Shelf-life of Food Products

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What is shelf-life of food product?

- The storage period of a food product under a given condition until it is considered undesirable for consumption or reaches the end of its shelf-life.
- One or more quality attributes of a food may reach an undesirable state.

When is a food expired?

- Unsafe for consumption: toxic and illness
- Unacceptable for consumption: not palatable, not attractive or loss of some key properties, e.g. color, texture, solubility, etc.

The condition of storage determines shelf-life.

Deterioration

Spoiled

Staled

≈ 5-7 days at room temperature

3 months at −18 °C

Warming before eating

1-2 weeks at 4 °C

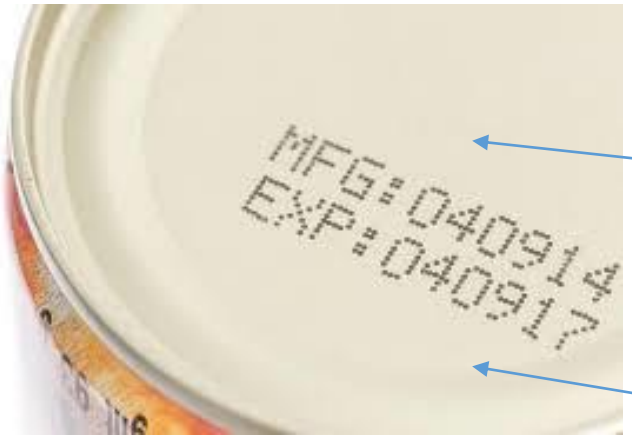
Warming before eating

Shelf-life information on food label

Abbreviation	Full word
MFG/MFD	Manufacturing date/Manufactured date
EXP/EXD BB/BBE	Expiry date/Expiration date Best before/Best before end

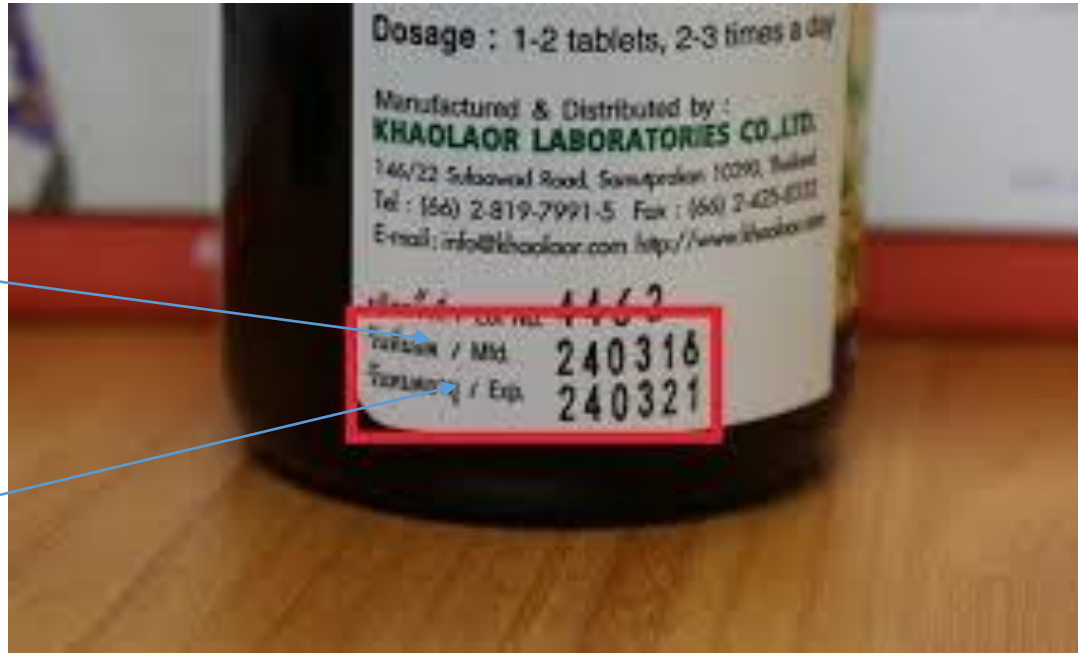
Shelf-life information

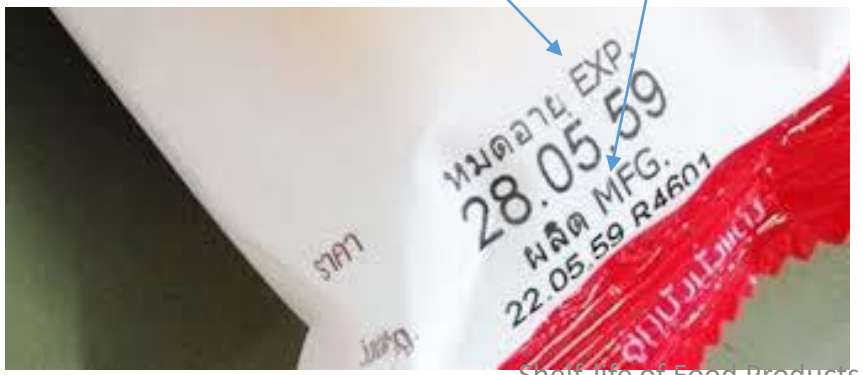
Examples



Manufacturing date (MGF)

Expiry date (EXP)





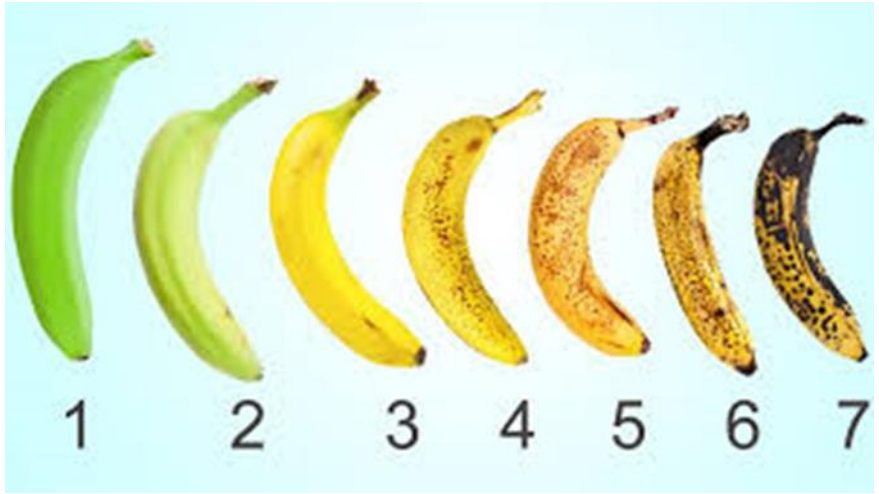
Examples

Best before/ Best before end (BB/BBE)

The significance of shelf-life determination

- Safety for consumers
- Production and market planning
- Product development

Food Deterioration



Food deterioration classification

1. Physical deterioration
2. Chemical deterioration
3. Biological deterioration
4. Sensory perception and consumer acceptance

Physical deterioration

- **Loss of crispiness**, e.g. cookies, crackers, potato chips
- **Loss of soft texture**, e.g. cake, bread, cooked rice
- **Oil phase separation**, e.g. salad cream, coconut milk
- **Water separation or syneresis** in semi-solid foods, e.g. agar based dessert, jam and jelly
- **Melting** of fat, sugar and ice crystal/**Soggy (wet and soft)** of dried products
- **Crumping** of powdered foods, e.g. milk powder, coffee powder, fruit powder
- **Sedimentation**, e.g. fruit juice, dipping or seasoning sauce
- **Broken pieces** of crispy foods, e.g. cookies, crackers, potato chips and snacks
- **Crystallization** of ice, sugar and fat

Example : Loss of crispy texture

Example: Loss of soft texture

Example: Oil phase separation

Coconut milk

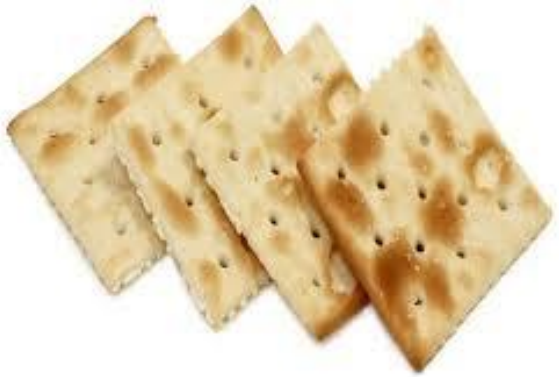
Curry soup

Example: Soggy/Melting

Example: Crumping

Example: Sedimentation

Example: Broken pieces



Example: Crystallization

Ice

Salt

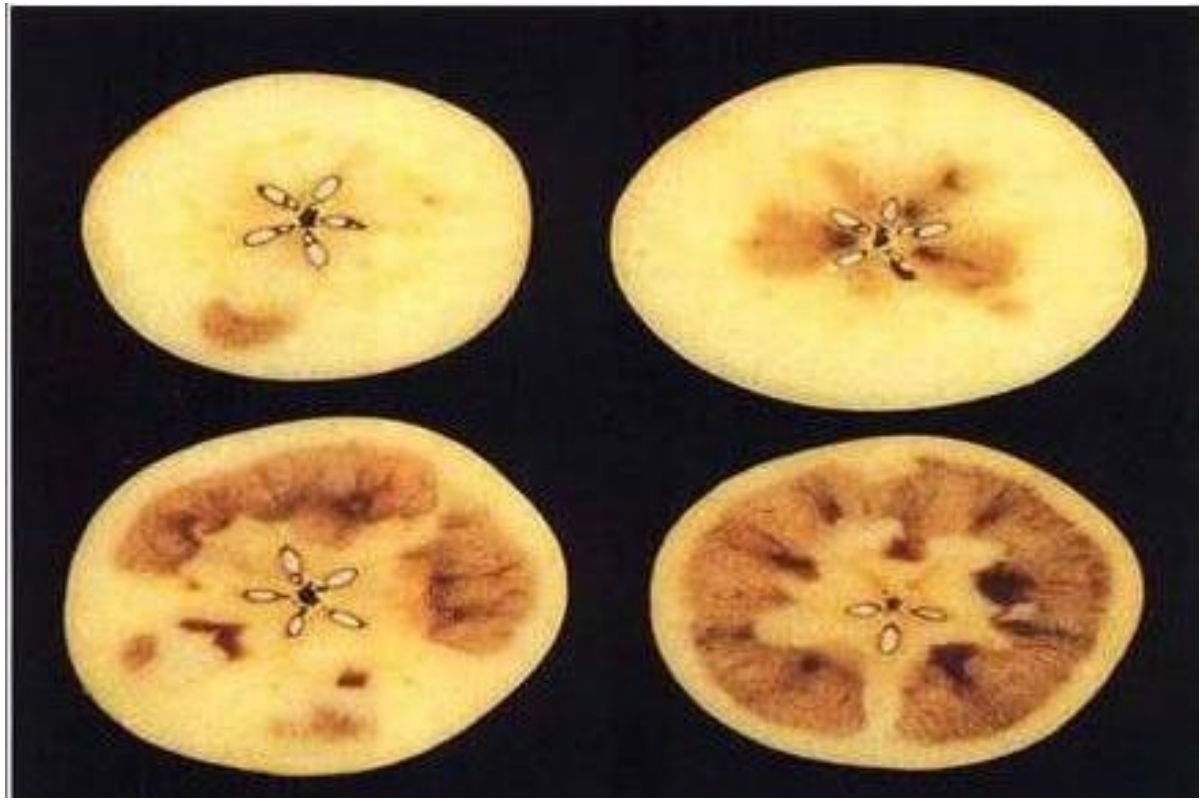
Sugar

Fat

Chemical deterioration

- Enzymatic browning reaction in fresh fruits and vegetables, e.g. fresh cut, processed forms
- Brown color from maillard reaction for foods containing protein and sugar, e.g. milk, fish sauce
- Lipid oxidation causing rancidity or off-flavor and free radical in food products such as fried foods and those containing fat and oil
- Degradation of nutrients such as vitamin A and Vitamin C

Example: Enzymatic Browning in cut apple



Nonenzymatic Browning (Maillard reaction)

Enzymatic vs Non-Enzymatic Browning Reactions

Factors	Enzymatic Browning	Nonenzymatic Browning (Maillard reaction)
Substrates	- Phenolic compounds - Polyphenol oxidase (PPO) - Oxygen (O_2)	- Reducing sugars - Amino acids, Proteins - No oxygen (O_2)
Temperature	- Accelerated at 25-40 ºC - Inactivated at > 80 ºC	- Accelerated by heat
pH	- Highly active at neutral pH	- Highly active at higher pH

Lipid reactions

Lipid → Hydrolysis / Lipolysis → Monoglyceride, Diglyceride, Free fatty acid -> Hydrolytic Rancidity

Water
Lipase

Lipid + O_2 → Enzymatic oxidation → Free Radicals, Off-flavor

Water
Lipoxygenase

Lipid + O_2 → Oxidation → Free Radicals, Polar Compounds, Aldehydes and Ketones -> Oxidative Rancidity

Light
Heat
Prooxidants

Lipolysis

- Hydrolysis of lipid with lipase enzyme producing free fatty acids that impart rancidity
- Accelerated by moisture or water and heat
- For instances, rice bran/flour, nut and bean

Lipid oxidation

- Reaction between lipid and oxygen giving rancid odor and harmful free radicals
- Accelerated by light, air, heat, moisture and metal ion, e.g. Fe^{2+} and Cu^{2+}
- e.g. Potato chips, crackers, fried foods and other fat and oil containing foods

Loss of nutrients

- Nutrient loss is mainly caused by oxidation reaction of nutritional substances.
- Accelerated by light, heat, oxygen, enzyme and metal ion
- For examples: Vitamin C loss in fruit juice, Vitamin B loss in cereals

Biological deterioration

- Microbial spoilage: bacteria, yeasts, and fungi
- Pathogenic microorganisms cause illness
- Growth of microorganisms is controlled by time, temperature, acidity, oxygen and moisture

Biological spoilage

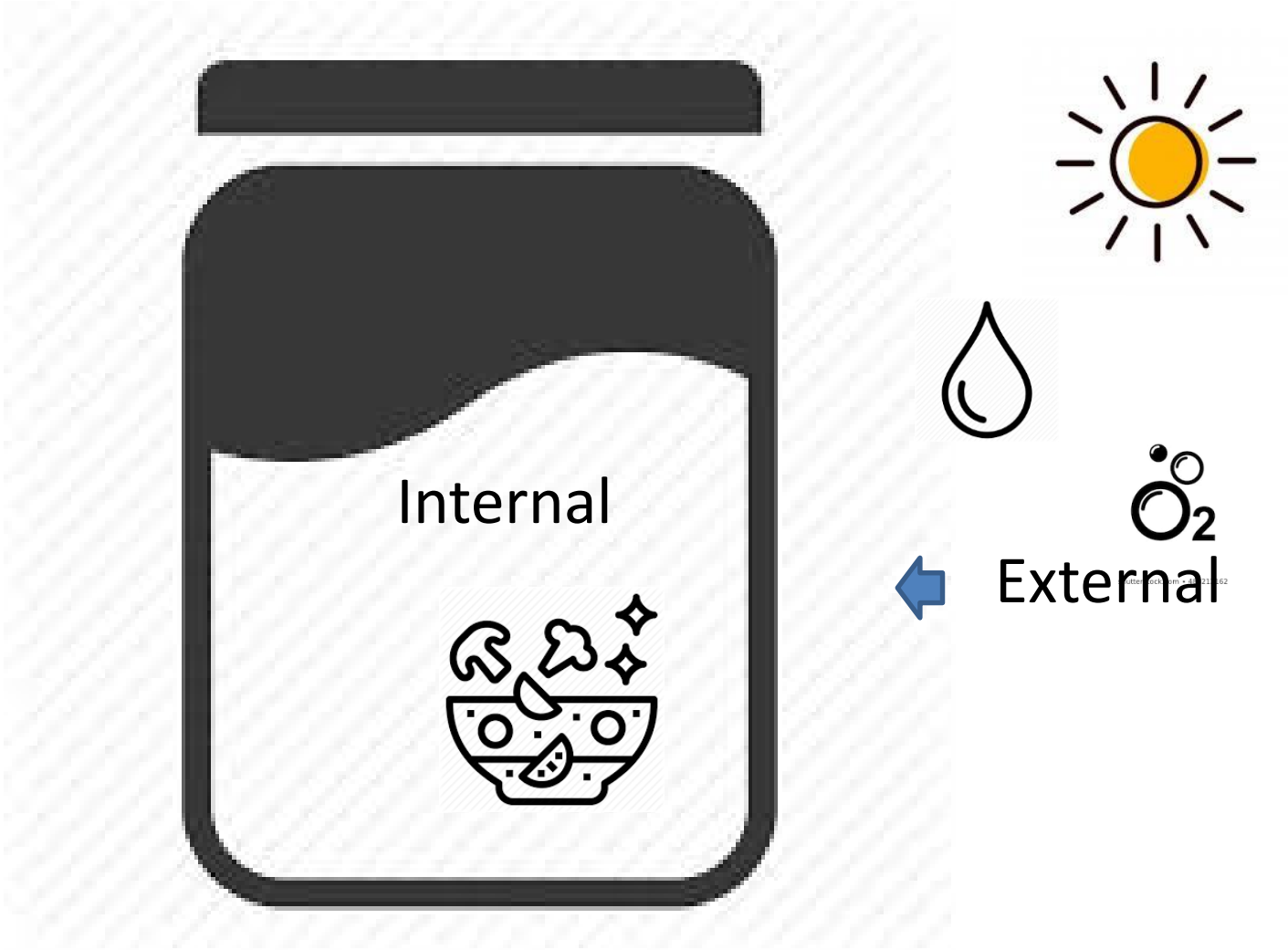
- Ripening of fresh fruits and vegetables
- Germination seeds or grains under suitable moisture
- Sprouting of garlic, onion and potato
- Insects and worms in fresh fruits and vegetables, moths in cereal grains

Sensory perception and consumer acceptance

- Usually caused by physical, chemical or biological changes of food products
- Degradation of food appearance, color, texture and flavor at certain level that is unacceptable by consumers

Factors determining shelf-life of food products

- Internal factors
- External factors



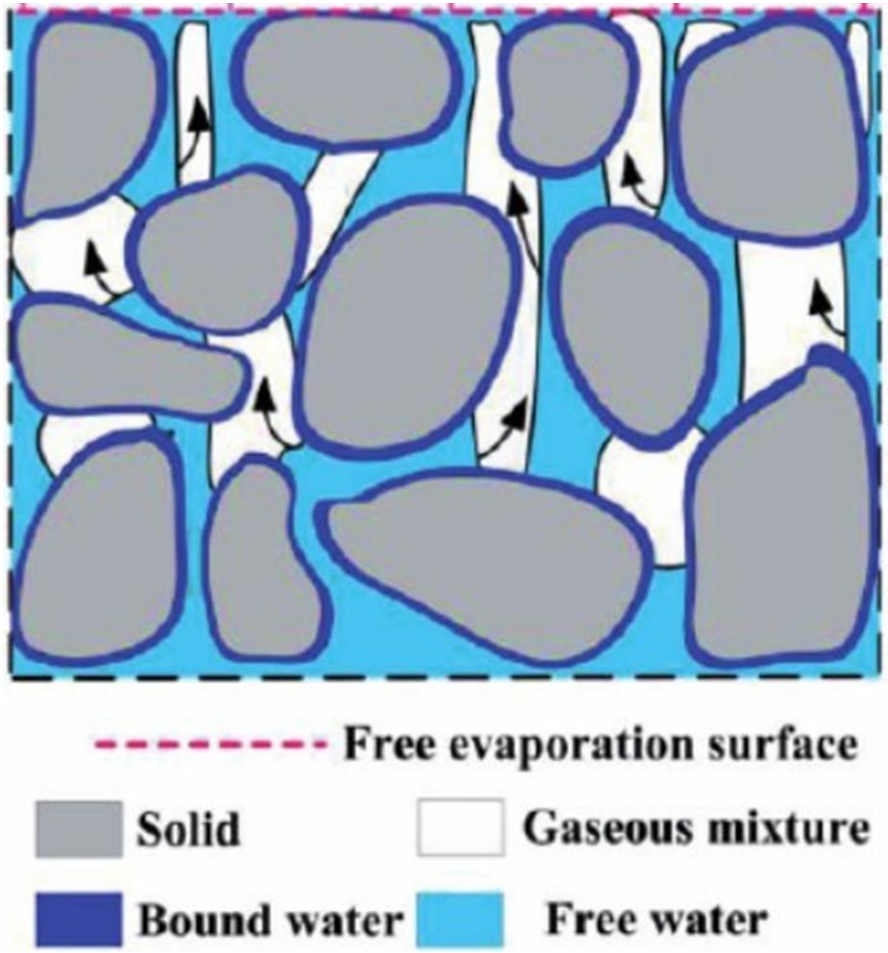
Internal factors

Involved directly to the product:

- Processing method: For instances; temperature and time for thermal processing. Thermal processed foods are normally long in shelf-life. The more thermal level applied, the longer the shelf-life of food products.
- Water content: Limited water amount inhibit growth of microorganisms and chemical reactions. Thus, the rate of deterioration of foods is reduced.

Water in foods

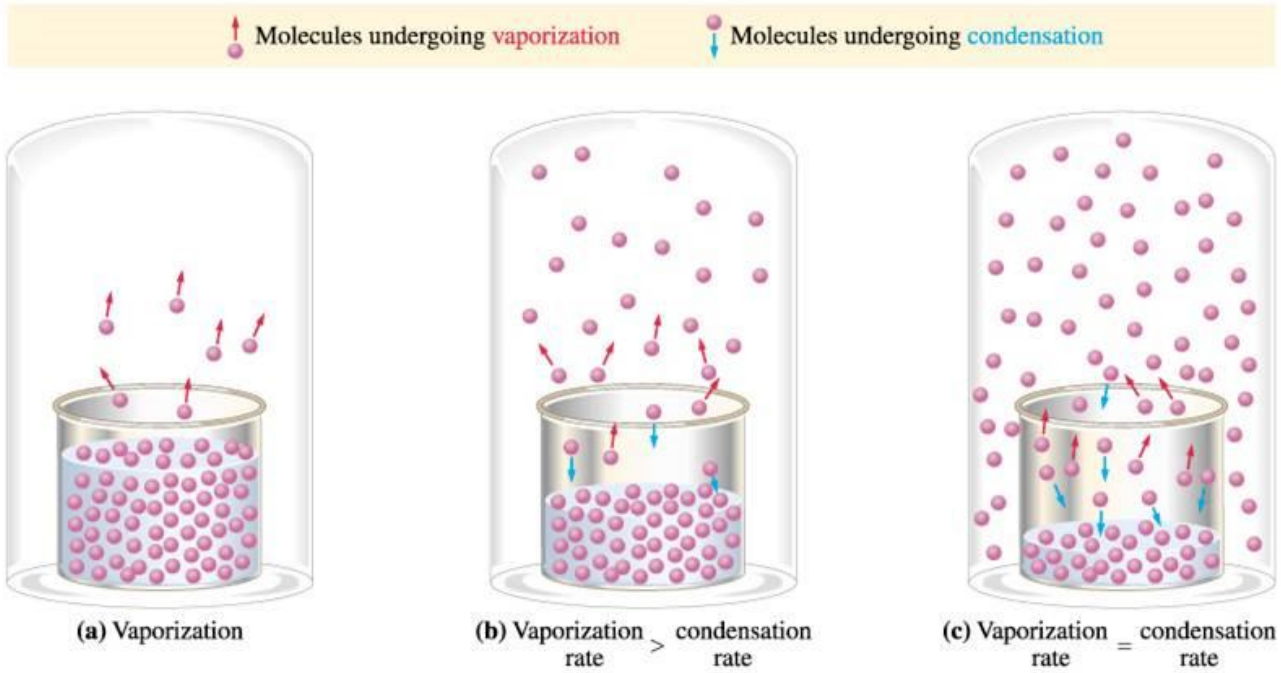
- Bound water:
  - The water retained in small capillaries at solid surfaces as solutions in cells or fibers.
  - It has lower vapor pressure than water at the same temperature.
  - Increase with salt and sugar
  - Limiting microorganism growth and chemical reactions
- Free water:
  - Any water other than the bound water and has the same vapor pressure as pure water.
  - Promotes microorganism growth and chemical reactions
  - Indicated by water activity (a_w)



https://www.linkedin.com/pulse/learning-vacuum-bound-unbound-moisture-tie-duan

Water activity (a_w) determination

An a_w value (0-1.0) is determined at Equilibrium Relative Humidity (ERH) under a given temperature and pressure



https://www.foodnetworksolution.com/wiki/word/1903/equilibrium-relative-humidity

$$a_w = ERH/100 \quad ; \quad \text{or}$$

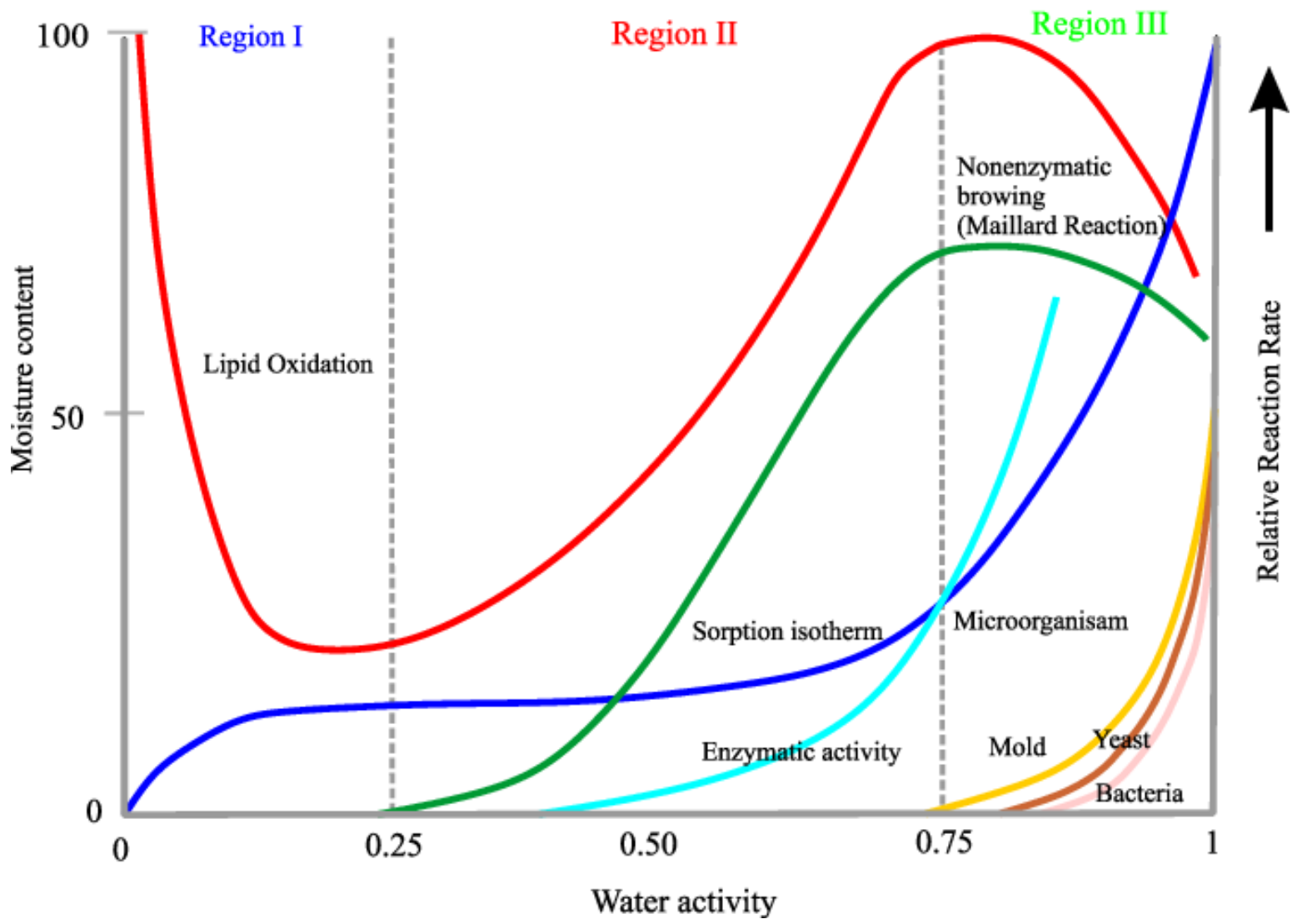
$$a_w = P/P_0;$$

P = Vapor pressure of food P_0 = Vapor pressure of pure water

Water activity and microbial growth

- $a_w < 0.85$ No pathogenic microorganisms
- $a_w < 0.70$ No fungi
- $a_w < 0.60$ No microorganisms

Food stability map



Source: Labuza (1972)

Water activity (RVP) – moisture sorption isotherms

Product	a_w
water	1
meet	0.97 - 0.99
milk	0.97
juice	0.97
cheeses	0.93 - 0.96
bacon	< 0.85
jams	0.82 – 0.94
saturated solution of NaCl	0.75
room air	0.5 - 0.7
honey	0.5 - 0.7
dry fruits	0.5 - 0.6

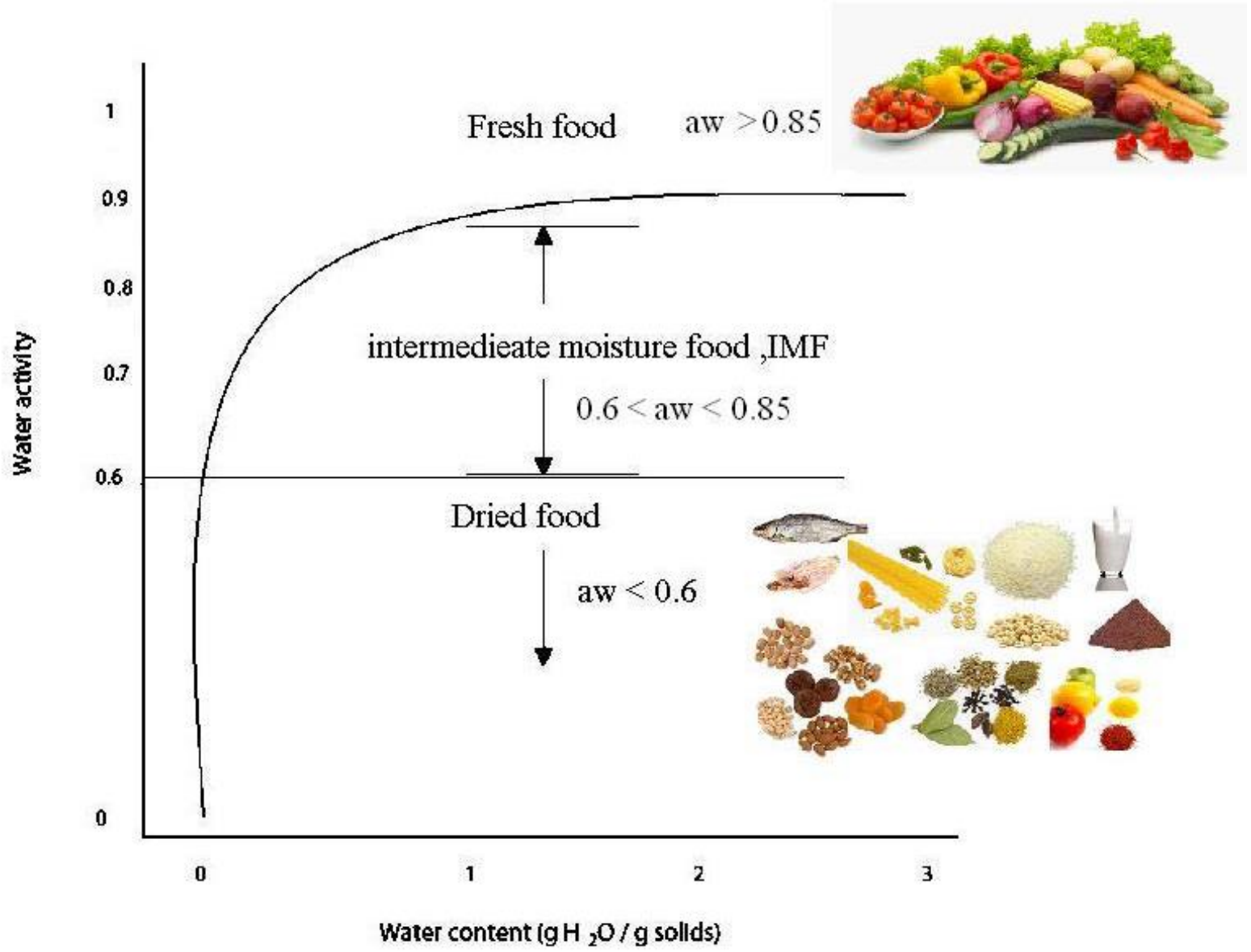
microorganism	a_w
Clostridium botulinum	0.97
Pseudomonas fluorescens	0.97
Escherichia coli	0.95
Clostridium perfringens	0.95
Salmonella	0.95
Vibrio cholerae	0.95
Clostridium botulinum A, B	0.97
Bacillus cereus	0.93
Listeria monocytogenes	0.92
Bacillus subtilis	0.91
Staphylococcus aureus	0.87
Most of the molds (fungi)	0.70
No development	0.60

Dried foods and those with $a_w < 0.60$ are safe from microbial spoilage without further thermal processing required.

Chemical reactions and microbial growth at each range of a_w

Reactions/ Microbial growth	a_w 0-0.3	0.3-0.85	0.85-1.0
Enzymatic activity	o	low	high
Non-enzymatic activity	o	Rapid increase	high
Lipolysis	o	Rapid increase	high
Lipid oxidation	high	Rapid increase	high
Fungi growth	o	low	high
Yeast growth	o	low	high
Bacterial growth	o	o	high

https://pirun.ku.ac.th/~b521020200/water5.html



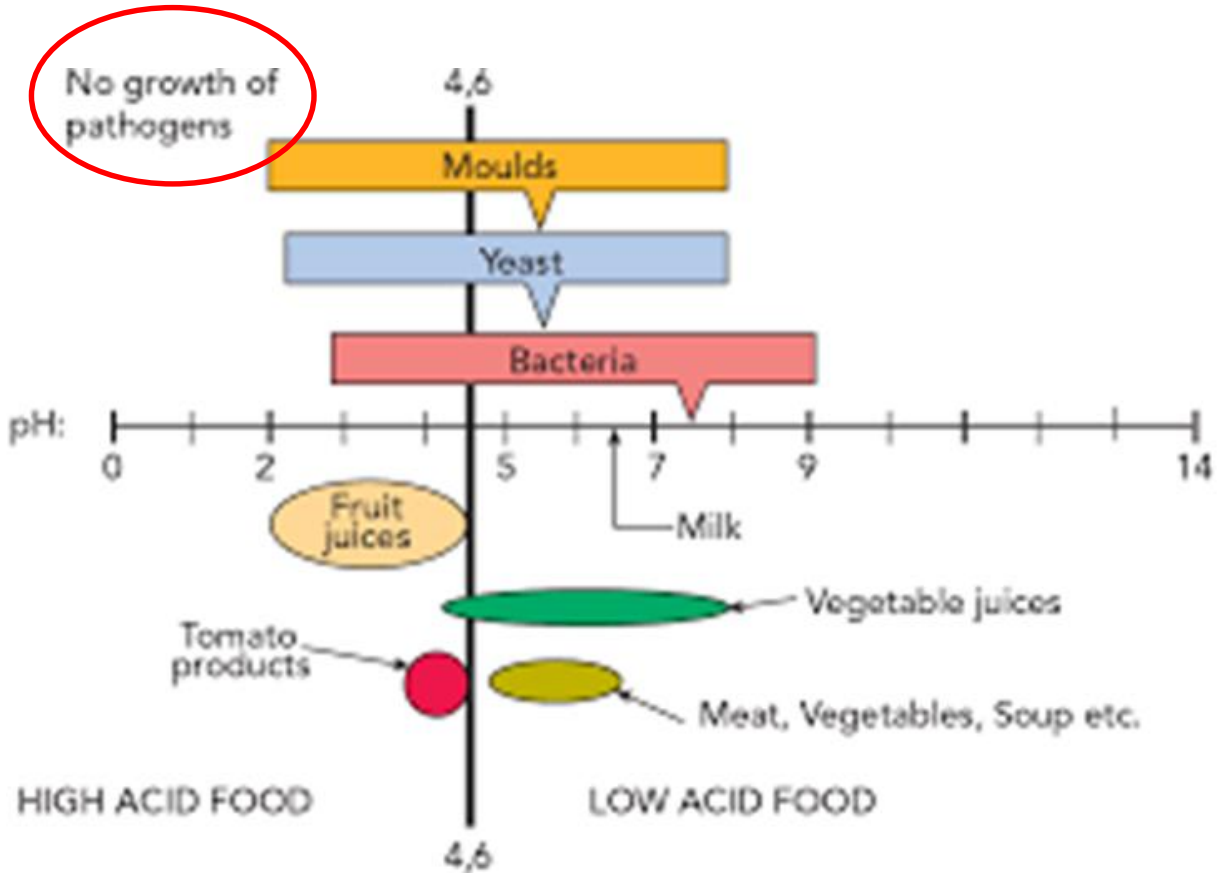
Short shelf-life

Long shelf-life

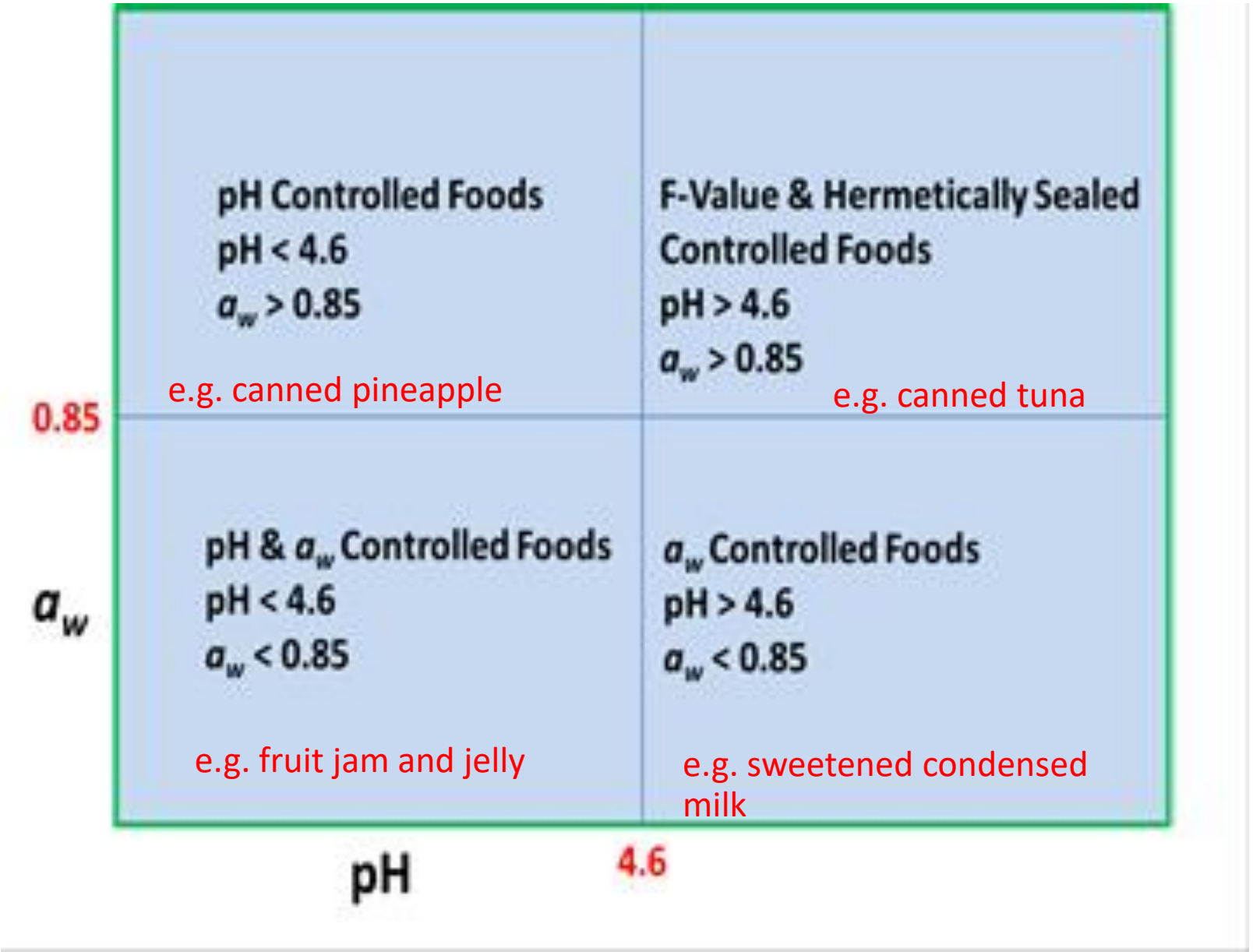
https://www.foodnetworksolution.com/wiki/word/0551/water-activity-

pH and microbial growth

Foods with pH<4.6 are safe from pathogenic microorganisms



Intermediate moisture and fresh food classification by pH and a_w



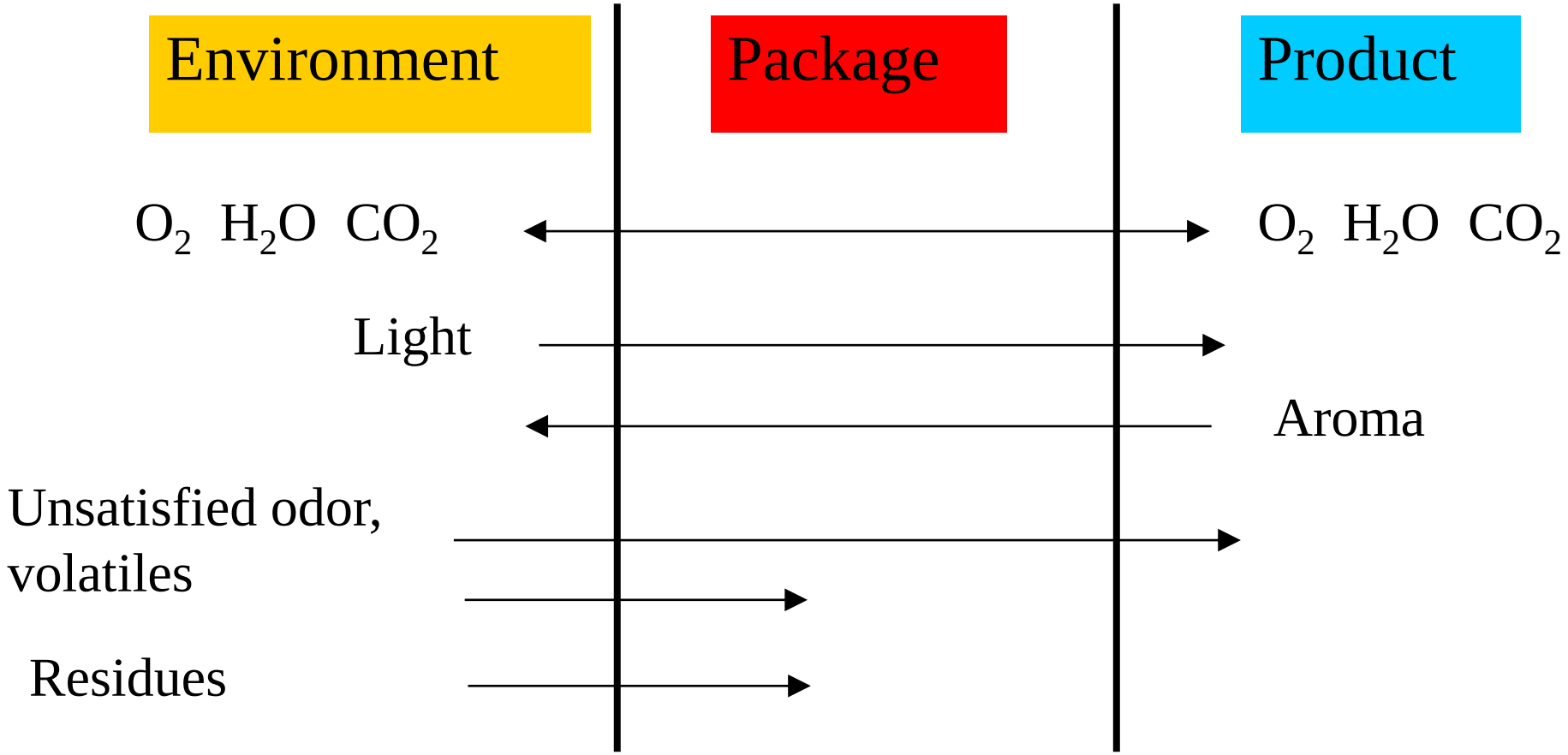
Internal factors (continued)

- Chemical ingredients of foods such as sugar, salt and acid preserve and prolong shelf-life of the product due to lower a_w and pH.

Internal factors (continued)

- Packaging materials and methods:
  - Packaging materials with low permeability of oxygen gas and water vapor limit chemical reactions and aerobic microbial growth
  - Atmosphere inside package also determines shelf-life of food products; e.g. vacuum packaging, modified atmosphere packaging, etc.

Permeability of packaging materials



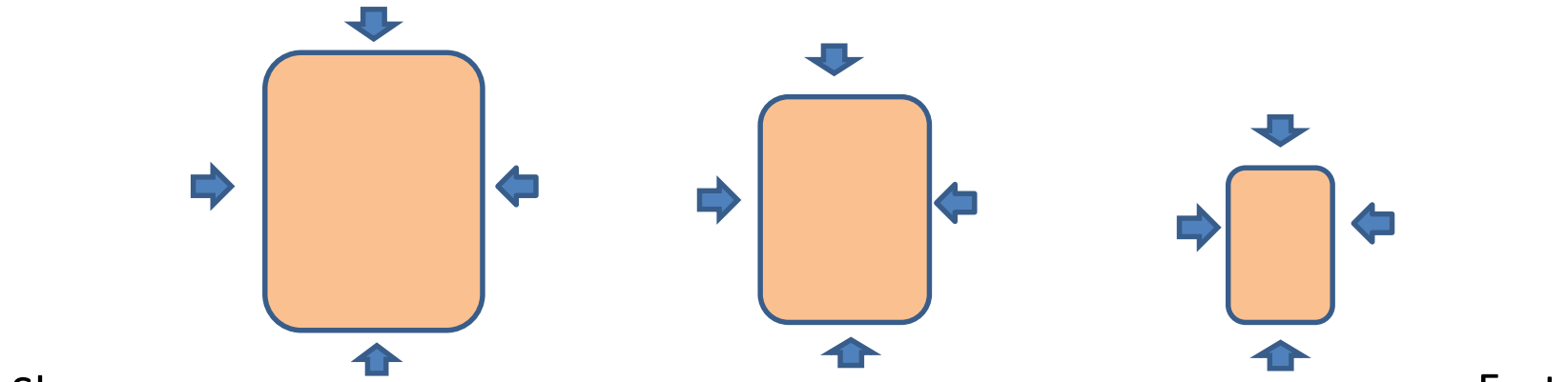
Internal factors (continued)

- Package size:

  Smaller size provides more surface to volume ratio.

  – Allows more chance of gas and vapor diffusion to the food center

  – Enhance rate of food deterioration






Internal factors (continued)

- Hygiene of raw materials and processing line: With low microbial contamination or initial load, food can be kept longer.

External factors

- Transportation condition: Shelf-life of a food could be shorten under high temperature, humid atmosphere and light exposure.
- Packaging damage will allow gas and vapor get in and react with food.

Example: Short shelf-life foods

Products	Deterioration	Factors	Shelf-life
Milk and dairy products	-Bacteria -Off-flavor -Rancidity	Oxygen, Temperature	7-30 days at 0-7 ◦C
Fresh bakery products, e.g. cake, bread	-Musty smell -Microbial spoilage -Staling -Rancidity	Oxygen, temperature, moisture	2 days (bread) 7 days (cake)
Fresh meat	-Bacteria -Pale	Oxygen,temperature, light	3-4 days at 0-7 °C
Fresh fish	- Bacteria - Off-flavor	Temperature	3-14 days at 0 °C
Fresh fruits and vegetables	- Respiration - Changes in composition - Microbial spoilage	Temperature, moisture, light, oxygen	Depending on each commodity

Source: Adapted and modified from Pimolsiriphol (2018)

Example: Moderately long shelf-life foods

Products	Deterioration	Factors	Shelf-life
Fried snacks	- Rancid - Loss of crispiness - Broken pieces	Oxygen, light, temperature, relative humidity	3-12 weeks
Cheese	- Rancid - Browning - Lactose crystallization - Fungi	Temperature, relative humidity	4-24 months
Ice cream	-Coarse texture -Pale	Temperature fluctuation during storage	1-4 months

Source: Adapted and modified from Pimolsiriphol (2018)

Example: Long shelf-life foods

Products	Deterioration	Factors	Shelf-life
Dried foods	- Browning - Rancid - Textural changes - Nutrients loss	Relative humidity, temperature, light, oxygen	1-24 Months
Skimmed milk powder	- Changes in flavor - Less solubility - Caking - Nutrients loss	Relative humidity, temperature	8-12 months
Breakfast cereals	- Rancid - Not crispy - Nutrients loss	Relative humidity, temperature	6-18 months
Dried pasta	- Textural changes - Musty smell - Nutrients loss - Broken loss	Relative humidity, temperature, light, oxygen	9-48 Months

Source: Adapted and modified from Pimolsiriphol (2018)

Example: Long shelf-life foods…(continued)

Products	Deterioration	Factors	Shelf-life
Frozen concentrated fruit juice	- Sedimentation - Vitamin loss - Changes in color and flavor - Yeast	Oxygen, temperature, defrost	18-30 months
Canned fruits and vegetables	- Losses of flavor and texture - Color change - Vitamin loss	Temperature	12-36 months
Coffee powder	- Rancid - Flavor loss	Oxygen, temperature, light,relative humidity	9-36 months

Source: Adapted and modified from Pimolsiriphol (2018)

Shelf-life examples:
Commercial dried foods

Preserved mixed fruits

Shelf-life: 1 year

Dried mixed fruits

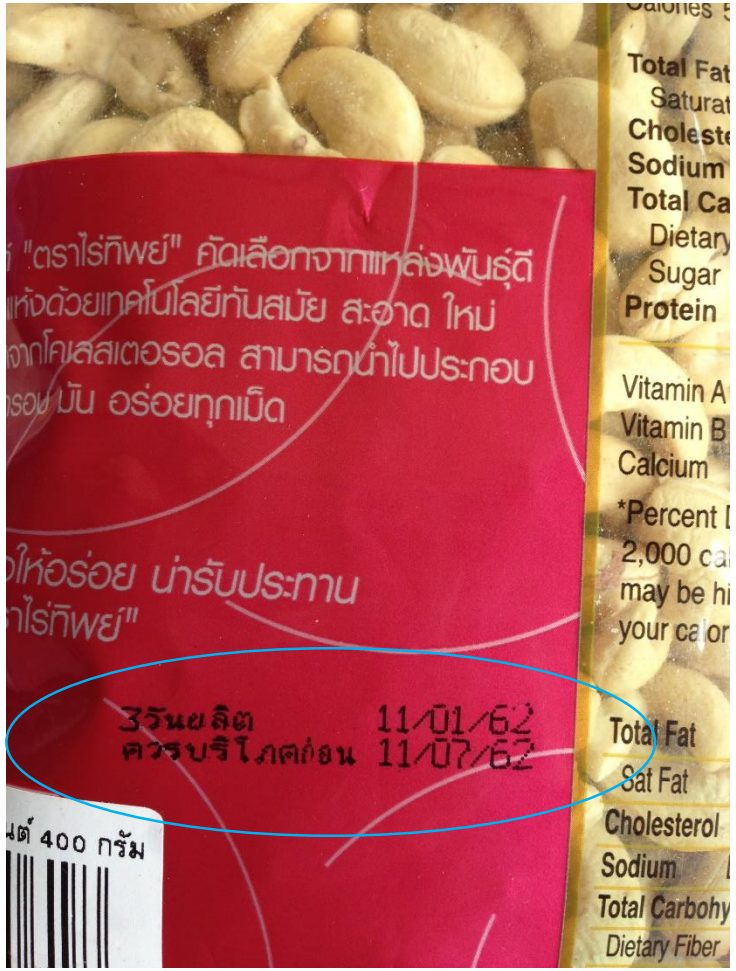
Shelf-life: 1 year

Dried longan

Shelf-life: 1 year

Raw cashew nuts

Shelf-life: 6 months



Dehydrated mango

Shelf-life: 6 months

Dried mango: low sugar

Shelf-life: 1 year

Mango sheet

Shelf-life: 10 months

Crispy vegetable: (Baked, No oil)

Shelf-life: 1 year

Shelf-life extension of food products

Protection against physical deterioration

- Loss of Crispiness: Prevent contact with moisture such as using packaging material with low moisture permeability, sealed plastic or glass bottle, or packed with moisture absorber sachet.
- Loss of softness: Adding some food additives; e.g. emulsifiers* in bread or cake.
- Gel syneresis: Using appropriate gelling agents

**Monoglycerides, polygycerol esters, lactic acid esters, polysorbates, emulsifiers may include monoglycerides, polypylene glycol monostearate (PGME), and acetylated mono glycerides.*

Protection against physical deterioration *(Continued)*

- Oil separation: Using emulsifiers, e.g. egg yolk, lecithin, and thickening agents (starch, gelling agents)
- Soggy: Packed in sealed container with moisture absorber sachet
- Melting: Avoid high temperature

Protection against physical deterioration *(Continued)*

- Caking: Adding anti-caking, packed in sealed container with moisture absorber sachet
- Sedimentation: Adding thickening agents in the combinations, e.g. starch, gelling agents
- Crystallization: Adding anti-crystallizing agents, e.g. emulsifiers* in ice cream and hydrocolloids in ice cream.

** Lecithin, sucrose fatty acid esters, mono(di)glycerol fatty acid esters, sorbitan fatty acid esters, triglycerol fatty acid esters, propylene glycol fatty acid esters, etc.*

Protection against chemical deterioration

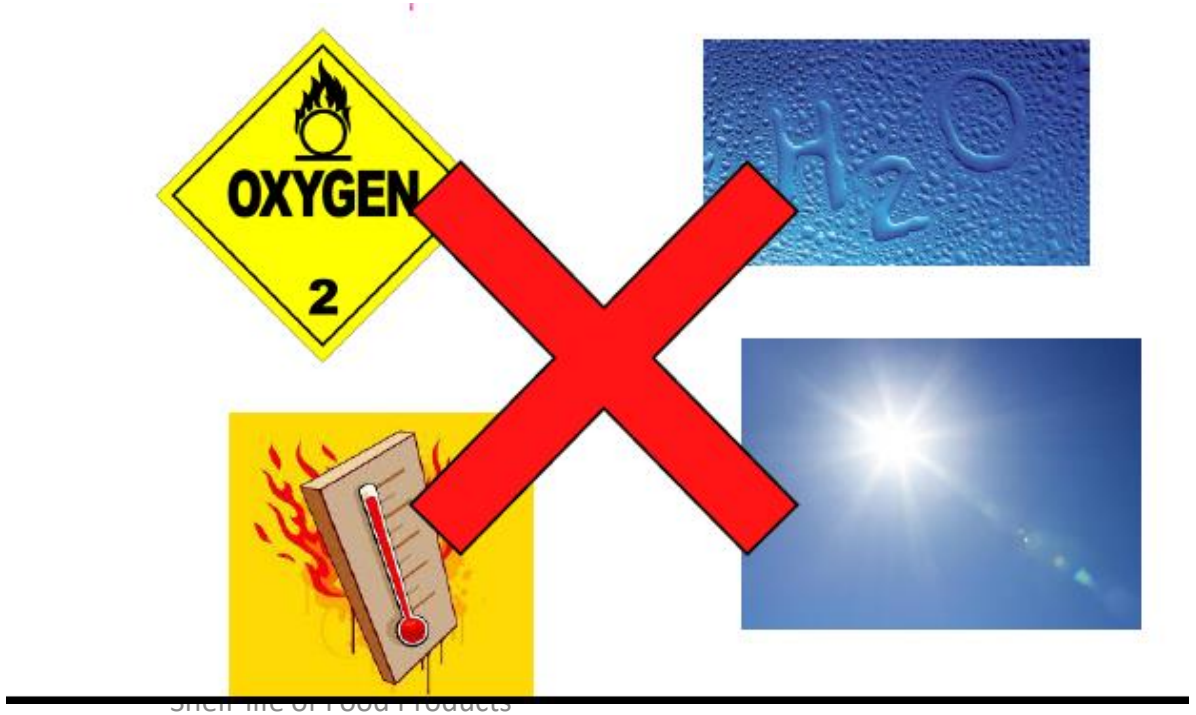
- Enzymatic browning: Blanching (80-90 °C), Soaking in acid solution (pH 2.5-3.0), Vacuum packed
- Non-enzymatic browning (maillard): Keeping at low temperature, Washing out sugar from food surface.

Protection against chemical deterioration (*Continued*)

- Lipid oxidation: Vacuum packed, sealed packaging with low transmission of moisture, oxygen and light, oxygen absorber sachet, nitrogen flushing, low temperature

Protection against chemical deterioration (*Continued*)

- Loss of nutrients: Avoid exposure to oxygen, light and heat or high temperature



Protection against biological deterioration

- Reduction of microorganisms contamination:
  - Sanitized raw materials
  - Processing hygiene
  - Water activity reduction

Protection against biological deterioration *(Continued)*

- Adding salt, sugar and acid: Osmotic dehydration, Fermentation
- Thermal processing: - Cooking (Boiling, Baking, Steaming, Frying, Roasting, Grilling, Smoking), Pasteurization (<100 °C), Sterilization (>100 °C)

Thermal processing of foods

Product	Thermal process	Temperature and time	Microorganisms elimination
Pasteurized foods	Pasteurization	<100 °C, e.g. 63 °C 30 min., 72 °C, 15 sec.	All pathogens and some spoilage microorganisms
Sterilized high acid foods (pH<4.6)	Sterilization	100-120 °C, >15 min.	All
Sterilized low acid foods (pH>4.6)	Sterilization	110-130 °C, >15 min.	All
UHT	Ultra high temperature	130-140 °C, 3-8 sec.	All

Shelf-life of thermal processed foods

Products	Packaging	Storage	Shelf-life	Sensory quality and nutrients retention
Pasteurized foods	Glass, Plastics, Box	- Chill - Room temperature (with preservatives)	- 3 days-1month - 3 months-1 year	High
Sterilized foods	Glass, Can, Pouch	Room temperature	1-2 year	Low
UHT	Box/Aseptic packaging	Room temperature	6 month- 1 year	Moderate

Protection against biological deterioration (Continued)

- Cooling: Chilling (0-10 °C), Freezing (<0 °C)
- Preservatives: e.g. Benzoate for high acid foods (fruit juice, jam), Propionate for low acid food (cake, bread)
- MAP (Modified Atmosphere Packaging)

Example for MAP: Thai desserts

Products	Packaging condition		
	Normal atmosphere (O_2 21%, N_2 78, Others 1%)	MAP (CO_2 20%, N_2 80%)	MAP (CO_2 60%, N_2 40%)
Sweet mung bean 	3	10	10
Foi Tong 	10	17	>28
Tong Ek 	3	7	10
Pui Fai 	3	7	10

Source: Modified from Mingmueng (2007)

Conclusions

- Food quality is subjected to physical, chemical and biological change during storage until it becomes expired or end of shelf-life.
- Shelf-life of a food product is determined by unsafe and/or unacceptable quality for consumption.
- Shelf-life of a food product is associated with internal and external factors determining rate of food deterioration.
- Shelf-life of food products can be prolonged by controlling internal and external factors in order to lower rate of food deterioration.

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