FE 122 INTRODUCTION TO FOOD SCIENCE AND TECHNOLOGY

Dr. Fahrettin GÖĞÜŞ

Reference Books

1. P. Fellows, ***Food Processing Technology***

2. R. Paul Sing, ***Introduction to Food Engineering***

3. Romeo T*. Toledo,* ***Fundamentals of Food Process Engineering***

Course Content

- Historical development of food science and technology
- Principles of biological and physical sciences related to the human food system.
- Structure and properties of food materials
- Unit operations in food processing
- Food legislation
- Environmental considerations

LEARNING OBJECTIVES:

- Introducing historical development of food engineering
- Learn about various unit operations used in the food processing industry to process raw materials into finished product
- Develop knowledge on the food legislation and environmental consideration

ASSESSMENT OF LEARNING OUTCOMES:

- Exams - There will be two mid-terms (in class closed book), and a final exam.

Evaluation	% of grade
1. Midterm	30
2. Midterm	30
Final exam	40

SCOPE OF FOOD SCIENCE AND FOOD TECHNOLOGY

FOOD SCIENCE

Application of the basic sciences and engineering to study the fundamental physical, chemical and biochemical nature of foods and the principles of food processing.

- Food Chemistry
- Food Microbiology
- Food Quality Control

FOOD TECHNOLOGY

Food technology is the use of the information generated by food science in the selection, preservation, processing, packaging and distribution, as it affects the the consumption of safe, nutritious and wholesome food.

- Process Control
- Fluid Mechanics
- Food Processing Operations

Scope of Food Science and Technology includes:

- Efforts to make it possible to supply great quantities of food to crowded populations (result of urbanization)
- Efforts to develop new (novel) foods agreeable to consumers (increase type, availability at all times)
- To maintain (if possible to improve) nutritional value and quality of foods.

CURRICULUM OF FOOD ENGINEERING DEPARTMENT

The core of food science and technology courses includes both lecture and laboratory components

FIRST SEMESTER			SECOND SEMESTER		
1. YEAR					
67 EEE 241 Computer Programming	3		30 EP 116 General Physics	4	
73 FE 111 General Chemistry	4		73 FE 122 Introduction to Food Science and Technology	2	
39 LENG 101 Freshman English I	4		73 FE 132 Organic Chemistry	4	
36 MATH 151 Calculus I	4		39 LENG 102 Freshman English II	4	
69 ME 101 Engineering Graphics	3		36 MATH 152 Calculus II	4	
22 TURK 100 Turkish	2		22 TURK 200 Turkish	2	
			Common Elective	-	
2. YEAR					
73 FE 211 Analytical Chemistry	4		73 FE 204 General Microbiology	4	
73 FE 221 Material and Energy Balances	4		73 FE 212 Biochemistry	3	
73 FE 243 Introduction to Statistics	3		73 FE 218 Food Systems	3	
73 FE 271 Food Chemistry	4		73 FE 222 Fluid Mechanics	4	
36 MATH 256 Differential Equations	3		73 FE 224 Engineering Thermodynamics	4	
23 HIST 100 Atatürk's Principles and the History of the Turkish Renovation	2		23 HIST 200 Atatürk's Principles and the History of the Turkish Renovation	2	
				-	
3. YEAR					
73 FE 301 Mass Transfer	4		73 FE 356 Applied Mathematics in Food Engineering	3	
73 FE 305 Food Microbiology	4		73 FE 376 Food Quality Control	3	
73 FE 311 Applied Kinetics of Biological Reactions	3		73 FE 382 Food Operations I	4	
73 FE 315 Instrumental Analysis	3		73 FE 384 Food Operations II	4	
73 FE 321 Heat Transfer	4		Elective 300	2	
				2	
				-	
4. YEAR					
73 FE 401 Food Technology	3		FE400 Internship	3	
73 FE 403 Food Process Control	3			3	
73 FE 411 Food Biotechnology	4			3	
73 FE 477 Food Engineering Design I	3			3	
Technical Elective 400	2			3	
	3			3	

HISTORICAL DEVELOPMENT OF FOOD ENGINEERING

The present day food industry has its origins in pre-history when the first food processing took place;

- To preserve foods against famine (for ex; sun drying of grain to extend storage life)
- Or to improve their eating quality (for ex; roasting of meat to improve flavor)

Mechanical processing equipment was developed to reduce the time labour involved in manual methods. For example, water, wind and animal power were used to mill grains.

The first biochemical processing began in Egypt with the development of fermented products, including cheeses and wines.

For a long period such preservation and preparation methods were only used on a domestic scale to serve the needs of the family.

As societies developed, specialization took place and trades developed (bakers and brewers)

These were the forerunners of current food industries.

Food processing techniques were developed;

- To allow food to be stored through the winter months
- To increase the availability of foods out of season and
- To allow foods to be transported from rural areas to urban areas

During the 19th century, larger scales of production were achieved in factories to produce basic commodities, including starch, sugar, butter and baked goods. These processes were based on tradition and experience, and no detailed knowledge of the composition of foods or changes during processing was available.

Towards the end of that century; an increase in scientific understanding started the change from craft-based industry to science-based industry that is continuing today.

The aims of the food industry today;

1. To extent the period during which a food remains the shelf life by preservation techniques which increase the stability during production, distribution and home storage
2. To increase variety in the diet by providing a range of attractive flavors,colors, aromas and textures in food

   wheat → flour, bread, macaroni, biscuits, cake, etc

   milk → cheese, yoghurt, butter,etc

   meat → sausage, kebab, köfte, etc
3. To provide the nutrients required for health (nutritional quality of food; vitamin, protein, fat, carbohydrate, mineral)
4. To generate income for the manufacturing factory

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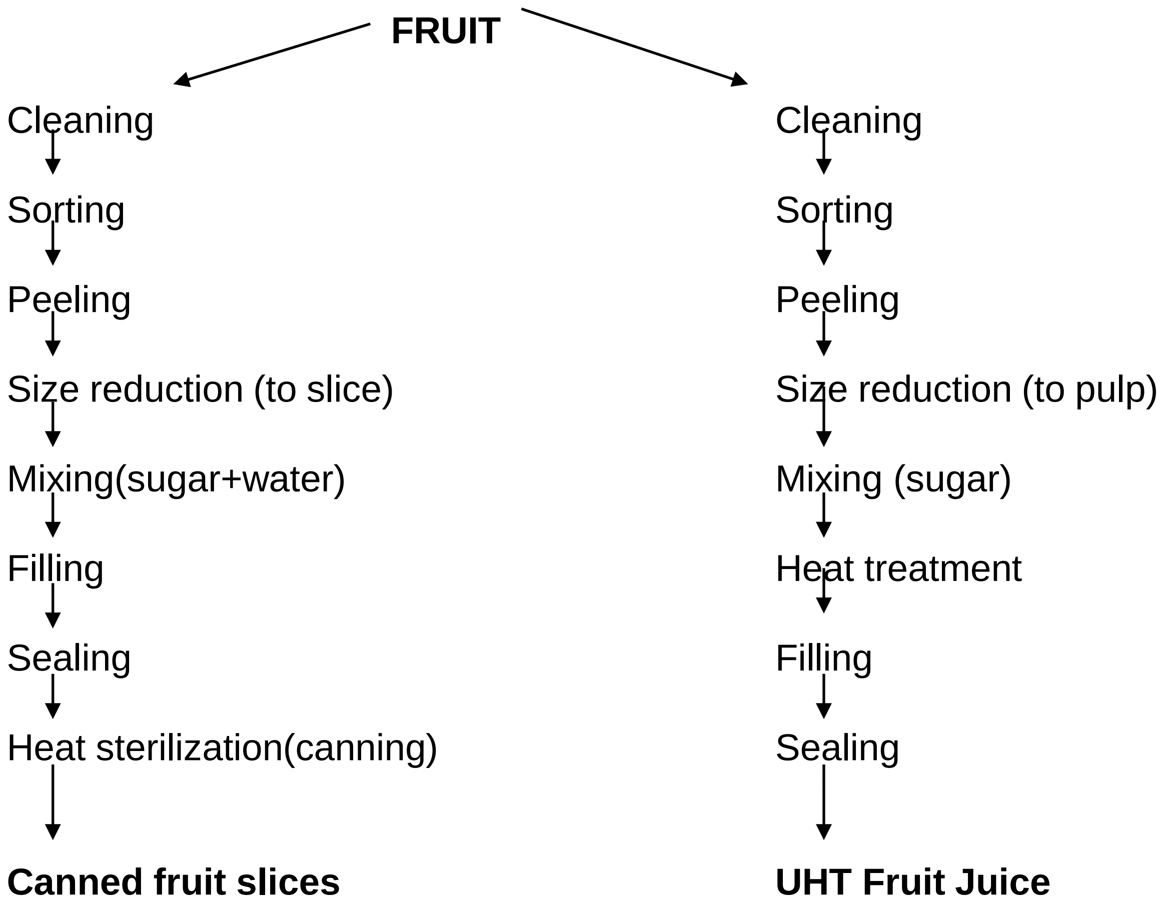
- All food processing involves a combination of procedures to achieve the intended changes to the raw materials. These are categorized as **unit operations.**

- Unit operations are grouped together to form a **process.** The combination and sequence of operations determines the nature of the final product.


FRUIT
Cleaning
Sorting
Peeling
Size reduction (to slice)
Mixing(sugar+water)
Filling
Sealing
Heat sterilization(canning)
Canned fruit slices
Cleaning
Sorting
Peeling
Size reduction (to pulp)
Mixing (sugar)
Heat treatment
Filling
Sealing
UHT Fruit Juice

Foods undergo changes as a result of processing, such changes may be;

- Physical
- Chemical
- Enzymatic
- Microbiological

So, there is a need of food engineer for all steps of food production from harvesting to consuming.

So, there is a relationship of food engineering to; Chemistry, Microbiology, Nutrition, Mathematics, Food processing, etc.

It is the starting point for need of Food Engineer.

Food Engineer is a person who blends principles with applications to food processing.

For ex;

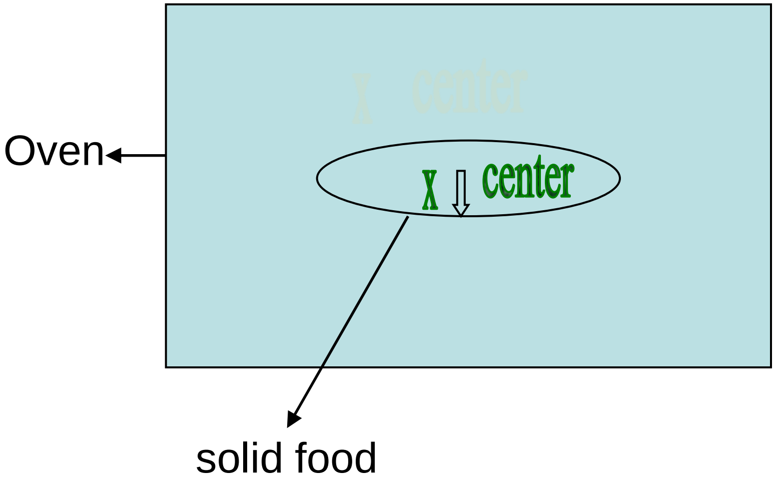
- If a food engineer is asked to design a food process that involves heating or cooling; she/he must be well aware of the physical principles that govern heat transfer.
- The engineer’s work is often expected to be quantitative, so, use of mathematic is essential
- Kinetic of chemical changes is a prerequisite to the design and analysis of food processes, so, he/she must be know these changes.

MATHEMATICAL PRINCIPLES AND APPLICATIONS IN FOOD PROCESSING

Variables and Functions

A **variable** is a quantity that can assume any value. A **function** represents the mathematical relationship between variables.

For ex; the temperature in a solid which is being heated in an oven may be expressed as a function of time and position using the mathematical expression; T = F(x,t)



- center cannot heat immediately
- heat flows through distance x
- within a time t interval

For equation, y = ax + b → a and b are constants

x and y are variables

Variables may be dependent or independent.

For y= F(x) → y is the dependent variable, x is the independent variable

For x= F(y) → x is the dependent variable, y is the independent variable

In physical or chemical systems;

- Independent variables are those fixed in the design of experiment
- Dependent variables are those which are measured.

For example; when determining the loss of ascorbic acid (vitamin C) in stored canned foods with time → - ascorbic acid concentration is the dependent variable

- time is the independent variable

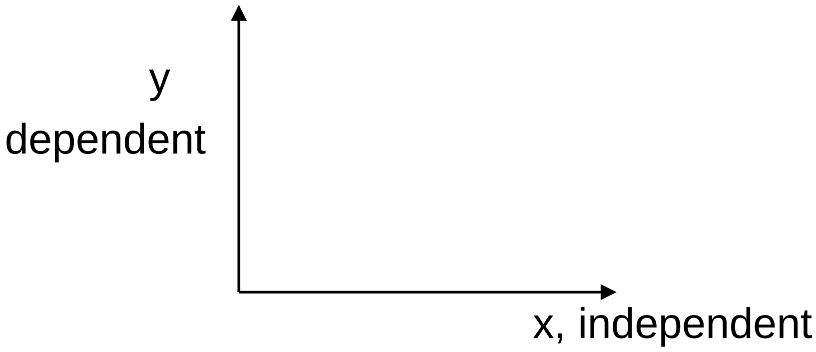
In an experiment where a sample of food is taken and both moisture content and water activity are measured, either of the two variables may be designated as dependent or independent variable.

Graphs

Each data point obtained in an experiment is a set of numbers representing the values of the independent and dependent variables. Experimental data are often presented as a graph.

When plotting experimental data;

- The independent variable is plotted on the horizontal axis, or *abscissa*
- The dependent variable is plotted on the vertical axis, or *ordinate*



Equations

An **equation** is a statement of equality. Equations are useful for presenting experimental data.

Fitting is the application of an equation to experimental data.

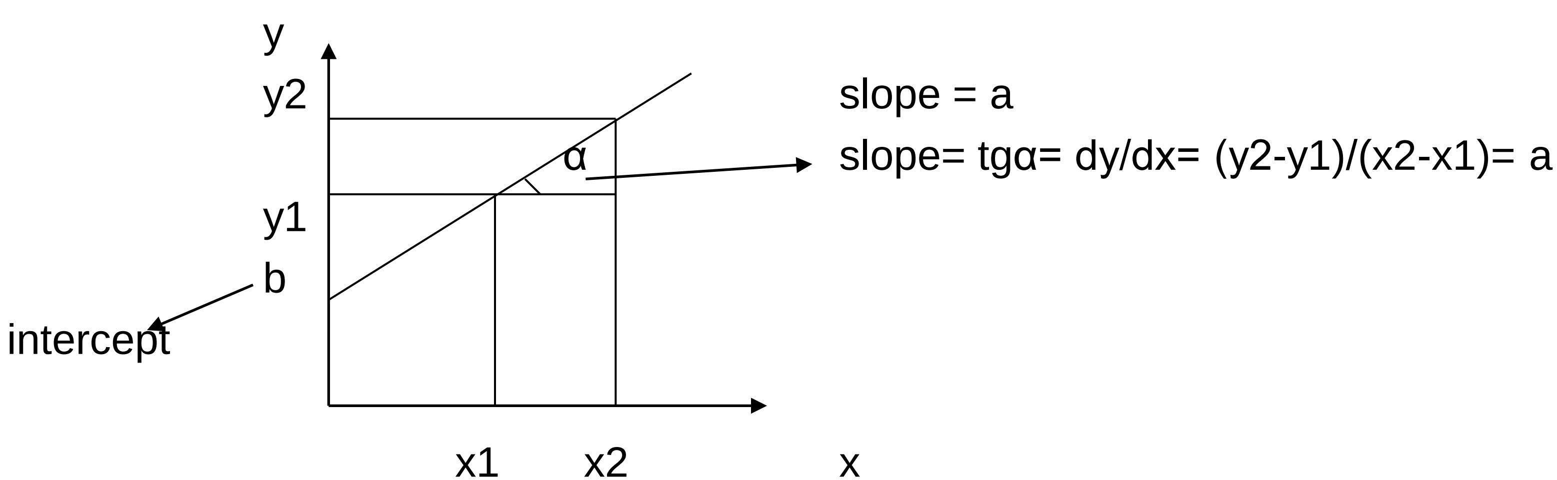
Experimental data may be fitted to an equation using any of the following techniques;

1. **Linear and polynomial regression:** Statistical methods are used to determine the coefficients of a linear or polynomial expression involving the dependent and independent variables
2. **Linearization:** The equation to which the data is being fitted is linearized
3. **Graphing:** The data are plotted to form a straight line and from slope and intercept, the coefficients of variables in the equation are determined.

Linear Equations In linear equations there is a linear relationship between variables,x and y.

1. **The slope-intercept form: y = ax + b**

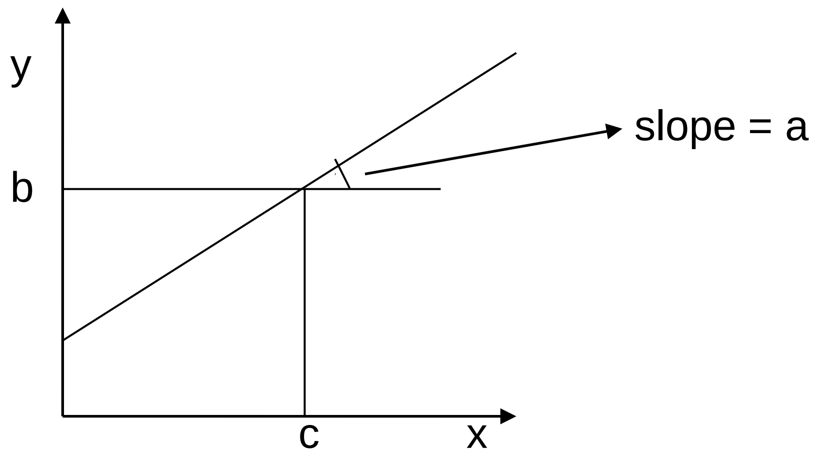
   a is the slope and **b** is the intercept when x= 0.



2. The point-slope form: (y-b) = a(x-c)

a is the slope

b and **c** represents coordinates of a point (c,b) through which the line must pass.



Nonlinear Equations are those equations in which the exponent of any variable in the equation is a number other than 1.

Polynomial

$$y=a+ bx^1 + cx^2 + dx^3$$

b=linear; c=quadratic; d=cubic ……….. Coefficients

Exponential

$$y= a\, e^{-bx}$$

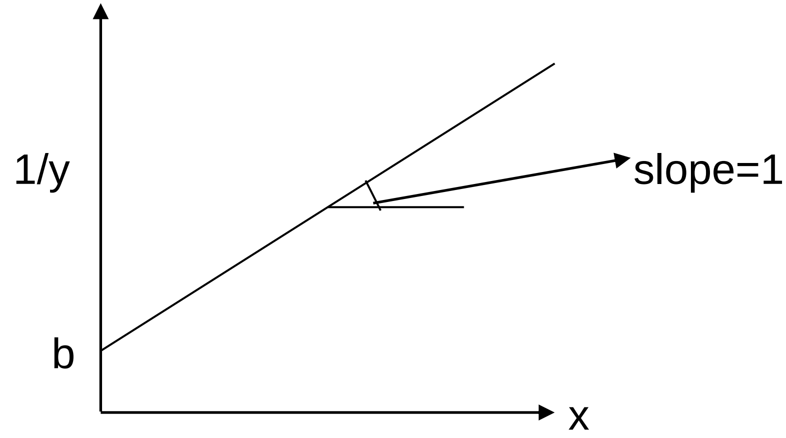
It is not easy to determine coefficients of a nonlinear equation as linear one. So, mostly these types of equations are linearized.

Examples

1. Hyperbolic function

$y= 1/b+x$ Nonlinear

$1/y=b+x$ Linear



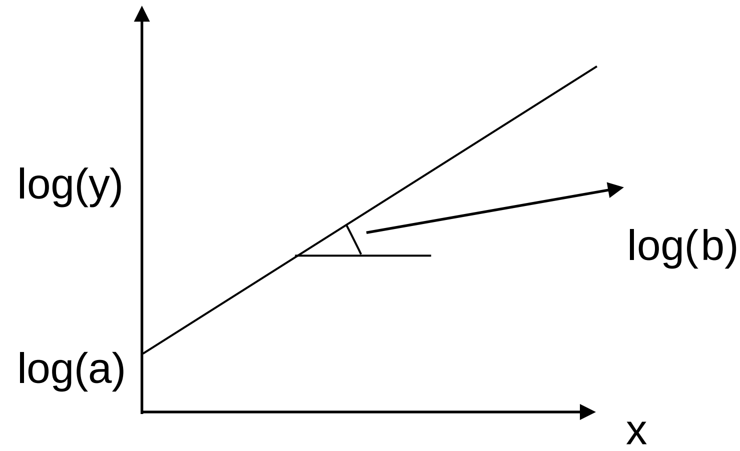
2. Exponential function

$y= a\,b^{x}$ nonlinear equ.

To linearize this take the logrithm of both sides as

$\log(y)= \log(a)+ x \log(b)$

$\underbrace{\log(y)}_{y} = \underbrace{\log(a)}_{a} + \underbrace{\log(b)}_{b}\, x$



slope = log (b)

Intercept = log (a)

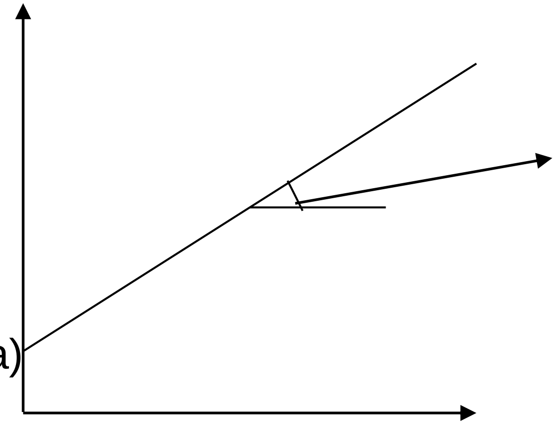
Examples

<u>3. Geometric function</u>

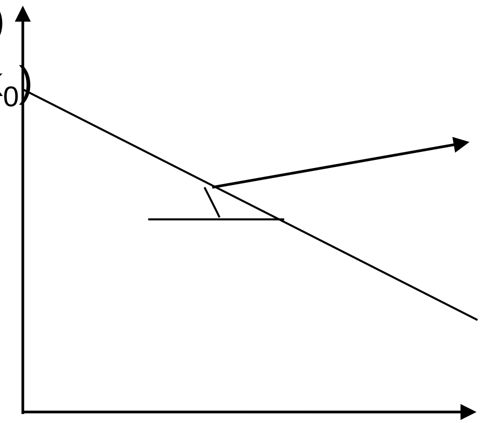
$y = a\,x^b$ Nonlinear

Take logarithm

$\log(y) = \log(a) + b \log(x)$ Linear



<u>4. Arrhenius Equation</u>



$k = k_0\, e^{(-Ea / RT)}$ nonlinear equ.

To linearize take natural logarithm (ln) of both sides as

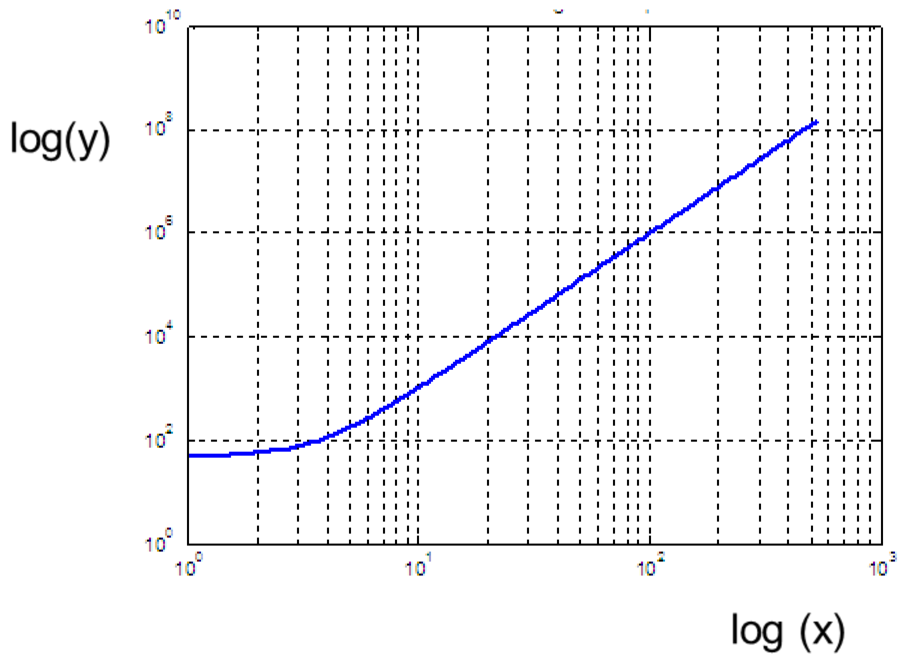
$\ln(k) = \ln(k_0) - E_a / RT \underbrace{\ln(e)}_{=1}$

$\ln(k) = \ln(k_0) - E_a / RT$ Linear equation

Logarithmic and Semi-logarithmic Graphs

1. A full logarithmic, or log-log, graphing paper has both the abscissa and ordinate in the logarithmic scale.

These graphs are used for **geometric functions**.



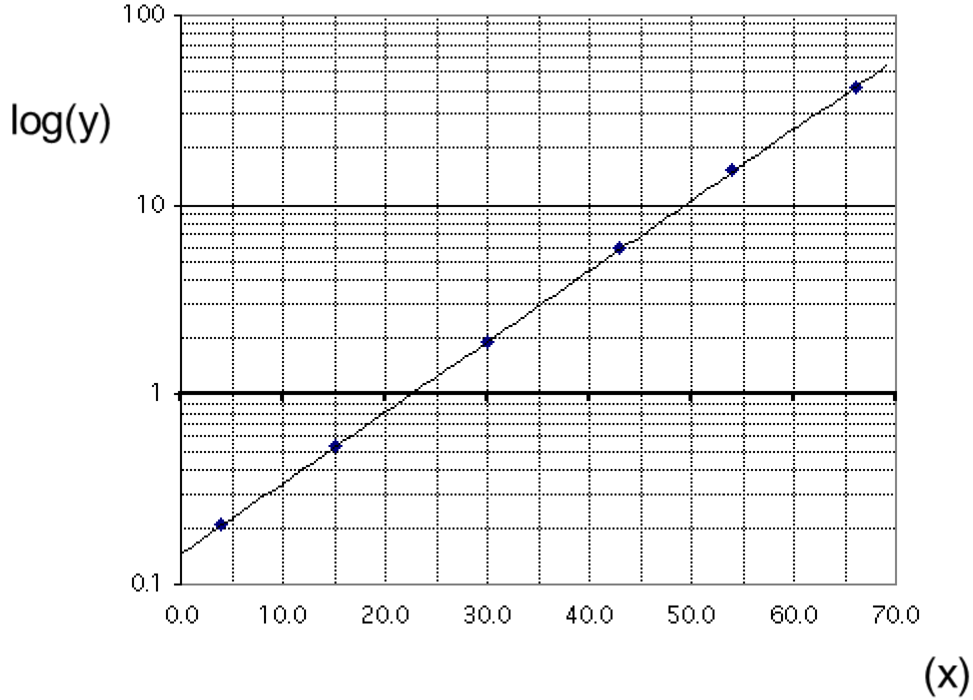
$$slope = \frac{\log y_2 - log y_1}{\log x_2 - log x_1}$$

y-axis intercept = log (y)

x-axis intercept = log (x)

2. A semilogarithmic graphing paper has the abscissa in the arithmetic scale and the ordinate in the logarithmic scale.

These graphs are used for **exponential functions**.



$$slope = \frac{\log y_2 - log y_1}{x_2 - x_1}$$

y-axis intercept = log (y)

x-axis intercept = (x)

Numerical values of data points are directly inserted on the logarithmic axis

Do not transform (take) logarithm of data when inserting on the log scale

Example: An index of the rate of growth of microorganisms is the generation time (g). In the logarithmic phase of microbial growth, the number of organisms (N) changes with time of growth (t) according to;

$$N = N_0\ [2]^{t/g} \qquad \text{(exponential function)}$$

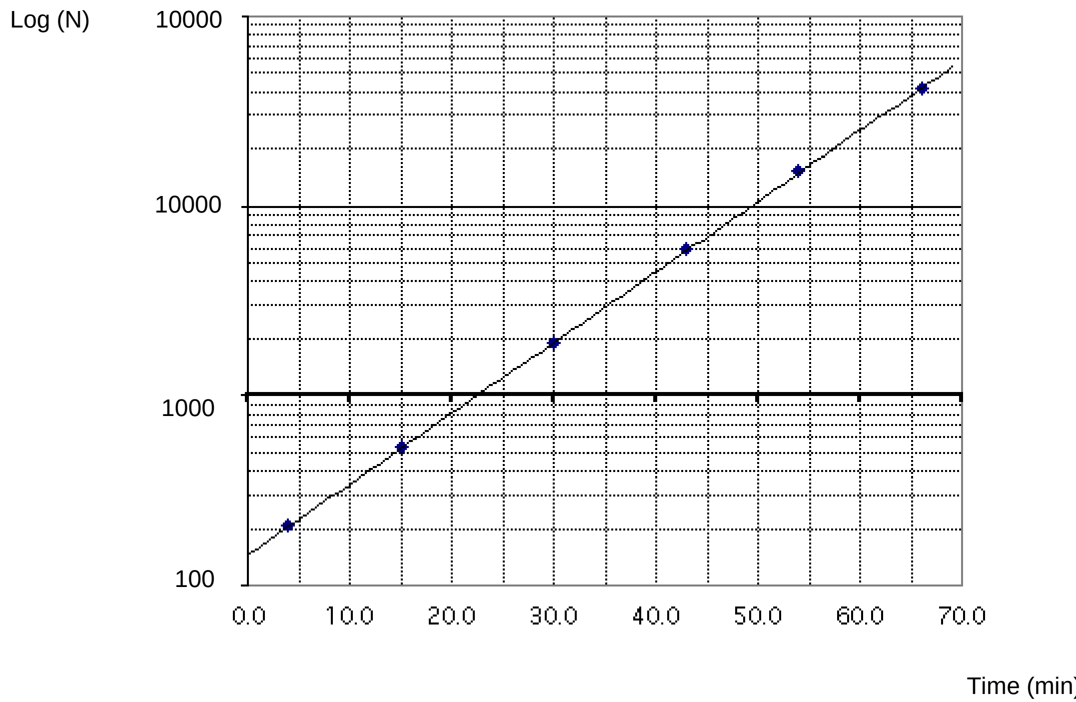
Find the generation time (g) of a bacterial culture which shows the following numbers with time of growth.

Time of growth, t (min)	Numbers, N
0	980
10	1700
30	4000
40	6200

Solution: Linearize the equation, take the logarithm

$$\log(N) = \log N_0 + \left(\frac{t}{g}\right) log2$$

$$\log(N) = \log N_0 + \left(\frac{log2}{g}\right) t$$



$$slope = \frac{\log(10000) - \log(1000)}{49 - 0.5}$$

From equation slope= log2/g = 1/48.5;   g=14.6 min

Example: Head lettuce is stored in an air tight storage. The heat generated with temperature is given below;

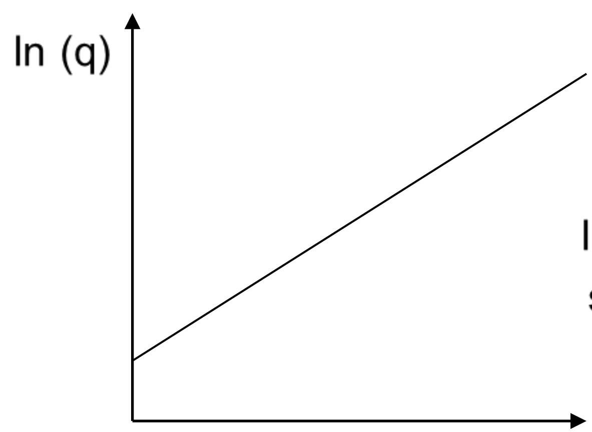
T (°C)	q (mW/kg)
4	37.96
8	53.98
12	76.75
16	109.14

Assume $q = a\,e^{b\,T}$ fits the data. Determine constants 'a' and 'b' by graphical method.

Solution: Linearize the equation, take the natural logarithm

$$\ln(q) = \ln a + b\,T$$

T (°C)	ln(q)
4	3.6365
8	3.9886
12	4.3405
16	4.6926



From graph intercept = 3.27

slope = 0.088

lna =intercept =3.28 ⟹ a= 26570

slope = b = 0.088

COMMON UNIT OPERATIONS

1 -Materials Handling

Includes various operations:

..Hand and mechanical harvesting on the farm

..Refrigerated trucking of perishable produce

..Box car transportation of live cattle

..Pneumatic conveying of flour from railcar to bakery storage bins.

..Aim: The movement of produce from farm to processing plant and of raw materials through the plant.

It may take many forms:

Example: Oranges are moved by truck trailers to the washing and grading area. The length of time is important since fruits and vegetables are alive and respire causing a rise in temperature of a batch. Thus, spoilage may occur.

Types of equipments for moving materials:

Pneumatic lift systems, Pneumatic conveyors, Screw conveyors, Bucket conveyors, Belt conveyors, Vibratory conveyors

2-Cleaning

Aim: Foods by the nature of the way they are grown or produced on farms in open environments often require cleaning before use.

Cleaning ranges from:

- Simple removal of dirt from eggshells with an abrasive brush to
- Complex removal of bacteria from a liquid food by passing it through a microporous membrane

Cleaning can be accomplished with:

Brushes, High-velocity air, Steam, Water, Vacuum, Magnetic attraction of metal contaminants,

Mechanical separation (depending on the product and the nature of dirt)

3-Separating

Separating can involve:

- Separating a solid from a solid–peeling of potatoes, shelling of nuts
- Separating a solid from a liquid–filtration
- Separating a liquid from a solid–pressing juice from a fruit
- Separating a liquid from a liquid–centrifuging oil from water
- Removing a gas from a solid or a liquid–vacuum removal of air from canned food in vacuum canning.

Forms of separation in the food industry:

- Hand sorting and grading (vegetables and fruits)
- Mechanical and electronicsorting devices (difference in color)
- Automatic separation (according to size by passing over different size screens, holes or slits.)

Example; The skins of fruits and vegetables may be separated using a lye peeler.

Peaches, apricots are passed through a heated lye solution.

The lye or caustic softens the skin,

So it can be slipped from the fruit by gentle action of mechanical fingers or by jets of water.

Differences in the density of the fruit and skin can then be used to float away the removed skin.

4-Disintegrating

Aim: To subdivide large pieces of food into smaller units or particles.

- Cutting
- Grinding
- Pulping
- Homogenizing

..The dicing of vegetables is done on automatic machines

..The cutting of meat represents a time-consuming, hand-labor operation

..Laser beams also can replace knives in some cutting applications.

..Homogenizing produces disintegration of fat globules in milk or cream from large globules and clusters into minute globules.

..The smaller fat globules then remain evenly distributed throughout the milk or cream with less tendency to separate from the water phase of the milk.

Ways to homogenize:

1.Forcing the milk or cream under high pressure through a hole with very small openings

2. Use of ultrasonic energy to disintegrate fat globules or break up particles.

5-Pumping

..Aim: Moving of liquids and solids from one location or processing step to another.

..There are many kinds of pumps and the choice depends on the character of the food to be moved.

- Gear pumps–effective for moving liquids and pastes, chew up chunk-like foods reducing them to purees.
- Screw pumps–best for moving food with large pieces without disintegration (cornkernels, grapes)

An essential feature for all food pumps is ease of disassembly for thorough cleaning.

6-Mixing

..Kinds of mixers depend on the materials to be mixed

..Mixing:

1. Solids with solids–Dry cake mix
2. Liquids with liquids–milk with coffee
3. Liquids with solids–sugar with water
4. Gases with liquids–coke

..Conical blender: for simple mixing of dry ingredients

..Ribbon blender: Cut the shortening into the flour, sugar and other ingredients (in cake mixes)

..A propeller type agitator-for mixing solids into liquids to dissolve them

..Increase in temperature is a problem during mixing.

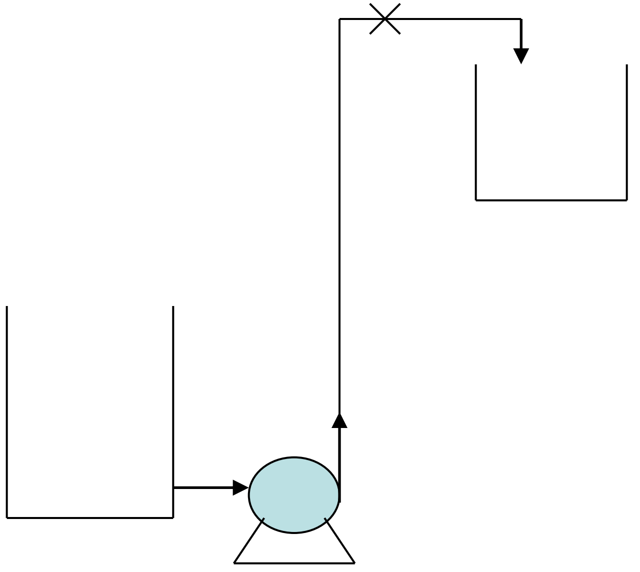
7. Fluid Flow: It concerns the principle that determine the flow or transportation of any fluid from one point to another.

A Fluid is a substance that does not permanently resist distortion.

For ex; gases; air, nitrogen, etc.

liquids; water, milk, fruit juice,etc.

A typical liquid transport system consist of 4 basic component; tank, pipe, pump and valve.



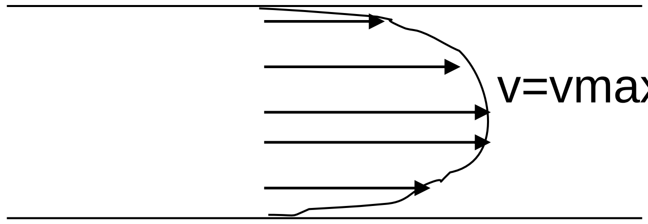
Fluids can be categorized as either compressible or incompressible fluid.

If density is moderately affected by changes in temperature and pressure, fluid is **compressible fluid**. Ex; gases.

If density is little affected by moderate changes in temperature and pressure, fluid is **incompressible fluid**. Ex; liquids.

Fluid flow takes place when stress is applied on a fluid. Stress is defined as force per unit area. When a force acting on a surface is perpendicular to it, the stress is called as **normal stress** (pressure).

When the force acts paralel to the surface, the stress is called as **shear stress (σ).** When shear stress is applied to a fluid, it flows.



When a fluid flows at low velocities, adjacent layers slide past one another like playing cards. Viscosity of a fluid determines its flow behaviour.

Viscosity is a measure of resistance to flow (μ).

When temperature ↑ viscosity ↘ }
concentration ↘ viscosity ↘ } flow is easy

Consider honey and water;

Viscosity of honey > viscosity of water

Heat honey ⟶ μ ↘ ⟶ flows easily (T effect)

Viscosity and density of a fluid is necessary for energy calculations of power requirements of a pump in a factory.

There is a science of fluid flow.

Rheology is the science of flow and deformation. It is applicable to solids and fluids.

When a material is stressed it deforms, the rate and nature of deformation which occurs characterize its rheological properties.

***8. Heat Transfer:** It deals with the principles that govern accumulation and transfer of heat and energy from one place to another.

Heat is a thermal energy, heat= f(T)

Heat cannot be measured directly, temperature can be measured

Heat can be transferred from one material to another when there is a difference in their temperatures.

There are 3 types of heat tranfer;

a) **Heat transfer by conduction:** When heat is transferred between adjacent molecules, the process is called **conduction**. This is the mechanism of heat transfer in solids (no motion of molecules).

Fourier's law of heat conduction:

Q = -k.A (dT/dx)

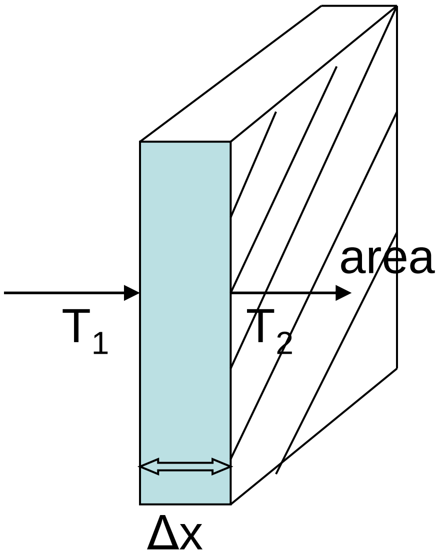
Q: rate of heat flow (Watt)

k: thermal conductivity (W/mK)

T: absolute temp. (K)

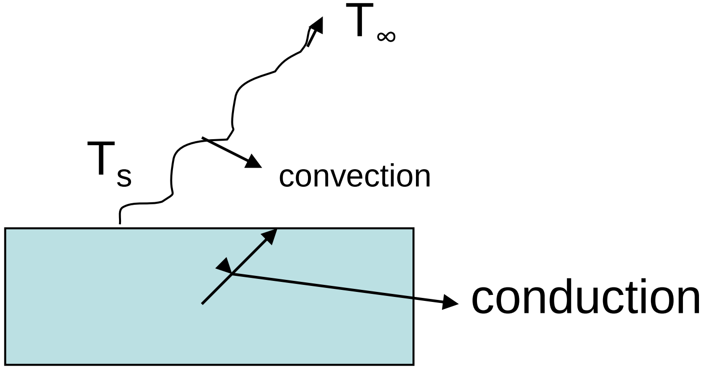
x: thickness (m)

A: area perpendicular to the direction of heat transfer (m^2)



b) Heat transfer by convection: It is the mechanism of heat transfer by bulk transport and mixing of macroscopic elements of warmer portions with cooler portions of a gas or a liquid. In convection, there is a physical movement of the medium undergoing heating or cooling.

$Q_{convection} = h.A.\Delta T$



hot iron block

$Q = hA(T_s - T_\infty)$

h: convective heat transfer coeffiecient (W/m^2K)

A: heat transfer area (m^2)

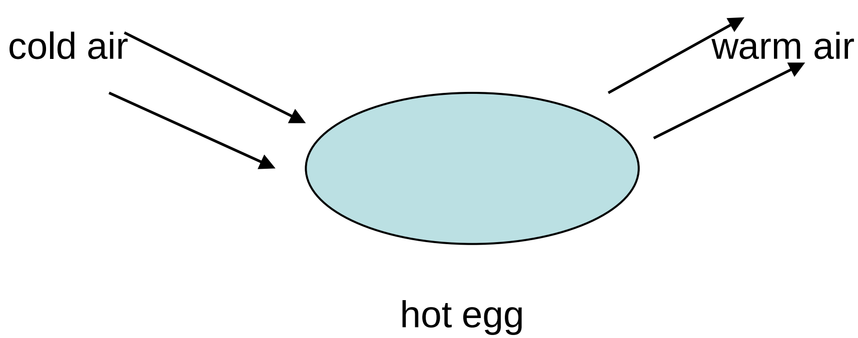
T_s: surface temperature (K)

T_∞: temp. of the fluid sufficiently far from the surface (K)

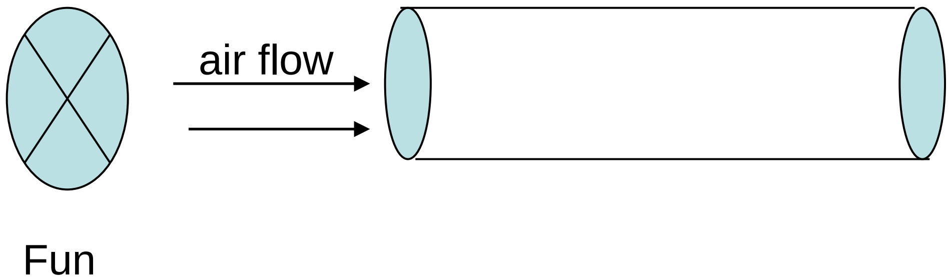
Heat transfer by convection

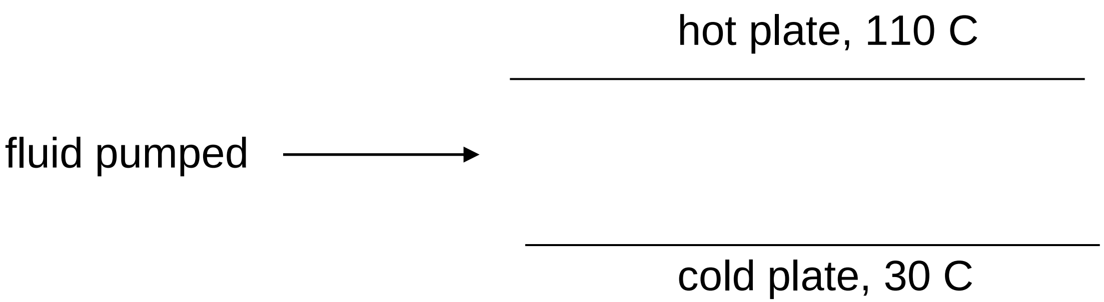
Natural (free) convection | Forced convection

1. **Natural convection:** Heat transfer occurs when a solid surface is in contact with a gas or liquid which is at a different temperature from the surface. Density differences in the fluid arising from the heating process provide the **buoyancy force** required to move the fluid. In natural convection, warmer or cooler fluid next to the solid surface causes a circulation because of a density difference resulting from the temperature difference in the fluid (buoyancy force).



1. **Forced convection:** The fluid is forced to flow over a surface or in a pipe by external means such as pump or a fun.





c) Heat transfer by radiation: Radiation is the transfer of energy through space by means of electromagnetic waves in much the same way as electromagnetic light waves transfer light. Radiation differs from conduction and convection in that no physical medium is needed for its propogation. The most important example is the transport of heat to the earth from the sun.

Stephen-Boltzman Law: $Q_{radiation} = A.\sigma.\varepsilon.T^4$

σ: stephen-boltzman constant ($5,6732 \times 10^{-8}$ W/m^2K^4)

ε: emmisivity, measure of the ability of a surface to absorb radiation

For black bodies: 1 and

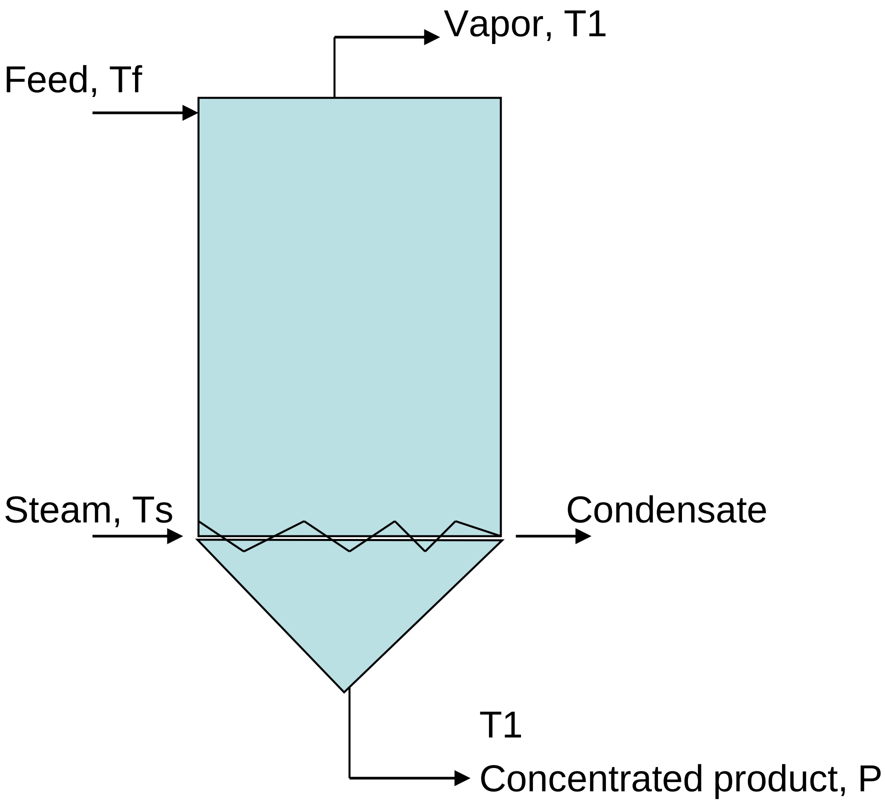
gray bodies< 1

Example for radiation: sun radiation (drying)

infrared radiation (drying, baking)

microwave radiation (heating, cooking, drying)

9. **EVAPORATION** is a special case of heat transfer, which deals with the evaporation of a volatile solvent such as water from nonvolatile solute such as salt or any other material in solution.



Q = U.A.ΔT

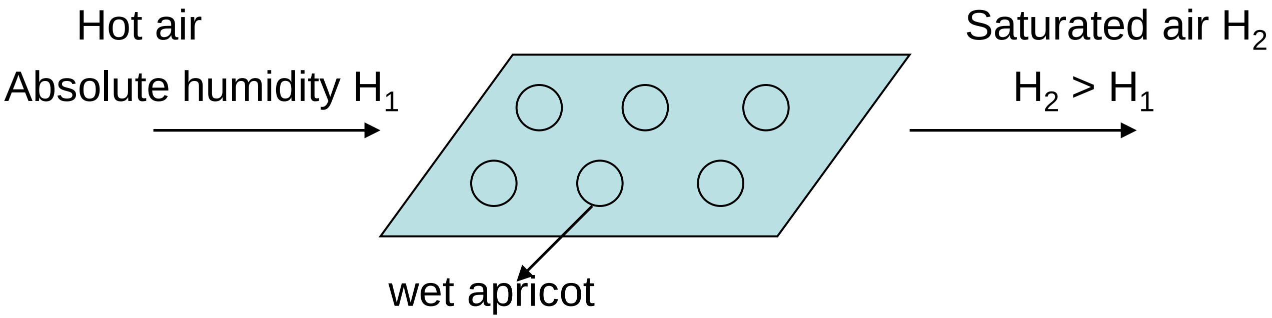
Q = U.A. (Ts-T1)

Mass balance: F= V+ P

Main functions of evaporation are:

- to preconcentrate foods prior to drying or freezing by reducing weight and volume
- It increases the solid content of foods and thus preserves it by reducing water activity
- It changes the flavour and/or colour of food

10. DRYING OR DEHYDRATION is defined as the application of heat under controlled conditions to remove the majority of water normally present in a food by evaporation. The main purpose of drying is to extend the shelf life of foods by reduction in water activity. This inhibits microbial growth and enzyme activity but the product temperature is usually insufficient to cause inactivation.



When hot air is blown over a wet food, heat is transferred to the surface and latent heat of vaporization causes water to evaporate. Water vapor diffuses through air.

When a liquid phase vaporizes to a vapor phase under its vapor pressure at constant temperature, the amount of heat needed is called the **latent heat of vaporization.**

11. DISTILLATION

Aim: Separation of components of liquid solution by boiling because of their differences in vapor pressure, which depends upon the distribution of these various components between a vapor and a liquid phase.

Example: distillation of alcohol-water solution in Rakı production.

Rakı is the distilled alcoholic beverage produced by fermentation of grape or raisin.

Grape → Ethanol-water mixture + grape pomace

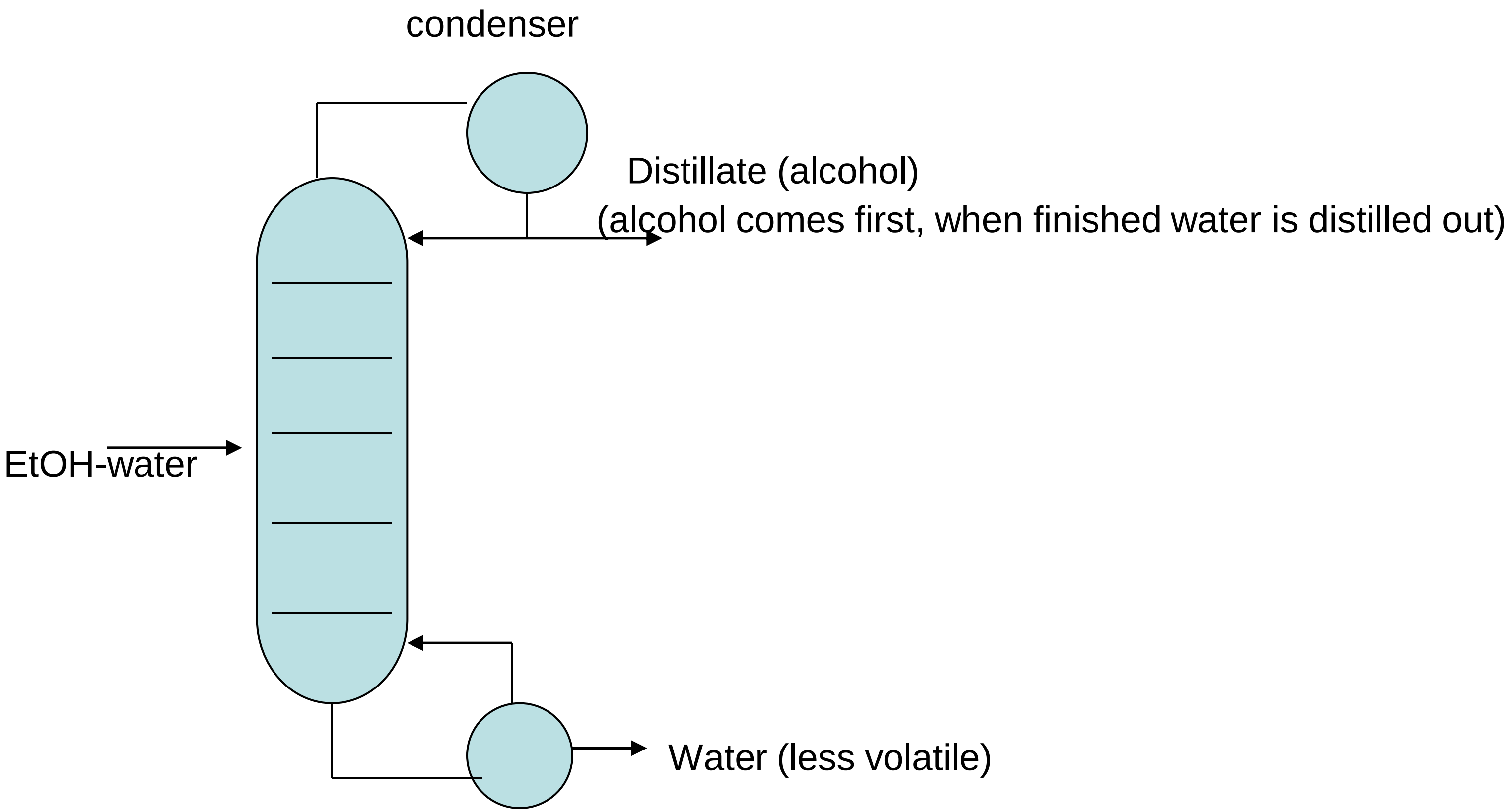
Ethanol-water mixture → Distillation → Ethanol+aniseed → Rakı

Distillation → Water

Fermentation is a chemical change brought about enzymes or living enzymes such as bacteria. During fermentation; large molecules are converted into small molecules:

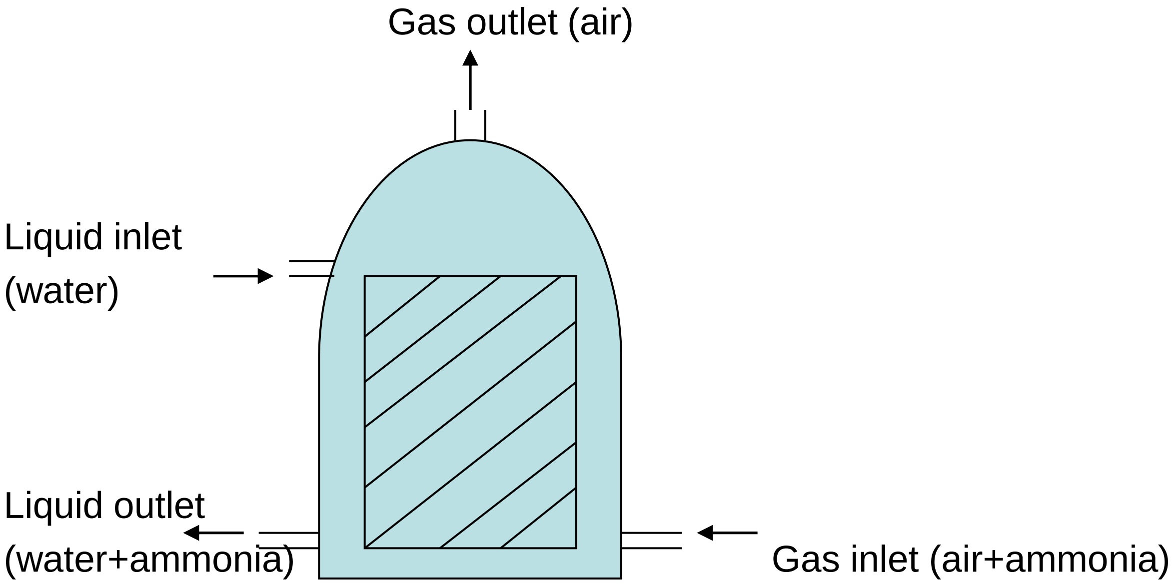
a) Milk ⟶ Yoghurt (acidulation of milk)
(lactose ⟶ lactic acid)

b) Starch or sugar ⟶ Ethanol+ CO_2 (decomposition of sugar)

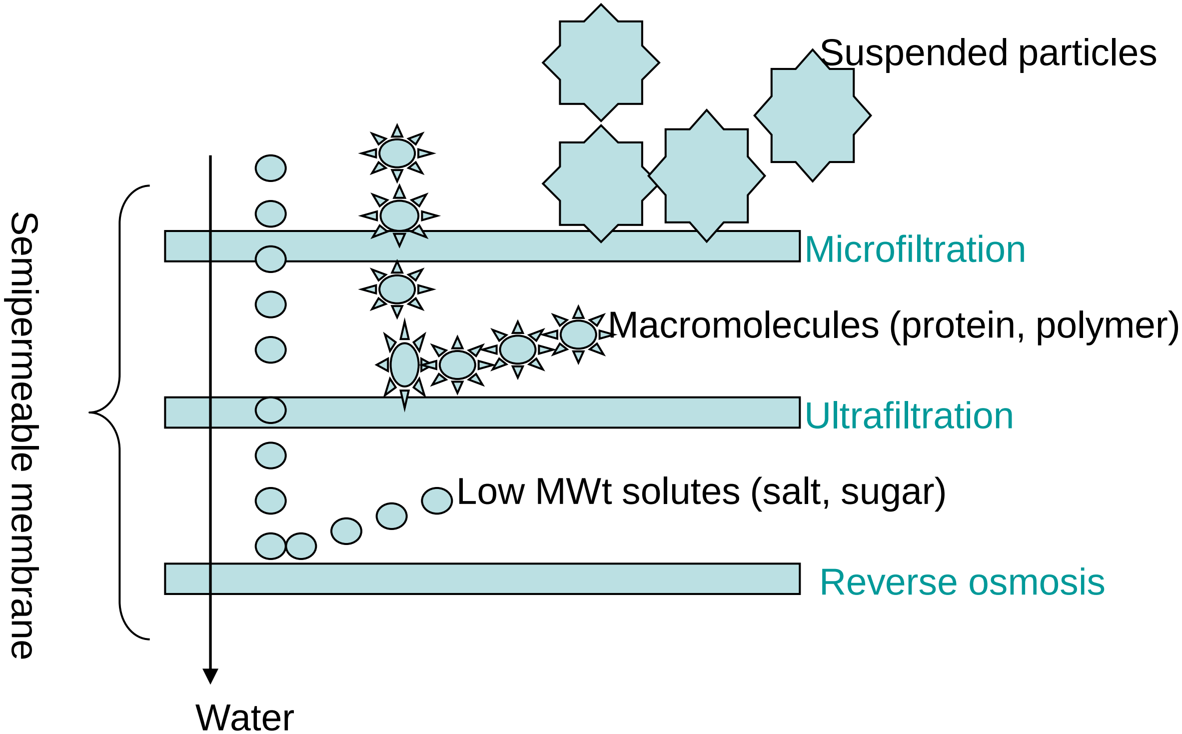


12. ABSORPTION When two contacting phases are a gas and a liquid, unit operation is called absorption.

Aim: absorption of solute from gas phase into liquid phase. For example; absorption of ammonia from air by liquid water. A common apparatus used for gas absorption is called packed tower.

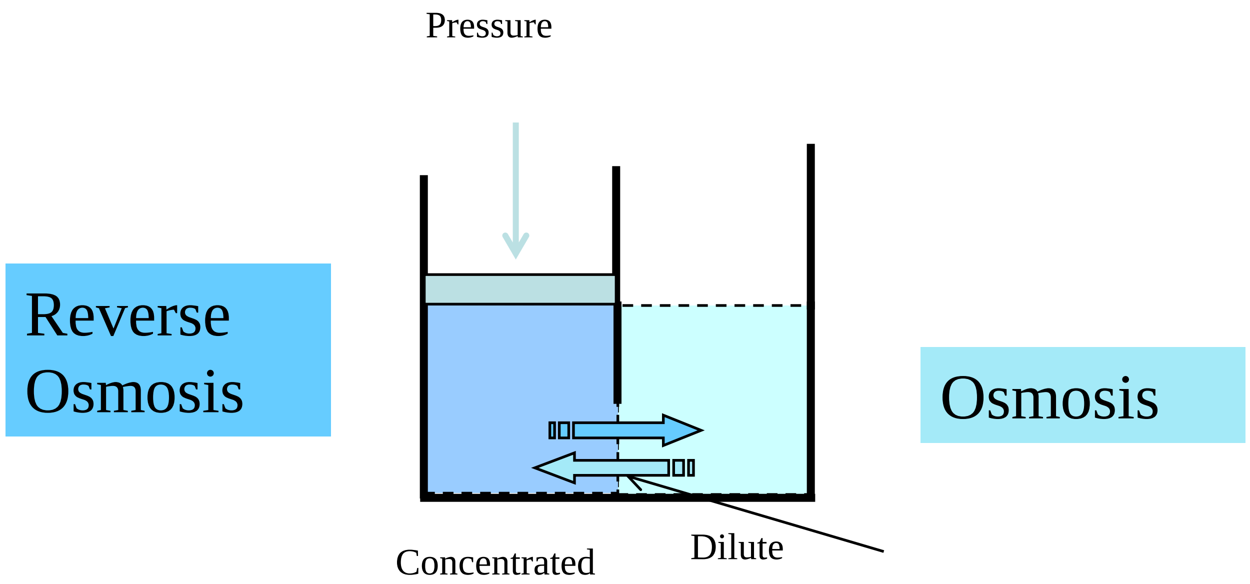


13. MEMBRANE SEPARATION The process involves the diffusion of a solute from a liquid or gas through a semipermeable membrane barrier to another fluid.



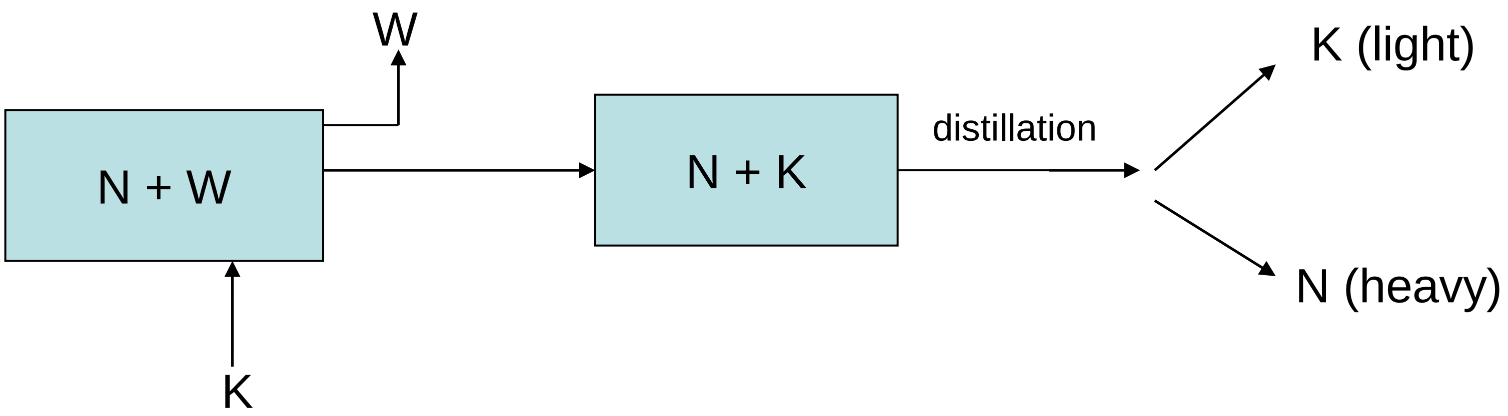
If the osmotic pressure of solution and that of solvent are different, the outward movement of solute will be accompanied by inward movement of pure solvent (osmosis).

Reverse osmosis: water movement from conc. Sol’n to dilute sol’n



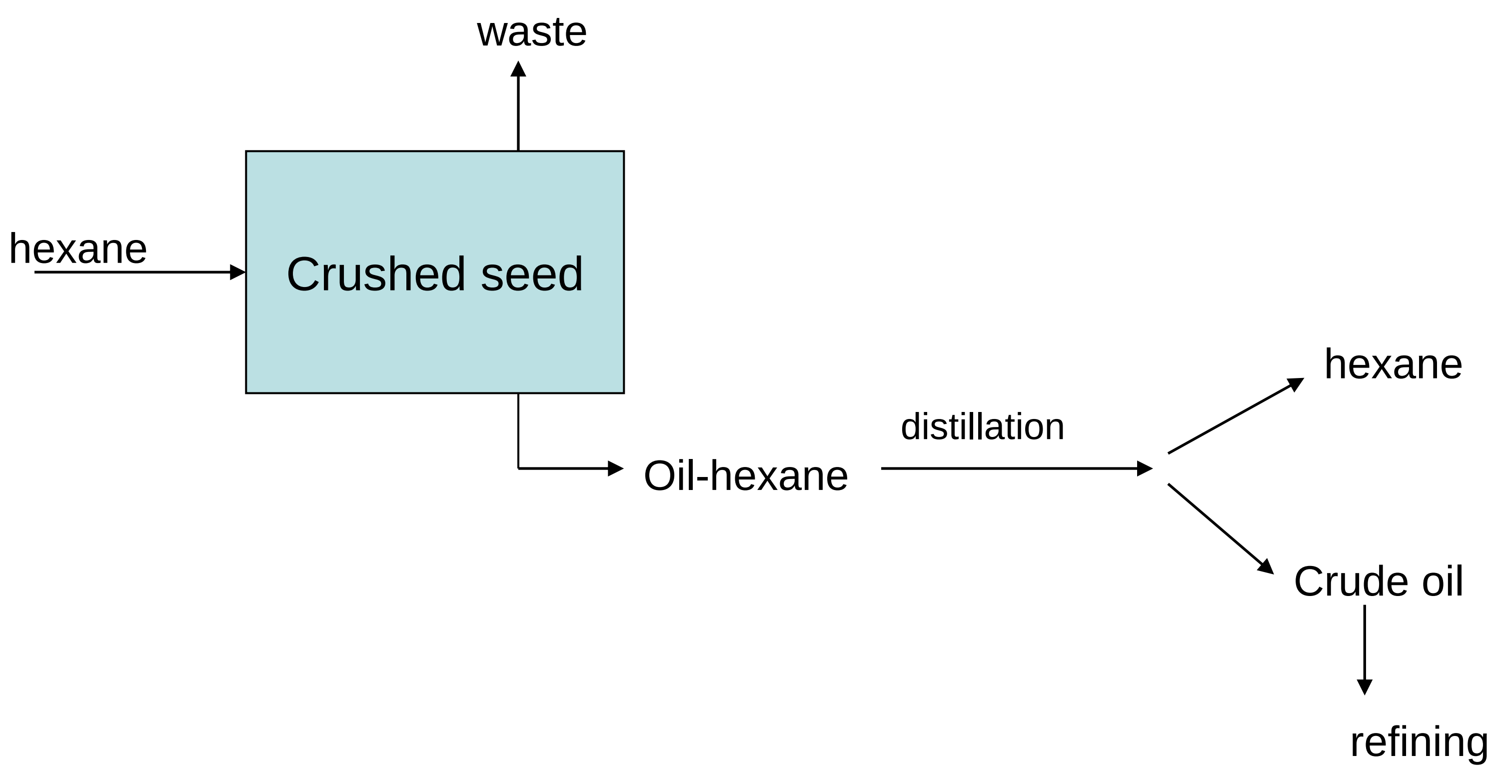
14. LIQUID-LIQUID EXTRACTION In this case a solute in a liquid solution is removed by contacting with another liquid solvent which is relatively immiscible with the solution.

Example: extraction of nicotine (N) in water (W) with kerosene (K);



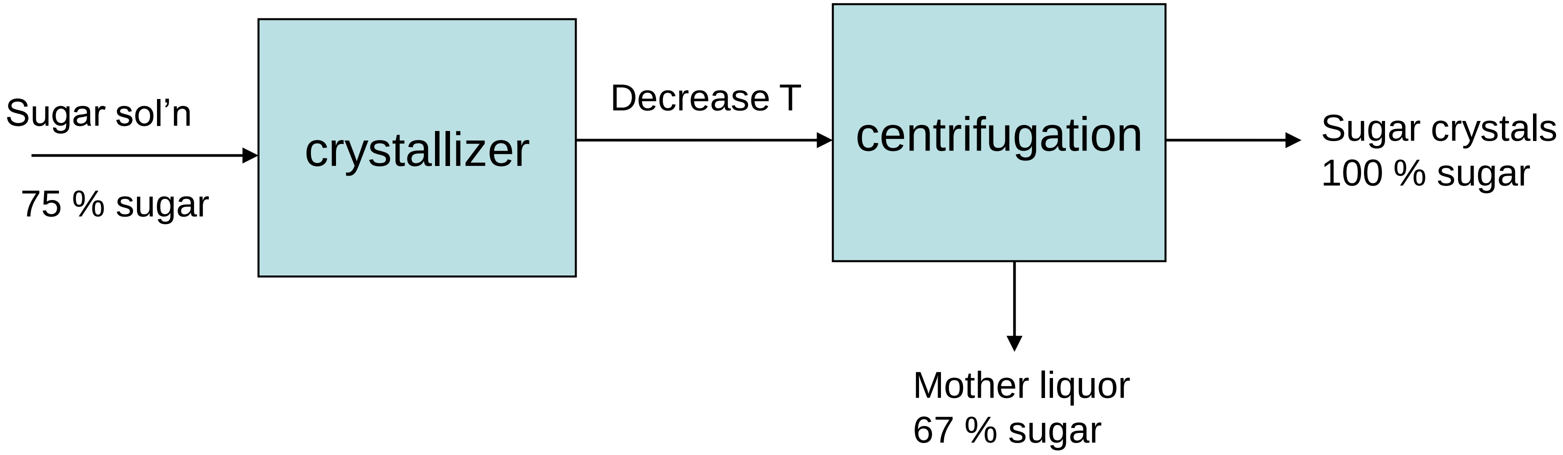
15. LIQUID-SOLID EXTRACTION (LEACHING): This involves treating a finely divided solid with a liquid (solvent) that dissolves out and removes a solute contained in the solid.

Example: extraction of oil from oil seeds by organic solvent, extraction of sugar from sugar beet.



16. CRYSTALLIZATION: This concerns the removal of a solute such as salt (or sugar) from a solution by precipitating the solute from the solution.

Example: crystallization of sucrose



17. PACKAGING

Purposes of packaging:

- Protect the food from microbial contamination, physical dirt, insect invasion, light, moisture pick up, flavor pick up,
- moisture loss, flavor loss, physical abuse
- Containment for shipping
- Unitizing into appropriate sizes
- Improve the usefulness of the product

Foods are packaged in: metal cans, glass and plastic bottles, paper and paperboard, a wide variety of plastic and metallic films, and combinations of these, by automatic machines.

Milk is packaged in paper cartoons. Containers are automatically formed from stacked paper flats, volumetrically filled, and sealed.

NEW PROCESSES

New processing technologies are constantly being developed :

Supercritical fluid extraction:

Uses gases such as carbon dioxide at high pressures to extract or separate food components. Example; extraction of caffeine from coffee to obtain decaffeinated product.

Ohmic heating:

The temperature of particulates in a conducting medium is raised quickly. Example; soups

High hydrostatic pressure:

Liquid foods such as fruit juices and beverages or particulate foods suspended in liquid are subjected to pressures as high as **several thousand atmospheres** Inactivate **microorganisms** and in some cases **enzymic activity**

FOOD SYSTEMS AND FOOD DISPERSIONS

FOOD SYSTEMS

-Edible tissue

a) fruits

b) vegetables

c) meat

FOOD DISPERSIONS: is a continuous phase with one or more dispersed phases.

a) milk

b) tomato juice

c) mayonnaise

PHYSICAL STATE OF INGREDIENTS IN FOOD SYSTEMS

Food Dispersions

1. True solution
2. Colloidal dispersion
3. Emulsion
4. Foam
5. Gel

Dispersions

1. Continuous phase
2. Dispersed phase

   May be solid, liquid, or gas.

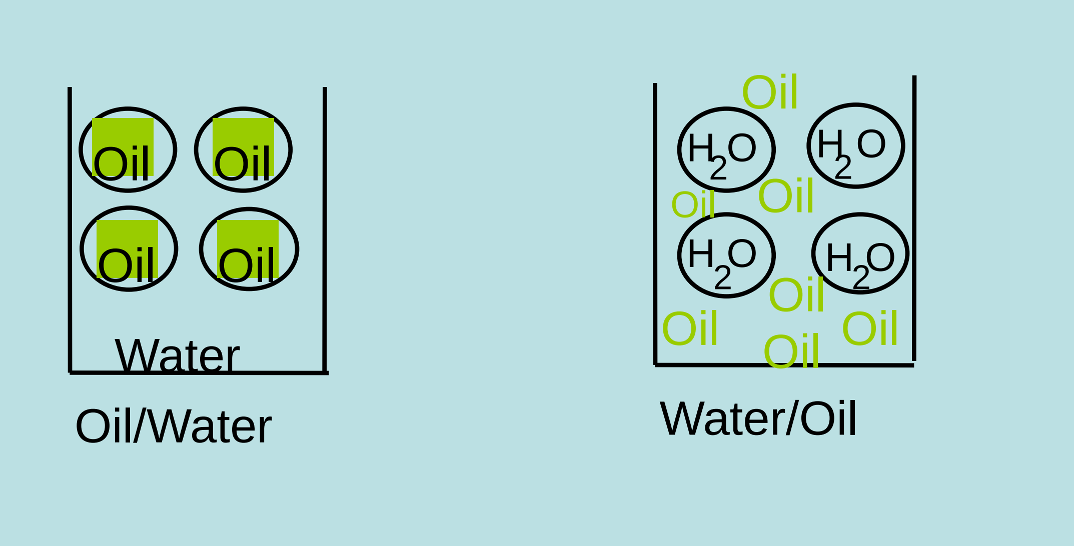
FOOD DISPERSIONS

Dispersed Phase	Continuous Phase	Name of Dispersion	Examples
Liquid (L)	Solid (S)	Gel	Gelatin
Solid (S)	Liquid (L)	SOL Colloidal disp.	Milk
Liquid (L)	Liquid (L)	Emulsion	Salad dressing
Gas (G)	Liquid (L)	Foam	Meringue
Gas (G)	Solid (S)	Solid Foam	Foam candy
Solid (S)	Gas (G)	Solid Aerosol	Smoke for flavoring food

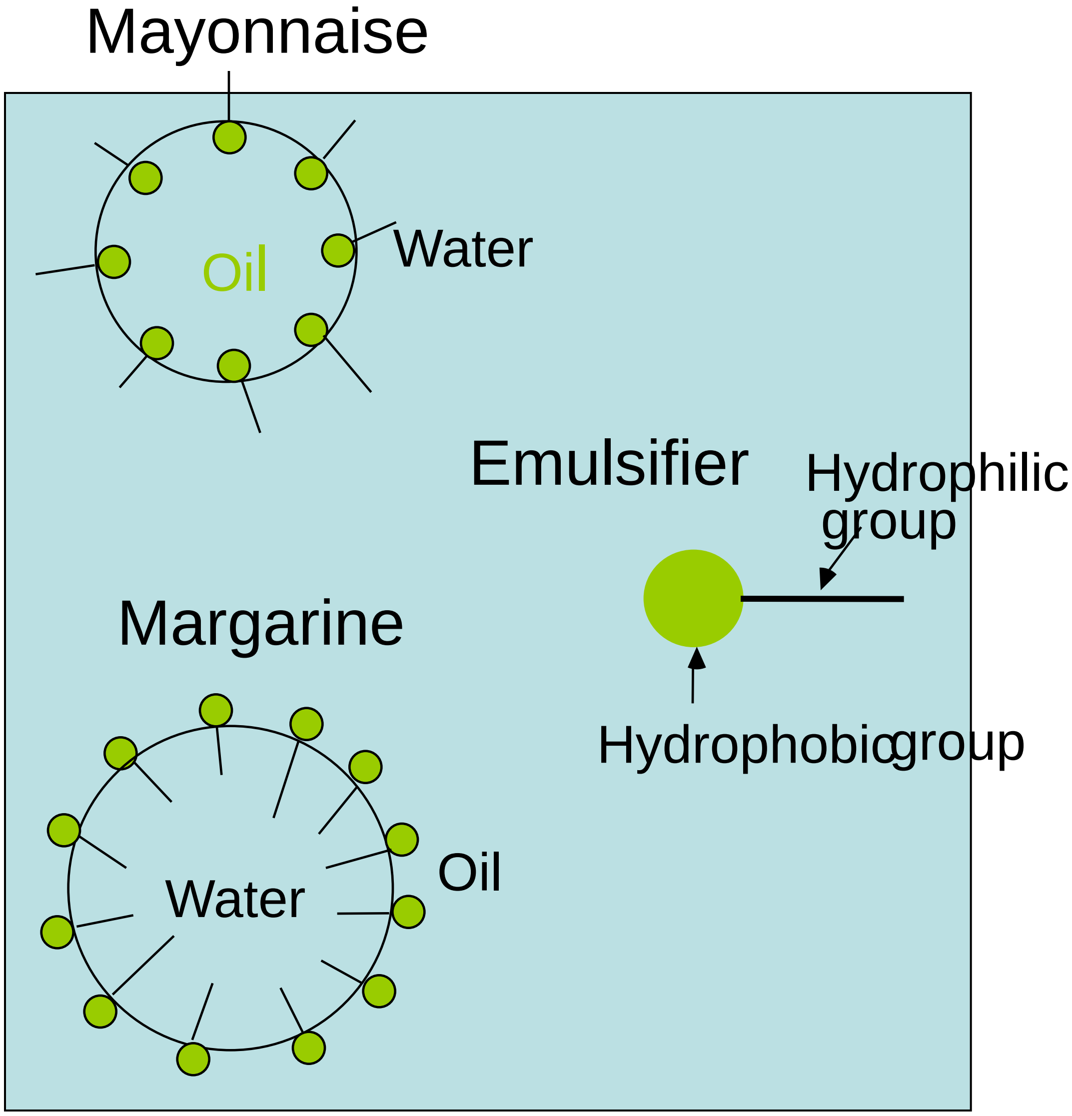
Emulsions

Liquid/liquid systems of 2 immiscible substances are called emulsion. Substances or particle size = 10-100 microns.

Examples: butter (w/o), margarine (w/o), mayonnaise (o/w), salad dressing (o/w), milk (o/w), cream (o/w), and chip-dip (o/w).

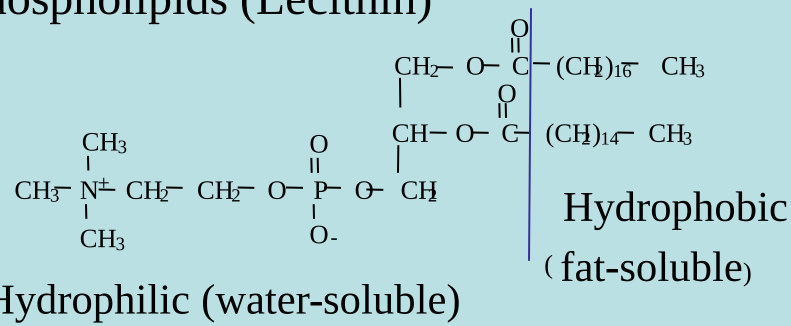


EMULSIFIER: To stabilize emulsion, emulsifying agents are generally used which lower the interfacial tension

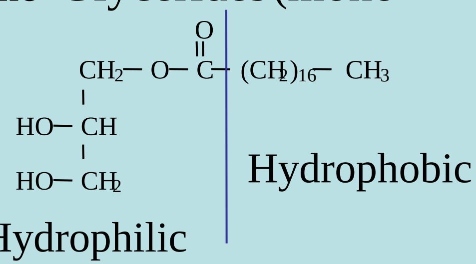


CHEMICAL STRUCTURE OF EMULSIFIERS

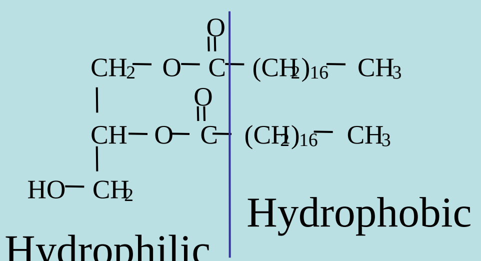
Phospholipids (Lecithin)



Mono-Glycerides (mono-stearate)



Di-glycerides (di-stearate)



Breakdown of Emulsions

- Creaming: formation of two emulsion layers

- Flocculence: agglomeration of droplets

- Coalescence: irreversible union of small droplets leading to the separation of two phases.

FOAM

Gas is dispersed in liquid or semi-liquid.

Dispersed-phase: gas

Continuous-phase: liquid

Examples; Ice-cream, cake, head on beer, etc.

It requires a 3rd component possessing protective or stabilizing properties to maintain the dispersion.

GEL

Gels can be defined as a 3-d polymeric network holding large quantities of solvent showing mechanical rigidity.

-semi-solid state with 2 continuous phases.

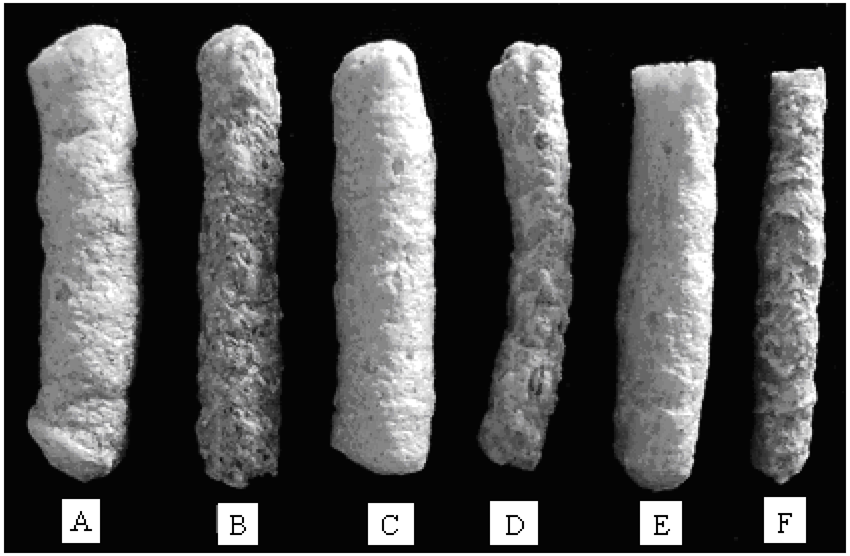
Continuous phase of interconnected particles and/or macro-molecules intermingled with a continuous phase of liquid phase such as water.

Examples: jello, jam

FOOD STRUCTURE

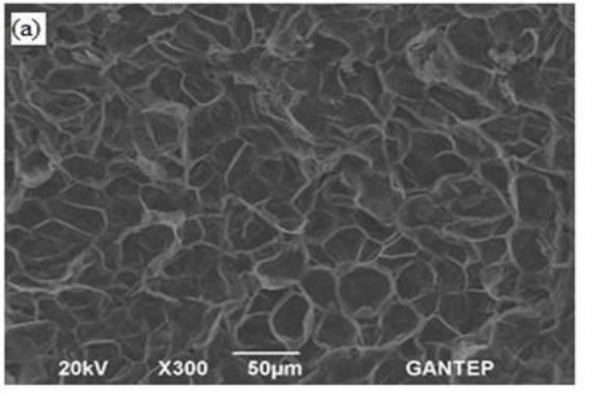
Foods are highly structured, multicomponent materials.

Proteins, carbohydrates and sometimes lipids interacting in an aqueous environment determine the native or processed structure of foods.



The majority of the food we eat has a defined structure. Even an apparently simple liquid such as milk contains protein micelles, stabilised fat droplets and dissolved proteins; all of which contribute to its appearance, taste and texture.

The integrated relationship between chemical components-structure-textural properties is a determinant in the acceptability and desirability of many foods.



It is possible to classify the food materials into three types according to their structures

1. Liquid solutions and gels

    (carbohydrates, milk, fruit juices,..)

2. Capillary-porous rigid materials

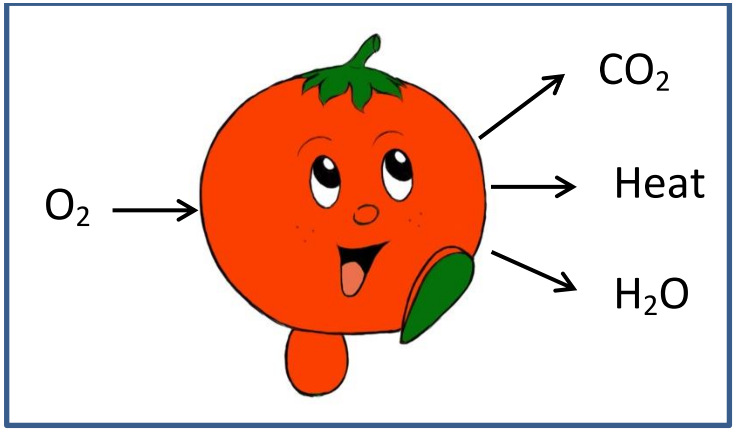
    (wheat, corn,…)

3. Capillary porous colloidal materials (they have the properties of the first two bodies)

    (vegetables, meats,….)

PRESERVATION OF FOODS

Vegetable tissue continue to respire although they have been separated from the parent body.



Animal tissue do not continue to respire but enzymatic changes can take place.

During the ordinary storage;

- Color loss
- Flavor loss
- ..
- ..
- So decay takes place
    - Results in unusability

The reasons of these deteriorations

- water
- air
- light
- temperature
- enzymes
- inorganic catalysts (such as traces of metals)
- microorganisms

Shortly, physical, chemical, enzymatic and microbial changes do occur!!!

A

Physical Changes

- Swelling
- Shrinkage
- Loss of volatiles
- ..

Chemical Changes

- Oxidation in fats
- Browning reactions
- ..
- ..

Biochemical Changes

Due to the activity of native enzymes in foods

Examples are;

- Fat cleavage by LIPASES
- Breakdown of proteins by PROTEASES
- Enzymatic oxidation by PHENOLASES, …

Microbial Changes

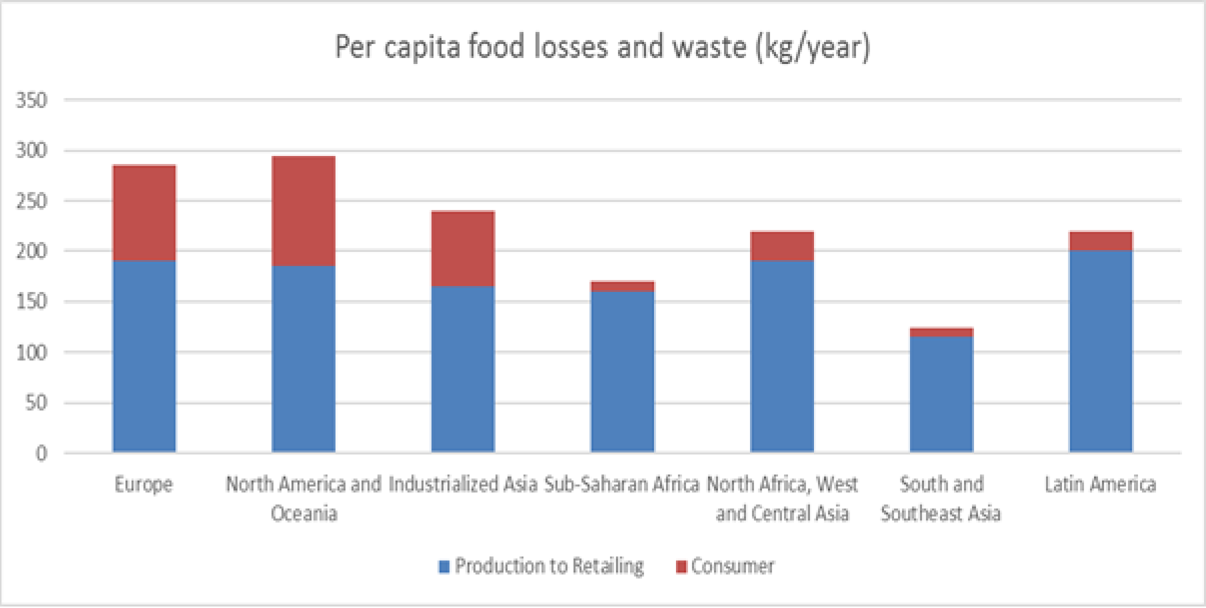
- Fermentation
- Moldiness
- Rottenness
- Formation of mycotoxins (e.g.; aflatoxin)

The easiest way to consume the foods while they are fresh.

However, it is difficult, because in certain seasons, many foods are overabundant.

The aim of the methods of food preservation

- To prolong keepability, palatability and nutritional quality of the natural products
    - Simply to preserve the foods



Methods of food preservation can be divided into two;

1. Physical methods
    - Cooling processes
    - Freezing processes
    - Sterilization
    - Pasteurisation
    - Drying
    - Irradiation
    - Filtration
    - …

2. Chemical methods

- Salting/Curing
- Smoking
- Sugaring
- Acidifying
- ….

Cooling and Freezing Processes

COOLING

- It is based on slowing down the decay at low temperatures
- Temperatures between +4 and -2 °C are used in the cold storage of fruits and vegetables.

- In many vegetable and animal foods the enzymatic processes continue during cold storage; this limits the usefulness of preservation using these temperatures alone.
- So it has a limited period.
- Cold storage can be continued longer if at the same time inert, neutral gases are used for atmospheric protection.

Cooling and Freezing Processes

FREEZING

- The temperatures used freeze the greater part of the cell fluids in anmal and plant tissues and so kill the cell.
- After the cells have been killed by freezing the enzymes present are still active and the enzymatic processes in the cell do not necessarily cease until a temperature of -40 °C is reached.
- To store at a temperature of -22 °C, product quality approaches the quality (taste, color, consistency, and nutrient content) of natural fresh foods.

Cooling and Freezing Processes

- Blanching is necessary to prevent any enzyme activity before freezing (for vegetables)

- Microorganisms are also affected by cold. In general no bacteria or fungi grow at below -12 C.

- The spores of bacteria and viruses are very resistant to cold.
- Growth and toxin formation is limited to the period before freezing and after thawing. But toxins which may have been formed before freezing and after thawing will not be destroyed by freezing.

Freezing systems can be classified into two groups

- 1. Direct contact system
- 2. Indirect contact system

Refrigerant: is a substance (chemical compounds), that is used in a refrigeration cycle to cool a space.

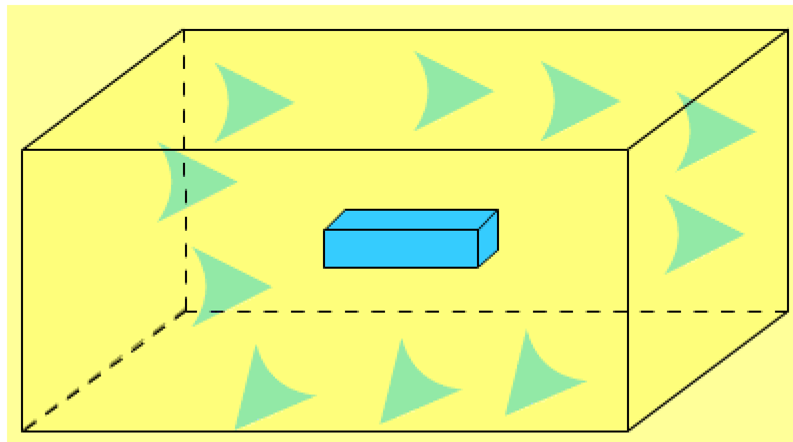
Refrigerants; nitrogen, carbondioxide, R407C, R507A

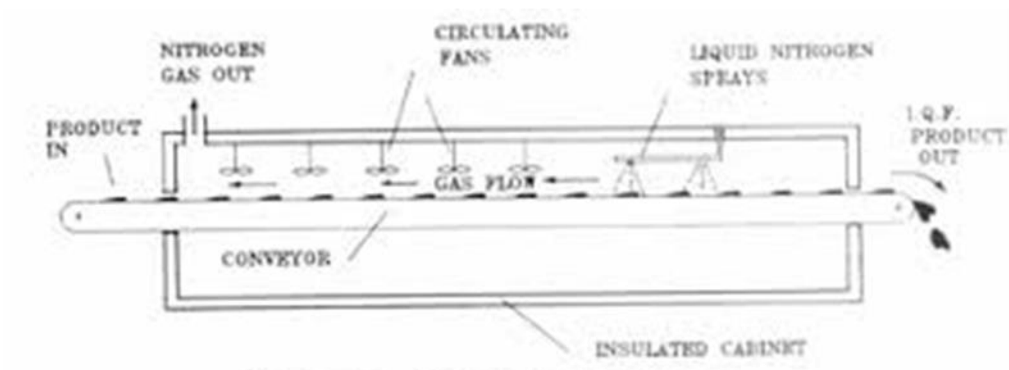
-Low boiling point (carbondioxide -78,46 °C)

- Inert

1. Direct contact system

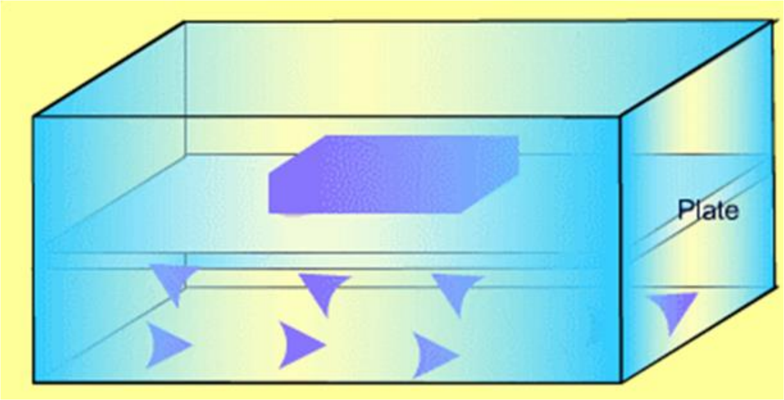
The product is in contact with the refrigerant.

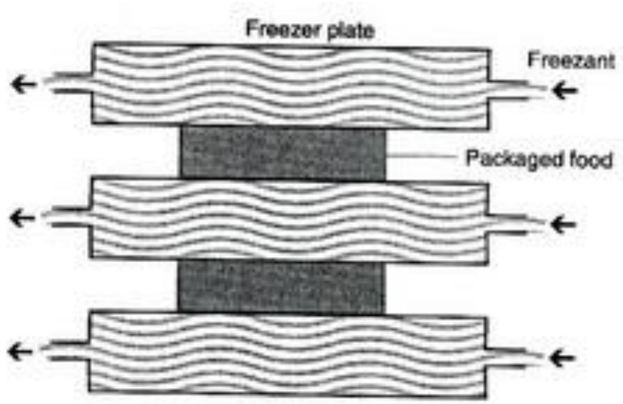




2. Indirect contact system

The food is separated from the refrigerant by some types of barrier (plate).





The rate of freezing is important

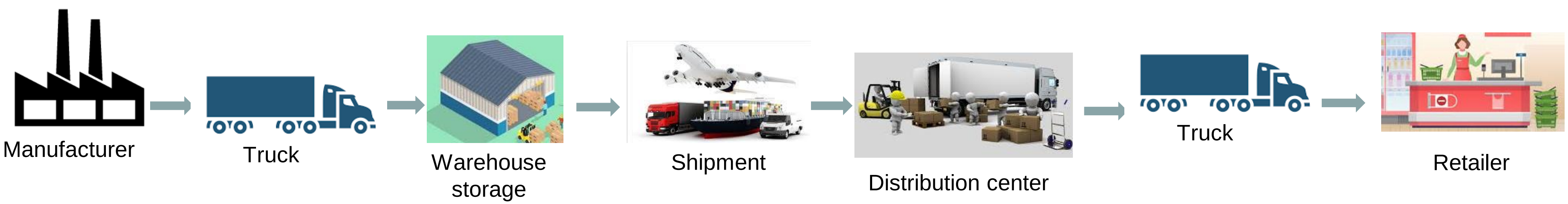
Fast freezing is desirable

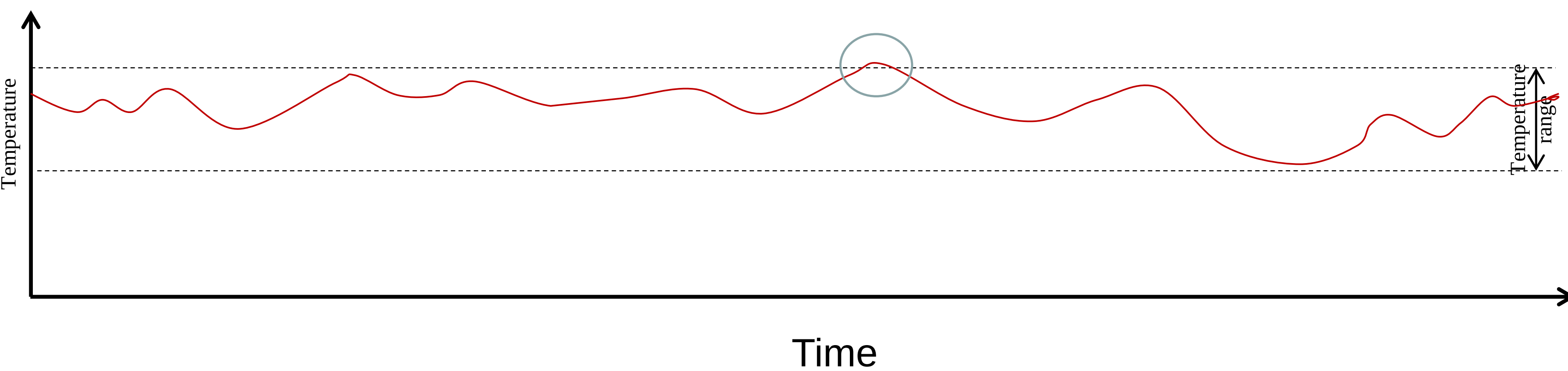
Fast freezing	Slow freezing
Ice crystals are small	Ice crystals are big
No damage of food cells	Damage of food cells
Deterioration is avoided	Loss of texture, color, flavor, ..
	

Cold chain:

The cold chain involves the transportation of food products along a supply chain through thermal and refrigerated packaging methods and the logistical planning to protect the integrity of the food products.

The cold chain must never be broken.





Sterilisation and Pasteurisation

PASTEURISATION

- Pasteurization reduces the microbial load and thus increases the shelf life of the product.
- The moderate heat treatment of pasteurization allows the destruction of pathogenic microorganisms, and a large number of spoilage microorganisms.
- The applied temperature is generally less than 100°C.
- All germs present are not eliminated, so the pasteurization stage must be followed by a rapid cooling.
- The conservation of pasteurized products is potentially short because the product has a temporary stabilization.
- Some examples of pasteurized products are : milk, ready-made meals in trays, sauces in pouches, vegetable soups in jars...

STERILISATION

- Sterilisation is intended to destroy all germs and particularly pathogenic bacteria in their vegetative and sporulated form.
- The temperature during the stop in this case is higher than 100°C.
- Sterilization therefore makes it possible to stabilize the product at room temperature permanently and to obtain a long shelf life (from a few months to a few years depending on the product).
- Some examples of sterilized products are: canned fish, babyfood in jars, canned or jarred vegetables, sauces in pouches, bottled milks, pet food in pouches, in trays, babyfood in pouches).

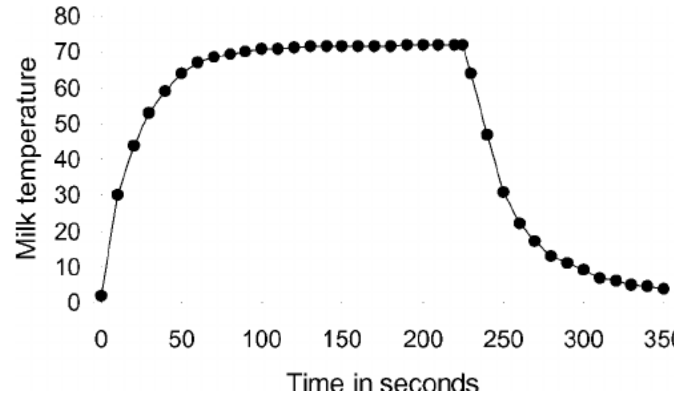
UHT STERILISATION

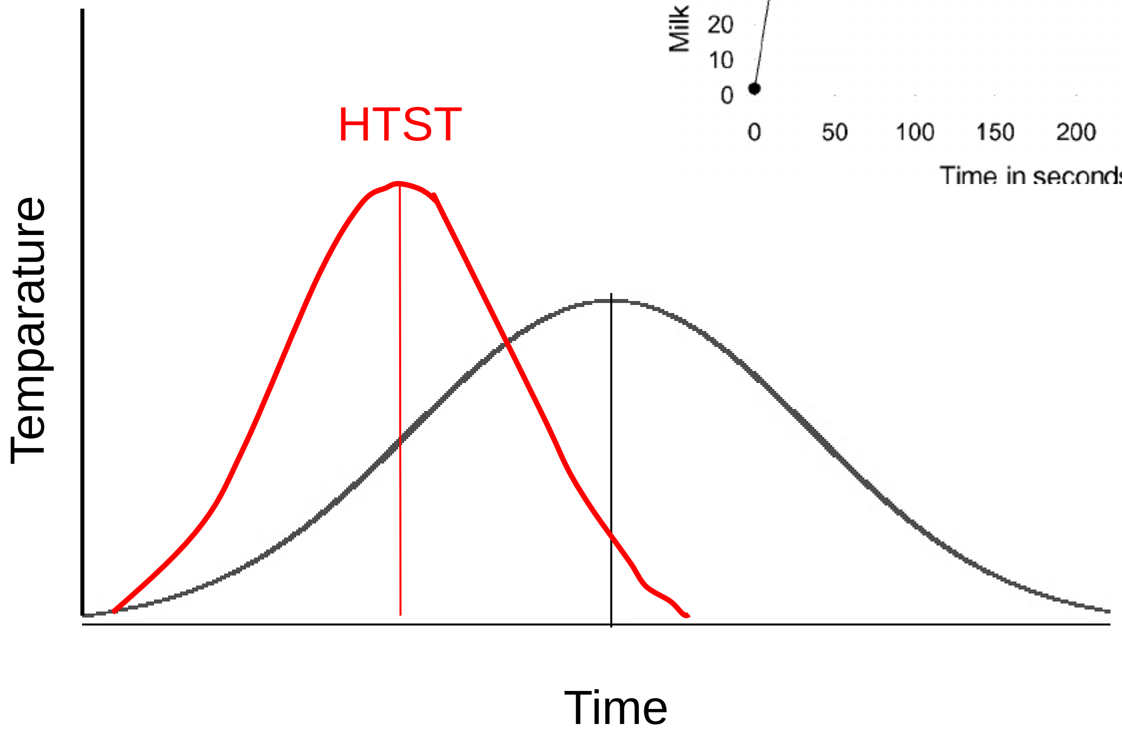
UHT treatment means a very short heat treatment at temperature of approximately 140°C (135 -150˚C) for only a few seconds. This results in a sterilised product with minimal heat damage to the product properties. UHT treatment is only possible in flow-through equipment. The product is thus sterilised before it is transferred to pre-sterilised containers in a sterile atmosphere. Example; UHT milk.

Differences between sterilisation and pasteurisation

Pasteurisation	**Sterilisation**
temperature is generally less than 100°C	temperature is higher than 100°C
Kills all pathogenic microorganisms, and a large number of spoilage microorganisms	Sterilization kills all microorganisms and their spores
Product has a shorter shelf life	Product has a longer shelf life
Can be accomplished with heat	Can be accomplished in many ways

HTST Treatment

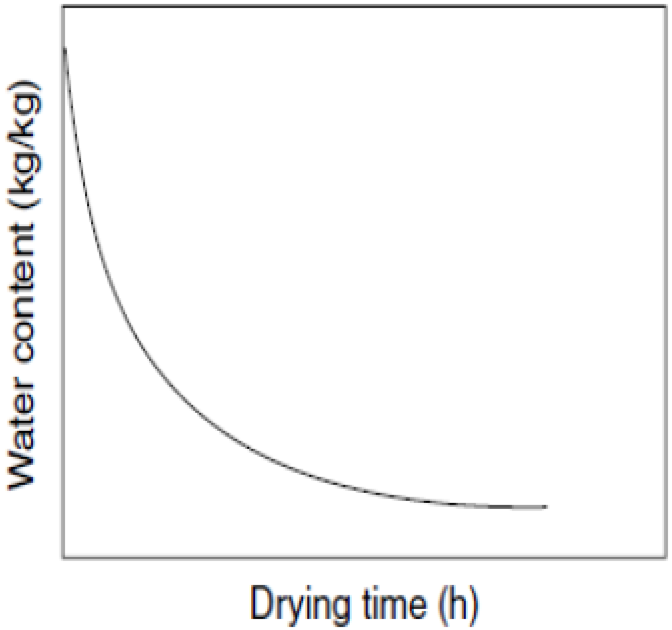




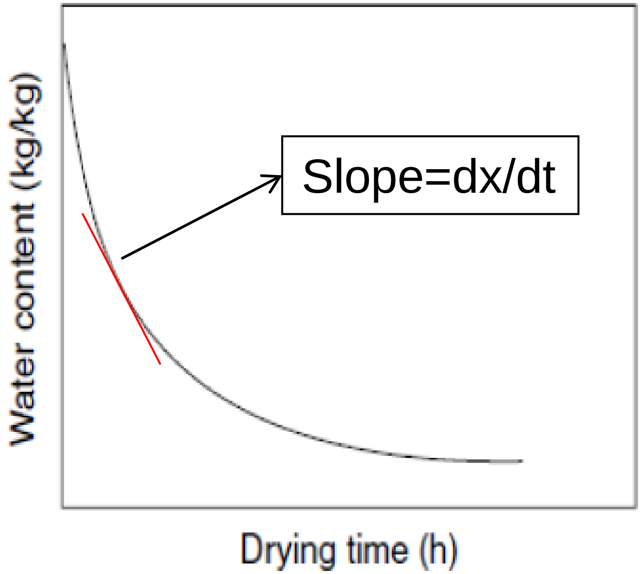
Dehydration of Foods

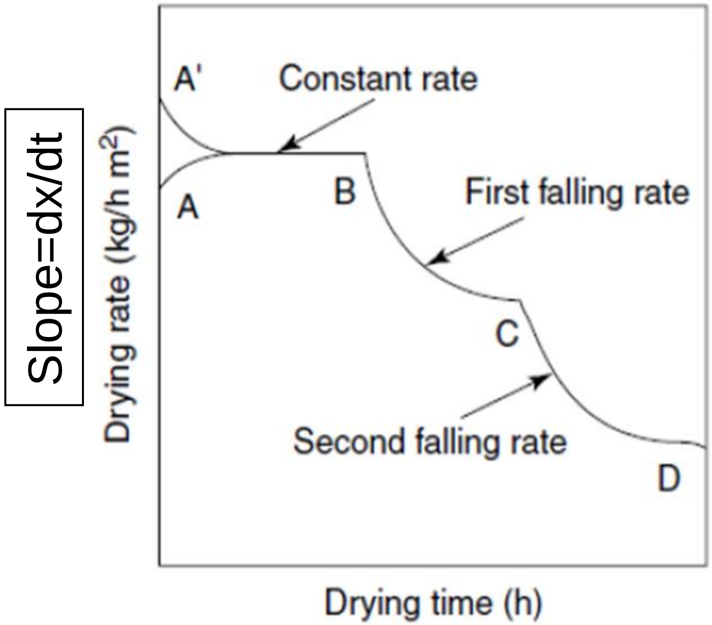
The aim of drying is

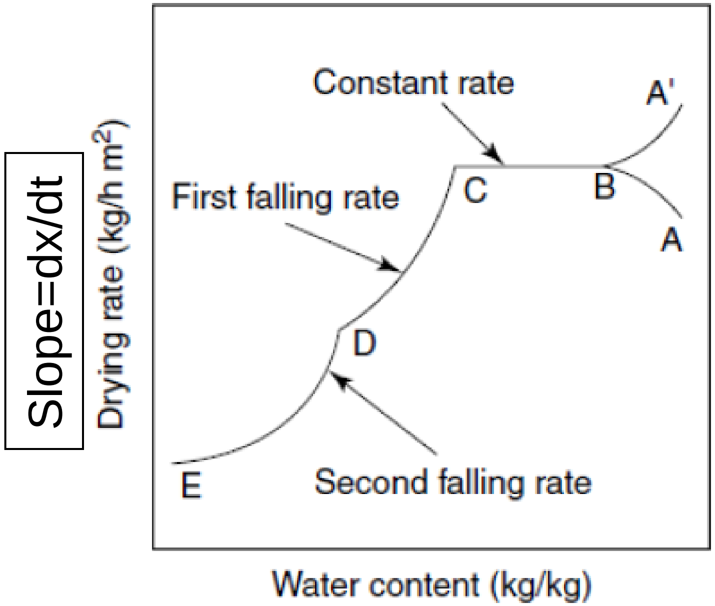
- to inhibit chemical and enzymatic reactions
- to prevent microbial growth



A typical drying curve







Typical drying rate curves

Changes in food during drying

- Growth of microorgansims
- Enzymatic changes
- Chemical conversions
- Physical changes

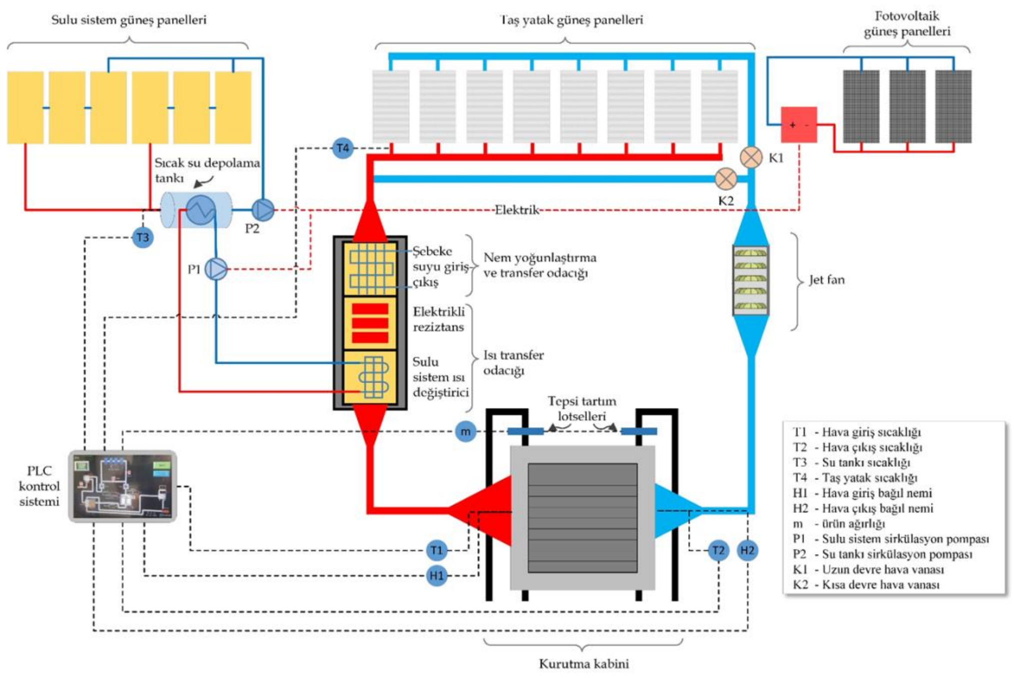
These changes depend on

- Temperature
- Water activity
- Time
- Structure of foodstuff
- pH
- Oxygen
- …

During drying processes

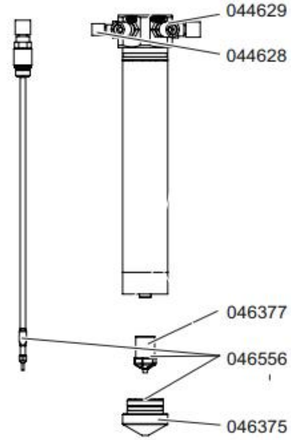
The heat is introduced and applied in various ways

- Conduction
- Convection
- Radiation

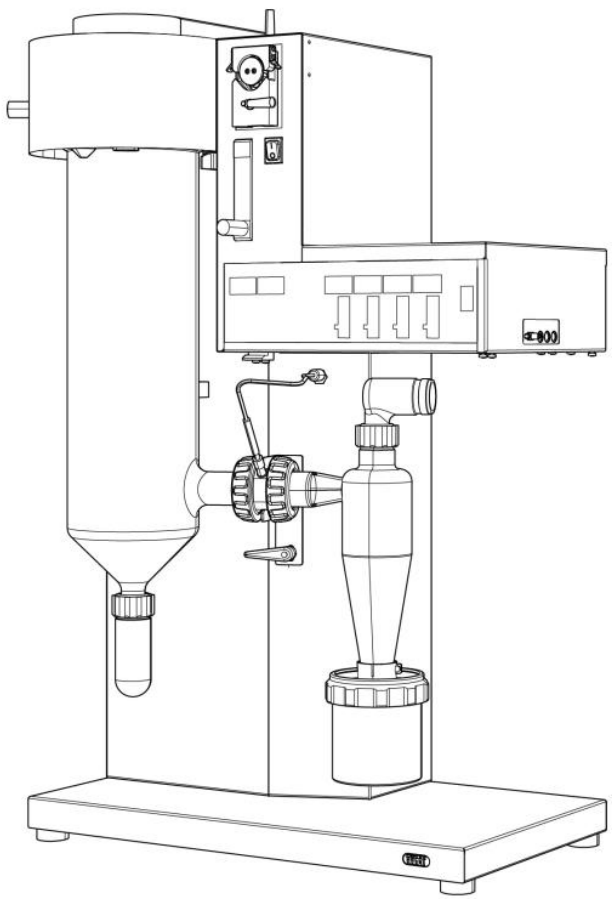


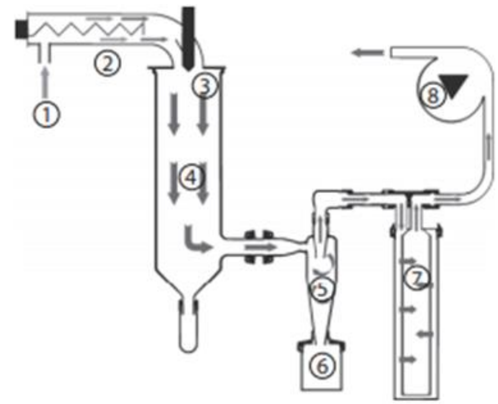
SPRAY DRYING (Atomisation)

- Liquid material converted into a spray by a nozzle
- The water is removed by a hot air or gas stream in a drying tower

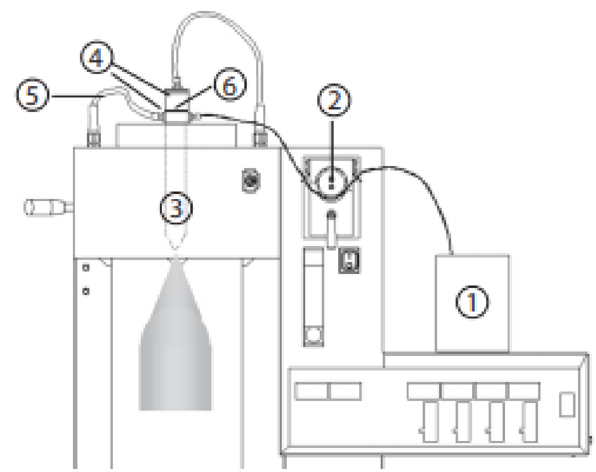


SPRAY DRYING





Principle of drying gas



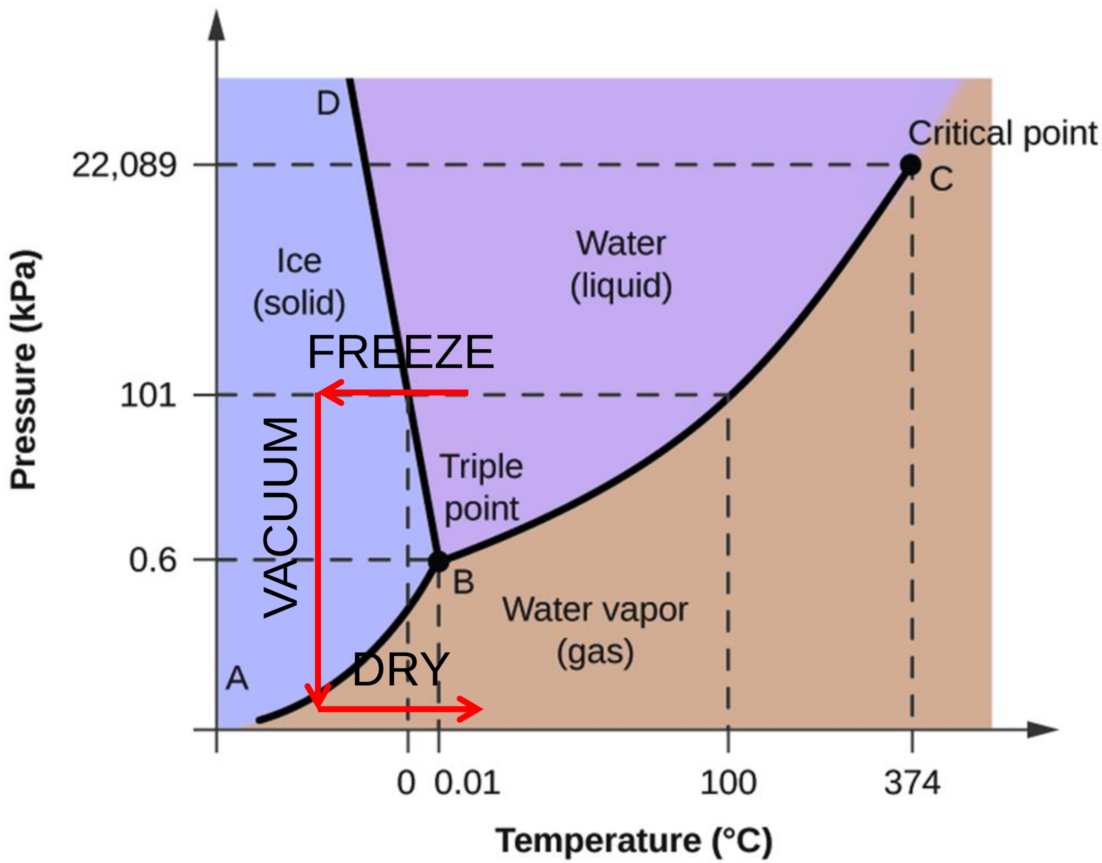
Principle of feed

FREEZE DRYING (Lyophilisation)

Lyophilization and freeze drying are terms that are used interchangeably depending on the industry and location where the drying is taking place.

Controlled freeze drying keeps the product temperature low enough during the process to avoid changes in the dried product appearance and characteristics.

FREEZE - The product is completely frozen, usually in a vial, flask or tray.
VACUUM - The product is then placed under a deep vacuum, well below the triple point of water.
DRY – Heat energy is then added to the product causing the ice to sublime.



In freeze drying compared to ordinary air drying;

Flavor and color loss is minimum.

Hşgh vacuum means lack of oxygen (Vitamin C and aroma lost is minimum)

The product is very soluble and rehydration is easy because of their porous nature.

Disadvantage;

Freeze dried is more susceptible because of their high porosity

oxygen

water vapor

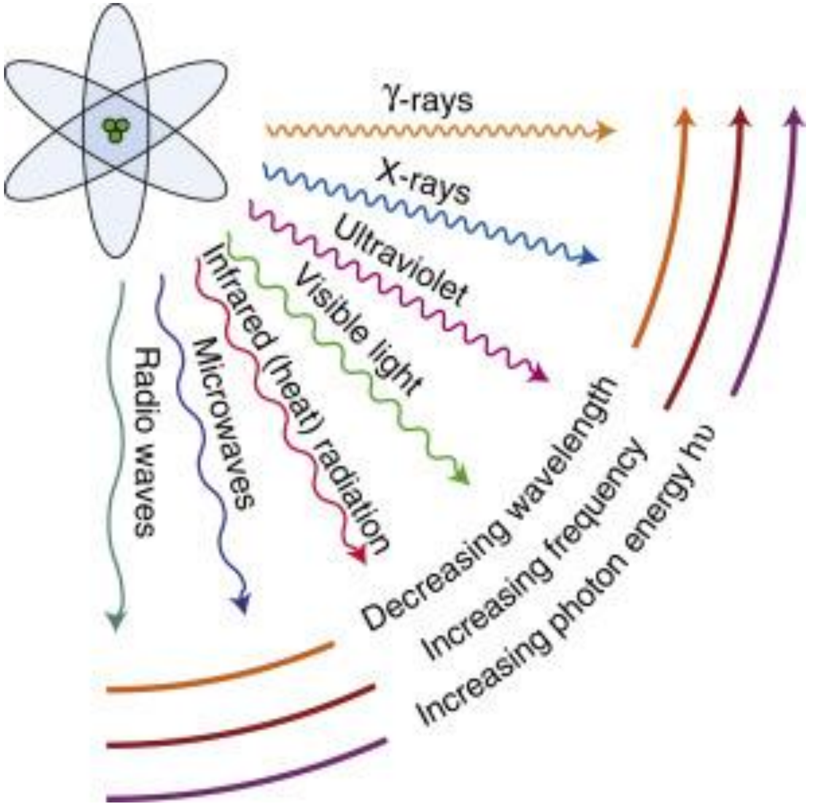
foreign odors

PACKAGING SHOULD BE PROPER

IRRADIATION

Electromagnetic radiation is a form of energy that propagates as both electrical and magnetic waves traveling in packets of energy called photons.

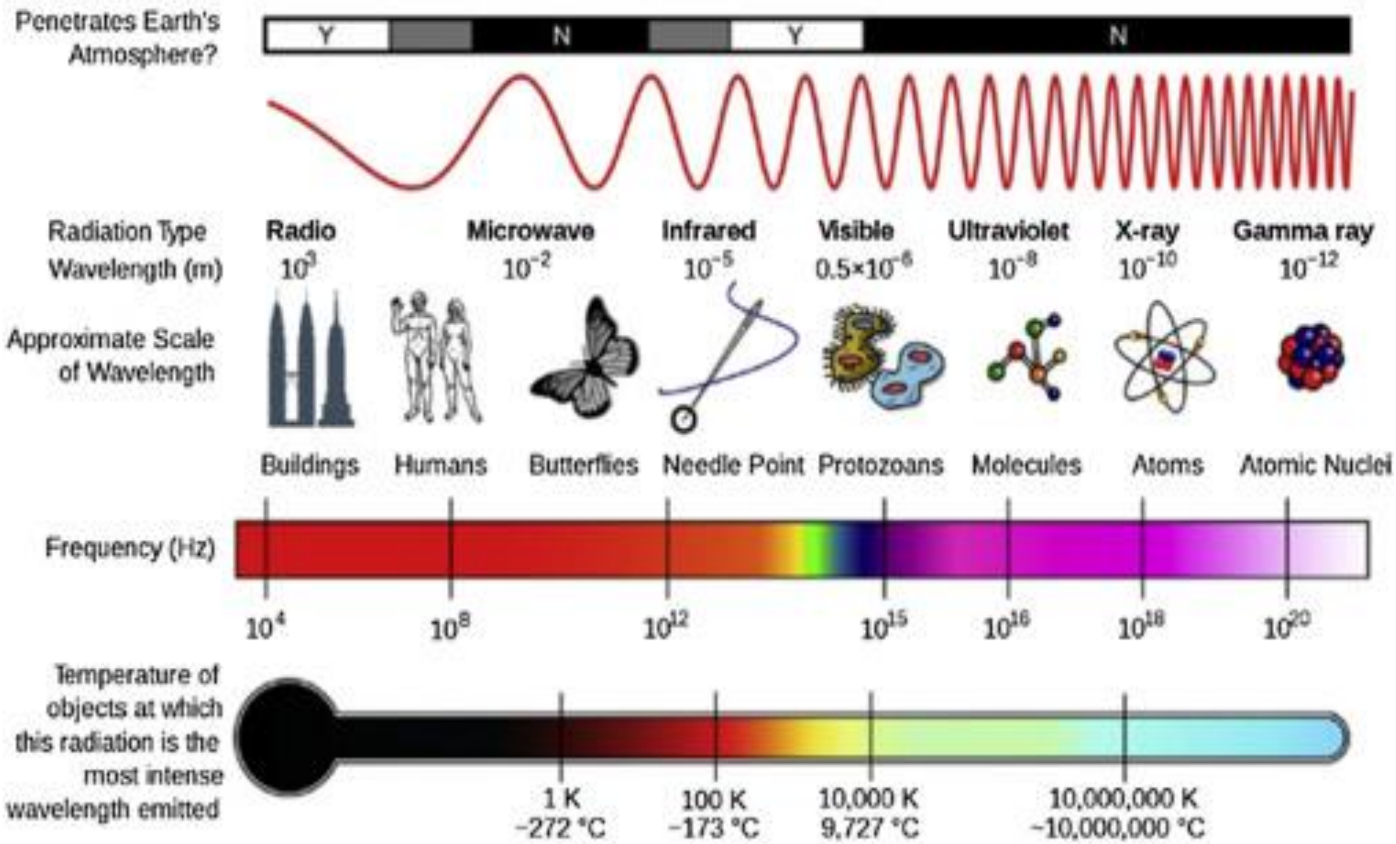
There is a spectrum of electromagnetic radiation with variable wavelengths and frequency.



There are 2 sources of radiation:

a) High energy rich sources: X-rays and Gamma rays

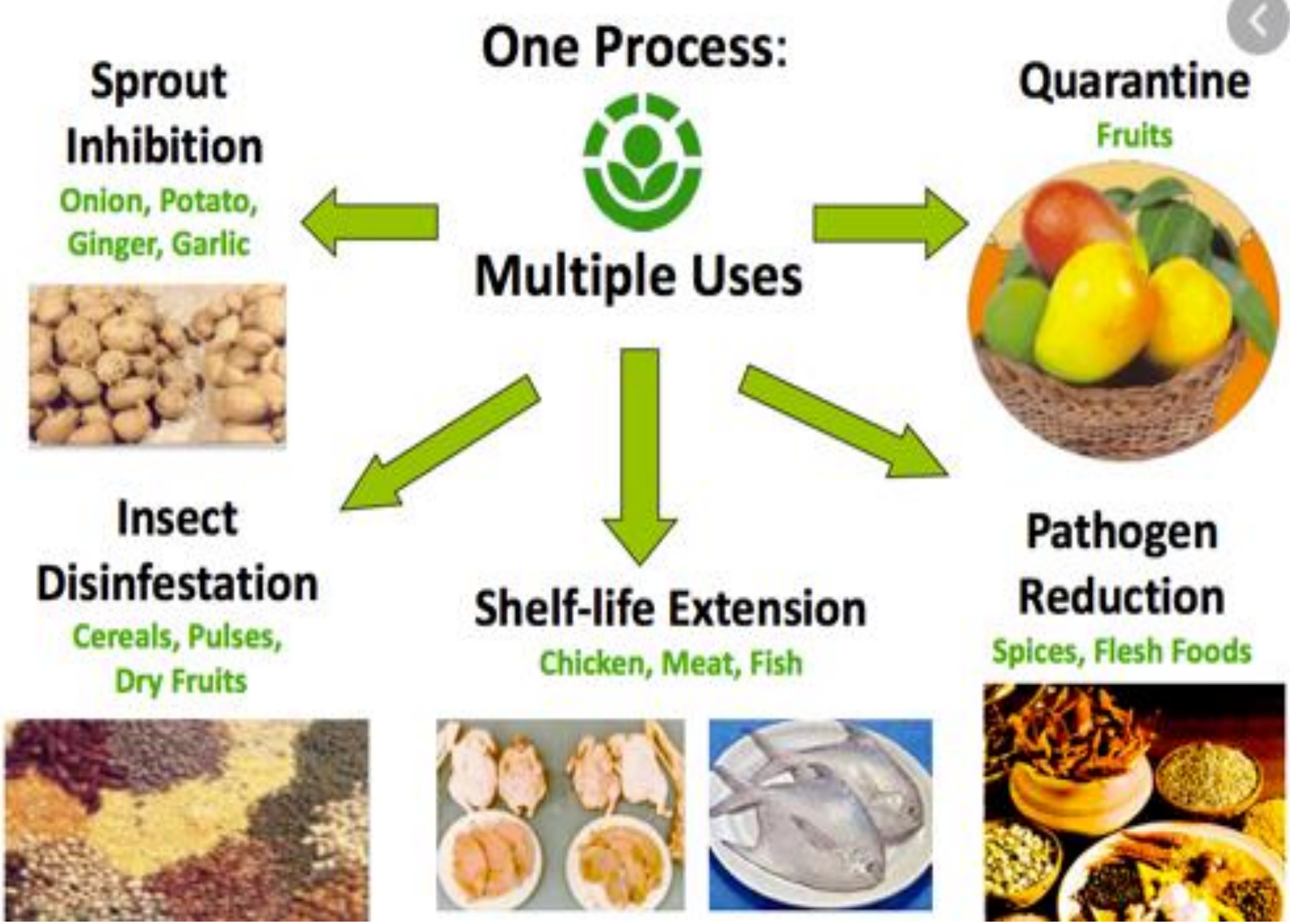
b) Low energy rich sources: UV and infrared radiation



Energy rich radiation: Food Irradiation

In principle, this process involves exposing food to ionizing energy in the form of X-rays, gamma rays or electrons in a special room for a specified duration.

Symbol indicating that a food product has been treated with ionizing radiation.


One Process:
Multiple Uses
Sprout Inhibition
Onion, Potato, Ginger, Garlic
Quarantine
Fruits
Insect Disinfestation
Cereals, Pulses, Dry Fruits
Shelf-life Extension
Chicken, Meat, Fish
Pathogen Reduction
Spices, Flesh Foods

The most common source of ionizing energy for treating food and non-food products is ^{60}Co and, to a lesser extent, ^{137}Cs (Caesium).

It can penetrate food (or any other substance) to a considerable depth.

Fig. 2. Comparison of irradiated potatoes with untreated potatoes after 6 months of storage.

The quantity of radiation energy absorbed by the food material is called radiation/irradiaton dose.

The unit of absorbed dose is the gray (Gy). It is defined as the energy given to matter per unit mass.

$$1 \text{ Gy} = 1 \text{ joule/kg}.$$

An older unit of radiation measurement is the rad

$$1 \text{ rad} = 0.01 \text{ Gy}$$

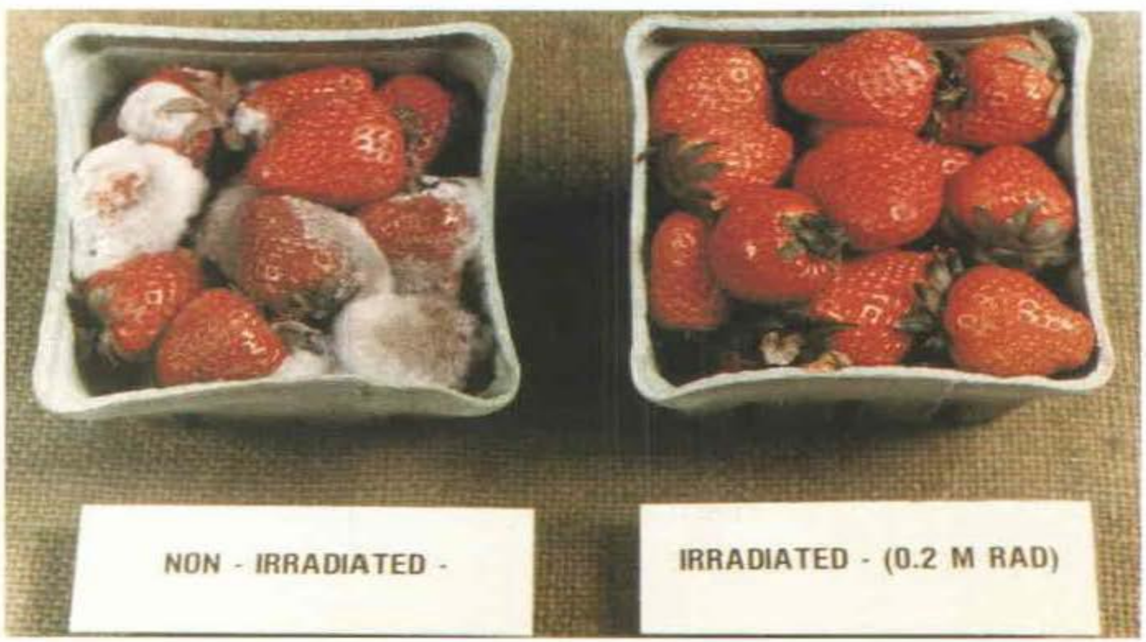
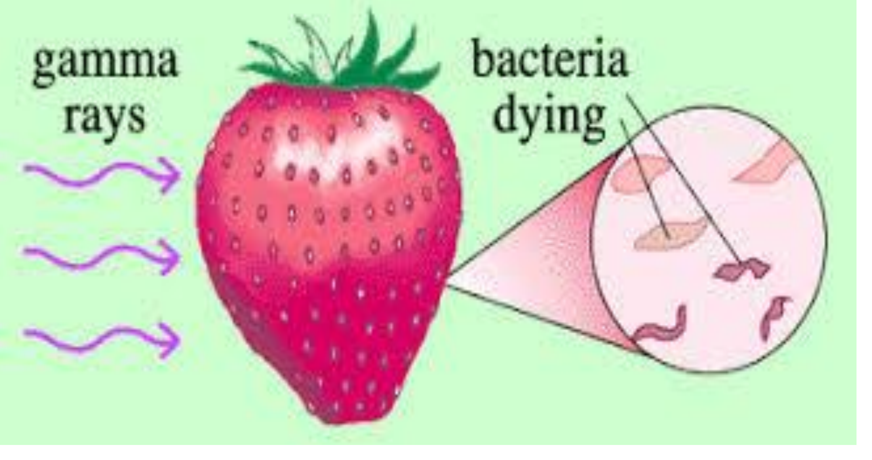


Fig. 3. Comparison of irradiated strawberries with untreated strawberries after 15 days of storage.

At present, the dose of radiation recommended for use in food irradiation does not exceed 10 kGy. This is very small amount of energy, equal to the amount of heat required to raise the temperature of water by 2.4 ^{o}C.

Max. dose for food sterilization is 50 kGy (5 Mrad) and rise in temperature is not more than 12 ^{o}C. It is called cold sterilization.



Application of food irradiation may be summarized as:

- Low dose (up to 1 kilogray)
  - (a) inhibition of sprouting
  - (b) insect disinfestation
  - (c) delay of ripening

- Medium dose (1 - 10 kilogray)
  - (a) extension of food shelf-life
  - (b) reduction of microbial load
  - (c) improvements of food properties

- High dose (10-50 kilogray)
  - (a) commercial sterilization
  - (b) elimination of viruses.

At high irradiation dose, it can cause change in flavour (undesirable)

It is mostly used for:

- destruction of insects in grain,
- against Salmonella for heat sensitive foods.

Advantages:

- No reduction in nutritive value
- No loss of biological value of proteins
- No vitamin loss

UV Radiation

UV light is divided into three areas:

UVA – longest wavelength of 320 to 400 nm

UVB – wavelengths in the range of 280 to 320 nm

UVC – shortest wavelengths of 100 to 280 nm

- 265 nm is effective for most microbes.

UV light des not have penetration power, so effective only for surfaces or transparent materials (water, air)

It is used for:

-sterilization of storage areas

-disinfection of instruments, vessels,..

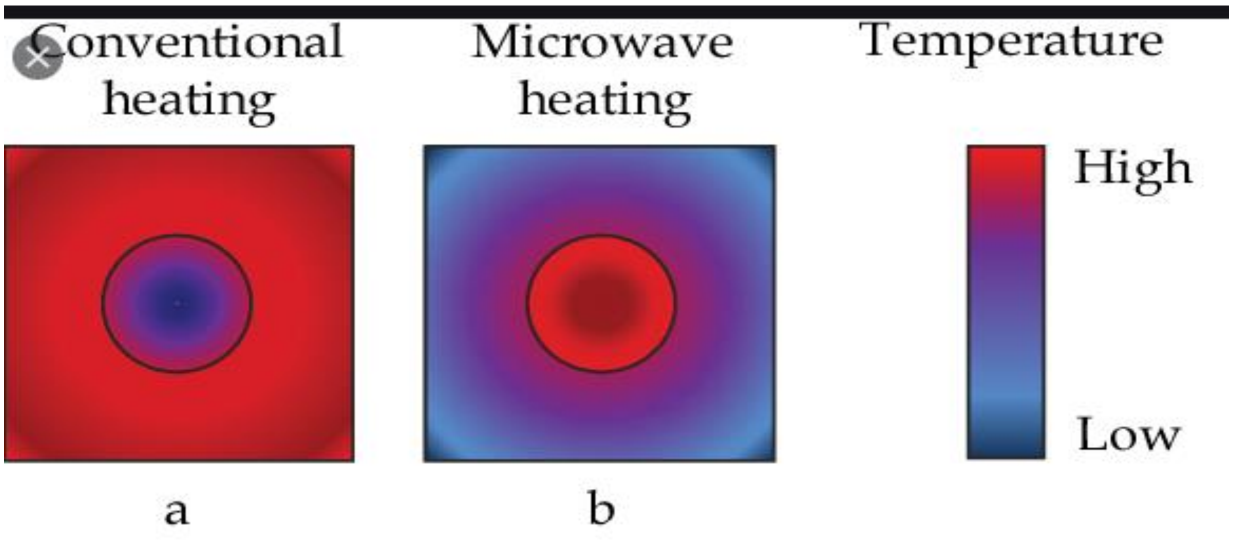
Infrared Radiation

Infrared radiation transfers electrical energy to the material. It is partially absorbed and so heats the absorbing layers of the food.

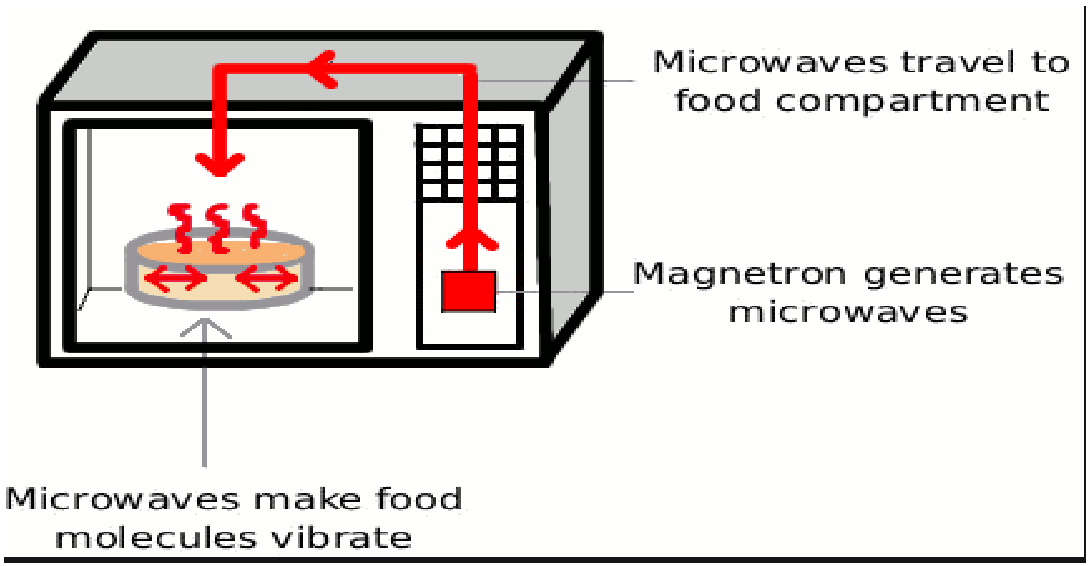
- No carriers such as metal or liquid
- The heating only at the point of absoption

High Frequency Heating: Microwave

In high frequency heating, the heat does not have to penetrate from the outside to the inside. It is produced everywhere in the food material.



The electrical energy is transformed into vibration energy of high frequency (upto about 5000 MHz) by means of a special tube, magnetron. These MW’s are able to penetrate organic materials to cause rapid vibration of molecules.



MW causes rapid vibration of molecules which produces friction, friction produces heat.

- Metals reflect MW (don't use, cause ignition)
- Glass, porcelain, certain artifical plastic materils can be used.

Microwave used for:

- Milk pasteurization
- To kill insects, spores and molds in flour
- Blanching of fruits and vegetables
- Bread baking → no browning or crust formation

FOOD LEGISLATION

GOVERNMENTAL REGULATION OF FOOD AND NUTRITION LABELING

Government worldwide regulate foods with these general objectives:

- To ensure the safety and wholesomeness of the food supply
- To prevent economic fraud or deception
- To inform consumers about the nutritional contents of foods

The food industry looks to government to set high standards and to enforce these standards in order to protect itself against unethical competition

- Recent years have seen an increased concern by the public over the safety of foods, especially with respect to intentional and unintentional chemical additives and the incidence of microbial food-borne diseases.

- Arguments have both defended and attacked food production practices including the use of food additives, pesticides, biotechnology, and irradiation.

- In Turkey, Ministry of Agriculture is responsible for inspecting food plants for ensuring food safety.
- In the United States the primary responsibility for ensuring the safety and labeling of foods lies with the Food and Drug Administration (FDA) for most foods and with the U.S. Department of Agriculture (USDA) for meat and poultry products.

Food is considered adulterated if it:

1. Contains poisons or harmful substances at high concentrations
2. Contains filth, is decomposed or is otherwise unfit.
3. Was prepared and handled under unsanitary conditions such that it may have become contaminated.
4. Is derived from a diseased animal
5. Was subjected to radiation, other than where permitted.

6. Has any valuable constituent omitted
7. Has a specified ingredient substituted by a nonspecified ingredient
8. Has a concealed defect
9. Is increased in bulk weight or reduced in its strength making it appear better then it is.
10. Contains a coloring agent that is not approved or certified.

- GMP: “Good Manufacturing Practice” defines requirements for acceptable sanitary operation in food plants.
- GRAS: “Generally Recognized As Safe” . These are substances added to foods that have been shown to be safe based on a long history of common usage in food.

Typical GRAS substances include the common spices, natural seasonings, and numerous flavoring materials, baking powder chemicals, fruit and beverage acids etc.

Food Additives must meet the following additional requirements:

- Intentional additives must perform an intended and useful function
- Additives must not deceive consumers or conceal faulty ingredients or defects in manufacturing practices
- An additive must not substantially reduce the food’s nutritional value.
- An additive cannot be used to obtain an effect that could be obtained by otherwise good manufacturing practices
- A method of analysis must exist with which to monitor the use of the additive in foods.

FOOD LABELING

- One of the main goals of governmental regulation of foods is ensuring that consumers are given complete and useful information about the food products they purchase.
- This information is important for both economic and health reasons.
- Ingredient labeling also helps people avoid foods to which they may be allergic.

The information to be supplied on the label:

- Food Name
- Net quantity of contents
- Ingredients
- Company name
- Product Dates
- Nutrition Information
- Other information (Trademark or copyright symbols, religious symbols, bar code etc.)

INTERNATIONAL FOOD STANDARDS AND CODEX ALIMENTARIUS

- In matters of international scope two important agencies are:

WHO – World Health Organization of the United Nations

FAO- Food and Agricultural Organization of the United Nations

- These are organized to increase and improve food resources, nutrition and health throughout the world.

The need for coordination in setting standards has long been recognized and in 1962 and international body operating under the auspices of the **United Nations through FAO/WHO was established and** designated as the **Codex Alimentarius Commission.**

The object of this commission:

- To develop international and regional food standards and publish them in a Codex Alimentarius.
- To develop agreements on international standards and safety practices for foods and agricultural products.

JECFA- The Joint FAO/WHO Expert Committee on Food Additives sets standards for purity of food additives.