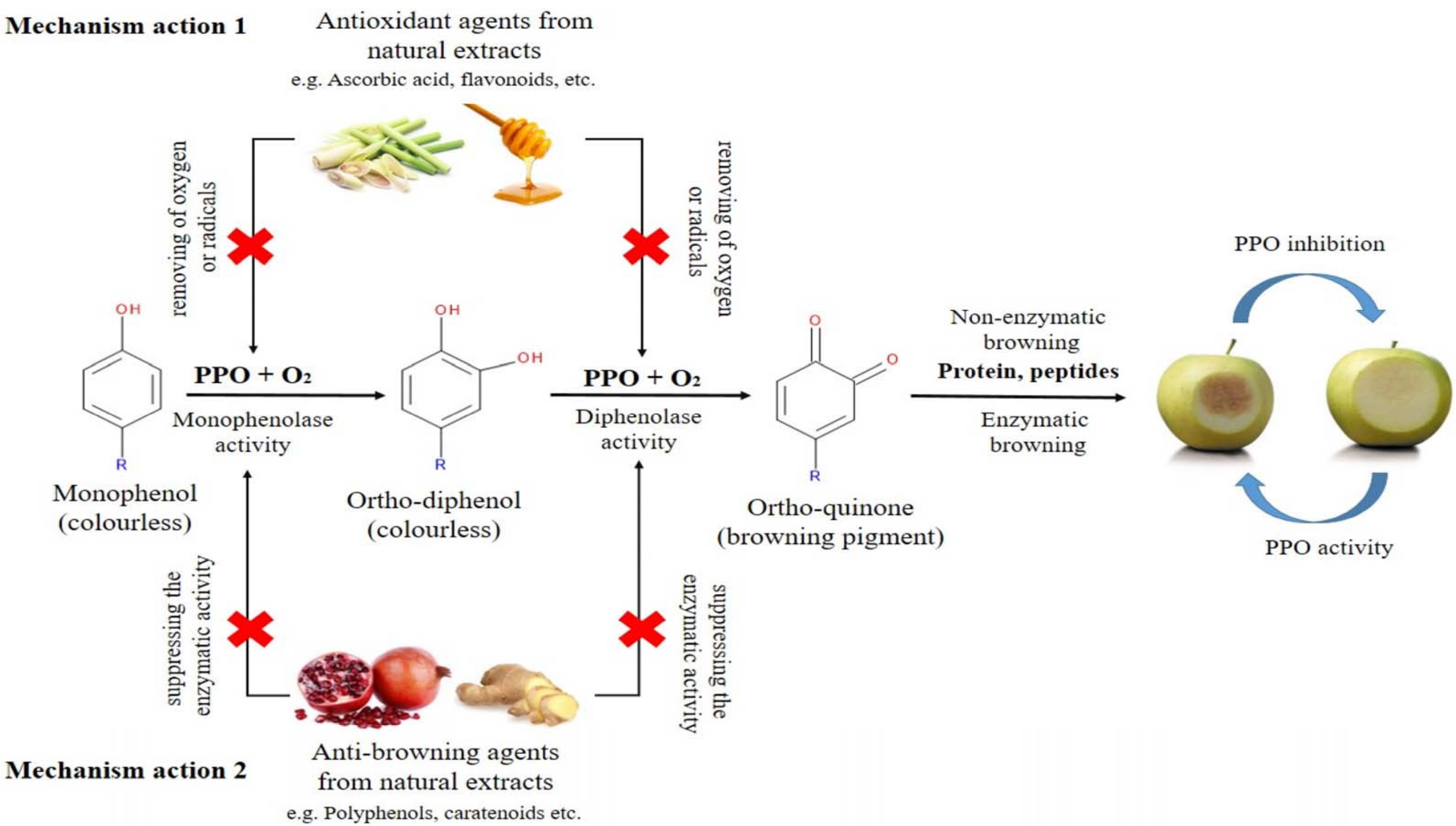
Effects on Food Quality

- **Discolored foods** are unappealing & low on consumer acceptance
- **Texture change**: fruits and vegetables may cause them to become mushy or soft
- **Nutritional Loss**: loss of vitamin c due to heat
- Directly affects the quality of food (Quality Indicator)
- Limits the **shelf-life & decreases market value** of the product
- Contributes to **post-harvest losses**

Methods for preventing enzymatic browning:

1. **Reducing Oxygen Exposure**:
    1. Packaging in airtight containers or vacuum-sealed bags.
    2. Submerging in water.
    3. Using antioxidants such as sulfur dioxide or ascorbic acid.
2. **Acidification**:
    1. Adding acidic ingredients like lemon juice or vinegar.
    2. Immersing in acidic solutions or dilute citric acid solutions.
3. **Blanching**:
    1. Briefly immersing in boiling water followed by rapid cooling.
4. **Temperature Control**:
    1. Storing at refrigeration temperatures.
    2. Freezing.
5. **Use of Enzyme Inhibitors**:
    1. Ascorbic acid (vitamin C).
    2. Sulfur dioxide.
    3. Enzyme inhibitors from natural sources like polyphenols found in tea or spices.
6. **Selective Breeding and Genetic Modification**:
    1. Developing varieties with reduced enzymatic browning potential through selective breeding or genetic modification.


Animal-based
Extract
Fruits
Extract
Prevent the browning
Extract
Plants
or
Herbs
Extract
Vegetables



Mechanism action 1
Antioxidant agents from natural extracts
e.g. Ascorbic acid, flavonoids, etc.
removing of oxygen or radicals
removing of oxygen or radicals
OH
R
Monophenol (colourless)
PPO + O2
Monophenolase activity
OH
OH
R
Ortho-diphenol (colourless)
PPO + O2
Diphenolase activity
O
O
R
Ortho-quinone (browning pigment)
Non-enzymatic browning
Protein, peptides
Enzymatic browning
PPO inhibition
PPO activity
suppressing the enzymatic activity
suppressing the enzymatic activity
Mechanism action 2
Anti-browning agents from natural extracts
e.g. Polyphenols, caratenoids etc.

Enzymatic Browning

- Raisin browning
  - Brown color is a property of raisins
  - Green raisin is prepared by preventing browning
  - Caftaric acid – phenolic compounds in grapes (vacuole)
  - Polyphenol oxidase (PPO), present in plastid, skin, seeds
  - During drying process the enzyme come in contact with caftaric acid
  - High moisture, prolonged drying time, High PPO activity, O2 availability, physical damage, Temperature
  - Potassium carbonate and ethyl oleate is used enhance dehydration fast

Enzymatic Browning

Non-Enzymatic Browning

Non-enzymatic

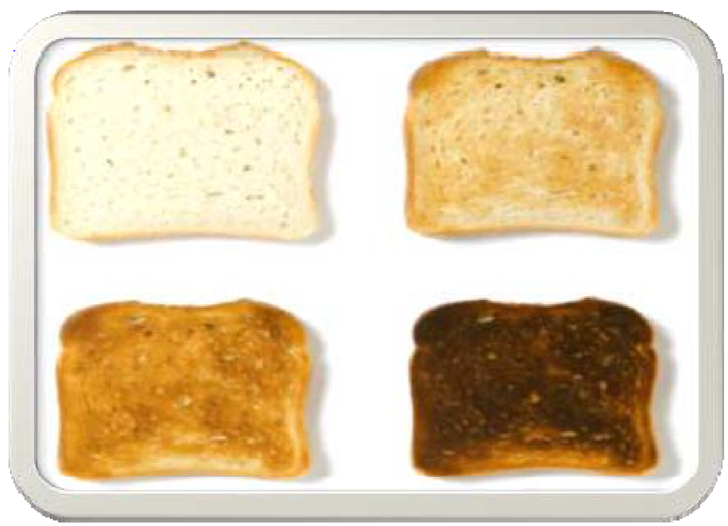
- Caramelization
- Maillard Reaction
- Ascorbic acid browning
- Metapolyphenol browning

Non-Enzymatic Browning

Non-enzymatic browning refers to browning reactions in food that occur without the involvement of enzymes.

Unlike enzymatic browning, which requires specific enzymes to catalyze reactions, non-enzymatic browning occurs through chemical reactions between sugars and amino acids, typically when exposed to heat.

The most common types of non-enzymatic browning reactions include the Maillard reaction and caramelization.



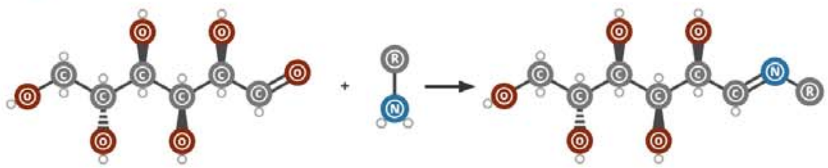
Non-enzymatic

- Caramelization
- Maillard Reaction
- Ascorbic acid browning
- Metapolyphenol browning

A GUIDE TO THE MAILLARD REACTION

The Maillard reaction occurs during cooking, and it is responsible for the non-enzymatic browning of foods when cooked. It actually consists of a number of reactions, and can occur at room temperature, but is optimal between 140-165°C. The Maillard reaction occurs in three stages, detailed here.

1 The carbonyl group on a sugar reacts with a protein or amino acid's amino group, producing an N-substituted glycosylamine.



SUGAR (GLUCOSE) + AMINO GROUP ⟶ GLYCOSYLAMINE (+ WATER)

2 The glycosylamine compound generated in the first step isomerises, by undergoing Amadori rearrangement, to give a ketosamine.

GLYCOSYLAMINE

1,2-ENAMINOL

AMADORI COMPOUND

3 The ketosamine can react in a number of ways to produce a range of different products, which themselves can react further.

ALKALINE CONDITIONS

FISSION PRODUCTS

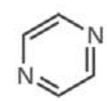
REDUCTONES

ACIDIC CONDITIONS

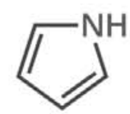
HYDROXYMETHYLFURFURAL

Classes of Maillard Reaction Products

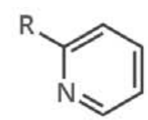
The Maillard reaction produces hundreds of products; a small subset of these contribute to flavour and aroma, some groups of which are described below. Melanoidins are also formed, brown, polymeric substances which contribute to the colouration of many cooked foods.



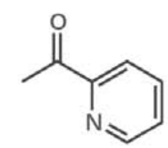
PYRAZINES
cooked
roasted
toasted



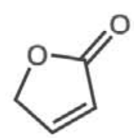
PYRROLES
cereal-like
nutty



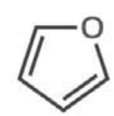
ALKYLPYRIDINES
bitter
burnt
astringent



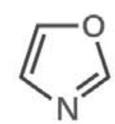
ACYLPYRIDINES
cracker-like
cereal



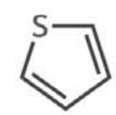
FURANONES
sweet
caramel
burnt



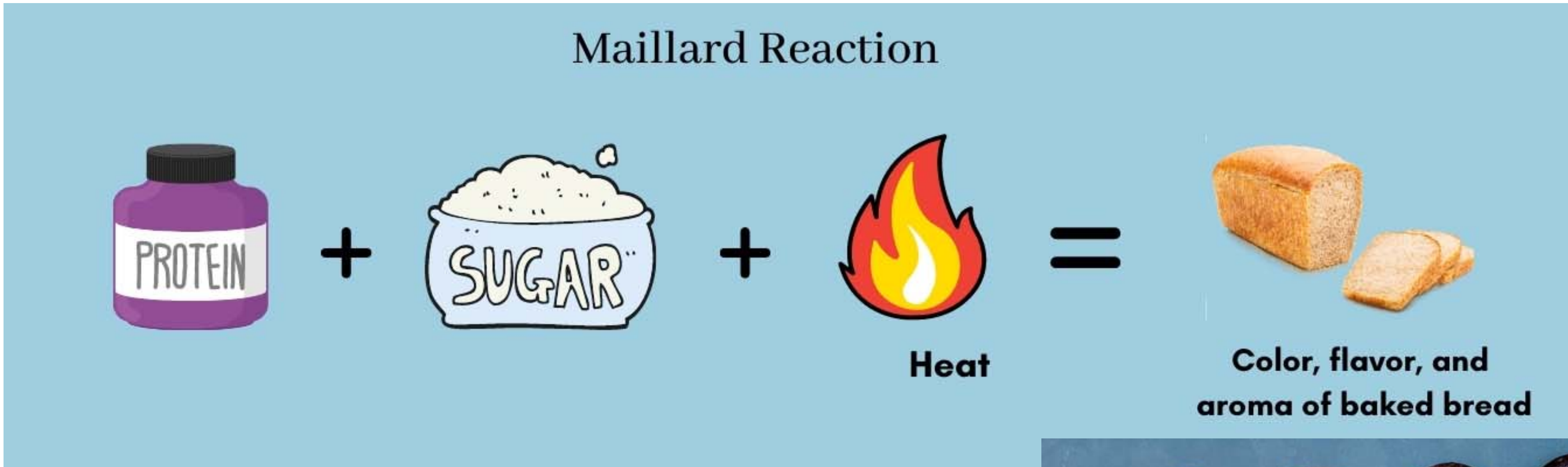
FURANS
meaty
burnt
caramel-like



OXAZOLES
green
nutty
sweet



THIOPHENES
meaty
roasted


Maillard Reaction
PROTEIN
+
SUGAR
+
Heat
=
Color, flavor, and
aroma of baked bread


240°C
220°C
200°C
180°C
5 min
10 min
15 min
20 min

Caramelization

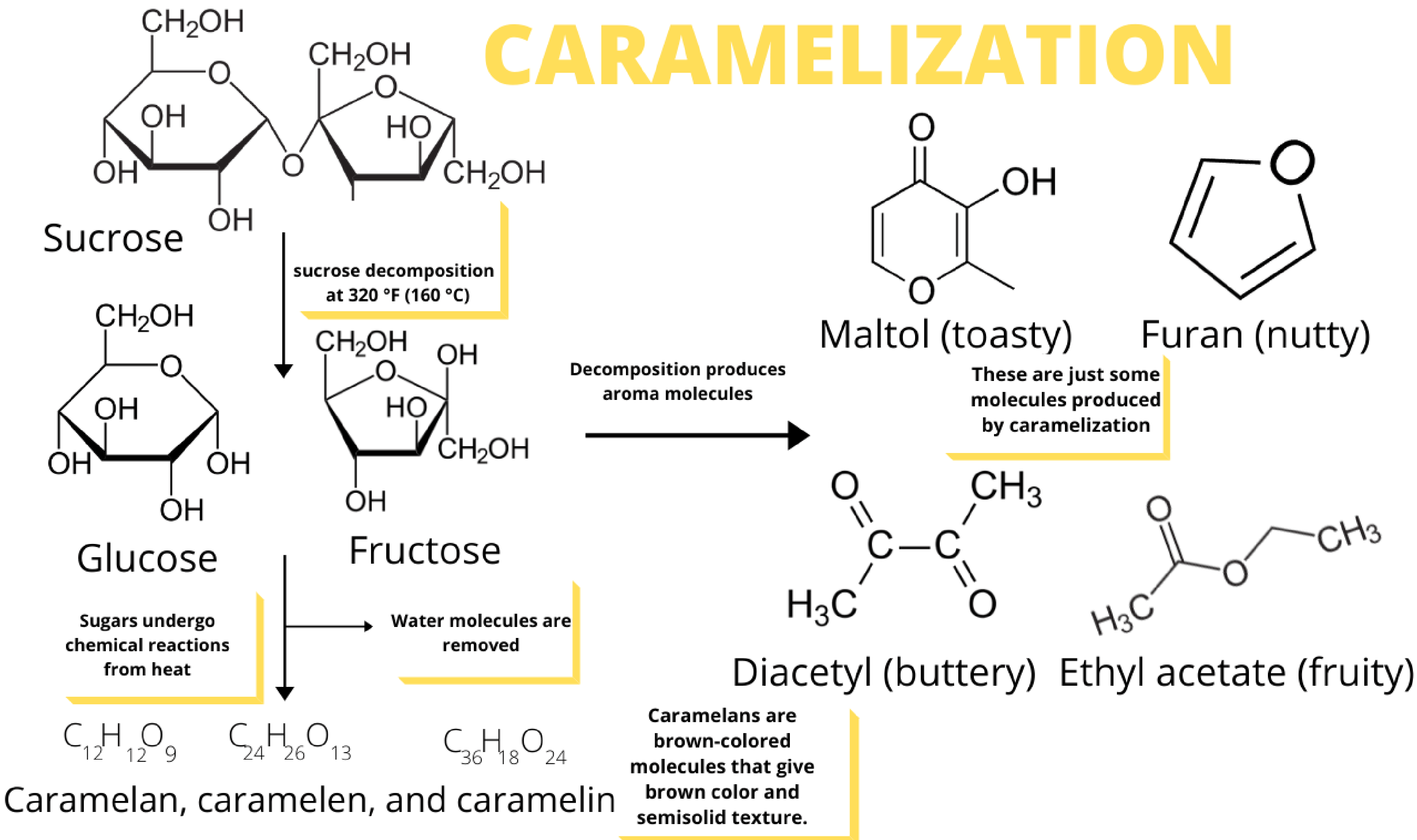
•Caramelization occurs when sugars are heated to high temperatures (typically above 160°C or 320°F) without the presence of amino acids.

• It involves the thermal decomposition and polymerization of sugars, leading to the formation of caramel, which contributes a sweet, nutty flavor and a characteristic brown color.

•Caramelization is commonly observed in the cooking of sugar-based foods such as caramel sauce, caramel candies, and certain desserts like crème brûlée.

•Unlike the Maillard reaction, caramelization does not involve amino acids and does not produce the same range of flavor compounds. Instead, it primarily results in the formation of caramelized sugars.

Caramelization at different temp


CARAMELIZATION
Sucrose
sucrose decomposition at 320 °F (160 °C)
Glucose
Fructose
Sugars undergo chemical reactions from heat
Water molecules are removed
C12H12O9
C24H26O13
C36H18O24
Caramelan, caramelen, and caramelin
Decomposition produces aroma molecules
Maltol (toasty)
Furan (nutty)
These are just some molecules produced by caramelization
Diacetyl (buttery)
Ethyl acetate (fruity)
Caramelans are brown-colored molecules that give brown color and semisolid texture.

Non-Enzymatic browning – Ascorbic acid Browning

- When ascorbic acid is heated in the presence of acids, furfural is formed
- The latter (dehydroascorbic acid), either by itself or after reacting with amino compounds, polymerizes to brown products
- Citrus juices, especially their concentrates, develop browning, which has been attributed to ascorbic acid degradation

WHY WORRY ABOUT IT???

AESTHETICS

- – Overly browned foods are not aesthetically attractive and may not be accepted
- – Also, due to the pyrazines produced by the Strecker degradation, these highly browned foods may have odd, off flavors and also not be accepted

NUTRITIONAL VALUE

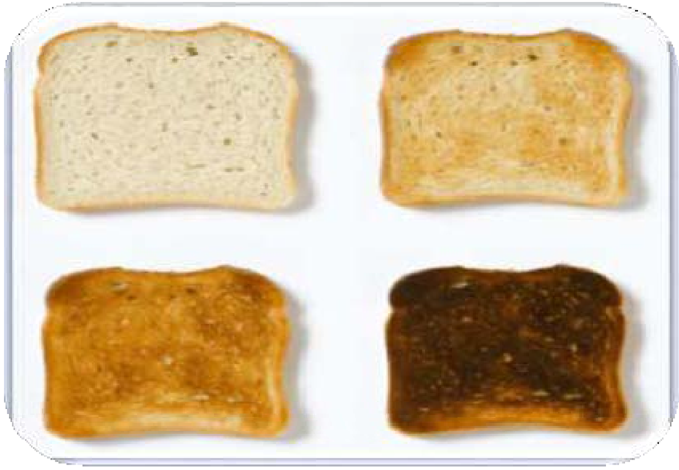
- – Amino acids that participate in the Maillard reactions are lost from a nutritional point of view.
- This may be especially important where the amino acid is very reactive and in foods where it is already in very low concentration. This would be the case for L-lysine in cereals.

MUTAGENICITY

- Some researchers find mutagenic products in browned model systems, others do not. But there is still the possibility that highly browned food may contain potential mutagens.

PRODUCTS

- caramel made from milk and sugar
- the browning of bread into toast
- the color of beer, chocolate, coffee, and maple syrup
- self-tanning products
- the flavor of roast meat
- the color of dried or condensed milk



Chemical Interactions:
Chemical interactions between food components can also contribute to spoilage:

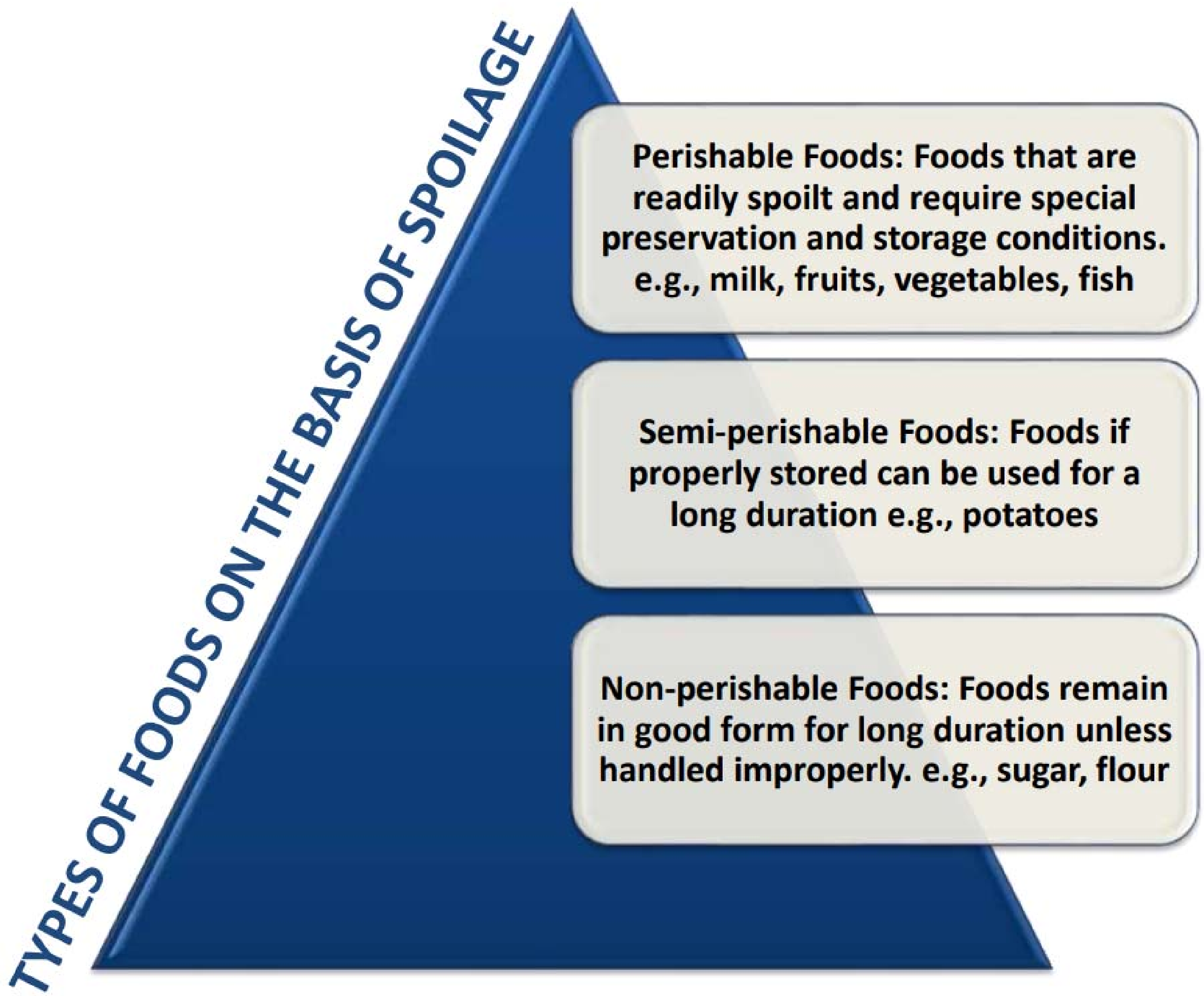
1.Metal-Ion Catalysis: Metal ions such as iron and copper can catalyze lipid oxidation reactions, accelerating rancidity in foods containing these metals. Examples include:

1. Rancidity in canned foods due to metal ions leaching from the can lining.
2. Rancidity in fortified breakfast cereals containing iron.

2.Acid-Base Reactions: Acid-base reactions can affect food pH, leading to changes in flavor, texture, and stability. Examples include:

1. Souring of milk due to the production of lactic acid by lactic acid bacteria.
2. Fermentation of pickles in acidic brine solutions.

Understanding these chemical factors and their effects on food quality is essential for implementing proper storage, packaging, and processing techniques to prevent or minimize food


TYPES OF FOODS ON THE BASIS OF SPOILAGE
Perishable Foods: Foods that are readily spoilt and require special preservation and storage conditions. e.g., milk, fruits, vegetables, fish
Semi-perishable Foods: Foods if properly stored can be used for a long duration e.g., potatoes
Non-perishable Foods: Foods remain in good form for long duration unless handled improperly. e.g., sugar, flour