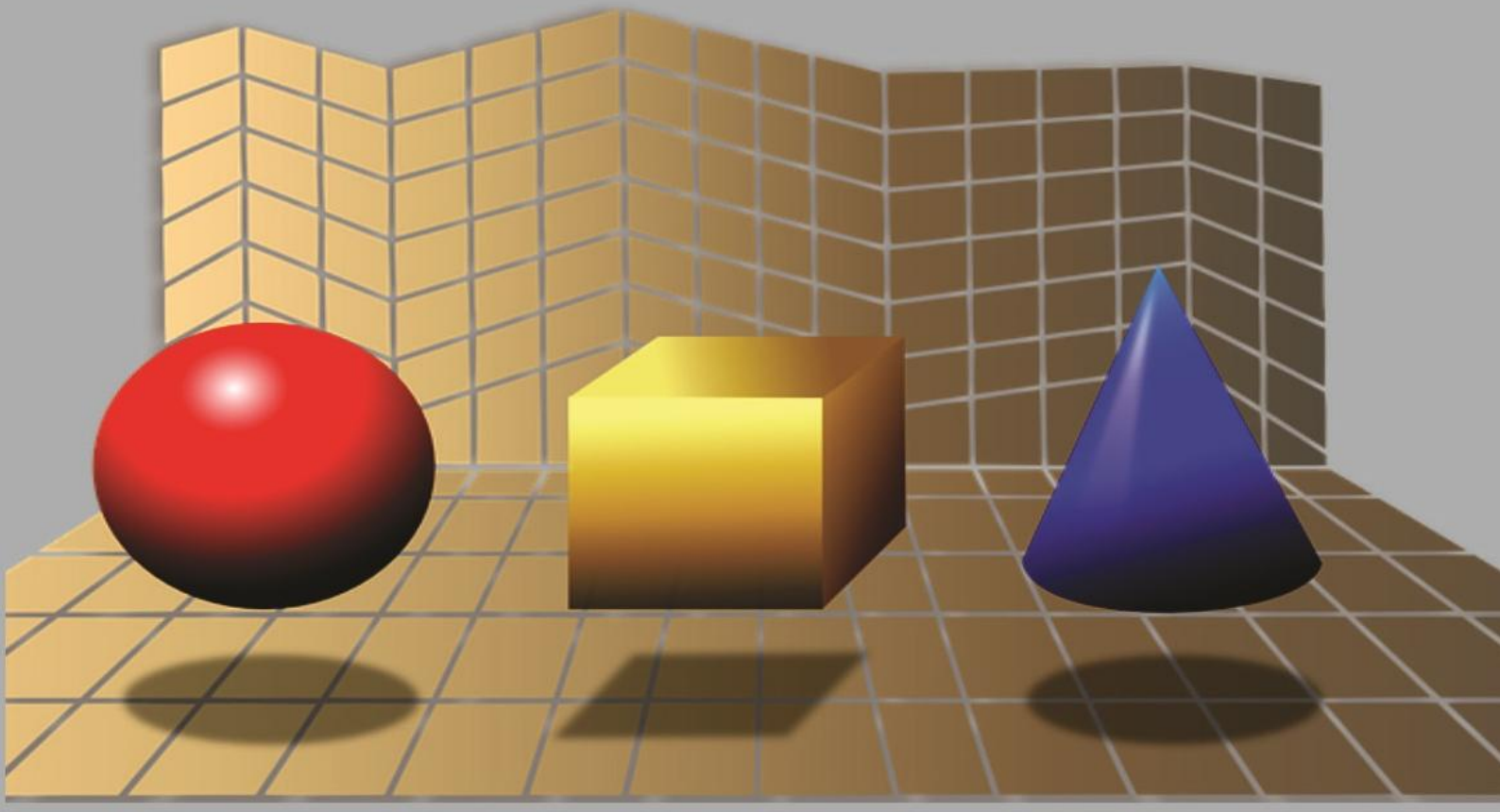
Engineering Properties of Biological Materials and Food Quality



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Module- 1 Engineering Properties of Biological Materials and Food Quality

Lesson 1. Introduction to engineering properties of biological materials and food quality

This chapter deals with the introduction to engineering properties of biological materials, classification of food properties, food quality and safety and regulations. Knowledge of properties of materials gives insight how the materials behave in different conditions and how it affects the final product quality. On the other hand, quality is a manifestation of human perception about the characteristic feature of a product. Quality and properties are interlinked and are often complementary to each other in as far as food is concerned. Product quality and safety is of utmost concern as it directly related to the wellbeing of human being, is not limited to microbial safety now.

1.1 INTRODUCTION:

Biological materials especially that are consumed as food or feed undergo various unit operations right from the pre-harvest to post harvest processing, primary, secondary and tertiary processing, formulation, preservation, packaging, storage distribution, retailing, domestic storage and finally consumption. Scientists and engineers need to know and understand the characteristics of the material to be processed, preserved and consumed to solve the problems while designing and selecting the means and modes of preservation, packaging, processing, storage, marketing, and consumption. Each of these unit operations has unique characteristics and need special tools and equipments. Designing and selecting such tools and equipments require information regarding various properties.

1.2. CLASSIFICATION OF FOOD PROPERTIES:

There are many classifications of properties of biological materials, which can generally be grouped under physical properties, mechanical properties, rheological properties, textural properties, electrical and dielectric properties, optical properties, acoustic properties, chemical, and nutritional properties etc. A more realistic approach was compiled by Rahman & McCarthy (1999) is presented here:

List of four classes of food properties

i. Physical and Physico-chemical Properties

A. Mechanical properties

- Acoustic properties
- Mass-volume-area-related properties
- Morphometric properties
- Rheological properties
- Surface properties

B. Thermal Properties

C. Thermodynamic properties

D. Mass transfer properties

E. Electromagnetic properties

F. Physico-chemical constants

ii. Kinetic Properties

A. Quality kinetic constants

B. Microbial growth, decline and death kinetic constants

iii. Sensory Properties

A. Tactile properties

B. Textural properties

C. Color and appearance

D. Taste

E. Odor

F. Sound

iv. Health Properties

A. Positive health properties

- Nutritional composition
- Medical properties
- Functional properties

B. Negative health properties

- Toxic at any concentration
- Toxic after critical concentration level
- Excessive or unbalanced intake

In nutshell the properties and their applications in various agro processing, storage is presented in the following sections:

Physical properties like size, shape, density, porosity has great implication in deciding the equipment for screening, separation, handling and storage of materials, they also come handy in calculating the heat transfer and mass diffusion rates. Frictional properties are useful in designing discharge and conveying devices; whereas, aerodynamic and hydrodynamic properties are useful in designing spouted bed, fluidized bed dryers, aspirators and pneumatic conveying system. Knowledge of thermal properties aids in designing thermal process and calculating thermal load for canning, retorting, sterilization, pasteurization, blanching, cooking and extrusion process. Electric and dielectric properties can be useful in designing and controlling thermal processing and moisture content determination. Optical properties are used widely in deciding the quality of food thus aiding in sorting, grading, contamination detection and food composition determination. Acoustic properties are also useful in determining non-destructive quality determination and pretreatment for various thermal processes and plant material extraction. Rheological properties give information how the product will behave in different systems and how consumer is going to be affected. It is useful in designing new product and product constituent, its stability and storability at different conditions. Since, the viscosity is of material is affected by temperature and most importantly the constituent of material; it has direct implication on the acceptability, storability and quality of the product.

Food consumption pattern is affected by cultural practices, climate and in many cases personal choice. Food is considered as a mean for psychological and emotional fulfillment and its relation to divinity is not exaggerating as this is the basic requirement for any life to exist. The information about consumers' preferences is relevant for the food industry both for modifying/improving the product according to these preferences and for the development of new products. Besides, knowledge about customers' age, gender, demographics, etc. is itself relevant: indeed, an important area for strategic product development is the identification of possible consumers segments and the evaluation of the influence of their individual characteristics on the liking patterns and on the uncertainty in the choice. The quality characteristics are often judged by instrumental methods of measurement and by sensory panel, where trained personnel act as human instrument.

Food laws and safety regulations are essential to provide consumer food that is safe to consume and cater the needs of various sections. Allergenicity of some naturally occurring chemicals from plant and animal sources, host metabolism, microbial contamination, non-biological contamination such as glass, metal pieces, chemicals entering into the food chain from various steps of processing also pose great risk to human safety and well being.

Sensory descriptive tests are among the most sophisticated tools used by sensory scientists and involve the discrimination and description of both the qualitative and quantitative sensory components

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Lesson 2. Application of engineering properties of biological materials

This chapter deals with the application of various engineering properties like physical, frictional, aerodynamic, thermal, optical, dielectric, electrical, acoustic, rheological and textural properties in the harvesting, post harvest handling, processing, storage and how it affects consumer's perception of food quality and safety.

2.1 INTRODUCTION

The engineering selection and design of food processes and equipment requires knowledge of the properties of food materials. These properties are of great importance in the simulation and design of food processes and in the computer-aided process engineering. Their influence is even greater in problems of conceptual design, in which a wrong estimation of a property can lead to an infeasible design plan. Not only the knowledge of properties aids in engineering design and control but also gives information about the product quality, its acceptability by the consumer of different groups and its behavior post production, during storage, during consumption and post consumption.

2.2. PHYSICAL PROPERTIES:

The knowledge of some important physical properties such as shape, size, volume, surface area, thousand grain weights, density, and porosity of different grains is necessary for the design of various separating, handling, storing and drying systems. The function of many types of machines is influenced decisively by the size and shape of the fruit participating. The size and shape are, for instance, important in their electrostatic separation from undesirable materials and in the development of sizing and grading machinery. Bulk density, true density, and porosity (the ratio of intergranular space to the total space occupied by the grain) can be useful in sizing grain hoppers and storage facilities; they can also affect the rate of heat and mass transfer of moisture during aeration and drying processes; Density is used to separate materials with different densities or specific gravities. Separation of properly matured peas can be separated from the immature and infected ones by water flotation methods. Grain bed with low porosity will have greater resistance to water vapor escape during the drying process, which may lead to higher power to drive the aeration fans. Cereal grain densities have been of interest in breakage susceptibility and hardness studies. For instance, bulk density values for raw and parboiled paddy have practical applications in the calculation of thermal properties in heat transfer problems, in determining Reynolds number in the pneumatic handling of the material, and in separating the product from undesirable materials. It plays an important role in other applications that include the design of silos and storage bins and the maturity and quality of paddy, which are essential to grain marketing. The resistance of bulk grain to airflow is in part a function of the porosity and the kernel size.

2.3. FRICTIONAL PROPERTIES:

Frictional properties such as angle of repose and coefficient of friction are important in designing equipment for solid flow and storage structures and the angle of internal friction

between seed and wall in the prediction of seed pressure on walls. The coefficient of static friction plays also an important role in transports (load and unload) of goods and storage facilities. It is important in filling flat storage facility when grain is not piled at a uniform bed depth but rather is peaked. Coefficient of friction is important in designing storage bins, hoppers, chutes, screw conveyors, forage harvesters, and threshers. The material generally moves or slides in direct contact with trough, casing, and other components of the machine. The various parameters affect the power requirement to drive the machine. The frictional losses are one of the factors, which must be overcome by providing additional power to the machine. Hence, the knowledge of coefficient of friction of the agricultural materials is necessary.

2.4. AERO AND HYDRO-DYNAMIC PROPERTIES:

The aerodynamic properties and hydrodynamic properties like terminal velocity and drag coefficient of agricultural products are important and required for the designing of air/ hydro conveying systems and the separation equipment. The physical properties, such as density, shape, size, etc., are required for calculating the terminal velocity and drag coefficient of the agricultural produce. In the handling and processing of agricultural products, air is often used as a carrier for transport or for separating the desirable products from unwanted materials, therefore the aerodynamic properties, such as terminal velocity and drag coefficient, are needed for air conveying and pneumatic separation of materials. As the air velocity, greater than terminal velocity, lifts the particles to allow greater fall of a particle, the air velocity could be adjusted to a point just below the terminal velocity. The fluidization velocity for granular material and settling velocity are also calculated for the body immersed in viscous fluid.

2.5. THERMAL PROPERTIES:

These properties are involved in almost every food processing operation. Knowledge of the thermal properties of foods is essential in the analysis and design of various food processes and food processing equipment involved in heat transport, with respect to heat transfer or energy use, such as in extrusion cooking, drying, sterilization, cooking etc. The most important thermal properties in food processing such as, specific heat capacity (Cp), thermal conductivity(k), and thermal diffusivity(a). Specific heat has an important role in determination of energy cost and for the dimensions of machinery and equipment that are needed in thermal processes. Furthermore, specific heat (Cp) of food materials changes according to their physical and chemical properties. The thermal conductivity (k) of food determines how fast heat can be evenly transferred to the entire food mass, which in turn affects the quality of the final product. When heating and cooling of materials involves unsteady state or transient heat conduction, the material temperature changes with time and knowledge of the thermal diffusivity (a) is required for predicting temperature in these processes.

2.6. OPTICAL PROPERTIES:

Light transmittance and reflectance properties of agricultural commodities are used for sorting, grading, maturity, surface colour and blemish determination. The use of hyperspectral, multispectral, infrared imaging and computer vision system have enabled

even determination of moisture and other chemical composition, contamination of agro commodities to greater satisfaction of consumer and trader and reduced the manual inspection, which might be subjected to error due to fatigue. These systems offer the potential to automate manual grading practices and thus to standardize techniques and eliminate tedious inspection tasks. The automated inspection of produce using machine vision not only results in labour savings, but also can improve inspection, objectivity.

2.7. DIELECTRIC PROPERTIES:

Dielectric properties play a major role in determining the interaction between the food material being processed and the electromagnetic energy. The degree of heating of a food material subjected to microwave or radio frequency processing is strongly influenced by the dielectric properties of the food. Dielectric heating or volumetric heating occurs due to polarization and ionization of molecules, which are effectively used in drying, sterilization, pasteurization and other thermal processing operations. Dielectric properties consist of dielectric constant (ε′) and dielectric loss factor (ε″). Dielectric constant is a measure of the ability of a material to store electromagnetic energy whereas dielectric loss factor is a measure of the ability of a material to convert electromagnetic energy to heat. Loss tangent (tan δ), a parameter used to describe how well a product absorbs microwave energy, is the ratio of ε″ to ε′. A product with a higher loss tangent will heat faster under microwave field as compared to a product with a lower loss tangent.

2.8. ACOUSTIC PROPERTIES:

Acoustic properties of biomaterial describes how the biological cell recats to sound waves, which carry enough energy through photons and capable of bring change in the product. Acoustic properties are long been used in medical diagnosis; its' use in food processing and in detecting the imperfections in agro commodities is gaining momentum. Moreover, the effect of high intensity sound waves on living cell also are being explored and effectively used in homogenizing liquid sample, extraction of plant materials and as pretreatment for drying and dehydration process. Ultrasound is the sound that is above the threshold of the human ear (above 18 kHz). Ultrasound is generated with either piezoelectric or magnetostrictive transducers that create high-energy vibrations. These vibrations are amplified and transferred to a sonotrode or probe, which is in direct contact with the fluid. Some known applications of high power ultrasound in agro- processing include the following: extraction (release of plant material), emulsification, homogenization, crystallization (formation of smaller ice crystals in freezing), filtration, separation, viscosity alteration, defoaming, a pretreatment for drying and extrusion. Ultrasound inactivates enzymes and bacteria by breaking the cell membranes due to the violence of cavitation and due to the formation of free radicals and hence used for pasteurization and blanching.

2.9. ELECTRICAL PROPERTIES:

Some electrical properties which are of importance in agro processing are electrical conductance, resistance, impedance. Electrical conductance or capacitance has been used for determining the moisture content of grain. Electrostatic separation of grains is also used for separating grains, based on the ability of the grain to hold electrostatic charge. Electrical conductivity of the grain decides the ability of the material to hold electrostatic charge.

Recently ohmic heating has been in use for drying, pasteurization, blanching and other thermal processing of foods, based on resistance heating. Ohmic processing, sometimes described as resistive heating,

consists of passing mains alternating current directly through a conductive food, which in turn leads to heat generation. Because heating accompanies the current; heat distribution throughout the product is far more rapid and even, which in turn can result in better flavor retention and particulate integrity compared to conventional processes. The efficiency of ohmic heating is dependent on the conductive nature of the food to be processed and hence knowledge of the conductivity of the food as a whole and its components is essential in designing a successful heating process.

2.10. RHEOLOGICAL PROPERTIES:

Knowledge of the rheological and mechanical properties of various food systems is important in the design of flow processes for quality control, in predicting storage and stability measurements, and in understanding and designing texture. The rheological behavior under limited deformation has been widely used to obtain information on the structure and viscoelasticity of materials. An understanding of flow behavior is necessary to determine the size of the pump and pipe and the energy requirements. The rheological models obtained from the experimental measurements can be useful in design of food engineering processes if used together with momentum, energy, and mass balances. Effects of processing on rheological properties must be known for process control.

2.11. TEXTURAL PROPERTIES:

Texture is one of the most important quality characteristics of foods. Foods have different textural properties. These differences are caused by inherent differences due to the variety difference, differences due to maturity, and differences caused by processing methods. Food texture can be evaluated by sensory or instrumental methods. Sensory methods need a taste panel containing trained panelists. It is hard to repeat the results. Instrumental methods are less expensive and less time consuming as compared to sensory methods.

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Module- 2 Physical Properties of Biomaterials

Lesson 3. Physical properties of biomaterials like shape, size, volume and surface area

In this chapter physical properties like shape, size, volume and surface area of the biological materials are discussed. The methods of measurement are discussed in brief.

3.0 Introduction:

When physical properties of grains, seeds, fruits and vegetables, eggs, forage, and fibers are studied by considering either bulk or individual units of the material, it is important to have an accurate estimate of shape, size, volume, specific gravity, surface area and other physical characteristics which may be considered as engineering parameter for the product.

Shape and size are required to describe an object satisfactorily. These are important physical attributes of biological materials that are used in screening, grading, and quality control of agro-commodities. They are also important in fluid flow and heat and mass transfer calculations, like drying, dehydration, pneumatic separation, screening etc. The shape and size of the materials can be determined by graphical methods, dimensional measurement, projected area method, electronic inspection systems.

3.1. SIZE:

Size is an important physical attribute of foods used in screening solids to separate foreign materials, grading of fruits and vegetables, and evaluating the quality of food materials. In fluid flow, and heat and mass transfer calculations, it is necessary to know the size of the sample. Size of the particulate foods is also critical as it affects the viscosity and dispersibility and stability of the product. In the context of postharvest operations, agro-produce size determination is important for several reasons (Moreda et al., 2009)

- It allows the sorting of fresh market various agro produces into size groups. This is helps in assigning market and price differentials of large and small produce, to match consumer preferences and to allow pattern packing. Pattern packing provides better protection of the produce, utilizes the volume in the shipping container, owing to the higher packing density that can be achieved with commodities of homogeneous sizes in comparison to that of jumble packing.

- Size determination is mandatory for modern or on-line fruit/ vegetables/ grain/spices density sorting, for which two size-related parameters, volume and weight, are required.

- Size measurement is important for determining produce surface area. The latter is also of use for quantifying the microbial population on the surface of a foodstuff, for assessing the rates of heat, water vapor and gas transfer, or for estimating the throughput of peeling operations.

- Fruit size can provide useful information for suitable working of some internal quality (IQ) sensors.
- Grading of agro produce into size groups is often necessary in the food industry, to meet the requirements of some primary and secondary processing machines, or to assign process differentials of large and small produce.
- Shape features can be measured independently or by combining size measurements. Hence, the determination of agro commodity size parameters allows simple shape sorting.

Produce can be sized according to different physical parameters, such as diameter, length, weight, volume, circumference, projected area, or any combination of these. It is easy to specify size for regular particles in terms of their major dimensions like length, width and thickness or major and minor diameter, but for irregular particles the term size must be arbitrarily specified.

3.1.1. Methods of measurement of size:

3.1.1.1. Projected area method

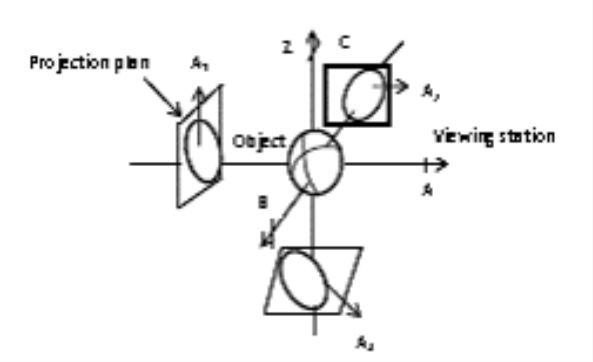


Figure 3.1 Size determination by projected area method

Size can be determined using the projected area method (fig 3.1). In this method, three characteristic dimensions are defined:

1. Major diameter, which is the longest dimension of the maximum projected area

2. Intermediate diameter, which is the minimum diameter of the maximum projected area or the maximum diameter of the minimum projected area.

3. Minor diameter, which is the shortest dimension of the minimum projected area.

Length, width, and thickness terms are commonly used that correspond to major, intermediate, and minor diameters, respectively

3.1.1.2. Micrometer measurement:

The dimensions can be measured using a micrometer or caliper (fig. 2a), grain shape tester. The micrometer is a simple instrument used to measure distances between surfaces. Most micrometers have a frame, anvil, spindle, sleeve, thimble, and ratchet stop (fig 2b). They are used to measure the outside diameters, inside diameters, the distance between parallel surfaces, and the depth of holes.

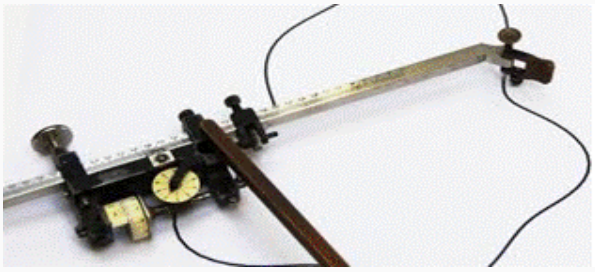


Fig. 3.2a. vernier caliper

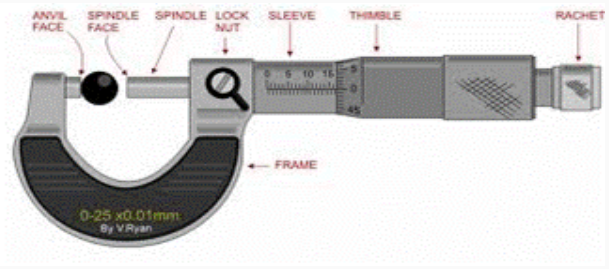


fig. 3.2b. Micrometer

3.1.1.3. Grain shape tester:

It consists of a plunger and a horizontal surface, in between which the grains is held and dimensions are measured by dropping down the plunger on to the grain body.

3.1.1.4. Electronic system:

Various electronic systems are employed to sort agro commodities through off-line or on-line inspection. This saves labour cost and eliminates human error. Some of the commercial and non-commercial systems used for agro produce sorting are as follows (Moreda et al., 2009):

- Systems based on measurement of the volume of the gap between the fruit and the outer casing of embracing gauge equipment.
- Systems that calculate fruit size by measuring the distance between a radiation source and the fruit contour, where this distance is computed from the time of flight of the propagated waves.
- Systems that rely on the obstruction of light barriers or blockade of light
- Two-dimensional (2-D) machine vision systems such as digital images received by web cameras, CCD cameras.
- Three-dimensional (3-D) machine vision systems such as multi spectral and hyperspectral imaging system.
- Other systems. This group includes systems based on internal images, such as computed tomography (CT) or magnetic resonance imaging (MRI), X-ray, ultrasound techniques as well as some other approaches not included in the other groups.

3.2. SHAPE:

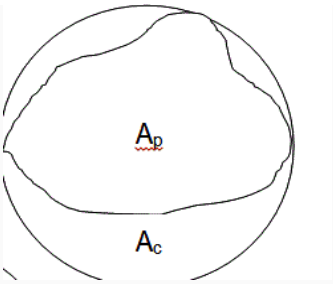
Shape describes the object in terms of a geometrical body. Shape is also important in heat and mass transfer calculations, screening solids to separate foreign materials, grading of fruits and vegetables, and evaluating the quality of food materials. The shape of a food material is usually expressed in terms of its sphericity, aspect ratio, ellipsoid ratio and slenderness ratio. Some of the shapes and their descriptions are given below in table 3.1. [Mohsenin, 1980]

Table 3.1: shape and description of various agro commodities

Shape	Description	Examples
Round	Approaching Spheroid	sapota, cherry tomato, pea
Oblate	Flattened at the stem end and apex	orange, pumpkin
Oblong	Vertical diameter greater than horizontal diameter	some apple varieties, capsicum, brinjal, rice, wheat
Conic	Tapered towered the apex	ladies finger, carrot, reddish
Ovate	Egg shaped & broad at stem end	Brinjal, apple and guava.
Oblique	Axis connecting stem and apex slated	some apple varieties, tomato.
Obovate	Inverted ovate-broad at apex	Mango, papaya
Elliptical	Approaching ellipsoid	rice, wheat, pointed guard etc
Truncate	Having both hand squared or flattened	capsicum
Unequal	One half larger than the other	mango
Ribbed:	In cross section, sides are more or less angular	plantain, ladies finger
Regular	Horizontal section approaches a circle	orange, apple, guava etc
Irregular	Horizontal section dearth materially from a circle	mango, ladies finger, capsicum etc.

<u>Roundness</u>: Roundness is a measure of sharpness of the corners of the solid

$$Roundness = \frac{A_p}{A_c}$$

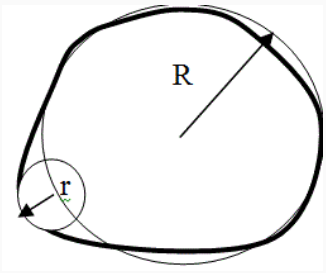


Where A_p = largest projected area of object in natural rest position

A_c = Area of smallest circumscribing circle

The object area in obtained by projection/tracing

\[Roundness = \frac{{ \sum \nolimits^ r}}{{NR}}\]

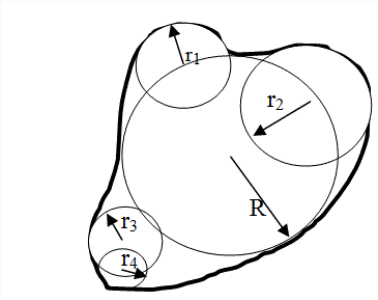


r = radius of curvature of all the corners

R = Radius of maximum inscribed circle

N = total number of corners

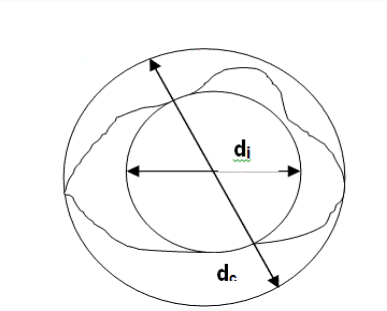
\[Roundnessratio = \frac{{{r_n}}}{{{R_m}}}\]



R_m = mean radius of the object

r_n = radius of curvature of the sharpest corner

Sphericity: **Sphericity is the degree to**



Which an object resembles a sphere. The geometric foundation of the concept of sphericity rests upon the isoperimetric property of a sphere. Sphericity can be expressed as:

\[Sphericity = \frac{{{d_i}}}{{{d_c}}}\]

d_i = diameter of largest inscribed circle

d_c = diameter of smallest circumscribed circle

A particle three dimensional expression can be stated for estimating the sphericity of an object using the following definition:

\[Sphericity = \frac{{{d_e}}}{{{d_c}}}\]

Where d_e is the diameter of the sphere of the same volume as the object and d_c is the diameter of the smallest circumscribed sphere or usually the longest diameter of the object. This expression for sphericity expresses the shape character of the solid relative to that of a sphere of the same volume.

Assuming that the volume of the solid is equal to the volume of a triaxial ellipsoid with intercepts a, b, c and that the diameter of the circumscribed sphere is the longest intercept of ellipsoid, the degree of sphericity can also be expressed.

d_e = diameter of sphere of the same volume of the object

d_c = diameter of the smallest circumscribing circle, usually the largest diameter of the object

\[Sphericity = {\left[{\frac{{volumeofsolid}}{{volumeofcircumscribedsphere}}} \right]^{\frac{1}{3}}}\]

\[= {\left[{\frac{{\frac{\pi }{6}abc}}{{\frac{\pi }{6}{a^3}}}} \right]^{\frac{1}{3}}} = {\left[{\frac{{bc}}{{{a^2}}}} \right]^{\frac{1}{3}}} = \frac{{{{\left[{abc} \right]}^{\frac{1}{3}}}}}{a}\]

a= largest intercept

b = longest intercept normal to a

c = longest intercept normal to a and b

Resemblance to geometric bodies

In some cases the shape can be approximated by one of the following geometric shapes:

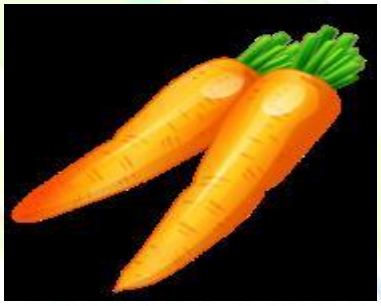
Prolate spheroid which is formed when an ellipse rotates about its major

axis.

A prolate spheroid is a spheroid in which the polar axis is greater than the equatorial diameter. e.g. lemon, lime, grape

Oblate spheroid is formed when an ellipse rotates about its minor axis. An oblate spheroid is a rotationally symmetric ellipsoid having a polar axis shorter than the diameter of the equatorial circle whose plane bisects it. e.g. grape fruit, pumpkin

Right circular cone or cylinders is formed when a frustum rotates about its axis e.g. carrot and cucumber.



After deciding on the shape of body, its volume and surface area can be calculated using the appropriate equations. For some agricultural products, the following formulas may be applicable. Volume, V, and surface area, S, of **prolate spheroid** are given by:

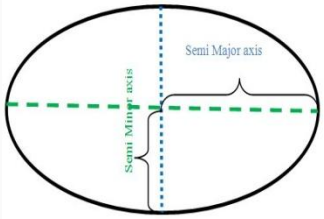
$$V_{prolatespheroid} = \frac{4}{3}\pi a{b^2}$$

$$S_{prolatespheroid} = 2\pi {b^2} + 2\pi \frac{ab}{e}{\sin ^{ - 1}}e$$

a = major semi axis of the ellipse

b = major semi axis of the ellipse

$$where,e = ([1 - {(b/a)^2}])$$



Volume and Surface area of **oblate spheroid** are given by following expressions

$$V_{oblatespheroid} = \frac{4}{3}\pi a^2 b$$

$$S_{oblatespheroid} = 2\pi a^2 + \pi \frac{b^2}{e}\ln \frac{1 + e}{1 - e}$$

Volume, V, and surface area of the frustum of a **right circular cone** are given by

$$V_{rightcone} = \frac{\pi }{3}h[r_1^2 + r_1 r_2 + r_2^2]$$

$$S_{rightcone} = \pi \left(r_1 + r_2 \right)\sqrt {\left[h^2 + {\left(r_1 - r_2 \right)}^2 \right]}$$

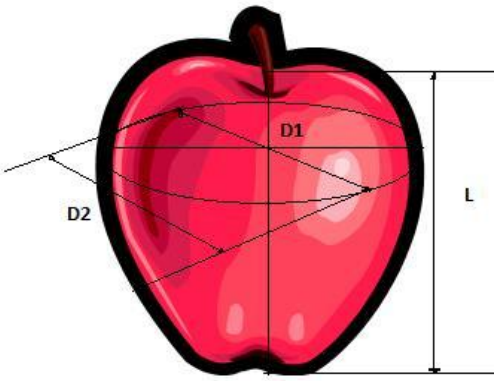
r_1 = radius of base

r_2 = radius of top (apex)

h = altitude

Having volume and surface area estimated in this manner, the actual volume and surface area can then be determined experimentally and a correction factor can be established for the "typical" shape of each variety of the product

Some of the interrelations between major dimensions of the ellipsoid give an idea of the shape of the object such as slenderness ratio which is usually used for grading rice.



Length : width=Slenderness ratio

Width: length = aspect ratio

Fruit size can be expressed in terms of major diameter, minor diameter and length.

Ellipsoid ratio = Major diameter: minor diameter

Aspect ratio= length: major diameter

Lesson 4. Physical characteristics of biomaterials: volume, density, specific gravity and surface area

In this lesson physical characteristics of biomaterials like volume, specific gravity and surface area and their methods of measurements are discussed. Their importance in handling, agro processing, storage and implications on the quality parameters are delineated.

4.1 INTRODUCTION:

Volume, density and specific gravity of food materials and agricultural products play an important role in many applications i.e. drying, storing, design of storage of mechanical compressing of ensilage, separation of undesirable material, determining the purity of seeds, separation and grinding maturity evaluations, for example texture and softer of fruits estimation of products, where their density increases with maturity. Volume, which affects consumer acceptance, can be calculated from the measured dimensions or by using various methods such as liquid, gas, or solid displacement methods and image processing. Volume measurement methods can also be used for measuring the density of solids. Volume/density can be expressed in different forms such as solid, apparent, and bulk volume/density depending on pores. Porosity is a physical property characterizing the texture and the quality of dry and intermediate moisture foods. Total porosity of particulate materials includes the voids within and among the particles. Porosity can be determined from the difference between bulk volume of a piece of porous material and its volume after destruction of all voids by compression, optical methods, density methods, or by using a pycnometer or porosimeter. Surface area measurement is required to estimate the pesticide application or weeding and other similar agricultural practices through image vision system. Surface area measurement can be done with planimeter, coating method, peeling method, and by image analysis.

4.2. Volume:

Volume is defined as the amount of three-dimensional space occupied by an object, usually expressed in units that are the cubes of linear units, such as cubic inches and cubic centimeters, or in units of liquid measure, such as gallons and liters. In the SI system, the unit of volume is m^3.

4.2.1Apparent volume/ bulk volume: The volume of substance includes all pores within the material (internal pores) and also the void volume outside the boundary of individual particles when stacked in bulk (external pores). Bulk volume can be calculated by measuring the volume of the bulk sample by keeping the material in a container.

4.2.2. Solid volume/ True volume: This volume is the actual volume of the solid granular material, which devoid of the volume of internal pore space as well as intergranular spaces.

4.2.3. Expression and measurement of volume: Solid volume of solid material including water including any interior pores that are filled with air. It can be determined by gas

displacement method, in which the gas is capable of penetrating all open pores up to the diamond of gas molecule.

$$volume\left({m^3} \right) = \frac{{wt.ofdisplacedwater(kg)}}{{wt.densityofwater(kg/{m^3})}}$$

$$specificgravity = \frac{{wt.inair \times Sp.gravityofwater}}{{wt.ofdisplacedwater}}$$

Air comparison pycnometer:-

This is a commercially available instrument for volume measurement. The apparatus consist basically of two chambers and two pistons, a valve connecting the two chambers, a different pressure indicator, and a digital counter calibrated for readings in cubic centimeters. With the connecting valve closed any charge of the position of one piston must be duplicate by an identical stroke in the other in order to maintain the same pressure on each side of the differential pressure indicator. If the connecting valve is closed and both pistons are advanced the same amount to a given position, inserting a sample in the measuring chamber would cause a pressure differential which is brought to zero by withdrawing the piston in this chamber. Under this condition, the distance that the measuring piston differs from its position before inserting the sample will be proportional to the volume being measured. This instrument measures the true volume of a sample. For measurement of the apparent volume, i.e., the volume of the sample enclosed by its outer surface plus the volume of its open pores, the manufacturer recommends filling the pores first by immersing the sample in molten wax bath. Knowing the apparent and true volume of sample, the open-pore volume can be calculated as an index of porosity.

Pycnometer Method:

For seeds and grains, the method of specific gravity bottle or pycnometer and toluene has been the practice for many years. Toluene has the advantages of (1) Little tendency to soak into kernel;(2) a low surface tension, enabling it to flow smoothly over the kernel surface;(3) little solvent action on constituents of the kernel especially fats and oils;(4) a fairly high boiling point;(5) not changing its specific gravity and materially on exposure to the atmosphere; and (6) having a low specific gravity.

Gas expansion pycnometer is also known as constant volume gas pycnometer. The simplest type of gas pycnometer (due to its relative lack of moving parts) consists of two chambers, one (with a removable gas-tight lid) to hold the sample and a second chamber of fixed, known (via calibration) internal volume – referred to as the reference volume or added volume. The device additionally comprises a valve to admit a gas under pressure to one of the chambers, a pressure measuring device – usually a transducer – connected to the first chamber, a valved pathway connecting the two chambers, and a valved vent from the second of the chambers. In practice the sample may occupy either chamber that is gas pycnometers can be constructed such that the sample chamber is pressurized first, or such that it is the reference chamber that starts at the higher pressure. Various design parameters have been analyzed by Tamari.[4] The working equation of a gas pycnometer wherein the sample chamber is pressurized first is as follows:

$$V= Vc + Vs /[1-p1/p2]$$

where Vs is the sample volume, Vc is the volume of the empty sample chamber (known from a prior calibration step), Vr is the volume of the reference volume (again known from a prior calibration step), P1 is the first pressure (i.e. in the sample chamber only) and P2 is the second (lower) pressure after expansion of the gas into the combined volumes of sample chamber and reference chamber.

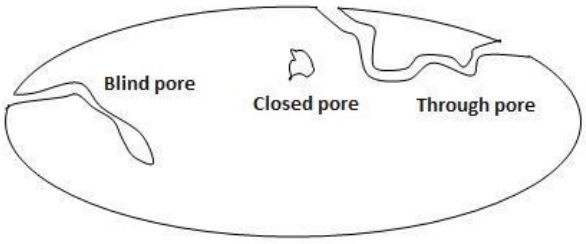
Variable volume pycnometer (or gas comparison pycnometer) consists of either a single or two variable volume chambers. The volume of the chamber(s) can be varied by either a fixed amount by a simple mechanical piston of fixed travel, or continuously and gradually by means of a graduated piston. Resulting changes in pressure can be read by means of a transducer, or nullified by adjustment of a third ancillary, graduated variable-volume chamber.

4.3. Density (r):

Bulk Density (r_b): It is the density of material when stacked or packed in bulk. Bulk density of the material is determined by dividing the material volume inclusive of voids to weight of product. There are two kinds of voids, voids between particles and void within particles. The bulk density is an important in packaging requirement and is often 2-20% of true density

Tapped Bulk Density: Tap bulk density is measured for powdery samples. The volume is measured after tapping the powdery material so that the product is adjusted to intergranular spaces, but it cannot eliminate all the intergranular spaces.

Particle density / true density (r_p): Density of solid material constituting the true volume of the occupied by the material, excluding any interior pores that are filled with air (blind and through pores). It can be calculated by dividing the sample weight by solid volume determined by the gas displacement method in which inert gas is capable of penetrating all open pores up to the diameter of the gas molecule. Gas displacement method is employed to find out the particle density. In gas displacement method, helium enters every nook and corner of material being lighter and inert gas.



Solid/substance density: is the density of a material measured when the material has been broken into pieces small enough to be sure that no closed pores remain.

Apparent Density: Apparent density (ρ_{app}) is the density of a substance including all pores within the material (internal pores). Apparent density of regular geometries can be determined from the volume calculated using the characteristic dimensions and mass measured. Apparent density of irregularly shaped samples may be determined by solid or liquid displacement methods.

- **Solid displacement method:**
- **Liquid displacement method:**
- **Gas displacement method:**
- **Image vision system:**

Mercury displacement is used to find out as mercury cannot enter the small inters-particles pores because of its high density and surface tension and does not wet the surface.

4.4. Porosity: (inter granular space)

It is the measure of void space between the materials.

It is defined on the percentage of volume of inter grain space to the total volume of grain bulk.

Porosity depends on-

- Shape
- Dimension/Size
- Roughness of grain surface

\[Porosity\left(\varphi\right)=1\]\[-\frac{{bulkdensity}}{{truedensity}}\]

Method of measurement:

Quality of food materials can be assessed by measuring their densities. Density data is required in separation process, such as centrifugation, sedimentation, hydraulic transport, for liquid, pumping power calculation.

Specific gravity balance: For, smaller objects such as small fruits, peas and beans, kernels of corns, etc., an analytical balance or more conveniently a specific gravity balance can be used to determine volume, density, and specific gravity employing the following expressions.

Sp. Gravity balance= volume =\[\frac{{wt.inair \times wt.inwater}}{{wt.densityofwater}}\]

Sp. Gravity =\[\frac{{wt.inair}}{{wt.inair - wt.inwater}} \times Sg.ofwater\]

=\[\left[{\frac{{wa.object}}{{\left({wa - ww} \right)both - \left({wa - ww} \right)\sin \ker }}} \right] \times Sg.ofwater\]

D= diameter of a sphere having volume equal to that of a grain Cv=(wt./density)

d = diameter of a sphere found by taking the geometric mean of the 3 mutually perpendicular measured seed dimension

d_{avg} =Average of maximum & minimum diameter of the fruit.

Specific gravity gradient tube:

Water = $997.T^3+3.143910^{-3}\ T^{-3}.757410^{-3}\ T^2$

CHO = 1599.1 - 0.31046T

Protein = 1330 - 0.5148T

Fat = 925.59 – 0.41754T

Ash = 2423.8 – 0.28063T

Ice = 916.89 – 0.1307T

4.5. Surface area:

Knowledge of surface area of some parts of plant materials, such as leaf area and surface area of fruits, is important to plant scientist as well as engineers handling and processing the products. Leaf area is an indicator of photosynthetic capacity and growth rate of a plant and its measurement is of value in studies of plants competition for light and nutrients, plant-soil-water relations, determining application rates of insecticides and fungicides. In crop like tobacco, where the leaf is the major commercial product, leaf area is a good indicator of yield potential. Likewise, surface areas of fruits are important in investigation related to spray coverage, removal of spray residues, respiration rate, light reflectance and color evaluation, and heat transfer studies in heating and cooling processes.

Leaf and stalk surface area: Some of the methods used for measuring leaf and stalk surface area are contact printing the surface on light sensitive paper and measuring the area by a planimeter; tracing the area on a graph paper and counting the squares; use of photographic projector similar to the method described for seeds and grains; light interception method and the use of photronic cell to measure the intercepted light ; use of an air flow planimeter which measure the area of a function of the surface obstructing the flow of air and a measurement of length and width of a leaf and relating these measurements to the area of the leaf.

Fruit surface area: For measurement of surface areas of fruits, the fruit is peeled in narrow strips and the planimeter sum of the areas of tracing of the strips taken as the surface area of the fruit.

Specific Surface by the Coating Method: The specific area of a number of grains may be determined by coating the grains with a single layer of metal powder and measuring the change in weight. A control group, consisting of geometric shapes of known surface area and of a density close to the grain being tested, is run through the coating process with the grain. A factor representing the coating weight per unit surface area for the control group is used to calculate the surface area of the grain. The bulk volume of the grain sample is measured and entered into the calculation of specific surface along with the calculated surface area.

Module- 3 Engineering Properties

Lesson 5. Basics of Thermal properties

Thermal properties are involved in almost every food processing operation. Knowledge of the thermal properties of foods is essential in the analysis and design of various food processes and food processing equipment involved in heat transport, with respect to heat transfer or energy use, such as in extrusion cooking, drying, sterilization, cooking etc. The most important thermal properties in food processing such as, specific heat capacity (c_p), thermal conductivity (k), and thermal diffusivity of food materials depend mostly on the food's composition, temperature and density. They have a significant effect on the rate of heat transfer into the particulates within the food product. When considering heat transfer during food processing, the thermal conductivity of the food plays an important role. The thermal conductivity (k) of food determines how fast heat can be evenly transferred to the entire food mass, which in turn affects the quality of the final product. Thermal conductivity depends strongly on moisture, temperature and structure of the material. In porous materials the void fraction and the pore structure and distribution affect thermal conductivity significantly. Generally, in multiphase systems (solids, water and air), the effect of geometric distribution of the phases is taken into account by using structural models.

5.1. Modes of heat transfer:
Conduction
Convection
Radiation

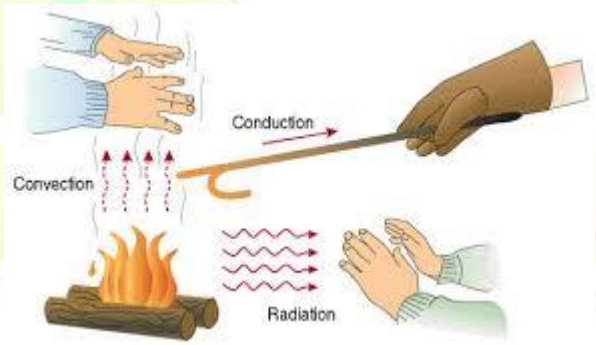


Fig. 5.1 Modes of heat transfer

When heating and cooling of materials involves unsteady state or transient heat conduction, the material temperature changes with time and knowledge of the thermal diffusivity is required for predicting temperature in these processes.

The interface heat and mass transfer coefficients are important in the design of food processes and processing equipment, and in the control of food packaging and storage. Heat transfer coefficients are essential in thermal processing, in cooling or freezing and in storage operations. Mass transfer coefficients are important in drying and storage of foods, and in separation processes. One basic feature of both coefficients is that they are affected strongly by the characteristics of the processing equipment and the geometry of the system.

Conduction:- Heat transfer from one part of the homogenous opaque solid to another, under influence of the temperature gradient (transfer of heat by direct contact of particles of matter).

- Heat is transfer by conduction when adjacent atoms brush against another or electron moves from one atom to another.
- Steady state amount of heat in heat out = unsteady state.

Convection:- transfer of thermal energy by the movement of molecules from one part of the material to another.

- Material convection
- Forced convection

Radiation:- transfer of heat energy through empty space.

All object with a temperature above absolute zero radiate energy. No medium is necessary, for it is transferred through electromagnetic waves.

Related Physical Properties:-

Space, size, volume, unit surface area, roundness sphericity average projected area are need to be defined as quantified before heat transfer problems involving biological problems can be solved.

For example heat transfer through slab is different than that of sphere.

Specific heat:-

Heat required to raise the temperature by 1˚C for unit mass of the body.

$C = \left[\frac{q}{m\Delta T}\right]$ q= heat, kcal
C = kcal/ kg˚C m= mass, kg

ΔT= temperature difference, ˚C

Thermal Conductivity:-

Thermal conductivity is defined as the amount of heat flows through unit thickness of material over an unit area per unit time for temperature difference.

$Q=-k\left[\frac{A\left(T1-T2\right)}{x}\times t\right]$
Ability to conduct heat: $q= kA\left[\frac{dt}{dx}\right]$
Thermal conductivity is the quantity heat that passes through a body (plate) of particular area & thickness when it's opposite faces difference in temperature.
$q = kA\left[\frac{dt}{dx}\right]$ t= Time, dT= temperature difference, dx= thickness
$\left[\frac{dQ}{d\theta}\right]= kA\left[\frac{dt}{dx}\right]$ A= Surface area, k= thermal conductivity.

Heat transfer from higher to lower so (dT) accounts for the negativity (So final temperature will have lower value then the initial) to negate that (-) sign. The final equation for

'**k**'$=\left[\frac{kcal-m}{m-hrk}\right]$ or

Thermal diffusivity:-

It is rate at which heat is diffused out of the materials. It is the ratio between thermal conductivity to volumetric heat capacity.

\[\alpha=\]m^2/s=\[\alpha={k\over{PCp}}\]= PC_p=Volumetric heat capacity

\[{{dt}\over{d\theta}}=\alpha\left({{{d2t}\over{dx2}}+{{d2t}\over{dy2}}+{{d2t}\over{dz2}}}\right)\]

Thermal Emissivity(E):-

It is a ratio of total Emissive power of a blackbody to the same temperature.

This thermal constant is associated with the rate of heat transfer by radiation from a hot body to a cold body.

$Q = AF_aF_e$\[\sigma\]$(T1^4-T2^4)$ **E = 1 black body FaFe<1 real object**

A= surface area

F_a = Angle factor, representing the angle that one body sees the other body.

F_e = Emissivity factor

\[\sigma\]= Stefan Boltzmann constant

T_1 &T_2 = Absolute temperature of body 1 and 2, respectively

While dealing with grey body Kirchhoff's law of thermal radiation is applied emissivity equals to absorptivity (for an object in thermal equilibrium) so that the body does not absorb all incident light will also emit less radiation then ideal blackbody.

Stefan Boltzmann's law:- The total energy radiated per unit surface area of a black body is unit time in proportional to the fourth power of the thermodynamic temperature.

\[\sigma\]=5.670410-^{8} W/ m^2k^{-4}

\[{P\over A}=\]\[\sigma\]T^4 J/ m^2s ____Stefan Boltzmann law

\[{P\over A}=E\[\sigma\]T^4 T_c = Colder temperature

$P = E$\[\sigma\]$(T^4 – T_c^4)$ E= Emissivity

Thermal Effusively:- Square root of the product of the materials thermal conductivity & Volumetric heat capacity.

$e = (K_pC_p)^{1/2}$ K= thermal conductivity

\[{{kal} \over {m2k\root {} \of {hr} }}\]

\[\sqrt{{{kal}\over{S.m.c}}\times{{mg}\over{m^3}}\times{{kal}\over{kg^\circ C}}}\] p = density, C_p= rp heat

A material thermal effusivity is a measure of its ability to exchange thermal energy with its surrounding.

If two semi-infinite bodies initially at temperature T & T2 are brought in perfect thermal contact, the temperature of the contact surface T_m will be given by their relative thermal effusivity.

$T_m = T_1+(T_2-$
$T_1)\[{{{\rm{e}}_{\rm{2}}}\over{\left({{\rm{e}}_{\rm{2}}+{\rm{e}}_{\rm{1}}}\right)}}\]$ (For semi infinite bodies in perfect thermal contact)

Diffusivity or diffusion constant is the proportionally constant between the molar flax due to molecular diffusion and the concentration gradient of the sphere.

Through Fick's law (m^2s^{-1})

Temperature dependence of the diffusion co-efficient
J =-D\[{{d\theta}\over{de}}\]\[\theta\]=Concentration gradient
-D W_w= flow rate, A= surface area, y = Any position

D= diffusion Coefficient\[{{dc_W}\over{dy}}=\]change in cold water m^2/s

Temperature Dependence

D=\[D_0e{{- E_a}\over{RT}}\] Arrhenius equation

D_o = maximum diffusion coefficient at infinite temp.

E_a = activation energy

T = Absolute temp, K

R = universal gas constant

Thermal diffusivity is determines the speed of heat of the 3- dimensional propagation or diffusion through the material.

Mass transfer coefficient:-

It is the ratio of mass there of vapour (w_w/A) at any point between the wet and dry surfaces to the difference in concentration of two boundary layers(lw_0-lw_c) between which mass is being transferred.

Kc=mass transfer coefficient,

Kc=\[{{n_A }\over{A\Delta c_A^{}}}\] \[\Delta c_A^{}\]=Conc. difference driving force, myl /m^3

A=effective man transfer area, m^2, n_A=man transfer rate(mol / s)

Kc=
This is an analogy with heat transfer coefficient

Coefficient of Thermal expansion:- The change in size with temperature / C^0

\[\alpha _V=\left({{1\over V}}\right)\left({{{dV}\over{dT}}}\right)\]V=Volumeofmaterial,\[{{dV}\over{dT}}\]=Rate of volume with temp.
\[{{\Delta T}\over V}=\alpha _VdT\]\[\alpha _V\]=Volumetric thermal expansion

Linear thermal expansion

\[\alpha _L={1\over L}{{dL}\over{dT}}\]
\[{{\Delta L}\over L}=\alpha _L LT\]
\[\alpha _V=3\alpha _L\]
\[\left({V+\Delta V}\right) =\left({L+\Delta L}\right)^3=L^3+3L^2\Delta L+3L\Delta L^2+\Delta L^2\L^3+3L^2\Delta\]
=\[V+3V{{dL}\over L}L^3+L^3\alpha _V\Delta T\]
=\[L^3+3L^3\alpha _L\Delta T+3L^3\alpha _L ^2\Delta T^2+L^3\alpha _L ^3\L^3 3L^3\alpha _L \Delta T\]

Since\[\Delta T\]is small the higher terms can be neglected.

\[\alpha _A={1\over A}{{dA}\over{dT}}\]
\[{{\Delta A}\over A}=\alpha _A \Delta T\]5

Table 5.1 dimensionless number used for calculation of thermal properties

Name	Symbol	Group of Physical properties	
Biot member	B_i		H=film heat coefficient or Convective heat
Fourier number	F_0		Transfer coefficient
Levies number	L_e()		L_c= characteristic length
Nusselt Number	Nu		K=Thermal conductivity of the body
Prandlt number	Pr		A=Thermal Diffusivity
Regnolds number	Rc		=length though which conduction occurs
Schmidt number	Sc		D= Man diffusivity
Stanton number	St		

$Sc=\left[\frac{V}{D}\right] = \frac{\mu}{PD}$

V= kinematic viscosity

$\eta\left(\mu\right) = dynamicvis\cos ity$

P= density

$Pr = \frac{v}{\alpha} = \frac{\mu C_p}{k}$

C_p= specific heat

v= velocity

$Nu=\left[\frac{hL}{ks}\right]$
$St=\left[\frac{h}{c_p pv}\right]$ h= convective heat transfer coefficient, P= density of fluid

$St=\left[\frac{Nu}{R_e .P_r}\right]$ C_p= sp heat, v= velocity of the fluid

Specific Heat calculation

C_{avg}= C_{ps}= Sp. Heat of solid not Fat, C_{pw}= Sp. Heat of water

C_{pw} = 4186.8M, C_{ps}=837.36

C_{avg}= 4186.8M+(1-M)837.36

C_{avg}=3349M+837.36 J/(ag.k)…….(1)

C_{pf} = Sp heat of fat = 1676.72

C_{avg} = 1674.72F + 7.36SNF + 4186.8M (J/ng^0)……(2)

Energy Balances

C_p(above freezing point)$=\left[\frac{4.19M}{110}\right] + \frac{0.84(100 - M)}{110}$.....kJ/kg^o C\]
C_p(above freezing point)$=\left[\frac{2.1M}{110}\right] + \frac{0.84(100 - M)}{110}$\]
$=\left[335 \times \frac{m}{100}\right]$,
$K =\left[\frac{0.55M}{100}\right] + \frac{0.26(100 - M)}{100}$\]
$Ku/Ou= \left[\frac{2.4M}{100}\right] + \frac{0.26()100 - M}{100}$\]

The thermal properties of food materials depend on the composition of the food. Since most foods are composite of many macro and micromolecules, the thermal properties vary with the composition type. So the properties of food would vary than that of the individual pure molecules. In this context boiling point rise and freezing point depression of the foods are discussed in the following section.

Boiling point Rise:- In liquid food boiling point rise refers to water evaporation in which water change from the liquid phase to steam or vapour phase, and water vapour pressure equals to the external pre liquid foods contain high molecules weight solids that cause the

boiling point be evaluated above that of pane water. The boiling point rise (\[\Delta T_r\]), is known as the increase in the boiling point over that of pure water in a given liquid food. As the vapour pressure of most aqueous solution is lower than that of water at the same temperature, the boiling temp(point) of the solution in higher than that of pure water.

Freezing point Depression: During freezing water in the food changes to ice which heat in removed by a refrigeration system. During heat removal, the unfrozen water will still contain dissolved solids. The presence of dissolved solids will depress the initial freezing point to certain amount \[\Delta Tf\] below the expected solidification temperature of pure water. Freezing point depression is defined as the temperature reduction \[\Delta Tf\].

Both the boiling point rise and freezing point depression of a food are related to its solution concentration.

Eutectic point:- Temperature where there no further concentration due to freezing , thus the solution frees. Temperature at which a crystal it indecision solute exists in equilibrium with unfrozen liquid rice. Crystallization occurs below eutectic point. The solution becomes super saturated.

A eutectic or eutectic mixture is a mixture of two or more phases at a composition that has lowest melting points & where the phases simultaneously crystallize from molten solution at this temperature. The proper ratios of phases to obtain a eutectic identified by the eutectic point on a phase diagram.

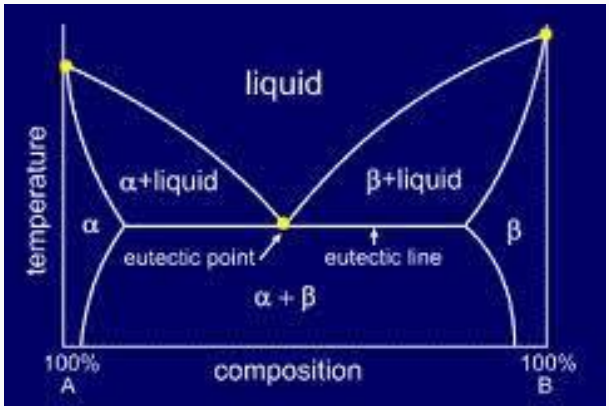


Fig. Eutectic point in a phase diagram

Frozen foods being thawed for are subjected to quality loss, if thawing is slow. Most concentrated solution that are last to freeze and slow to thaw, since they are eutectic mixture. The eutectic mixture is a solution of such composition that it frozen thaws as separation of pure ice. The frozen eutectic has a constant properties of ice crystal intermingled with solution crystal. The temperature at which a eutectic mixture is formed is called eutectic point or eutectic temperature. Freeze drying should be concerned out at this point. Maximum crystals formations is not possible until this temperature reached

Table 5.2 the eutectic point of different commodities

commodity	Eutectic Temperature
Ice cream	55°C
Meat	50-60°C
Bread	70°C

Application :

Freeze drying:- If eutectic point is not reached quickly the food have pure texture.

Thermal imaging: Infrared imaging for food quality determination

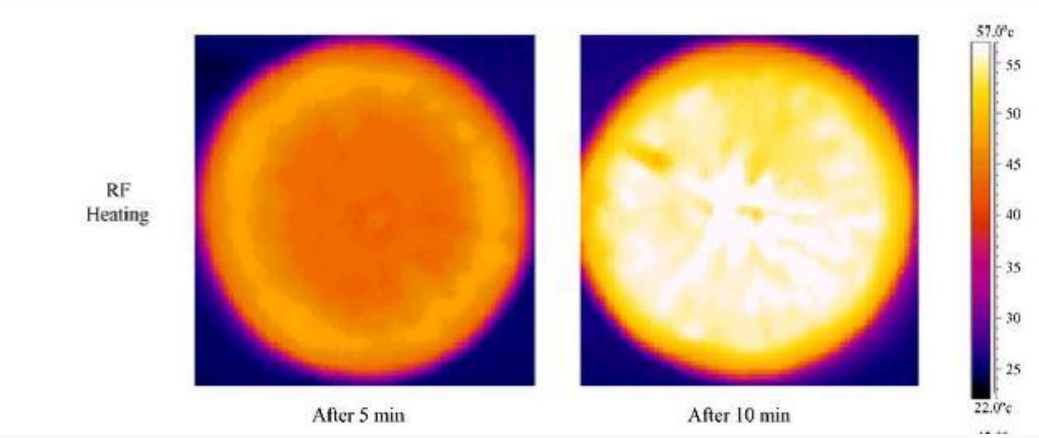


Fig. Thermal imaging of oranges when heated with radio frequency heating system (source: Birla et al., 2004)

Lesson 6. Measurement of thermal properties of biomaterials

Measurement of thermal properties of biomaterials

Thermal conductivity measurement techniques can be divided into three major groups: a. Steady state Techniques, b. Quasi-steady techniques, c. Transient techniques. The two most used techniques are the Guarded Hotplate and the Heated Probe. It is highly affected by physical properties of the material such as the moisture content, the temperature and structure, such as distribution of component phases, and fiber orientation.

Measurement of Thermal Conductivity

Measurement of thermal conductivity can be done by either steady-state or transient-state methods. There are a number of experimental measurement techniques under each of these two categories.

The advantages of steady-state methods are the simplicity in the mathematical processing of the results, the ease of control of the experimental conditions, and often quite high precision in the results. However, a long time is required for temperature equilibration. The moisture migration and the necessity to prevent heat losses to the environment during this long measurement time are the disadvantages of steady-state methods. In addition, these methods require definite geometry of the sample and relatively large sample size.

On the other hand, the transient methods are faster and more versatile than the steady-state methods and are preferable for extensive experimental measurements. Transient methods are preferred over steady-state methods because of the short experimental duration and minimization of moisture migration problems.

A. Steady State Methods

In steady-state methods, two sides of a flat object are maintained at constant but different temperatures and the heat flux through the sample is measured. Steady-state methods are longitudinal heat flow, radial heat flow, heat of vaporization, heat flux, and differential scanning calorimeter methods.

(a) Longitudinal Heat Flow Method: The most common method in this group is guarded hot plate method. This method is suitable mostly for determination of thermal conductivity of dry homogeneous materials in slab forms. It is the most widely used and the most accurate method for the measurement of thermal conductivity of materials, which are poor heat conductors.

In this method, the heat source (T1), the sample, and the heat sink (T2) are placed in contact with each other and with a thermal guard heated electrically. The thermal guard plates are kept at the same temperature as the adjacent surfaces, in a way that no heat leakage takes place from source, sample, or sink boundaries. Thermal conductivity is measured after the

sample has reached steady state condition. However, achieving steady-state conditions may take several hours. It is assumed that all of the measured heat input is transferred across the sample. The thermal conductivity is calculated by measuring the amount of heat input required to maintain the unidirectional steady-state temperature profile across the test sample.

(b) Radial Heat Flow Methods. These methods are suitable mostly for loose, powdered, or granular materials.

(i) Concentric Cylinder Method: In this method, the sample is placed between two concentric cylinders. This method is preferable for liquid samples. The heater is usually located at the outer cylinder. A coolant fluid flows through the inner cylinder. The heat that the coolant absorbed is assumed to be equal to the heat transferred through the sample. Thermal conductivity can be calculated from the unidirectional radial steady-state heat transfer equation as

The length-to-diameter ratio of the cylinder must allow the radial heat flow assumption. End guard heaters may be used to minimize the error due to axial heat flow.

(ii) Concentric Cylinder Comparative Method: This method uses a central heater followed by a cylindrical sample and a cylindrical standard. The temperatures T1 and T2 at radii r1 and r2 of the sample, respectively, and temperature T3 and T4 at radii r3 and r4 of the standard, respectively, are measured. Assuming radial heat flow, the thermal conductivity can be determined

Sphere with Central Heating Source. In this method, the sample is placed between the central heater which has a radius r1 and the outer radius of sphere, r2. The sample completely encloses the heating source so that end losses are eliminated. Assuming that the inner and outer surfaces of the sample are T1 and T2, respectively, after the steady state has been established heat flow will essentially be radial thermal conductivity can be determined as:

This is the most sensitive method among the steady-state methods because the error due to heat losses can be practically eliminated. However, it cannot be widely used because of the difficulty in obtaining suitably shaped food samples. This method has been used mainly for granular materials. Samples should be filled in a vacuum environment because air bubbles trapped inside the sphere could increase contact resistance.

(c) Heat of Vaporization Method: In this method, a small test sample is put between two silver plates, one of which is in contact with a liquid A at its boiling point and the other one is in contact with liquid B. Heat transferred through the sample vaporizes some of the liquid B, which has a lower boiling point. Since the time necessary to vaporize a unit mass of liquid B is known, the thermal conductivity of the sample is calculated:

(d) Heat Flux Method: The heat flow meter is a device for measuring heat flux. In this technique, a heat flux sensor is attached to the inner surface of the wall with a very thin layer of high thermal conductivity adhesive. A temperature difference of 5 to 7◦C is maintained within the system and the thermal conductivity is evaluated at the arithmetic mean temperature.

(e) Differential Scanning Calorimeter (DSC): An attachment to a differential scanning calorimeter was designed to measure thermal conductivity of foods. The sample of uniform cross section (possibly cylindrical) is placed in the sample pan, the opposite end of which is in contact with a heat sink at constant temperature. Initially, the sample is maintained at a constant temperature. At a predetermined time, the pan temperature is immediately increased to a predetermined higher value. A new steady state is reached in a few minutes and the heat flow into the DSC pan levels off. The difference in heat flow between the two states is recorded from the thermogram. Then, thermal conductivity of the sample can be calculated using Fourier's heat conduction equation:

where L is the sample thickness, A is the cross-sectional area,

T1 is the initial temperature difference, and T2 is the final temperature difference.

This method is simple and suitable for small size samples, for both low- and high-moisture foods. Time to achieve the new steady state is small enough (10 to 15 min) to prevent moisture migration since the sample is small. This approach may be modified to measure thermal conductivity as a function of temperature by using small thermal perturbations. However, measurement of thermal conductivity under ultrahigh temperature (UHT) conditions may require extensive equipment modification. Thus, it is more expensive than either the line heat source or modified Fitch methods, which are the most commonly used unsteady-state thermal conductivity measurement methods in food systems.

Using D.S.C based on steady state method.

\[k =\left({{L\over {\Delta Q}}}\right)\left({{A\over{\Delta T_2 -\Delta T_1}}}\right)\] L= sample length,\[\Delta Q\]=difference in energy Required to maintain pan temperature (W)

A= sample area perpendicular to flow (m^2)

\[\Delta T_2=\]Final temperature difference between DSC heating pan & sample (k)

\[\Delta T_1=\]Initial temperature difference between DSC heating pan & sample (k)

Assumption

Good contact between DSC & sample

Negligible heat loss from radial direction

No thermal gradient in the heat sink

B. Unsteady-State Methods

The most important transient methods are the thermal conductivity probe method, transient hot wire method, modified Fitch method, point heat source method, and comparative method.

(a) **Thermal Conductivity Probe Method**: This method is the most popular method for determining thermal conductivity of food materials because of its relative simplicity and speed of measurement. In addition, this method requires relatively small sample sizes. On the other hand, it requires a fairly sophisticated data acquisition system. In this method, a constant heat source is applied to an infinite solid along a line with infinitesimal diameter, such as a thin resistant wire. The electrical wire must have a low resistance so that the voltage drop across it is negligible compared to the voltage drop across the heater. For measurement of thermal conductivity, the container is filled with sample and the line heat source probe is inserted at the center of the container. The container is placed in a constant temperature bath and equilibrated at room temperature. After the initial temperature is recorded, the probe heater is activated and heated at a constant rate of energy input. Then, the time versus temperature adjacent to the line heat source is recorded.

(b) Transient Hot Wire Method: This method involves a thin heater wire similar to the line heat source method. However, in this case, the hot wire is located at the interface between the sample and a reference of known thermal conductivity. The heater and temperature sensor in the hot wire thermal conductivity apparatus consist of a single wire that is exposed to the material, while in the thermal conductivity probe there are separate wires that are usually sealed in a tube. When electrical power is applied to the heater wire, the temperature rise T at a point located on the interface between the two materials at a distance x from the heater wire may are calculated.

(c) Modified Fitch Method:. One of the most common transient methods used to measure the thermal conductivity of low conductivity materials is the Fitch method. The Fitch method consists of a heat source or a sink in the form of a vessel filled with constant temperature liquid, and a sink or a source in the form of a copper plug insulated on all sides except one face through which heat transfer occurs. The sample is sandwiched between the vessel and the open face of the plug. Then, the temperature of the plug varies with time depending on the heat flow rate through the sample. Copper may be considered as lumped system since its thermal conductivity is high enough, and its temperature history may be used together with its mass and physical properties for calculation of the sample thermal conductivity.

(d) Point Heat Source Method: This method involves a point heat source, which is heated for a period of time followed by monitoring of its temperature as the heat dissipates through the sample. The typical device used for this purpose is a thermistor that serves as both a heating element and a temperature sensor.

(e) Comparative Method: The comparative method is simple and a range of sample sizes can be handled via this method. Overall thermal conductivity measurement is possible rather than local measurement. Therefore, it is suitable for porous foods such as cakes. This method involves cooling of two spheres side by side in a well stirred ice/water bath. One sphere contains the sample and the other contains a reference of known thermal conductivity. The thermal conductivity of the sample is calculated from the time–temperature data of the cooling spheres. It is based on the analytical solution for the center temperature of a sphere being cooled with convection boundary conditions.

Thermal conductivity measurement:-

Thermal conductivity measurement of food grains varies from 0.3 to 0.6 kcal/m hr˚C, for bulk is about 0.10 to 0.15 kcal/ m hr˚C, which is due to presence of air space in it. Thermal conductivity of air is 0.02 kcal/ m hr˚C. The thermal conductivity is measured with

For wheat,

k= 0.060+0.002m kcal/ m hr˚C (for m.c between 10% to 20%)

k= thermal conductivity

m= m.c(% db)

For water = 0.5 to 0.6 w/m.k

Specific heat & Measurement:-

It could be the seam of specific heat of bone dry matter & of its moisture content.

$$C_p=\left({{m\over{100}}}\right)C_W+\left({{{100 - m}\over {100}}}\right)C_d$$ For M.C above 8% only

Or $$C_p=\left({{m\over{100}}}\right)+\left({{{100-m}\over{100}}}\right)C_d$$ kcal/kg˚C

C_d= Sp. Of bone dry material, C_w of water = kcal

m= m.c content in wet basis

Sp.heat of bone dry grain varies between 0.35-0.45 Kcal/kg°C

Mixture method:-

Most widely used for measuring Sp. heat. In this method, the specimen of a union mass temperature is placed in a calorimeter of a known sp. heat containing water or a liquid with known temperature & mass.

One unknown sp. heat of the specimen is then computed using a heat balance between the heat gained by or lost by the water or liquid & calorimeter & the heat cost or gained by the specimen.

$m_s\ c_p(T_{em}$ - $T^{0C})=\[c_{pw}(m_w+w)(T_{oc}-T_{em})\]$

$c_p= {{{\rm{c}}_{{\rm{pw}}}}(m_w + w)(T_{oc}-T_{em})}\over{m_s (T_{em}-T_{ls})}}\]$

c_p= Sp.heat of sample in temperature range of $T_{oc} toT_{em}$](J/ng k)

c_{pw}= average heat of water in the temperature $T_{oc} toT_{em}$

m_w = man of water(kg)

m_s = man of sample(kg)

W= water equivalent of the system (kg)

T_{oc}= Initial temperature of calorimeter

T_{em}=Final equilibrium temperature of the mixture

T_{es}=Initial temperature of sample

The main source of the temperature is thermal leakage from the calorimeter even though losses are negligible.

Specific heat measurement by DSC:

To find out the specific heat of the food sample usually a reference sample of nown specific heat is carried out prior to running the test for the food sample. The reference samples are usually a sapphire disc or distilled water. The sample of uniform cross section (possibly cylindrical) is placed in the sample pan, the opposite end of which is in contact with a heat sink at constant temperature. Initially, the sample is maintained at a constant temperature. At a predetermined time, the pan temperature is immediately increased to a predetermined higher value. A new steady state is reached in a few minutes and the heat flow into the DSC pan levels off. The difference in heat flow between the two states is recorded from the thermogram. The two curves (one for the reference sample) and the food sample thermogram is then compared to find out the specific heat of the sample.

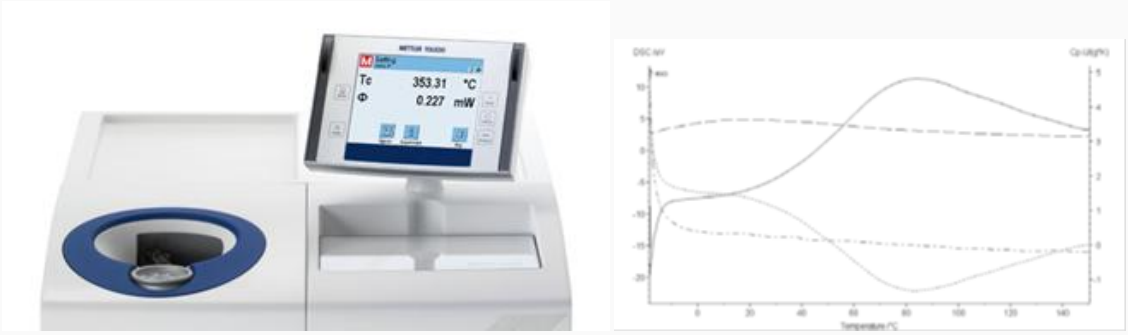


Figure of DSC (a) (source: Mettler Toledo) and thermogram(b) source: Mohapatra & Bal, 2003)

<u>Calculations Sp.heat measuring problems</u>

Two compartment calorimeter method

Comparision calorimeter method

$$\left(\frac{dQ}{dt}\right)_A=\left(C_{PA}m_A\right)+\left(C_{pw}m_w\right)\frac{dT}{\Delta t_A}$$

$$\left(\frac{\Delta Q}{\Delta t}\right)_B=\left(C_{PB}m_B+C_{ps}m_s\right)\frac{\Delta t}{dt_B}$$

Adiabatic chamber Method:-

Q =\[\left({m_{cp}\Delta T}\right)_{sample}+\left({m_{cp}\Delta T}\right)_{Conyainer}+\left({m_{cp}\Delta T}\right)_{chamber}\]
When no heat or moisture transfer through the chamber is required

A measured quantity of heat is added by heating a wire buried in the bulk of the contains placed in chamber.

\[{{DifferntialScanningcalorimeter}\over{Sphereasfunctionoftemperature}}\]
\[{{dQ}\over{dt}}=\] heat flow rate
w(J/s)\[C_p={\raise0.7ex\hbox{${\left({{{dQ}\over{dt}}}\right)}$}\!\mathord{\left/{\vphantom{{\left({{{dQ}\over{dt}}}\right)}{m_s }}}\right.\kern-\nulldelimiterspace}\!\lower0.7ex\hbox{${m_s}$}}\left({{{dT}\over{dt}}}\right)\]
\[{{dT}\over{dt}}=\] heating rate k/s or c/s , m_s=mass/hg

Thermal properties of food constituent at approximately 20°C

Component	Sp. heat kJ/kg°C	Thermal conductivity W/m °C
Water	4.18	0.60
Carbohydrate	1.42	0.58
Protein	1.55	0.20
Fat	1.67	0.18
Air	0.96	0.25
Ice	2.09(-2°C)	-2.4(below °C)
Steam	2.01(110°C)	-
Inorganic minerals	0.84	-
Metals	0.05-1.0	50-400

Lesson 7. Aerodynamic properties of biomaterials

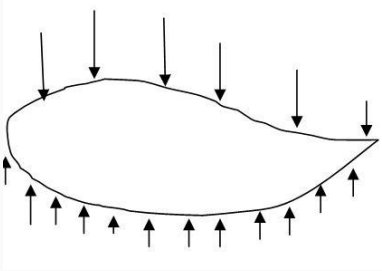
Introduction:

Aero and /or hydrodynamic properties are very important characters in hydraulic transport and handling as well as hydraulic sorting of agricultural products. To provide basic data for the development of equipment for sorting and sizing of agro commodities, several properties such as: physical characteristics and terminal velocity are needed. The two important aerodynamic characteristics of a body are its terminal velocity and aerodynamic drag. By defining the terminal velocity of different threshed materials, it is possible to determine and set the maximum possible air velocity in which material out of grain can be removed without loss of grain or the principle can be applied to classify grain into different size groups. In addition, agricultural materials and food products are routinely conveyed using air. For such operations, the interaction between the solid particles and the moving fluids determine the forces applied to the particles. The interaction is affected by the density, shape, and size of the particle along with the density, viscosity, and velocity of the fluid. This chapter discusses briefly with the different aerodynamic properties and their methods of measurement.

7.1. Drag Coefficient:-

It is used to quantify drag or resistance of an object is a fluid environment such as air or water. It is a dimensionless quantity. Drag coefficient is always associated with surface area:

Figure



When fluid flow occurs about immersed objects, the action of the forces involved can be illustrated as follows. The pressure of the upper side of the object is less than that of lower side is great than that of & that of lower side is greater than the pressure p in the undisturbed fluid stream. In addition to these force normal to the surface of the object, there are shear stresses, C acting tangential to the surfaces in the direction of flow & resulting from frictional effects.

The resultant force for may be resolved into components, F_D the drag & F_V the lift force.

\[{F_D} = {f_1}({A_P},{\rho _f},\eta ,E,V)\] \[{A_P}\]=Projected area of the object

\[{F_L} = {f_2}({A_P},{\rho _f},\eta ,E,V)\] r_f=Fluid density, h=Viscosity of fluid

E= modulus of Elasticity

V= Velocity of the object relative to fluid

Employing dimensional analysis.

\[{F_D} = {C_D}\frac{{{A_p}{\rho _f}{V^2}}}{2}.....1\]

\[{F_L} = {C_L}\frac{{{A_p}{\rho _f}{V^2}}}{2}.....2\]

\[{C_D}\] &\[{C_L}\] are drag coefficient & lift Coefficient

\[{F_r} = \frac{1}{2}C{A_p}{\rho _f}{V^2}.....3\]

\[{F_r}\]=resistance drag force Wt. of particles at thermal velocity

C= overall drag coefficient

In certain cases it is desirable to resolve the resultant force into components of force into components of frictional drag to tangential force on the body surface & profile drag due to pressure distribution around the body. In laminar or low velocity flow where variation in fluid density is small and viscous action governs the flow, the profile or pressure drag is negligible. In thermal or high velocity flow where fluid compression & not viscous action governs the flow, the frictional drag is negligible.

e.g. Frictional drag:- drag force exerted on one side of a smooth flat plate aligned with flow.

e.g. Profile drag:- drag force on blunt object.

Frictional Drag: - for Flat laminar boundary layer

\[{C_f} = \frac{{1.328}}{{{{\left({{N_R}} \right)}^{0.5}}}}.....4\]

For flat plate turbulent boundary layer

\[{C_f} = \frac{{0.455}}{{\log {{\left({{N_R}} \right)}^{2.58}}}}.....5\]

\[{N_R}\]=Reynolds number \[{N_R} = \frac{{Vdpf}}{\eta }.....6\]

d=length or diameter of a sphere (dimension of an object)

η=absolute viscosity,

V= relative velocity

r_f= fluid density

For transition region

$$C_f = \frac{0.455}{\log (N_R)^{2.58}} - \frac{1700}{N_R} \quad \text{.....7}$$ Drag should be multiplied by 2 for plates of 2 side.

Profile or Pressure Drag:

When a blunt object, known as sphere is placed in a fluid flow, the frictional drag can be neglected because of the small surface area on which frictional effects can work. The exception is the case of flow at very low Reynolds number is less than unit, where stokes low is applicable. Here inertia force may be neglected & those of viscosity alone considered, the flow closes behind a sphere like object & profile drag is composed primarily of frictional drag.

Stoke's law of drag force

$$F\Delta = 3\pi \eta V d_P \quad \text{.....8}$$ d_P= diameter of sphere, diameter of sphere,

viscosity

Equating (9) equation (1)

$$F_D = \frac{C_D A_P \rho_f V^2}{2} = 3\pi \eta V d_p$$

$$3\pi \eta V d_p = \frac{C_D A_P \rho_f V^2}{2} \quad N_R = \frac{\rho V d_p}{\eta}$$

$$3\pi \eta d_p = \frac{C_D \pi^2}{2 \times 4} d_P^2 \rho_f V \quad A_P = \frac{\pi}{4} d_p^2$$

$24 = C_D N_R$ $$24 = C_D \rho_f \frac{V d_P}{\eta}$$

$$C_D = \frac{24}{N_R} \quad \text{.....9}$$

As Reynolds number exceeds unity, the stokes law is no longer applicable because flow opens up behind the blunt object & the drag force is a combination of frictional drag as well as pressure drag in a range up to N_R =1000. N_R above frictional effect may be negligible.

Terminal Velocity:

In free fall, the object will attain a constant terminal velocity V_t at which, where acceleration will be zero.

Net gravitational accelerating net upward equals to the sum of buoyant force and drag force

Gravitational force acting downward= buoyant force exerted by the fluid on the body in upward direction+ drag force (frictional resistance due to motion of the body in the fluid medium)

$$m_p g = m_p a_f + \frac{1}{2}\left(A_p P_f V t^2 \right) \quad \text{.....10}$$

\[{m_p}g\left({\frac{{{\rho _p} - {\rho _f}}}{{{\rho _p}}}} \right) = \frac{1}{2}\left({{A_p}{\rho _f}V{t^2}} \right).....10\] g= acceleration due to gravity

\[{V_t} = \left[{\frac{{2W({\rho _p} - {\rho _f})}}{{{\rho _f}{\rho _p}{A_P}C}}} \right]\] g= acceleration due to gravity

\[{V_t} = \left[{\frac{{2W({\rho _p} - {\rho _f})}}{{{\rho _f}{\rho _p}{A_P}C}}} \right]\]
\[{m_p}\]= mass of particles, W=wt. of particles

\[e = \left[{\frac{{2W({\rho _p} - {\rho _f})}}{{{\rho _f}{\rho _p}{A_P}C}}} \right].....11\] \[{P_p}\]=mass density of particles, \[{P_f}\] = mass density of fluids

For spherical Bodies

\[{A_p} = \frac{\pi }{4}d_P^2 = W = \left({\frac{\pi }{6}} \right){P_p}gd_P^3\]

\[{V_t} = {\left[{4g{d_P}({p_P} - {p_f})/3{p_f}} \right]^{1/2}}.....12\]

For laminar flow, the value of C in calculated from for Reynolds number L1.0, substituting C in NR.

\[{V_t} = g{d_P}^2({p_P} - {p_f})/18\eta .....13\]

For turbulent flow $10^3 < N_R < 2\times10^5$ c=0.44

\[{V_t} = 1.74{\left[{g{d_P}({p_P} - {p_f})/{p_f}} \right]^{1/2}}.....14\]

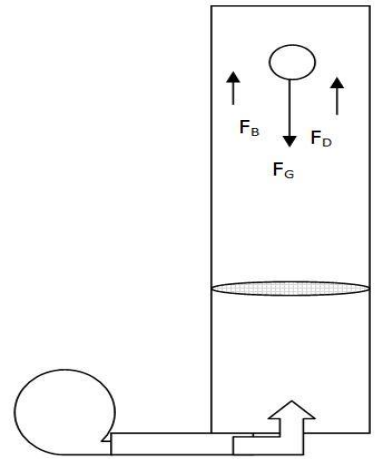
Finally for intermediate region $2 < N_R < 10^3$

\[C = \frac{{18.5}}{{({N_R})0.5}}.....15\]

\[{V_t} = \frac{{0.153{g^{0.714}}{d_{}}^{0.142}{{({p_P} - {p_f})}^{0.714}}}}{{{p_f}^{0.286}{\eta ^{0.428}}}}.....16\]

Measurement of terminal velocity:

Most scientists and researchers employ air column to find out the terminal velocity of grains. The set up usually consists of a vertical air column, which is blown from the bottom and passes through the screen. The screen uniformly distributes the air velocity. The air column is also attached with velocity measuring device. The blower maintains variable speed. When grains are allowed to drop into the column, initially they attains acceleration, once the velocity is adjusted they fall to the bottom with a constant velocity. This constant velocity is termed as terminal velocity



Factors affecting aerodynamic properties of biomaterials:

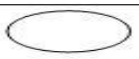
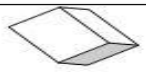
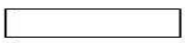
- Frontal area
- Particles size orientation(In turbulent region particles assumes position of maximum resistance)

	Sphere	Thin disk normal to face	Thin disk parallel to face	Infinite cylinder normalize
Reynolds's Number Equation	$d_P V P_f / n$	$d_P V P_f / n$	$2LVP_f / n$	$d_P V P_f / n$
Frontal area, A_P	$\frac{\pi}{4} d_P^{\,2}$	$\frac{\pi}{4} d_P^{\,2}$	$d_P L$	$d_P K$
mass, m_p	$P_P\left[\frac{\pi}{6}\right] d_P^{\,3}$	$P_P\left[\frac{\pi}{4}\right] d_P^{\,2} L$	$P_P\left[\frac{\pi}{4}\right] d_P^{\,2} L$	$P_P\left[\frac{\pi}{4}\right] d_P^{\,2} L$
Drag relationship stream line flow	$3\pi\eta V d_P$	$8\eta V d_P$	$\left(\frac{16}{3}\right)\eta V d_P$	$\left(\frac{4\pi}{K}\right)\eta V L$
$C_D N_R$	24	$\frac{64}{\pi}$	$\frac{64}{3}$	$\frac{8\pi}{K}$
Turbulent Flow C_D (avg)	0.44	1.12	-	1.2
N_R(range)	$1\times10^3 - 2\times10^5$	> 1000	-	$1\times10^2 - 2\times10^5$
Terminal velocity	$\frac{4gd_P(p_P - p_f)}{3CP_f}$	$\frac{2gL(p_P - p_f)}{CP_f}$	$\frac{gd_P(p_P - p_f)}{2CP_f}$	$\frac{gd_P(p_P - p_f)}{2CP_f}$

L= thickness of disk, length of rod or cylinder length of flat ϕ late along director of flow

K=2002/n N_R

Grains	Terminal velocity, m/s	
Wheat	9-11.5	
Barley	8.5-10.5	
Small oats	19.3	
Corn	34.9	
Soybean	44.3	
Rye	8-5-10.0	
Oats	8.0-9.0	
Grains	Bulk Density	Particle density
Wheat	850	1480-1410
Paddy	575	1411-1342
Parboiled rice	522-566	1405-1346
Rice	507-565	946-991
Bean	750	
oat grain		1380.0

Shape	Drag	Coefficient
Sphere		0.47
Half sphere		0.42
Cone		0.50
Cube		1.05
Angled cube		0.80
Long Cylinder		0.82
Short Cylinder		1.15
Stream lined Body		0.01
Streamlined half body		0.09

- In the handling and processing of agricultural products, air is often used as a carrier for transport or for separating the desirable products from unwanted materials, therefore the aerodynamic properties, such as terminal velocity and drag coefficient, are needed for air conveying and pneumatic separation of materials. As the air velocity, greater than terminal velocity, lifts the particles to allow greater fall of a particle, the air velocity could be adjusted to a point just below the terminal velocity. The fluidization velocity for granular material and settling velocity are also calculated for the body immersed in viscous fluid.

Application to Agricultural products

- Separation of foreign materials from seeds, grains potato, blue berry
- Conveying and handling of grains, chopped forage small & large fruits
- Hydraulic handling of apples, cherries, mango& potatoes etc.

Working principle of Aspirator:- Under steady state condition, where terminal velocity has been achieved, if the particles density is greater than fluid density, the particles motion will be downward. If particles density is smaller than the fluid density, the particle will be rise.

Lesson 8. Frictional properties of biomaterials

Frictional properties such as angle of repose and coefficient of friction are important in designing equipment for solid flow and storage structures and the angle of internal friction between seed and wall in the prediction of seed pressure on walls. The coefficient of static friction plays also an important role in transports (load and unload) of goods and storage facilities. It is important in filling flat storage facility when grain is not piled at a uniform bed depth but rather is peaked. Coefficient of friction is important in designing storage bins, hoppers, chutes, screw conveyors, forage harvesters, and threshers. The material generally moves or slides in direct contact with trough, casing, and other components of the machine. The various parameters affect the power requirement to drive the machine. The frictional losses are one of the factors, which must be overcome by providing additional power to the machine. Hence, the knowledge of coefficient of friction of the agricultural materials is necessary.

Angle of Repose

The angle of repose is measured with a square box, which is filled to the top and then removing lid, by allowing the granular material to fall freely, resulting in a conical shape of the sample (Fig 8.1). By measuring the base and height of the cone, angle of repose is calculated as per the following equation:

\[\theta={{\tan^{-1}2(H_2)}\over D}\].....8.1
where

H= height of the cone (cm)

D = base of the cone (cm)

θ= angle of repose (degrees)

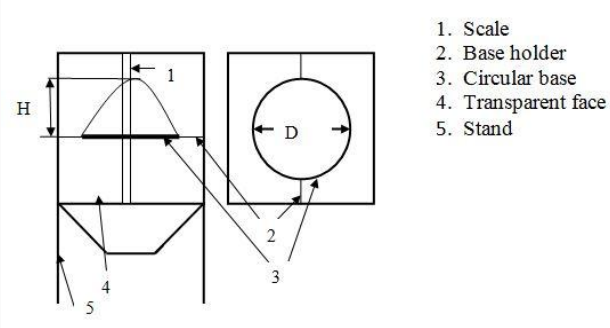


Fig. 8.1 Schematic diagram of angle of repose measuring tool

Angle of repose of two types, static angle of repose and dynamic angle of repose

Static angle of friction: Angle of friction takes up by granular solid to about slide upon itself. Angle repose depends on Size, shape, Moisture content and orientation of the particles.

Dynamic angle of repose: It arises when bulk of the material is in motion.

*Angle of internal friction and angle of repose of granular materials are different.

Coefficient and Angle of Internal Friction

The coefficient of internal friction is the friction of seeds against seeds. It is measured with the set up shown in figure 8.2a. In this experiment, a guide frame of size 20x15x5 cm is placed under a cell of size 8.5x8.5x5 cm. The guide frame and the cell are filled with the sample material. The cell is tied with the cord passing over a pulley attached to the pan. Then, weights (W_2) are placed in the pan to cause the cell to just slide. Next, the cell is emptied and weights (W_1) to initiate sliding over the guide frame are noted. The coefficient of internal friction is calculated as follows:

$$\mu=\frac{W_2-W_1}{W} \quad \text{.....8.2}$$

where

μ= coefficient of internal friction

W_1 = weight to cause sliding of the cell when empty (g)

W_2 = weight to cause sliding of the cell filled with sample material (g)

W = weight due to the sample material in the cell = volume of cell (cm^3) x bulk density (g/cm^3)

The angle of internal friction (for free flowing solids) is calculated as per the following equation

$$\theta_i=\tan^{-1}\mu_i \quad \text{.....8.3}$$

Coefficient of Friction on Material Surfaces

The coefficient of friction on material surfaces is measured using a setup similar to figure 8.2b, except that a table is provided with changeable surface, instead of a grain bed. The coefficient of friction on material surfaces is calculated as the ratio of limiting force to the corresponding normal pressure:

$$\mu_e=\frac{W_2-W_1}{W}$$

Where

μ_e = coefficient of external friction

W_1 = weight to cause sliding of the cell when empty (g)

W_2 = weight to cause sliding of the cell filled with sample material (g)

W = weight due to the sample material in the cell = volume of cell (cm^3) bulk density (g/cm^3)

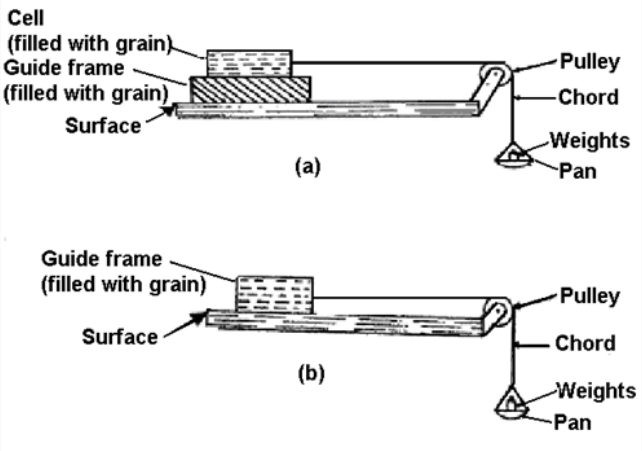


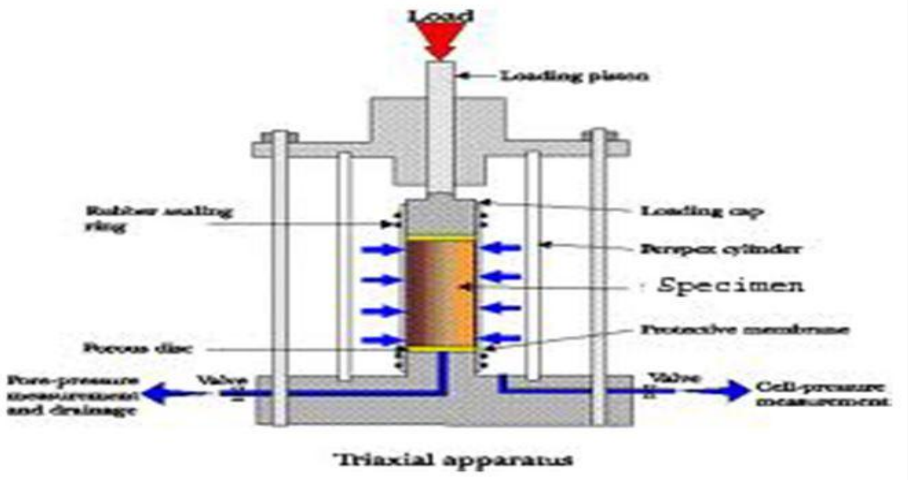
Figure 8.2 Measurement of (a) coefficient and angle of internal friction (b) coefficient of friction on material surfaces

Angle of internal friction (coefficient of friction between granular material) for stored grains in bins and silos:

Angle of internal friction (friction angle). A measure of the ability of a unit of solid material to withstand a shear stress. It is the angle (φ), measured between the normal force (N) and resultant force (R), that is attained when failure just occurs in response to a shearing stress (S). Its tangent (S/N) is the coefficient of sliding friction. Its value is determined experimentally. Angle of Internal Friction, can be determined in the laboratory by the Direct Shear Test or the Triaxial Stress Test.

Angle of internal friction determination:

Triaxial test: In this apparatus, grain cylinder is enclosed in rubber membrane, σ_3 = builds up as vaccum was broken. Then triaxial test compression, gives σ_1 and σ_3 from the motions of the lateral and vertical pressure, angle of internal friction of grain is determined.



Triaxial apparatus

$$pressure\ ratio\ (K) = \frac{1-\sin\varphi}{1+\sin\varphi}$$

$$K = \frac{\sigma_3}{\sigma_1}$$

σ_3 = Lateral Pr.

σ_1 = vertical Pr.

$\sigma_3 = Wy \tan^2(45 - j/2)$

j= angle of internal friction

y = depth of grain, below the top of the wall

W = weight density of grain

Rolling resistance:

In some material handling application, rolling resistance or maximum angle of stability in rolling agricultural material with rounded shape is considered. eg. Gravity conveying of fruits and vegetables. When a ball or a cylinder rolls over a horizontal surface with a force F, of the surface deforms, there will be a resultant force R.

Moment at that point

$\sum Mb = F*b - W*c = 0$

For small deformation of the surface for r

So that c= Fr/W or F = c W/r

'c' = coefficient of rolling resistance

F = rolling resistance

More rigid the surface smaller 'c' in rolling resistance.

Rolling resistance is directly proportional to the weight of the rolling object, indirectly proportional to the effective radius of the rolling object and directly proportional to coefficient of rolling resistance which depends on the rigidity of the supporting surface.

Module- 4 Rheological Properties of Biomaterials

Lesson 9. Some basic concepts of rheologi

Application:

•Design / select equipment such as pumps, pipe lines, extruders, mixers, heat exchangers etc.

•Rheological behavior relates to food texture and sensory data

•To determine ingredient functionality in product development

•Shelf life testing

•To obtain some information about atomic and molecular scale phenomena

•To obtain constitutive relations

MECHANICALPROPERTIES are defined as those having to do with the behavior of the material under applied forces. Following this broad definition, such properties as stress strain behavior of a material under static and dynamic loading as well as flow characteristics of the material in air or in water, can be classified as mechanical properties

Rheology has been defined as" a science devoted to the study of deformation and flow. "Therefore, when the action of forces result in deformation and flow in the material, the mechanical properties will be referred-to as rheological properties. Moreover, rheology considers the time effect during the loading of a body.

Definition:

Rheology is the branch of science that deals with flow and deformation of materials under applied load.

Rheology also deals with the branch of mechanical properties where products have both solid and liquid like behavior.

Generally mechanical properties deal with deformation under applied load, whereas, rheology deals with both flow and deformation under applied stress.

Mechanical properties are intertwined with rheology when including strength properties.

Rheology: Group of physical properties that derive from the structure of the food.

Mohsenin (1986) defines mechanical properties as “those having to do with the behavior of the material under applied forces.” Rheology has been defined as “a science devoted to the study of deformation and flow,” or as “the study of those materials that govern the relationship between stress and strain.” “Stress” is defined as force components acting on a

body per unit cross-sectional area or area of the deformed specimen (SI units in Pa). "Strain" is the change in size or shape (SI units in mm or percentage) of a body in response to the applied force (at a certain time or during continuous change as stress is applied). Rheologically, the behavior of a material is expressed in terms of stress, strain, and time effects. Therefore, properties that deal with the motion of the material as a result of an applied force can be included as mechanical forces.

There are three stresses that are commonly applied to characterize foods mechanically: compressive (directed toward the material), tensile (directed away from the material), and shearing (directed tangentially to the material). Shear stress is the most prevalent with fluids or viscous materials. Since strain is the response of the material to stress, compressive shear and tensile strains can be found. When small deformations are exerted under compression, foods can show a straight line in the stress strain plot, and its slope is called the "Young modulus of elasticity." Rheologically, a material can deform in three ways: elastic, plastic, or viscous; it can be denoted by a spring friction element and a dashpot arranged in series or parallel, respectively, in rheological models.

Some basic terminologies in rheology:

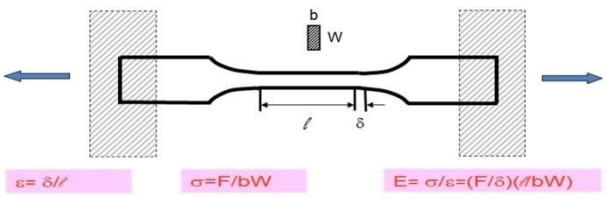
Strain: the unit change , due to force, in the size or shape of a body referred to its original size or shape. Strain is non-dimensional quantity, but it is frequently expressed centimeter per centimeter, m/m, mm/mm etc.

1. **Linear (tensile/ compressive) strain**: the change per unit length due to force in an original linear dimension
2. **Axial strain**: linear strain in a plane parallel to the longitudinal of the specimen.
3. **Transverse strain**: linear strain in a plane perpendicular to the axis of the specimen.
4. **Shear strain (angular strain**): the tangent of the angular change, due to force, between two lines originally perpendicular to each other through a point in a body.

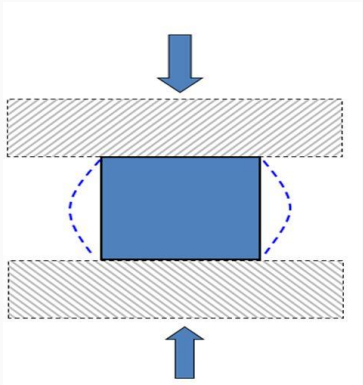
Stress: the intensity of a point in a body of the internal forces or components of force that act on a given plane through the point. Stress is expressed in force per unit area (kg-force/ mm^2)

Normal stress: The stress component perpendicular to a plane on which the forces act. Normal stress may be either**Tensile stress:** it is the normal stress due to forces directed away from the plane on which they act.

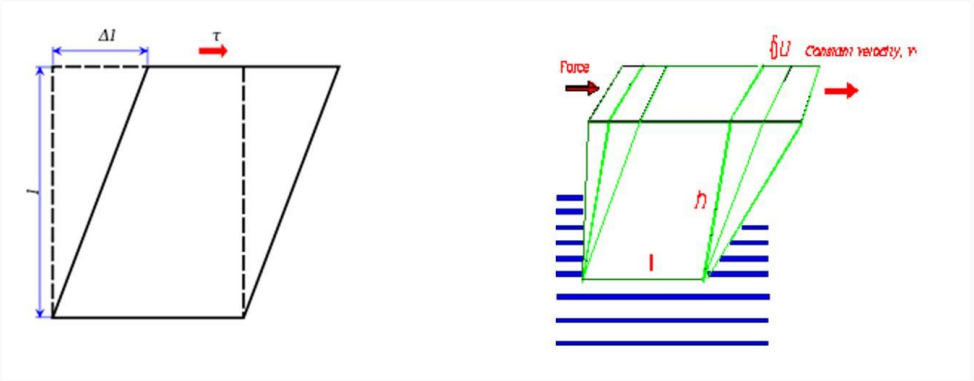
1. **Tensile stress:** it is the normal stress due to forces directed away from the plane on which they act.



2. Compressive stress: it is the normal stress due to forces directed toward the plane on which they act.



Shear stress: stress component tangential to the plane on which the forces act.



This type of deformation (lower fixed upper moving) is defined as a SHEAR DEFORMATION. The deformation δ u and h are used to define the:Shear Strain=δu/h The shear strain is simply a ratio of two lengths (displacement/gap) and so has no units. It is important since it enables us to quote pre-defined deformations without having to specify sizes of sample etc.

Shear Stress: The SHEAR STRESS is defined as F/A (A is the area of the upper surface of the cubel xw) Since the units of force are Newtons and the units of area are m^2 it follows that the units of Shear Stress are N/M^2 This is referred to as the PASCAL (i.e.1N/m2=1Pascal) and is denoted by the symbol σ. Shear Rate Consider the case of a cube of material that behaves as an ideal fluid. When we apply a shear stress (force) the material will continually deform at a constant rate as illustrated in figure.

The rate of change of strain is referred to as the **SHEAR STRAIN RATE** often abbreviated to SHEAR RATE and is found by the rate of change of strain as a function of time i.e. the differential SHEAR STRAIN /differential TIME.

Tensile strength: the maximum tensile stress that a material is capable of sustaining. Tensile strength is calculated from the maximum load during a tension test carried to rupture and the original cross sectional area of specimen.

Compressive strength: the maximum compressive stress that a material is capable of sustaining. Compressive strength is calculated from the maximum load during a compression test and the original cross sectional area of specimen

Strength: the resistance to applied force (kg/cm)

Ultimate strength: the stress corresponding to the rupture point (kg/cm^2)

Bioyield strength: the stress corresponding to the bioyield point.

Pressure: a measure of the mean normal stress on a point of body (kg/cm^2)

Deformation:

Deformation or distortion is the relative displacement of points within a body. Deformation like stress is a vector quantity. Ingeneral, deformation is accompanied either by change of volume or by change of shape. The change of shape is brought about by shear stresses. Material can be deformed by uniaxial compression, uniaxial tension, shear, and bulk compression:

Elastic limit: the greatest stress which a materials is capable of sustaining without any permanent strain remaining upon release of the stress.

Proportional limit: the greatest stress which a materials is capable of sustaining without any deviation from proportionality of stress to strain (Hooke's law).

Yield point: the first stress in a material, less than the maximum attainable stress, at which an increase in strain occurs without an increase in stress.

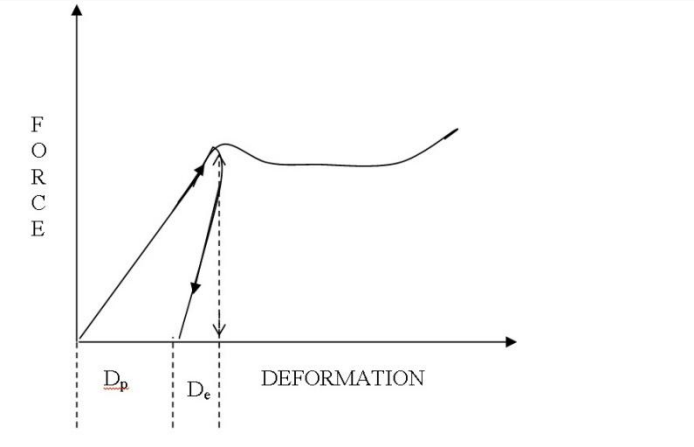
Bioyield point: a point, as y on the stress-strain or force-deformation curve at which there occurs an increase in deformation with a decrease or no change of force. In some agricultural products, the presence of this bioyield point is an indicative of initial cell rupture in the cellular structure of the material. The bioyield point may occur at any point beyond the point LL, where the curve deviates from the initial straight line porti

A possible force-deformation curve for an agricultural product, LL: linear limit, y: yield point, R: rupture point

Rupture point: a point on the stress-strain or force-deformation curve at which the axially loaded specimen ruptures under a load. In biological materials, rupture may cause puncture of shell or skin, cracking or fracture planes. It may be stated that a "bioyield point" in these materials corresponds to a failure in the macrostructure of the specimen. In force deformation may occur at any point beyond the bioyield point. In a brittle material, rupture may occur in the early portion of the curve. In a tough material, rupture may take place after considerable plastic floe at such point as R.

Elasticity: the capacity of a material for taking elastic or recoverable deformation. In those portions of the curve before the point LL is reached, elongations are, in large part at least. Recoverable, and are a measure of elastic deformation.

Plasticity: the capacity of a material for taking plastic or permanent deformation. Since deformations from the bioyield point to the point of rupture are not all recoverable, the recoverable part can be taken as a measure of plastic deformation.



A possible force-deformation curve for an agricultural product, LL: linear limit, y: yield point, R: rupture point

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Plasticity: the capacity of a material for taking plastic or permanent deformation. Since deformations from the bioyield point to the point of rupture are not all recoverable, the recoverable part can be taken as a measure of plastic deformation.

Degree of elasticity from a loading-unloading curve

Degree of elasticity: the ratio of elastic deformation to the sum of elastic and plastic deformation when a material is loaded to a certain load and then unloaded to zero load.

D_e= elastic or recoverable deformation

D_p= plastic or residual deformation

Degree of elasticity: $D_e/ (D_e+D_p)$

Toughness: the work required to cause rupture in the material. This can be approximated by the area under the stress-strain or force-deformation curve up to the point selected as the

rupture point. If in estimating toughness, a force-deformation curve is uses, the size of the specimen and the loading surface area should be specified.

Resilience: the capacity of a material for storage of strain energy in the elastic range. Thus the area under the unloading curve is a measure of resilience of the material. As in the case of toughness, when a force-deformation curve is uses, the size of the specimen and the loading surface area should be specified.

Stiffness: stiffness or rigidity is indicated by the slope of the initial straight line portion of the curve. The ratio of stress to strain in this more or less elastic region of the curve may be referred to as the modulus of elasticity or "Young's modulus"(kg/cm^2)

In the case of non-linear stress-strain behavior, stiffness or apparent modulus can be defined in terms of

- Initial tangent modulus
- Secant modulus
- Tangent modulus
- Chord modulus

Modulus of elasticity:

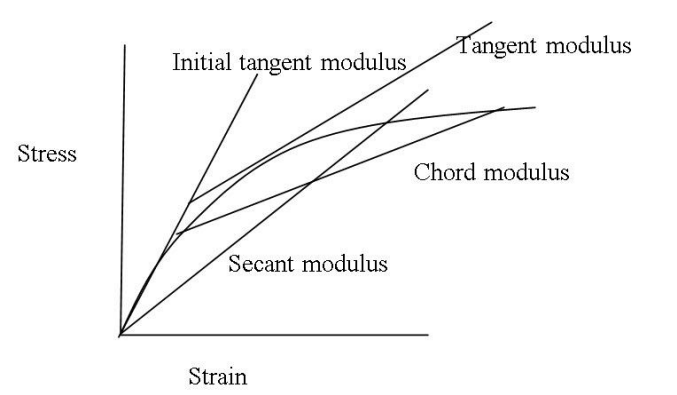
The ratio of stress to corresponding strain below the proportional limit

Initial tangent modulus: The slope of the stress-strain curve at the origin

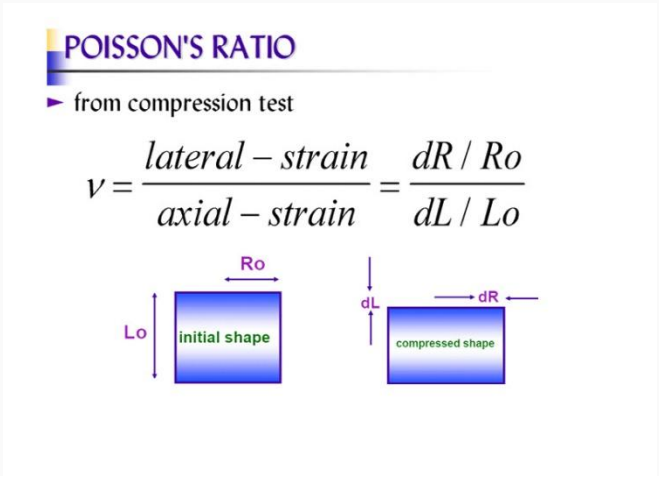
Tangent modulus: The slope of the stress-strain curve at any specified stress or strain

Secant modulus: The slope of secant drawn from the origin to any specified point on stress – strain curve

Chord modulus: The slope of chord drawn between any two any specified point on stress – strain curve.



Poisons ratio: the absolute value of the ratio of transverse strain to the corresponding axial strain resulting from uniformly distributed axial stress below the proportional limit of the material.



Lesson 10. Fluid flow behavior

Rheological tests express stress–strain relationships and study of strain rate dependency. Ideal solids deform in an elastic Hookean manner, while ideal liquids flow in a viscous medium.

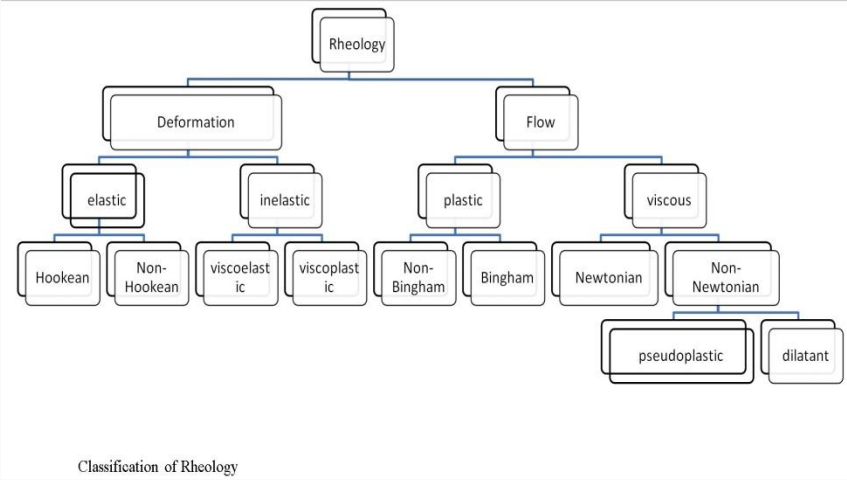
Newtonian manner; in each case the behavior is independent of the strain rate. Nonetheless, foods are strain-rate dependent. They usually contain some solid and liquid attributes and, rheologically, are termed viscoelastic bodies. In addition, many possess structural elements that "yield" or rupture when forces are applied, thus changing the stress–strain behavior not only with the applied rate of strain, but also with the applied amount of strain. Foods are anisotropic in nature and their mechanical properties may vary in the direction of the stress application.

Different mechanical situations define how stress can act on a food: static (constant stress or strain), dynamic (varying stress or strain), or impact (stress exerted and removed after a very short period of time). Impact during mechanical handling is the most common cause of mechanical damage to foods. Behavior under static or dynamic stresses governs the extent of potential mechanical injury (for example, during hopper storage or discharge) and can provide valuable information on the design of handling machinery. In cases like these, definitions of creep (when constant stress is applied to a body increasing in strain as a function of time) or stress relaxation (when constant strain is applied to a body) play a role. Solid foods are mechanically characterized by compression tests or impact tests. Universal testing machines give curves of normal force versus deformation, shear forces, creep, and stress relaxation measurements.

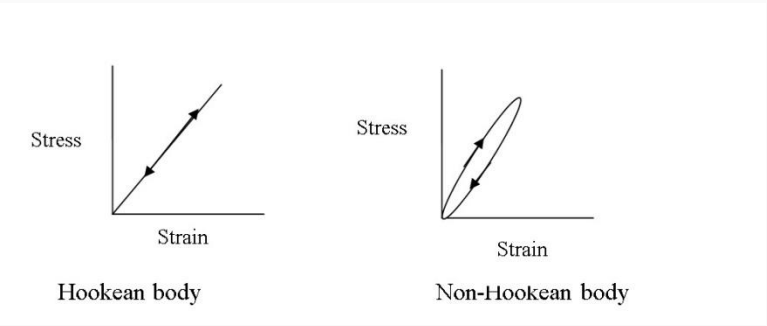
The most important mechanical-rheological behavior of fluid or viscous foods is the flow behavior, which can be basically defined as Newtonian, pseudoplastic, and Bingham, indicating viscosity of the material and its dependence on shear rate. In processing, flow properties can influence pumping requirements, flow of fluid through pipes, or even extrusion properties. Flow properties can be determined using any variety of available rheometers or viscometers.

Knowledge of the rheological and mechanical properties of various food systems is important in the design of flow processes for quality control, in predicting storage and stability measurements, and in understanding and designing texture.

The classification of rheology is depicted in the fig

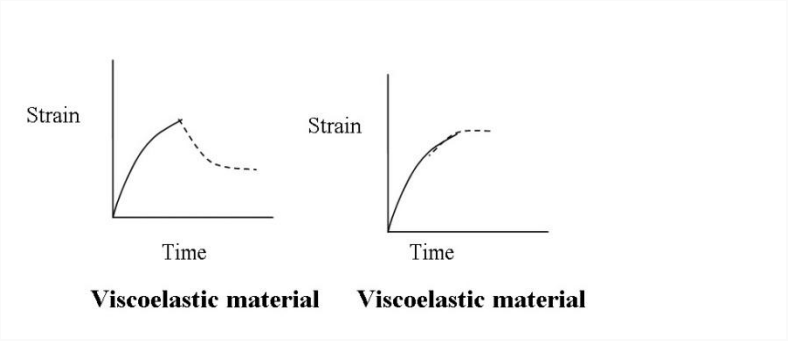


Classification of Rheology



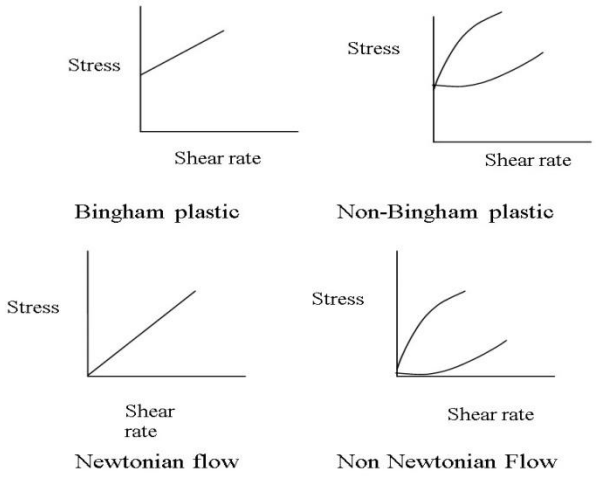
Hookean body Non-Hookean body

Hooke's law is a principle of physics that states that the force needed to extend or compress a spring by some distance is proportional to that distance.



Viscoelastic material **Viscoelastic material**

Viscoelasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. Viscous materials, like honey, resist shear flow and strain linearly with time when a stress is applied. Elastic materials strain when stretched and quickly return to their original state once the stress is removed. Viscoelastic materials have elements of both of these properties and, as such, exhibit time-dependent strain.



Flow behavior of biological materials

Viscosity and consistency

Viscosity/ dynamic viscosity/absolute viscosity: it is the internal friction of a liquid or its tendency to resist flow.

$$\mu=\frac{\sigma}{\dot\gamma}$$

$$\begin{array}{l}{\rm =shear\ stress}\\{\rm =viscosity}\end{array}$$

$$\dot\gamma=shearrate$$

The unit of viscosity is poise. One poise is defined as that viscosity in which a velocity gradient of 1 cm sec-1 is obtained when a force of 1 dyne is applied to two surfaces. It has the dimension of ML-1T-1

One centipoises (cP) is one of the commonly used unit, which is equal to 0.01 poise. Water at 20°C has a viscosity of 1.0 SI unit of dynamic viscosity is Pascal-second. 1 pascal-second is 10 Poise.

Fluidity: this is the reciprocal of viscosity

$$\varphi=\frac{\dot \gamma }{\sigma }$$

Kinematic viscosity: this is defined as the absolute viscosity divided by the density of fluid:

$$\vartheta=\frac{\mu }{\rho } = \frac{\sigma }{ {\gamma \rho }\limits^ }$$

$$\vartheta=inematicviscosity,stokes$$

m=viscosity in poise,

r= density, g cm-3

The dimension of kinematic viscosity is M2L-3

Apparent viscosity (m_a): this is the viscosity of a non-Newtonian fluid expressed as though it were a Newtonian fluid.

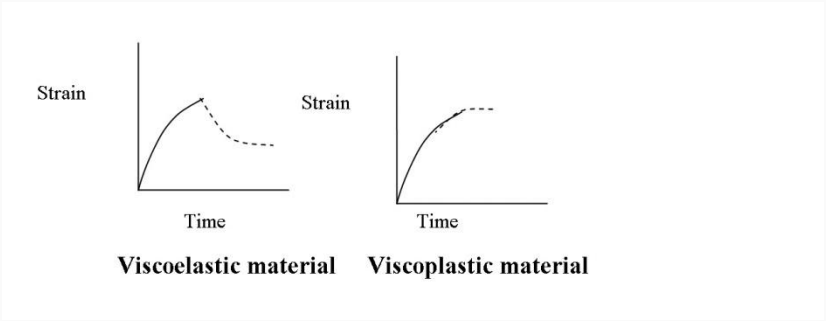
Shear rate: this is the velocity gradient in a fluid as a result of an applied shear stress. It is expressed as reciprocal of seconds

Factors affecting Viscosity:

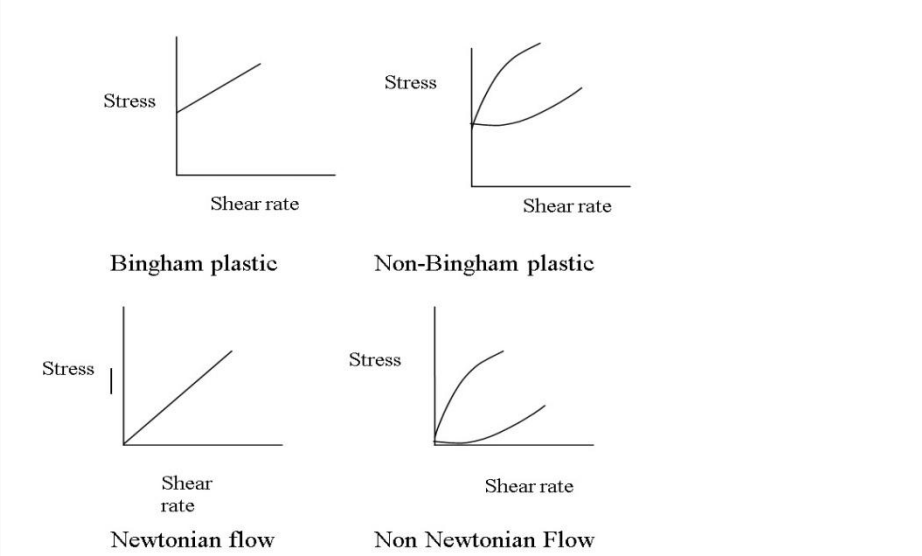
- Temperature: a reciprocal relationship
- Concentration of solids: direct non-linear relationship
- Molecular weight of solute: direct non-linear relationship
- Pressure: essentially constant over a pressure range of 0-100 atm and can be ignored for foods
- Suspended matters: increases the viscosity

Types of viscous behavior:

Newtonian and non Newtonian fluid:



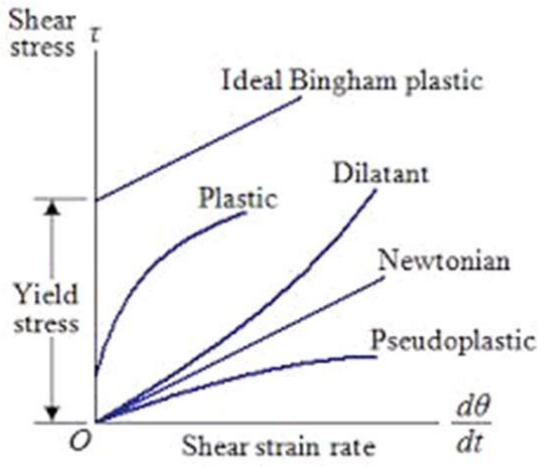
Viscoelasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. Viscous materials, like honey, resist shear flow and strain linearly with time when a stress is applied. Elastic materials strain when stretched and quickly return to their original state once the stress is removed. Viscoelastic materials have elements of both of these properties and, as such, exhibit time-dependent strain.



Newtonian fluid: Fluids are termed as Newtonian if the viscous stresses that arise from its flow, at every point, are proportional to the local strain rate i.e. the rate of change of its deformation over time. Eg. Water, carbonated beverages, sugar syrup, most honey, edible tea, filtered juice, milk

Non –Newtonian Fluid: A non-Newtonian fluid is a fluid whose flow properties differ in any way from those of Newtonian fluids or they are dependent on the shear rate or time and the viscosity is termed as consistency or apparent viscosity.

Most food materials exhibit non-Newtonian behavior.



Shear rate dependency:

Bingham plastic: a minimum shear stress known as 'Yield stress" must be exceeded before flow begins. Eg: tomato ketchup, whipped egg white, whipped cream, mayonnaise, margarine

Pseudoplastic: In this type of flow an increasing shear force gives a more than proportional increase in shear rate, but the curve begins at origin. Eg. Salad dressing

Dilatant: the shear stress-shear ra**te** plot of this type of a flow begins at the origin but is characterized by equal increments in shear stress giving less than equal increment in the shear rate.

Example: High solids, raw starch suspensions, chocolate syrups, 60% corn starch suspension is rare in finished foods

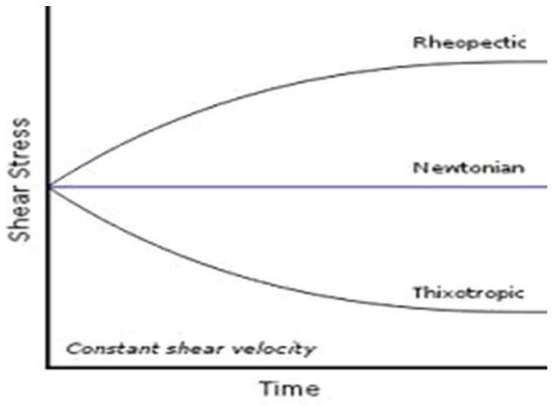
Time dependent behavior

Rheopectic: the apparent viscosity increases with time and the change is reversible; that is, the fluid will revert back to its original state on standing. Eg not found in food system

Shear thickening: the apparent viscosity increases with time and the change is irreversible; that is, the fluid stays in thick state when the shear stress is removed. Eg. Whipped egg white becomes stiff after beating

Thixotropy: the apparent viscosity decreases with time and the change is reversible; that is, the fluid will revert back to its original state on standing. Eg. Some starch gel

Shear thinning: the apparent viscosity decreases with time and the change is irreversible; that is, the fluid stays in thinner state when the shear stress is removed. Eg. starch pastes, gum solutions



Time dependency flow behavior

Lesson 11. Stress relaxation and Creep behaviour

Stress relaxation: Decay of stress with time when the material is suddenly deformed to a given deformation-constant strain.

Relaxation time: The rate of stress decay in-a material subjected to a sudden strain. It is the time required for the stress in the Maxwell model, representing stress relaxation behavior, to decay to (1/e) or approximately 37 percent of its original value.

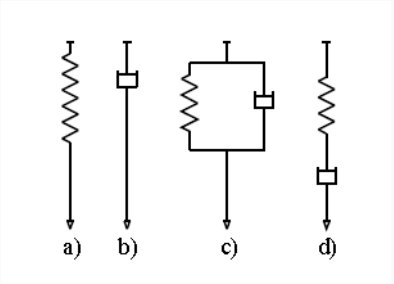
Creep: Deformation with time when the material is suddenly subjected to a dead load-constant stress.

Retardation time: The rate at which the retarded elastic deformation takes place in a material creeping under dead load. It is the time required for the Kelvin model, representing creep behavior, to deform to (1-(1/e)) or about 63 percent of its total deformation.

The mechanical models

To get some feeling for linear viscoelastic behaviour, it is useful to consider the simpler behaviour of analog mechanical models. They are constructed from linear springs and dashpots, disposed singly and in branches of two (in series or in parallel). As analog of stress and strain, we use the total extending force and the total extension. We note that when two elements are combined in series [in parallel], their compliances [moduli] are additive. This can be stated as a combination rule: creep compliances add in series, while relaxation moduli add in parallel.

The Hooke model: The spring (Fig. a) is the elastic (or storage) element, as for it the force is proportional to the extension; it represents a perfect elastic body obeying the Hooke law (ideal solid). This model is thus referred to as the Hooke model. If we denote by m the pertinent elastic modulus we have Hooke model : $\sigma(t) = m\varrho(t)$,



In this case we have no creep and no relaxation so the creep compliance and the relaxation modulus are constant functions: $J(t) \equiv Jg \equiv Je = 1/m$;

$G(t) \equiv Gg \equiv Ge = m$

Newton Model: The dashpot (Fig. b) is the viscous (or dissipative) element, the force being proportional to rate of extension; it represents a perfectly viscous body obeying the Newton law (perfect liquid). This model is thus referred to as the Newton model. If we denote by b1 the pertinent viscosity coefficient, we have

Newton model : $\sigma(t) = b1(d\varrho/dt)$

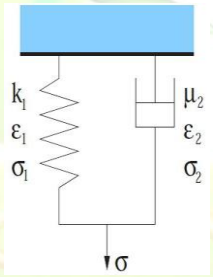
$J(t) = t/b1$, $G(t) = b1\ \delta(t)$

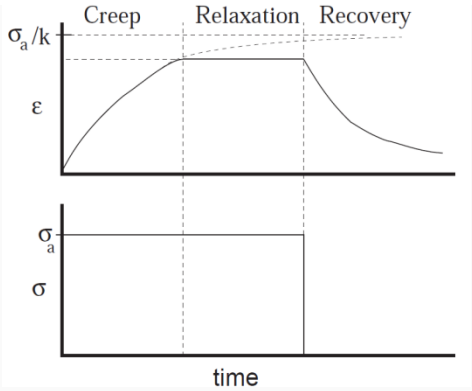
KELVIN-VOIGT MODEL

Kelvin-Voigt viscoelastic solid element consists of a Hookean elastic element (HE) and a Newtonianviscous element (NE) connected in parallel fig. c. In a Kelvin-Voigt model, the resulting stress is the sum of the components of stress carried by the elastic element (σ1) and the partial stress carries by the Newtonian viscous element (σ2). A branch constituted by a spring in parallel with a dashpot is known as the Kelvin–Voigt model.

$$\sigma={\sigma _1} + {\sigma _2}= k\varepsilon+\mu\dot\varepsilon$$

$$\varepsilon={\varepsilon _1} ={\varepsilon _2}$$





The retardation time is basically a measure of the degree of elastoviscosity of a material and hence governs the degree of rigidity (or fluidity) of a viscoelastic material. A very low retardation time indicates the material to be a highly elastic solid. In such a condition, the material behaves as a rigid body. On the other hand, when the retardation time is very high, the viscous property of the material overpowers the elastic property. Under such conditions, the material behaves as a fluid with instantaneous initial rigidity.

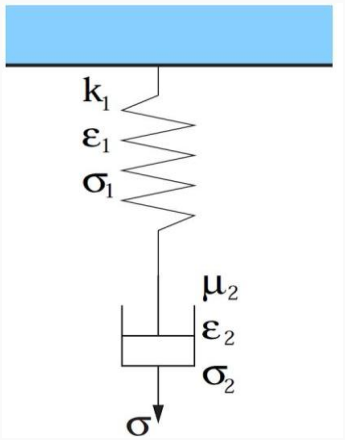
It is also understood that the presence of a viscous dashpot in parallel to an elastic element significantly reduces the magnitude of strain generated in the viscoelastic element. The Kelvin-Voigt model exhibits an exponential (reversible) strain creep but no stress relaxation; it is also referred to as the retardation element.

- Handles creep fairly well
- Handles Recovery fairly well
- Does not account for relaxation

MAXWELL MODEL

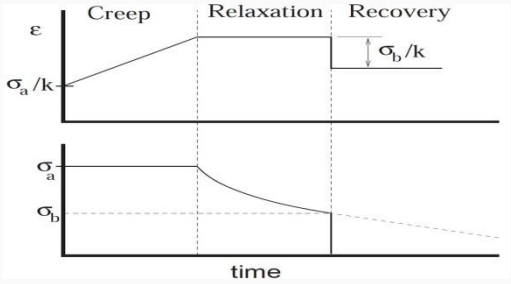
The spring and dashpot are connected in series (fig. d).

If the stress $\sigma = \sigma_o$ does not vary with time i.e. the element is subjected to a constant stress, the element undergoes creep. The total strain at any



instant of time e is expressed as a summation of instantaneous elastic strain $e_1$and the creep strain (e_2) defined by the following expression

Stress and Strain are connected as



$$\sigma = \sigma_1 = \sigma_2$$

$$\epsilon = \epsilon_1 + \epsilon_2$$

$$\dot{\epsilon} = \frac{\sigma}{\mu} + \frac{\dot{\sigma}}{k}$$

The Maxwell model exhibits an exponential (reversible) stress relaxation and a linear (non reversible) strain creep; it is also referred to as the relaxation element.At the instant of unloading, elastic recovery due to the retreat of the Hookean elastic element is observed and the initial instantaneous strain is entirely recovered.

- Handles Creep badly
- Handles Recovery badly (model only recovers elastic deformation, and does so instantly)
- Accounts fairly well for Relaxation

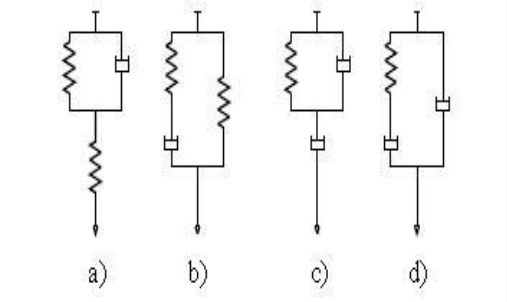
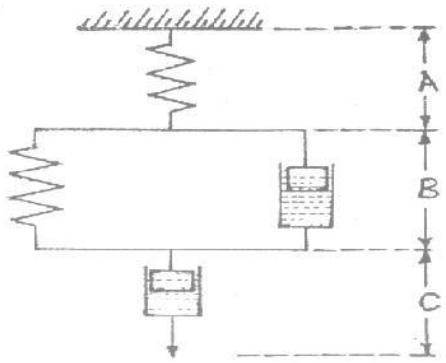
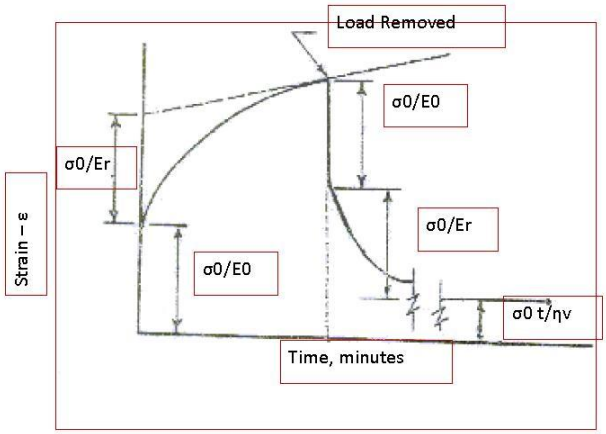


Fig. The mechanical representations of the Zener model, see a), b) and of the anti–Zener model, see c), d), where: a) spring in series with Voigt, b) spring in parallel with Maxwell, c) dashpot in series with Voigt, d) dashpot in parallel with Maxwell.

4-Element model (Burgers model):

Burger'smodel-states that the behavior of agricultural materials under stress can be represented by a spring (representing elastic behaviour) in series with a dashpot and a combined spring and a dashpot (representing viscous behaviour) in parallel.





Typical creep and recovery curve in a viscoelastic material exhibiting instantaneous elasticity, retarded elasticity and viscous flow.

Model parameters for different types of fluids:

\[\tau={\tau _o} + K{\dot \gamma ^n}\]

The power law model with or without a yield term has been employed extensively to describe the flow behavior of viscous foods over wide ranges of shear rates where 'K' is the consistency coefficient (consistent index, $Pa.s^n$), and 'n' is the flow behavior index (dimensionless) is also known as the **Herschel-Bulkley model**.

t_o=0: (For Newtonian fluid: n=1, Psedoplastic fluid: 0<n<1 and dilatant fluid: n>1) and for plastic fluid: n=0, the flow begins only after a yield stress t_o is reached.

Table 12.1 SI and equivalent rheumatic units

Quantity	SI Unit	Equivalent CGS unit
viscosity	Pa.s	10 P(poise) or 1000 cP(centipoises)
Kinematic viscosity	m^2s^{-1}	10^4 Stoke or 10^6 (centistokes)
Shear stress	Pa.s	0.1 $dyne.cm^{-2}$
strain	unitless	-
Shear rate	s^{-1}	s^{-1}
modulus	Pa	0.1 $dyne.cm^{-2}$
compliance	Pa^{-1}	10 cm^2 $dyne^{-1}$
frequency	Hz	
Angular frequency	2.f	
Phase angle	rad	

Table 12.2 SI derived units expressed in terms of base units

Symbol	Special name	Other SI Unit	SI base unit
Pa	Pascal	Nm^{-2}	$Kg.m^{-1}s^{-2}$
Hz	Hertz	s^{-1}	s^{-1}
rad	Radian		$m.m^{-1}$

Lesson 12. Rheological properties measurement and equipment's

A viscometer (also called viscometer) is an instrument used to measure the viscosity of a fluid. For liquids with viscosities which vary with flow conditions, an instrument called a rheometer is used. Viscometers only measure under one flow condition

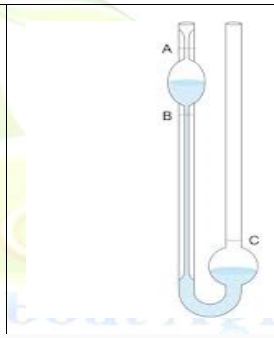
In general, either the fluid remains stationary and an object moves through it, or the object is stationary and the fluid moves past it. The drag caused by relative motion of the fluid and a surface is a measure of the viscosity. The flow conditions must have a sufficiently small value of Reynolds number for there to be laminar flow.

Methods for measuring viscosity:

1. Capillary type:

The device is also known as U-tube viscometer or Ostwald viscometers, named after Wilhelm Ostwald. The time for a standard volume of fluid to pass through a length of capillary tubing is measured. This type of flow is described by Poiseuille equation

μ= fluid viscosity
p= driving pressure
r= radius of capillary
t= time of flow
V= volume of flow
l= length of capillary



Another version is the Ubbelohde viscometer, which consists of a U-shaped glass tube held vertically in a controlled temperature bath. In one arm of the U is a vertical section of precise narrow bore (the capillary). Above this is a bulb, with it is another bulb lower down on the other arm. In use, liquid is drawn into the upper bulb by suction, then allowed to flow down through the capillary into the lower bulb. Two marks (one above and one below the upper bulb) indicate a known volume. The time taken for the level of the liquid to pass between these marks is proportional to the kinematic viscosity. Most commercial units are provided with a conversion factor, or can be calibrated by a fluid of known properties. The time required for the test liquid to flow through a capillary of a known diameter of a certain factor between two marked points is measured. By multiplying the time taken by the factor of the viscometer, the kinematic viscosity is obtained.

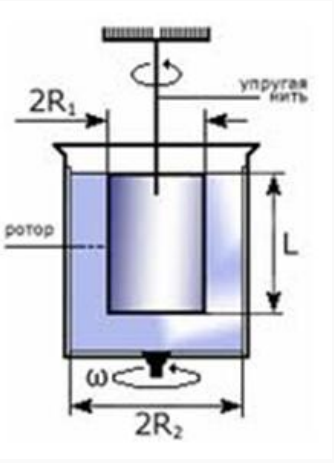
2. Orifice type:

This can be considered as a very short capillary type viscometer. The time for a standard volume of fluid to flow through an orifice is measured. This is a simple, inexpensive rapid

method that is widely used in quality control of Newtonian and non-Newtonian fluids where extreme accuracy is not needed.

This consists of a stainless –steel 44 ml capacity cup attached to a handle with a calibrated circular hole in the bottom. In operation the cup is filled by dipping into the fluid and withdrawing it. A stopwatch is started as soon as it is withdrawn and stopped when the first break occurs in the issuing stream; the elapsed time gives an empirical value of viscosity.

3. Coaxial rotational viscometer:

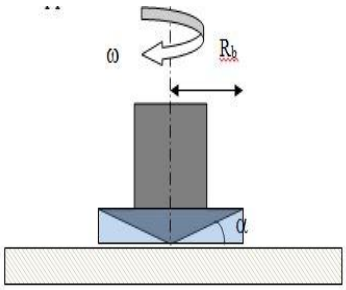


These are also known as concentric cylinder viscometer. A spindle having circular cross section is placed inside a cup containing the test liquid. Either the cup or the spindle is rotated and the drag of the fluid on the spindle is measured by means of torque sensor. It can be used for both Newtonian and non-Newtonian fluids and this type is widely used in food industry Eg. Haake rotoviscometer, rheometers,

4. Cone and plate viscometer:

The fluid is held by its own surface tension between a cone of small angle that just touches a flat surface. The torque is caused by the drag of the fluid on the cone is measured as one of the members is rotated while the other member remains stationary.

For a Newtonian fluid following equation applies:

Where, μ= fluid viscosity a= angle of cone, 2° M= torque w=angular velocity R_b = radius of cone	

5. Falling ball viscometers

Stokes' law is the basis of the falling sphere viscometer, in which the fluid is stationary in a vertical glass tube. A sphere of known size and density is allowed to descend through the liquid. If correctly selected, it reaches terminal velocity, which can be measured by the time it takes to pass two marks on the tube. Knowing the terminal velocity, the size and density of the sphere, and the density of the liquid, Stokes' law can be used to calculate the viscosity of the fluid.

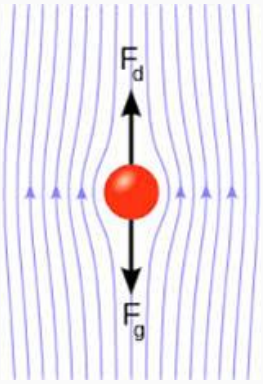


Fig. Falling sphere

In 1851, George Gabriel Stokes derived an expression for the frictional force (also called drag force) exerted on spherical objects with very small Reynolds numbers (e.g., very small particles N_{Re}<1) in a continuous viscous fluid by changing the small fluid-mass limit of the generally unsolvable Navier-Stokes equations:

where:

F_D= frictional force,

r= radius of the spherical object,

m= fluid viscosity, and

v =particle's velocity.

If the particles are falling in the viscous fluid by their own weight, then a terminal velocity, also known as the settling velocity, is reached when this frictional force combined with the

buoyant force exactly balance the gravitational force. The resulting settling velocity (or terminal velocity) is given by:

where:

V_s = settling velocity (m/s) (vertically downwards if $\rho_p > \rho_f$ upwards if $\rho_p < \rho_f$),

r= Stokes radius of the particle (m),

g =gravitational acceleration (m/s2),

ρ_p=density of the particles (kg/m3),

ρ_f =density of the fluid (kg/m3), and

m=is the (dynamic) fluid viscosity (Pa s).

6. Falling Piston Viscometer:

The principle of viscosity measurement is based on a piston and cylinder assembly. The piston is periodically raised by an air lifting mechanism, drawing the material being measured down through the clearance (gap) between the piston and the wall of the cylinder into the space which is formed below the piston as it is raised. The assembly is then typically held up for a few seconds, then allowed to fall by gravity, expelling the sample out through the same path that it entered, creating a shearing effect on the measured liquid, which makes this viscometer particularly sensitive and good for measuring certain thixotropic liquids. The time of fall is a measure of viscosity, with the clearance between the piston and inside of the cylinder forming the measuring orifice. The viscosity controller measures the time of fall (time-of-fall seconds being the measure of viscosity) and displays the resulting viscosity value.

7. **Oscillating Piston Viscometer**

Invented at Cambridge Viscosity in 1986, this viscometer is also referred to as electromagnetic viscometer or EMV viscometer. The instrument comprises a measurement chamber and magnetically influenced piston.

Measurements are taken whereby a sample is first introduced into the thermally controlled measurement chamber where the piston resides. Electronics drive the piston into oscillatory motion within the measurement chamber with a controlled magnetic field. A shear stress is imposed on the fluid due to the piston travel and the viscosity is determined by measuring the travel time of the piston. The construction parameters for the annular spacing between the piston and measurement chamber, the strength of the electromagnetic field, and the travel distance of the piston are used to calculate the viscosity according to Newton's law of viscosity.

8. Vibrational viscometers

The fluid viscosity is measured by the damping of an oscillating electromechanical resonator immersed in it. The resonator generally oscillates in torsion or transversely (as a cantilever

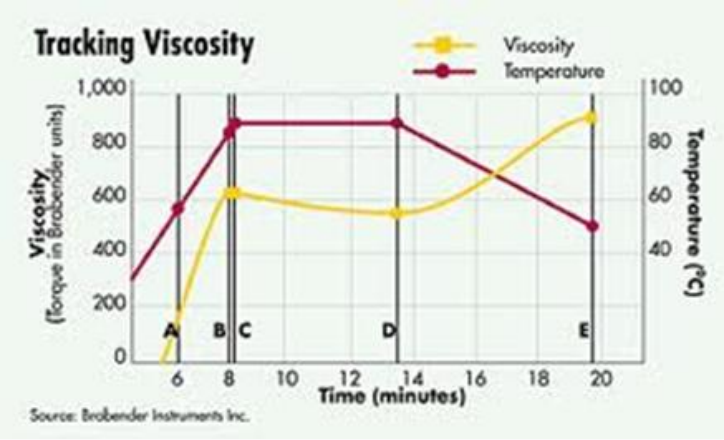
beam or tuning fork). The higher the viscosity, the larger the damping imposed on the resonator. The resonator's damping may be measured by one of several methods:

1.Measuring the power input necessary to keep the oscillator vibrating at a constant amplitude. The higher the viscosity, the more power is needed to maintain the amplitude of oscillation.

2.Measuring the decay time of the oscillation once the excitation is switched off. The higher the viscosity, the faster the signal decays.

3.Measuring the frequency of the resonator as a function of phase angle between excitation and response waveforms. The higher the viscosity, the larger the frequency change for a given phase change.

9. Other rotational viscometer:



There are some empirical viscometers in which a paddle, a cylinder, or bars rotate in a container, usually with large clearance between the rotating member and the wall. Eg. Brookfield viscometer, FMC consistometer, Brabender viscoamylograph

Module- 5 Food Quality

Lesson 13. Introduction to Food Quality

What is quality?

Quality is a term which denotes a degree of excellence, a high standard or value. Quality of foods may be defined as the composite of those characteristics that differentiate individual units of a product, and have significance in determining the degree of acceptability of that unit to the user Kramer (1965).

Food Quality:

The four principal quality factors in food are the following:

1. **Appearance**, comprising colour, shape, size, gloss, etc. is based on optical properties and visual manifestation of size and shape.
2. **Flavor**: comprising taste (perceived on tongue) and odour (perceived in the olfactory centre in the nose), is the response of receptor in the oral cavity to chemical stimuli.
3. **Texture**, is the response of the tactile senses to physical stimuli that result from contact between some part of the body and the food
4. **Nutrition** Cost, convenience and packaging are also important but not considered quality factors. Of the above listed the first three are termed as "sensory acceptable factors" because they are perceived by the senses directly. Nutrition is a quality factor that is not an acceptability factor as it is not perceived by the senses.

As consumers, these four attributes typically affect us in the order specified above, for example we evaluate the visual appearance and color first, followed by the taste, aroma, and texture. The appearance of the product usually determines whether a product is accepted or rejected; therefore this is one of the most critical quality attributes. Nutritional value is a hidden characteristic that affects our bodies in ways that we cannot perceive, but this quality attribute is becoming increasingly valued by consumers, scientists, and the medical profession Kramer (1965).

Food Texture:

The importance of texture in overall acceptability of foods varies widely, depending upon the food

1. **Critical**: Those foods in which texture is the dominant quality characteristics, eg. Meat, porato chips

2. **Important**: Those foods in which texture makes a significant but not a dominant contribution to the overall quality, contributing, more or less equally, with flavor and appearance eg. Most fruits, vegetables, bread, candy.

3. **Minor**: Those foods in which texture makes a negligible contribution to the overall quality, eg most beverages and thin soups.

Table 1 Most frequently used Texture words

USA	Japan
crisp dry juicy soft creamy crunchy chewy smooth stringy hard	hard soft juicy chewy crunchy crisp creamy slippery viscous greasy
78 words	406 words

Japanese use 406 descriptive words whereas in USA people use 78 descriptive words to describe food texture.

Definition of texture:

Texture means those perceptions that constitute the evaluation of a food' s physical characteristics by the skin or muscle senses of the buccal cavity, excepting the sensations of temperature or pain (Matz, 1962).

By texture we mean those qualities of food that we can feel with fingers, the tongue, the palate or the teeth. (Potter, 1968).

Texture is the attribute of a substance resulting from a combination of physical properties and perceived by the senses of touch, sight and hearing. Physical properties may include size, shape, number, nature and conformation of constituent structural elements (Jowitt, 1974).

Texture: all the rheological and structural attributes of a food product perceptible by means of mechanical, tactile and when appropriate visual and auditory receptors (International Organization for standards, standard 5492/3, 1979)

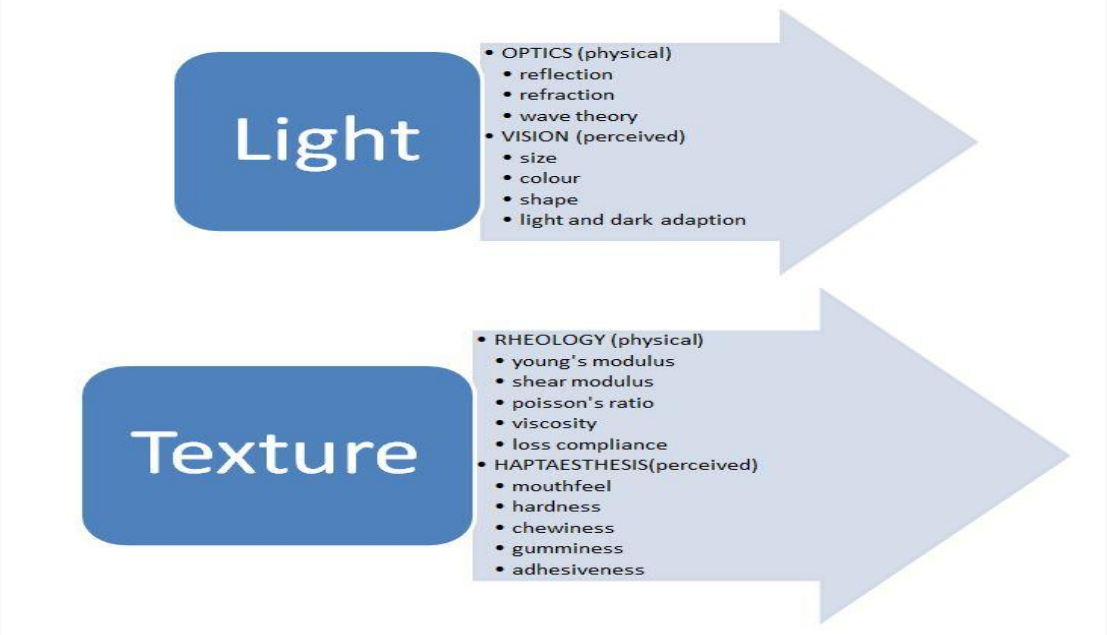
Texture of foods has the following characteristics:

1. It is a group of physical properties that derive from the structure of the food.
2. It belongs under the mechanical or theological subheading of physical properties.
3. It consists of a group of properties, not a single property.
4. Texture is sensed by the feeling of touch, usually in mouth, but other parts of body may be involved (hands).
5. It is not related to chemical senses of taste or odour.
6. Objective measurement is by means of functions of mass, distance and time only.

Table 2 Relationship between textural properties and popular nomenclature

Mechanical characteristics	Secondary parameters	Popular terms
Hardness Cohesiveness Viscosity Elasticity Adhesiveness	brittleness chewiness gumminess	soft→firm→hard crumbly→crunchy→brittle tender→chewy→tough short→mealy→pasty→gummy thin→viscous plastic→elastic sticky→tacky→gooey

Geometrical characteristics		examples
Particle size and shape		Gritty, grainy, coarse, etc.
Particle shape and orientation		Fibrous, cellular, crystalline etc.
Other characteristics Primary parameters	Secondary parameters	Popular terms
Moisture content		
Fat content	oiliness	Dry→moist→wet→watery
	greasiness	oily
		greasy



Other definitions:

Kinesthetics: Those factors of quality that the consumer evaluates with his sense of feel, especially mouthfeel.

Body: The quality of food or beverage, relating either to its consistency, compactness of texture, fullness, flavor or to a combination thereof (American Society for Testing and Materials, standard E253-78a).

Chewy: Tending to remain in the mouth without rapidly breaking up or dissolving, Requiring mastication.

Haptic: Pertaining to the skin or to the sense of touch in its broadest sense

Mealy: A quality of mouthfeel denoting a starchlike sensation. Friable.

Possessing the textural property manifested by the presence of components of different degrees of firmness or toughness.

Mouthfeel: "The mingled experience deriving from the sensations of the skin in the mouth during and /or after ingestion of a food or beverage. It relates to density, viscosity surface tension, and other physical properties of the material being sampled.

Getaway: the textural property perceived as shortness of duration of moutfeel.

Consistency: "All the sensations resulting from stimulation of the mechanical receptors and tactile receptors, especially in the region of the mouth, and varying with the texture of the product".

Hard: " As a texture characteristics, describes a product which, displays substantial resistance to deformation or breaking".

Soft: "As a texture characteristics, describes a product which displays slight resistance to deformation"

Tender: "As a texture characteristics, describes a product which, during mastication, displays slight resistance to breaking"

Firm " As a texture characteristics, describes a product which, during mastication, displays moderate resistance to breaking".

Body-Texture Interactions:

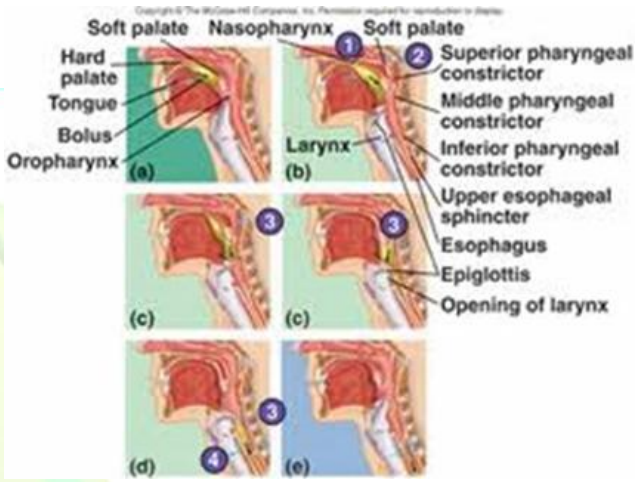
The properties of texture and viscosity are perceived by the human senses. Hence in order to understand texture and viscosity, it is necessary to understand how human body interacts with food.

Some definitions:

Masticate: To chew, grind or crush with teeth and prepare for swallowing and digestion.

Bolus: a mass of chewed food in mouth.

Deglutition: The act or process of swallowing food.

Teeth Lips Cheeks Tongue Palate Gums Salivary gland Upper jaw (maxilla) Lower jaw (mandible) Oral cavity Pharynx Other (neck, arm, shoulder muscle)	 

Reasons for mastication of food:

- Gratification
- Comminution
- Mix with saliva
- Temperature adjustment
- Release flavor
- Increase surface area

Lesson 14. Objective Texture measurement

Foods are classified into different groups:

- Liquids, gels, fibrous foods, agglomerates of turgid cells, unctuous foods, friable structures, glassy foods, agglomerates of gas filled vesicles and combination of these (Matz, 1962).
- Liquid, fruits and vegetables, meats and others (Amerine et al., 1965)
- Gel like foods, fibriform foods, edible oils and fats and powdered foods (Sone, 1972).

Objective		Subjective	
Direct	Indirect	Direct	Indirect
fundamental	optical	mechanical	fingers
empirical	chemical	geometrical	hand
Imitative	Acoustical	chemical	other
	Electromagnetic		
	other		

Fundamental tests:

These tests measure well-defined rheological properties.

Most commonly used fundamental tests are:

$$Young's\ modulus\ of\ Elasticity(E) = \frac{stress}{strain} = \frac{F/A}{\Delta l/l}$$

$$Shear\ modulus\ (G) = \frac{shearing\ stress}{shearing\ strain} = \frac{F/A}{\gamma/l}$$

$$Bulk\ modulus\ (K) = \frac{hydrostatic\ pressure}{volumetric\ strain} = \frac{P}{\Delta V/V}$$

$$Poisson's\ ratio = \frac{change\ in\ width\ per\ unit\ width}{change\ in\ length\ per\ unit\ length} = \frac{\Delta D/D}{\Delta l/l}$$

$$viscosity(\mu) = \frac{shear\ stress}{shear\ rate} = \frac{\sigma}{\dot{\gamma}}$$

The relationship between these parameters are following:

$$G = \frac{3EK}{(9K - E)}$$

$$K = \frac{E}{3(1-2\mu)} = \frac{EG}{(9G-3E)} = \frac{G[2(1+\mu)]}{3(1-2\mu)}$$

$$E = 9GK/(3K+G) = 2G(1+\mu) = 3K(1-2\mu)$$

$$\mu = (E-2G)/2G = (1-E/3K)/2$$

Fundamental tests generally assume that

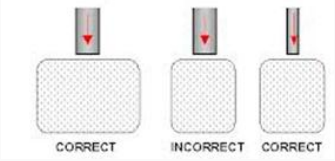
1. Small strains (1-3%), 2. The material is continuous, isotropic, and homogenous, 3. The test piece is of uniform and regular shape.

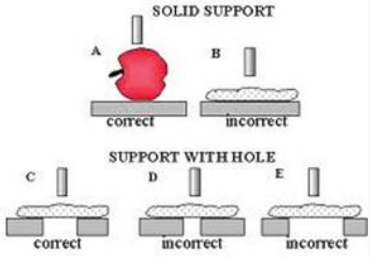
Force measuring instruments:

1. Puncture, 2. Compression-extrusion, 3. Shear, 4. Crushing, 5. Tensile, 6. Torque and 7. Bending and snapping.

Puncture test: This test measures the force required to push a punch or probe into a food. The puncture test assumes that the sample is semi-infinite in size. That is, the sample is much larger than the punch that the edge effects and bottom effects are insignificant.

- Bloom gelometer,
- Texture analyser

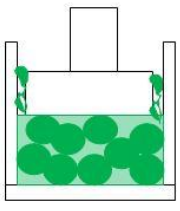




Compression-extrusion testing: this test consists of applying force to a food until it flow through an outlet that may be in the form of one or more slots or holes that are in the test cell.

Eg. Compression-extrusion testing of fresh green peas

Back extrusion cell



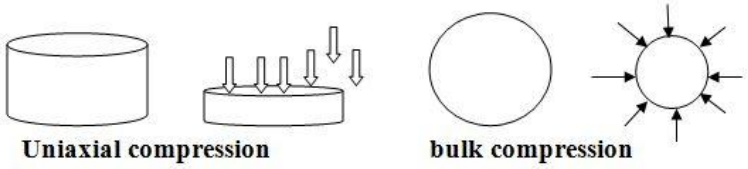
Shear testing: for food technologist shear testing means cutting the food across the food. Eg. Warner-Bratzler shear test. Kramer shear press, texture analyser shear testing unit.

Fig. Shear testing of foods

Compression and crushing:

Compression and crushing are widely used tests done for food materials as mastication involves compression. There are two main types of compression tests.

1. Uniaxial compression: the sample is compressed in one direction and is unstrained in other two dimensions
2. Bulk compression: the sample is compressed in all directions



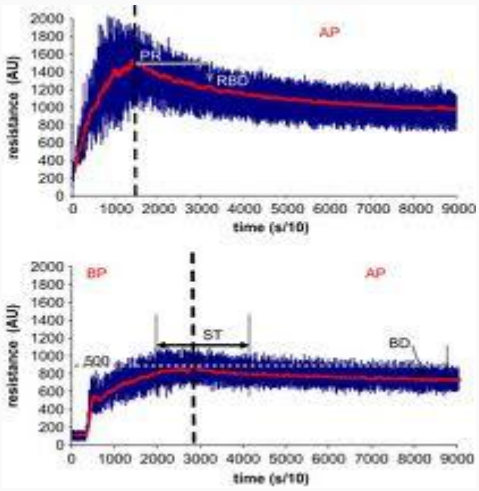
Since most foods are viscoelastic in nature rather than elastic and are usually subjected to large compression tests, the concept of young's modulus is seldom applied, however Young's modulus of elasticity is applied as well as poison's ratio.

Tensile tests: Tensile tests are not widely used in foods, which is understandable because the process of mastication involves compression , not tension, of the foods between molars. Eg. Tensile test for meat, chewing gum, or as a stickiness measurement, brabender extensograph, Instron, texture analyser.

Fig. Noodle tensile testing (source: stable microsystem ltd.)

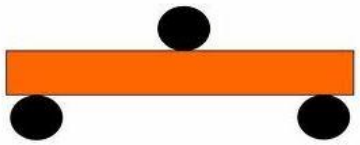
Torsion: in a torsion test force is provided that tends to rotate or twist one part of the object around an axis with respect to the other part.

Farnograph and mixographs are torsion measuring equipments for dough



Bending and snapping: bending and snapping tests are usually applied to foods that are in the shape of bar or sheet.

3 point bending tests, for cookies, crackers, food bars



Distance measuring instruments:

- Linear measuring instruments
- Area measurement with dimension length^2
- Volume measurement with dimension length^3

Linear measuring instruments: simple distance measuring instruments.

Penetration distance (cone penetrometer for butter firmness), Rebound distance (cooked peas), Deformation (defoemation test of foods in Instron), Eg. Botstwick consistometer, penetrometer

volume measuring instruments

eg. loaf volume meter, succulometer (volume of juice)

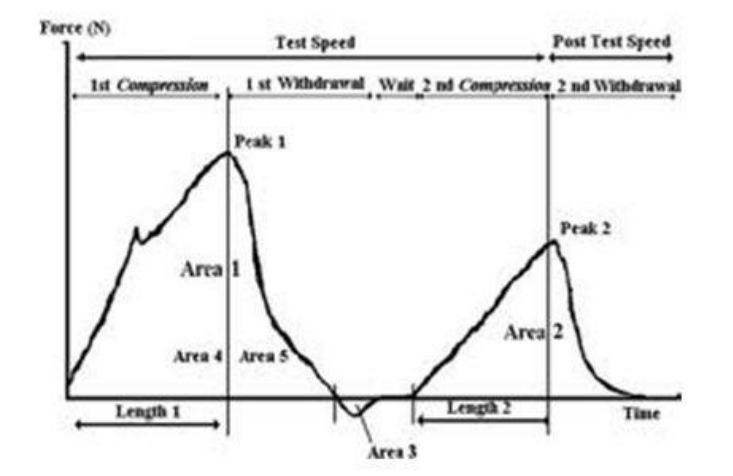
Multiple measuring instruments:

Texture profile analysis:

Simulation of mastication of food in mouth

Hardness: The hardness value is the peak force of the first compression of the product. The hardness need not occur at the point of deepest compression, although it typically does for most products. (Newton, Dyne,gforce, kgf, $M^1L^1T^{-2}$)

Fracturability/brittleness: it is defined as the force of the significant break in the curve on the first bite of the force and deformation curve. (force: unit, N, gf, gforce dimensional analysis: $M^1L^1T^{-2}$)



Cohesiveness: Cohesiveness is how well the product withstands a second deformation relative to how it behaved under the first deformation. It is measured as the area of work during the second compression divided by the area of work during the first compression. (A2/A1).

Adhesiveness: The negative force area (A3) of the first bite, represents the work necessary to pull the compressing plunger away from the sample.

Springiness: Springiness is how well a product physically springs back after it has been deformed during the first compression. The spring back is measured at the downstroke of the second compression. Springiness is measured by the distance of the detected height of the product on the second compression (Length 2 on the below graph), as divided by the original compression distance (Length 1).

Gumminess: Product of hardness and cohesiveness (units force: Newton, Dyne, $M^1L^1T^{-2}$); generally applied to semisolid foods.

Chewiness: Product of gumminess and springiness, generally applied to solid food. It is the energy required to make the solid food ready to swallow.

Resilience: Resilience is how well a product "fights to regain its original position. The calculation is the area during the withdrawal of the first compression, divided by the area of the first compression. (Area 5/ Area4).

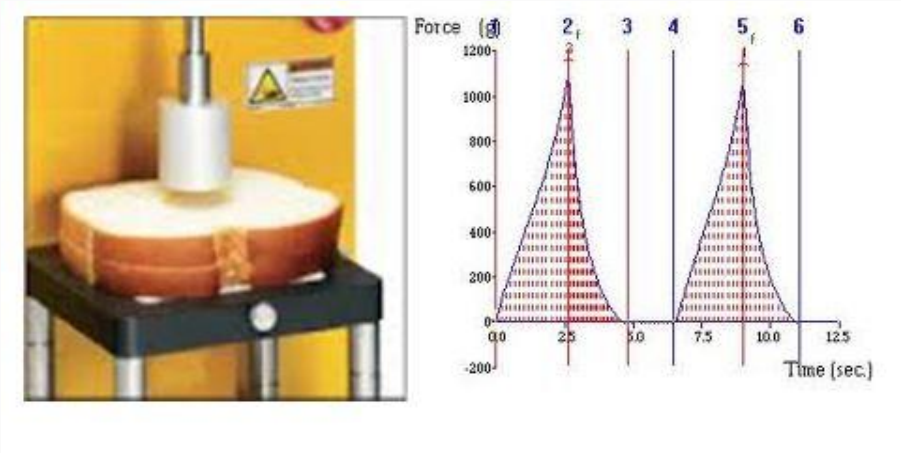


Fig. Typical force –deformation curve in texture profile analysis

Lesson 15. Concept of colour in food quality

Quality is not a single well-defined attribute but comprises many properties or characteristics. Appearance is one of the major factors the consumer uses to evaluate the quality of food products. Appearance is one of the most important sensory quality attributes of fresh and processed food, products and their marketing. It is an all-inclusive term involving size, shape, texture, mass, gloss, colour and others. The colour of food surface is the first quality parameter evaluated by consumers, and it is critical to product acceptance. Food appearance determined mostly by surface colour is the first sensation that the consumer perceives and uses as a tool to either accept or reject food. Visual appearance of the food manifested as its colour has a strong influence on a consumer's opinion about the food quality. Colour can be correlated with other quality attributes such as sensory, nutritional and visual or non-visual defects and helps to control them immediately.

Colour of agri-food products such as fruit and vegetables is derived from natural pigments, many of which change as the plant proceeds through maturation and ripening. The primary pigments imparting colour quality are the fat-soluble

chlorophylls (green), carotenoids (yellow, orange, and red), water-soluble anthocyanins (red, blue), flavonoids (yellow) and betalains (red). Colour features can be used to detect defects in food products, such as those on the surface of apples, or to classify products having different qualities (Leemans et al. 1998). The product should look fresh, have normal size and colour associated with the particular fruit or vegetable, and be without blemishes or signs of decay. The absence of blemishes or signs of decay is also of utmost importance.

Optical properties of food are those which govern the way food materials respond to absorption of electromagnetic radiation in the optical wavelength and frequencies. Includes visible light and color, reflection and refraction

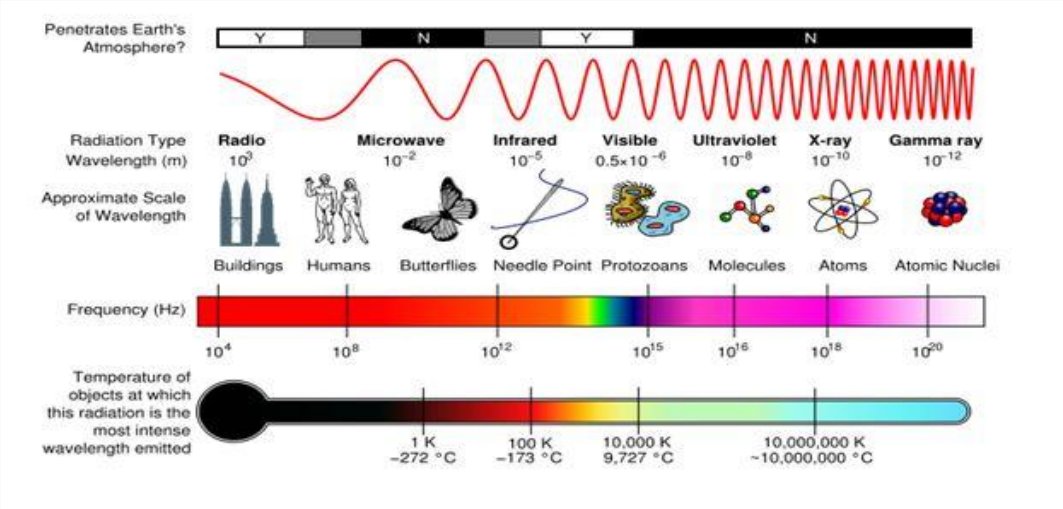


Fig. Electromagnetic spectrum

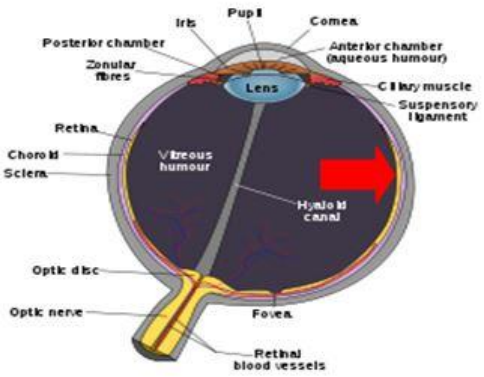
How do we see colours?

Colour is a perceptual phenomenon that depends on the observer and the conditions in which the colour is observed. It is a characteristic of light, which is measurable in terms of intensity and wavelength. The colour of a material becomes

visible only when light from a luminous object or source illuminates or strikes the surface.

Electromagnetic spectrum	wavelength
Ultra violet	**< 400 nm**
Violet	400-450nm
Blue	450-500 nm
Green	500-570 nm
Yellow	570-590 nm
Orange	590-620 nm
Red	620-760 nm
Infrared	>760 nm

Human eye can see the objects in the visible range.



Cones and rods:

Table 1 : Relationship between absorption and visual colour

Wavelength absorbed (nm)	Colour absorbed	visual colour
400-430	violet	Yellow-green
435-480	Blue	Yellow
480-490	Green-blue	orange
490-500	Blue-green	red
500-560	Green	purple
560-580	Yellow-green	Violet
580-595	Yellow	blue
595-605	Orange	Green-blue
605-750	Red	Blue-green

Terms in colourimetry:

Hue: is the attribute described by colour name such as red, green, blue etc

Saturation: is the colorfulness judged in proportion to its brightness

Chroma: is the colorfulness relative to the brightness of its surrounding

Lightness: is the relative brightness unaffected by luminance, as it is the proportion of light reflected

Brightness: depends on the luminance

Colourfulness: is the visual sensation according to which an area appears to exhibit more or less chromatic colour

Gloss: is a measure of reflected light. It is a visual aspect of quality that depends on the ability of a surface to reflect light.

Gloss on the outside of the whole fruit tends to be a desirable attribute for whole fruits. Products that are freshly harvested often have a bright, glossy surface, and this appearance factor can be greatly reduced with weight loss and other postharvest handling conditions. Freshly cut fruits and vegetables must appear to be fresh, generally indicated by the brightness of colour and the absence of visual defects or drip. Sheen on the outside of most cut fruits is preferred to a dried appearance.

Sahin S. & Sumnu, S. G. 2006. Physical Properties of Foods. Springer, USA

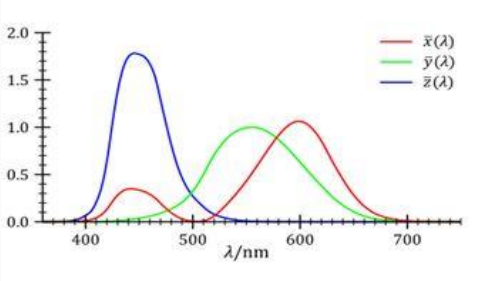
Lesson 16. Colour measurement methods

Colour is an important quality attribute in the food and bioprocess industries, and it influences consumer's choice and preferences. Food colour is governed by the chemical, biochemical, microbial and physical changes which occur during growth, maturation, postharvest handling and processing. Colour measurement of food products has been used as an indirect measure of other quality attributes such as flavour and contents of pigments because it is simpler, faster and correlates well with other physicochemical properties.

Colour Systems (Colour Spaces)

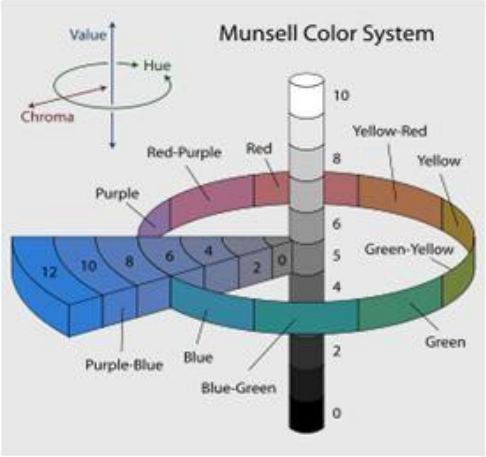
The colour of an object can be described by several colour coordinate systems. Some of the colour systems used in the food industries are munshell colour system, RGB system, Hunter L a b, Commission Internationale de l'Eclairage's (CIE) L*a*b*, CIE XYZ, CIE L*u*v*, CIE Yxy, and CIE LCH. These differ in the symmetry of the colour space and in the coordinate system used to define points within that space.

Tristimulus colour values:



According to CIE concepts, the human eye has three colour receptors—red, green and blue—and all colours are combinations of those. The amounts of red, green and blue needed to form any particular colour are called the tristimulus values and are denoted X, Y and Z, respectively. The most commonly used notations are the CIE XYZ colour space devised in 1931 by the International Commission on Illumination. The system is based on the trichromatic principle, but instead of using real red, green and blue primaries with their necessity for negative matching, it uses imaginary positive primaries, X, Y and Z. It uses the chromaticity diagram to designate various colours. Primary Y, known as luminous reflectance or transmittance, contains the entire lightness stimulus. The application of the weighting to a reflectance curve gives the tristimulus values, which are denoted by the capital letters X, Y and Z. These values are then used to calculate the chromaticity coordinates, designated by lowercase letters x (red), y (green) and z (blue). The value for x can be calculated as x0X/(X+Y+Z). The values for y and z can be calculated by replacing X with Y and Z, respectively, in the numerator

Munshell colour system:



In colorimetry, the Munsell color system is a color space that specifies colors based on three color dimensions: hue, value (lightness), and chroma (color purity). It was created by Professor Albert H. Munsell in the first decade of the 20th century and adopted by the USDA as the official color system for soil research in the 1930s. The system consists of three independent dimensions which can be represented cylindrically in three dimensions as an irregular color solid: hue, measured by degrees around horizontal circles; chroma, measured radially outward from the neutral (gray) vertical axis; and value, measured vertically from 0 (black) to 10 (white).

Munshell Hue:

Each horizontal circle is divided into five principal hues: Red, Yellow, Green, Blue, and Purple, along with 5 intermediate hues halfway between adjacent principal hues. Each of these 10 steps, with the named hue given number 5, is then broken into 10 sub-steps, so that 100 hues are given integer values. In practice, color charts conventionally specify 40 hues, in increments of 2.5, progressing as for example 10R to 2.5YR. Two colors of equal value and chroma, on opposite sides of a hue circle, are complementary colors, and mix additively to the neutral gray of the same value.

Munshell Value:

Value, or lightness, varies vertically along the color solid, from black (value 0) at the bottom, to white (value 10) at the top. Neutral grays lie along the vertical axis between black and white.

Munshell Chroma:

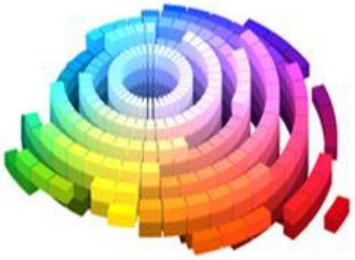
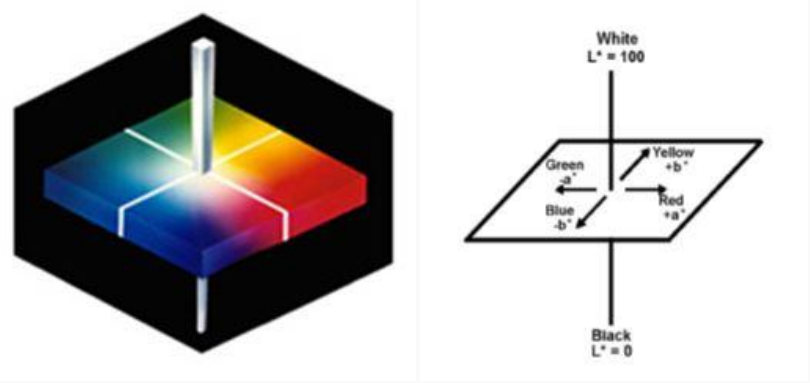


Fig. Munshell colour system

Chroma, measured radially from the center of each slice, represents the "purity" of a color, with lower chroma being less pure. Different areas of the color space have different maximal chroma coordinates. For instance light yellow colors have considerably more potential chroma than light purples, due to the nature of the eye and the physics of color stimuli. This led to a wide range of possible chroma levels—up to the high 30s for some hue–value combinations.

Hunter Lab colour value:

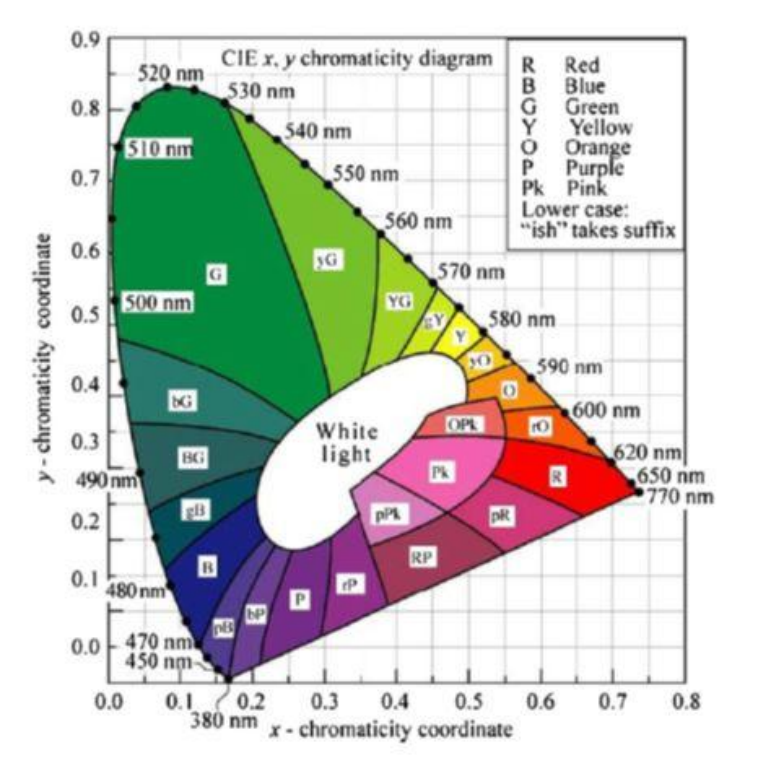


The Hunter L a b developed in 1948 for photoelectric measurement and the CIE L*a*b* colour space devised in 1976 provide more uniform colour differences in relation to human perception of differences.

An object, a light source or an illuminant, and an observer are required for the presence of colour. A light source can be turned on and off and can be used to view an object. However, an illuminant is a mathematical description of a light source. In 1931, the CIE recommended three standard illuminants. Illuminant A defines light typical of that from an incandescent lamp, illuminant B represents direct sunlight, and illuminant C represents average daylight

from the total sky. In 1966, the CIE proposed a fourth series, the D illuminants. These illuminants represent daylight more completely and accurately than illuminants B and C. The D illuminants are usually identified by the first two digits of their colour temperature. In 1986, the CIE recommended the use of an E series of illuminants for fluorescent lamps.

CIE colorimetry:



Lovibond tintometer:

In the 1860s, Joseph Lovibond, the founder of The Tintometer Ltd, developed the original Lovibond Color system, which was based on a calibrated series of red, yellow and blue glass color standards. Used for analysis of products such as edible and industrial oils, fuel oils, chemicals, coatings and beverages.

Quantification of Colour:

The HunterLab L*,a*,b* and the modified CIE system called CIELAB colour scales were opponent-type systems commonly used in the food industry. The CIELAB coordinates (L*, a*, b*) were directly read. It was considered the CIELAB uniform space in which two colour coordinates, a* and b*, as well as a psychometric index of lightness, L*, were measured. The parameter a* takes positive values for reddish colours and negative values for the greenish ones, whereas b* takes positive values for yellowish colours and negative values for the bluish ones. L* is an approximate measurement of luminosity, which is the property according to which each colour can be considered as equivalent to a member of the greyscale, between black and white.

Chroma: Chroma (C*), considered the quantitative attribute of colourfulness, is used to determine the degree of difference of a hue in comparison to a grey colour with the same lightness. The higher the chroma values, the higher is the olour intensity of samples perceived by humans.

Hue angle: Hue angle (h*), considered the qualitative attribute of colour, is the attribute according to which colours have been traditionally defined as reddish, greenish, etc., and it is used to define the difference of a certain colour with reference to grey colour with the same lightness. This attribute is related to the differences in absorbance at different wavelengths. A higher hue angle represents a lesser yellow character in the assays. An angle of 0° or 360° represents red hue, whilst angles of 90°, 180° and 270° represent yellow, green and blue hues, respectively. It has been extensively used in the evaluation of colour parameters in green vegetables, fruits and meats.

Derived General Objective Colour Indices

Total Colour Difference

Colour changes can be measured as the modulus of the distance vector between the initial colour values and the actual colour coordinates. This concept is named total colour difference. Total colour difference indicates the magnitude of colour difference between stored/ processed and control samples. Total colour difference (ΔE) indicates the colour difference from the standard plate.

Whiteness index:

Whiteness indices (WI) are widely measured to yield numbers correlating closely with consumers' preferences for white colours. It mathematically combines lightness and yellow–blue into a single term. The WI represents the overall whiteness of food products that may indicate the extent of discoloration during the processing.

Yellowness Index

Yellowness is associated with scorching, soiling, and general product degradation by light, chemical exposure and processing. Yellowness indices are used chiefly to quantify these types of degradation with a single value. They can be used when measuring clear, near-

colourless liquids or solids in transmission and near-white, opaque solids in reflectance. Yellowness index (YI) indicates the degree of yellowness.

Browning Index:

Browning colouration is an important phenomenon in food handling and processing, including baking, drying and frying, because it affects appearance quality. Therefore, the measurement and quantification of browning is important in food research and industrial practice during sorting and grading to meet market requirements. It results from both enzymatic and non-enzymatic oxidation of phenolic compounds. The browning index (BI) is used to characterise the overall changes in browning colour. It is defined as brown colour purity and is one of the most common indicators of browning in food products containing sugar.

Conversion of Hunter Values to CIE values

$$BI = 100 \times \left(\frac{X - 0.31}{0.17} \right), \text{ where, } X = \frac{(a + 1.75L)}{(5.645L + a - 3.012b)}$$

$$Y = (0.01L)^2, \qquad X = 0.9804\left(Y + \frac{0.01a}{175}\right), \qquad Z = 1.181\left(Y - \frac{0.01b}{70}\right)$$

Lesson 17. Concept of Flavor in food quality

We eat with our eyes. The shape, size, gloss, and vibrant color of the food attract us and entice us into picking it up by hand or fork. Once we are attracted by the appearance and color of a product, we put it into our mouths, where the aroma and taste take over. Freshness, spiciness, sweetness, and other flavor attributes are critical to our eating pleasure. Aroma refers to the smell of a food product, whereas flavor includes both aroma and taste.

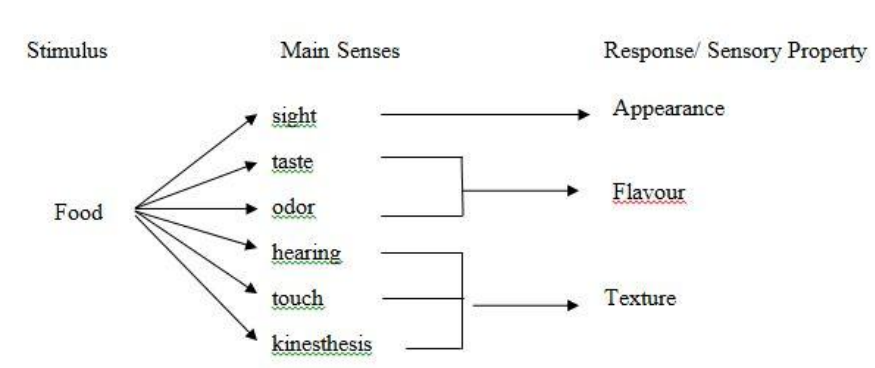
Definition of Flavor

1. "Flavor is the sensation produced by a material taken in the mouth, perceived principally by the senses of taste and smell, and also by the general pain, tactile, and temperature receptors in the mouth. Flavor also denotes the sum of the characteristics of the material which produces that sensation."

2. " Flavor is one of the three main sensory properties which are decisive in

the selection, acceptance, and ingestion of a food.

3. "A mingled but unitary experience which includes sensations of taste, smell, and pressure, and often cutaneous sensations such as warmth, color, or mild pain".



How do we recognize flavor:

The five basic taste sensations are mediated by specialised epithelial cells, the taste receptor cells,that are located within the taste buds of the papillae on the surface of the tongue. These elongated taste receptors cells are deeply embedded in the surrounding epithelium and just contact the outside world in the gustatory porus of the taste buds. Thus, the porus is the place where tastants interact with the taste receptor molecules that are located at the apical site of the taste receptor cells. In contrast to obsolete textbook knowledge, humans can perceive all taste qualities on any area of the tongue that contains papillae. Only the perceived intensities of the taste qualities differ depending on the tongue region and papilla type. Sweet taste saccharin for instance is highest at the tip of the tongue whereas the bitter taste of quinine is best perceived at the back of the tongue. Interestingly, the anterior part of the tongue is innervated by the VII cranial nerve whereas the posterior part of the tongue is

innervated by the IX cranial nerve. These innervations are also reflected by the distribution of the taste papilla types. The fungiform papillae are located at the anterior part of the tongue and thus are innervated by VII cranial nerve. In contrast, the foliate and vallate papillae that is located at the back of the tongue that is innervated by the IX cranial nerve. This nerve also innervates isolated taste buds in the palate and epiglottis.

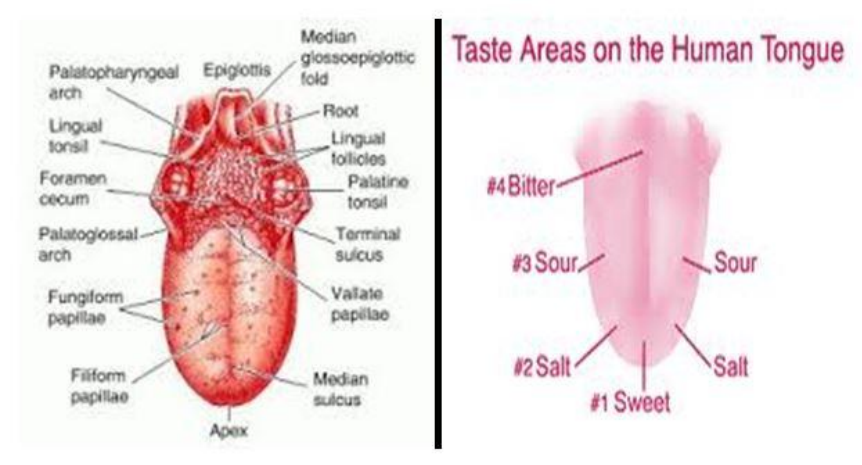


Fig. Human Tongue and taste areas on the human tongue

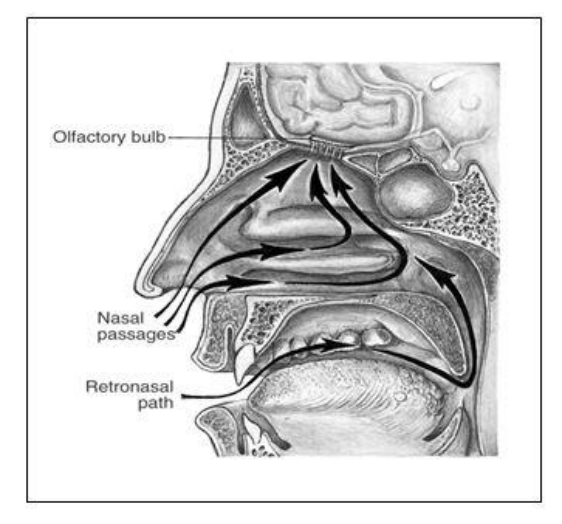


Fig. Human Olfactory system

Flavor is typically described by aroma (odor) and taste. Aroma compounds are volatile—they are perceived primarily with the nose, while taste receptors exist in the mouth and are impacted when the food is chewed. While color and appearance may be the initial quality attributes that attract us to a food product, the flavor may have the largest impact on acceptability and desire to consume it again.

The five basic taste qualities are exclusively mediated by specialized epithelial receptor cells that are located in taste buds. Most taste buds lie within taste papillae on the human tongue, but some of them are also distributed on the palate and epiglottis. The taste buds in the oral cavity are innervated by gustatory fibres of the VII, IX and X cranial nerve.

Thus, the perception of Taste has been divided into five primary tastes:

- **Sweet**: Sweet taste is predominantly elicited by carbohydrates and indicates energy-rich food sources.
- **Sour**: Strong sour taste is also repulsive and prevents the ingestion of unripe fruits and spoiled food, which often contain acids.
- **Salty**: Salt taste is elicited by sodium chloride and other salts and contributes to electrolyte homeostasis, salt taste is attractive at low concentrations and repulsive at high concentrations.
- **Bitter**: Bitter taste is evoked by many compounds that belong to multiple chemical classes. The common denominator of most bitter compounds is their pharmacological activity or toxicity. Therefore, due to its task to avoid harmful compounds strong bitter taste is aversive. Nevertheless humans can accept moderate bitter taste or even find it attractive. A reasonable explanation for this observation is that bitter and sour tastes should not deter us from advantageous food containing low concentrations of harmful compounds.
- **Umami**(a taste associated with salts of amino acids and nucleotides): The broth-like umami taste, that is mainly triggered by glutamate and enhanced by ribonucleotides such as inositol monophosphate (IMP), identifies protein-rich food.

Odors are much more diverse and classified as:

- Spicy:
- Flowery:
- Fruity:
- Resinous or balsamic:
- Burnt:
- Foul:

Flavors in food:

- **Desirable flavor**: orange juice, potato chip, roast beef
- **Undesirable flavors:** oxidized, stale, rancid, warmed-over

Classification of flavors:

Flavor class	Subdivision	Representative sample
Fruit flavour	Citrus type flavor (terpeny) Berry type flavor (non- terpeny)	Grape fruit , orange Apple, banana
Vegetable flavour		Lettuce, celery
Spice flavor	Aromatic Lachrymogenic hot	Cinnamon, peppermint Onion, garlic Pepper, ginger
Beverage flavor	Unfermented flavor Fermented flavor Compounded flavor	Juices, milk Wine, beer, tea Soft drinks
Meat flavor	Mammal flavor Sea food flavor	Lean beef Fish, clams
Fat flavor		Olive oil, coconut fat, pork fat, butter fat
Cooked flavor	Broth Vegetable Fruit	Beef bouillon Legume, potatoes marmalade
Processed flavor	smoky flavor Broiled, fried flavor Roasted , toasted, baked flavor	Ham Processed meat products Coffee, snack foods, processed cereals
Stench flavor		cheese

Other Factors That Affect Flavor Perception

- Temperature
- Consistency
- Presence of contrasting tastes
- Presence of fats
- Color

Sources of flavors

- Natural flavors
  - herbs and spices (Reaction after cutting)
  - Fruit (Biosynthesis during ripening)

- Process flavors
- browning
- lipid oxidation
- fermentations
- Artificial flavors
- character impact compounds

Food Flavor Profiles:

- Top notes or high notes: The sharpest first flavors or aromas
- Middle notes: The second wave of flavor, more subtle
- Low notes: The most dominant lingering flavor
- Aftertaste or finish: The final flavor
- Roundness: The unity of a dish's various flavors
- Depth of flavor: A broad range of flavors

Mechanism of flavor development:

- Enzymatic reaction: Volatile flavors developed in most food plants mainly at the ripening stage - the result of plant metabolism through enzymatic reaction.
- Non-enzymatic reaction: Raw meat must be heated before it develops any organoleptically acceptable flavor, flavor development in baked cereals, nuts, coffee etc.

Flavor analysis: Flavor may be evaluated with either **instrumental or sensory** methods, but most scientists would agree that sensory methods are the most critical to this particular quality attribute. Instrumental techniques may determine that tens or hundreds of compounds are present in a particular food product, but such methods do not give a measure of the contribution of that specific compound unless they are accompanied by a sensory measurement of odor or flavor activity. For this reason, flavor may be the most challenging quality attribute to both measure and correlate to consumer acceptability. There are some characteristics of flavor that may be determined instrumentally.

- **Sensory Analysis**
- **Discrimination tests**
- Difference tests
- Threshold tests

- **Analytical intensity rating testsConsumer tests**
- Types of scales
- Descriptive analysis
- Time-intensity
- **Consumer tests**
- **Instrumental Methods**
- Flavor Identification by Spectrometric MethodsElectronic nose
- Ultra Violet Spectrometry
- Infrared Spectrometry
- Nuclear Magnetic Resonance Spectrometry
- Mass Spectrometry
- Electronic nose

Sweetness can be approximated by HPLC determination of individual sugars, or more rapidly but less accurately by a refractometer or hydrometer that measures total soluble solids. Indicator papers exist for rapid determination of glucose in some commodities, such as potatoes. It is possible to measure chloride and/or sodium content as an approximation of saltiness. Sourness may be determined by either pH or more accurately by measurement of total acidity. Both indicator papers and pH meters are available for the determination of pH. Astringency may be indicated by measuring total phenolics and bitterness by analysis of compounds such as alkaloids or glucosides.

Some terms in flavor:

1) **Seasoning**: An item added to enhance the natural flavors of a food without changing its taste, eg. Salt is the most common seasoning.

2) **Flavoring**: An item that adds a new taste to food and alters its natural flavors, eg. **Herbs** (Any of a large group of aromatic plants whose leaves, stems or flowers are used as a flavoring, used either dry or fresh), **spices** (Any of a large group of aromatic plants whose bark, roots, seeds, buds or berries are used as flavoring. Usually used in dry form, whole or ground), **vinegars** and **condiments** (Any item added to a dish for flavor, including herbs, spices and vinegars. Also refers to cooked or prepared flavorings such as prepared mustards, relishes, bottled sauces and pickles).

Lesson 18. Flavor extraction and Measurement methods

Extraction of flavors:

I. Extraction Techniques

A. Solvent Extraction: Solvent extraction is a selective separation procedure for isolating and concentrating a valuable material from an aqueous solution with the aid of organic acids. The extraction process depends on the solubility of the flavouring compounds in the solvent. A compound can be separated from impurities in a solution by extracting the compound from the original (or first) solvent into a second solvent. For the process to be selective, the compound must be more soluble in the second solvent than in the first solvent, and the impurities must be insoluble in the second solvent. Additionally, the two selected solvents must be immiscible, or not soluble in one another, so that they produce two separate solvent layers. After dissolving the mixture in the first solvent, the solution is added to a second solvent.

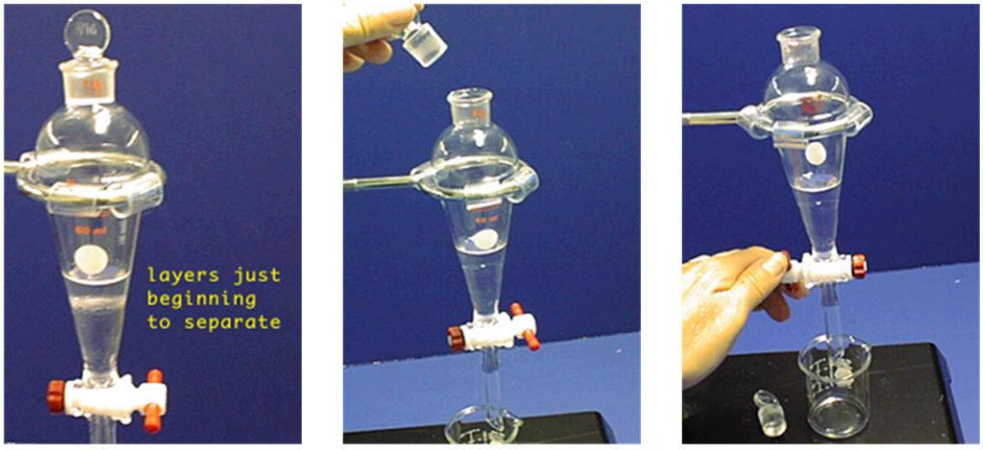


Fig. liquid-liquid extraction (Source: Lab and Kelly)

B. Solid Phase Extraction (SPE): The principle of SPE is similar to that of liquid-liquid extraction (LLE), involving a partitioning of solutes between two phases. However, instead of two immiscible liquid phases, as in LLE, SPE involves partitioning between a liquid (sample matrix or solvent with analytes) and a solid (sorbent) phase. SPE is typically performed by loading the complex sample onto a preconditioned extraction cartridge containing a chromatographic sorbent.

C. Solid phase micro extraction (SPME): solid-phase microextraction is a solvent-free sampling technique based on the sorption characteristics (adsorption or absorption) of fiber coating materials. The analytes (volatiles or semivolatiles) from gaseous, liquid, or solid matrices are first released from the matrices and sorbed onto a fiber coated with an ad(ab)sorbent polymer introduced into the headspace. Following sorption, analytes are either thermally desorbed onto a gas chromatographic (GC) inlet or solvent desorbed into a high-performance liquid chromatographic (HPLC) inlet.

D. Steam Distillation: Many organic compounds tend to decompose at high sustained temperatures. Separation by normal distillation would then not be an option, so water or steam is introduced into the distillation apparatus. By adding water or steam, the boiling points of the compounds are depressed, allowing them to evaporate at lower temperatures, preferably below the temperatures at which the deterioration of the material becomes appreciable. If the substances to be distilled are very sensitive to heat, steam distillation can also be combined with vacuum distillation. After distillation the vapors are condensed as usual, usually yielding a two-phase system of water and the organic compounds, allowing for decantation.

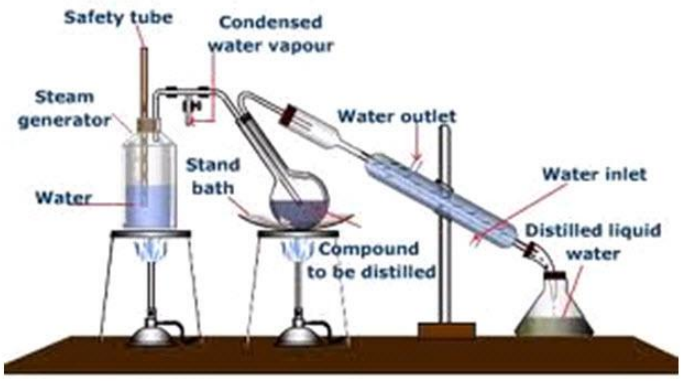


Fig. steam distillation

E. Super critical fluid extraction: A supercritical fluid is any substance at a temperature and pressure above its critical point, where distinct liquid and gas phases do not exist. It can effuse through solids like a gas, and dissolve materials like a liquid. In addition, close to the critical point, small changes in pressure or temperature result in large changes in density, allowing many properties of a supercritical fluid to be altered. Supercritical fluids are suitable as a substitute for organic solvents in a range of industrial and laboratory processes. Carbon dioxide and water are the most commonly used supercritical fluids.

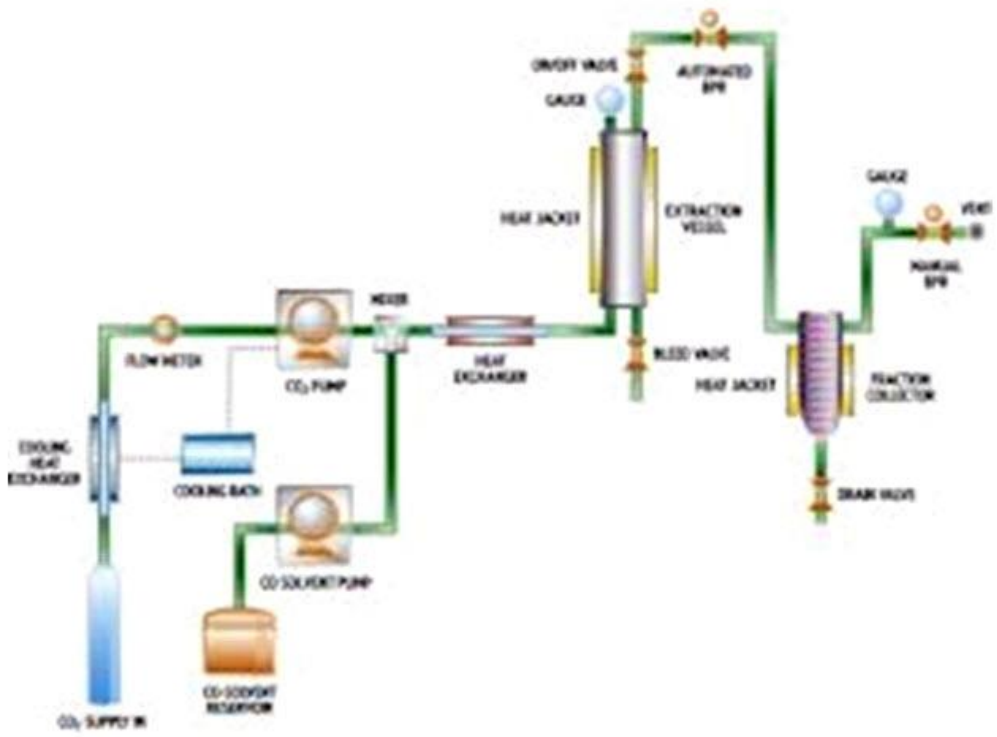


Fig. Super critical fluid extraction

F. Microwave aided extraction: Microwaves cause bipolar rotation of polar molecules like water, which generates heat due to molecular friction. Even though dried plant material is used for extraction in most cases, but still plant cells contain minute microscopic traces of moisture that serves as the target for microwave heating. The moisture when heated up inside the plant cell due to microwave effect, evaporates and generates tremendous pressure on the cell wall due to swelling of the plant cell. The pressure pushes the cell wall from inside, stretching and ultimately rupturing it, which facilitates leaching out of the active constituents from the ruptures cells. This process is very fast compared to other techniques and saves considerable amount of solvent and time.

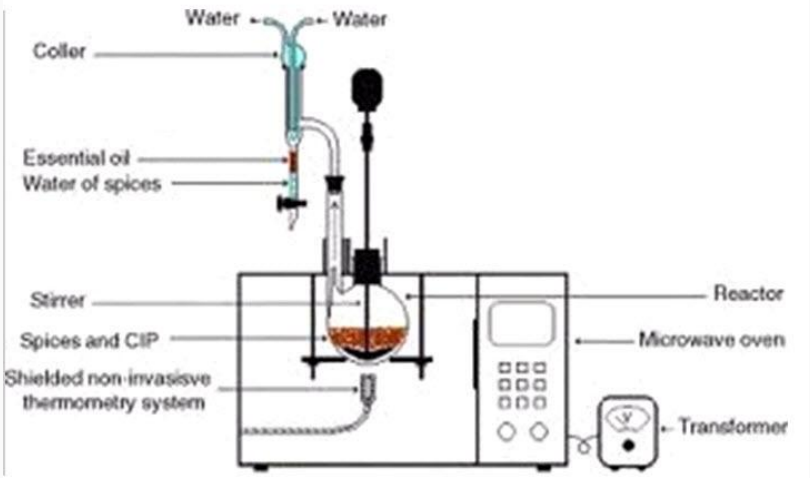


Fig. microwave aided extraction of flavoring compound

G. Ultrasound aided extraction: Sound waves can be classified into three categories i.e. supersonic (frequency< 20 Hz), audible (20 Hz <frequency>20 kHz), or ultrasound (frequency>20 kHz). Ultrasound is simply sound pitched above human hearing. Ultrasound waves can be classified into two categories(i) high-power, low-frequency ultrasound from 20 kHz to 2 MHz, (ii)) and 5 MHz to several GHz), low-power ultrasound. Power ultrasound usually refers to the frequency range between 20-40 kHz. Power ultrasound has been used to accelerate processes such as dehydration, drying, freezing and thawing, tenderization of meat, crystallization of lactose and fat and to improve processes such as cutting, extraction, emulsification, ageing of wines and esterification etc. Power ultrasound waves, when propagated through any food medium, result in cavitations and bubble formation, compression and rarefaction, cavitations, heating due to absorbance of acoustic energy on the product interfaces and streaming. Cavitation occurs when acoustic waves propagate through liquid media, forming very small bubbles. If the bubbles are of critical size, as determined by the wave frequency; then they explode releasing energy in the form of impulses which can have local point temperature about 1000K and pressure of 1000 atm. But it does not raise the temperature of the liquid food material; if the bubbles explode near the boundary then it gets evaporated. These phenomena result in structural disintegration and energy dissipation to the medium. Structural disintegration leading to cell permeabilization makes way for the water molecules to travel to the surface and this phenomena aid in mass transfer rate during extraction process.

II. Headspace Sampling

A. Static Headspace

B. Dynamic Headspace

C. Thermal Desorption

Flavor analysis: Flavor may be evaluated with either **instrumental or sensory** methods, but most scientists would agree that sensory methods are the most critical to this particular

quality attribute. Instrumental techniques may determine that tens or hundreds of compounds are present in a particular food product, but such methods do not give a measure of the contribution of that specific compound unless they are accompanied by a sensory measurement of odor or flavor activity. For this reason, flavor may be the most challenging quality attribute to both measure and correlate to consumer acceptability. There are some characteristics of flavor that may be determined instrumentally.

Sensory Analysis

- **Discrimination tests**
  - Difference tests
  - Threshold tests
- **Analytical intensity rating testsConsumer tests**
  - Types of scales
  - Descriptive analysis
  - Time-intensity
- **Consumer Tests**
- **Instrumental Methods**

Volatile analysis:

- **GC-MS**
- **GC-Olfactometry**Electronic nose
  - Flavor Identification by Spectrometric Methods
    - Ultra Violet Spectrometry
    - Infrared Spectrometry
    - Nuclear Magnetic Resonance Spectrometry
    - Mass Spectrometry
- Electronic Nose

Sweetness can be approximated by HPLC determination of individual sugars, or more rapidly but less accurately by a refractometer or hydrometer that measures total soluble solids. Indicator papers exist for rapid determination of glucose in some commodities, such as potatoes. It is possible to measure chloride and/or sodium content as an approximation of saltiness. Sourness may be determined by either pH or more accurately by measurement of total acidity. Both indicator papers and pH meters are available for the determination of pH. Astringency may be indicated by measuring total phenolics and bitterness by analysis of compounds such as alkaloids or glucosides.

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Module- 6 Food Sampling

Lesson 19. FOOD SAMPLING

Introduction 19.0

The term "food" refers to the broad range of edible materials that comprise the essential body nutrients required for life and growth, such as proteins, carbohydrates, fats, vitamins, or minerals. Foodstuffs are described variously as "liquid" or "solid", and "wet" or "dry", depending on the amounts of water and fat they contain. Samples of plant origin are classified for analytical purposes as having a high or medium water content and a lower content of saccharides (from 5% to 15%), very low water content (dry), or a high content of oils. Similarly, food samples can be divided into four main groups based on water and fat content.

Lot: A quantity of food or food units produced and handled under uniform conditions.

Sample: A number of food units that resembles the characteristics of the lot

A **sample** is a limited quantity of something which is intended to be similar to and represent a larger amount of that thing(s). The things could be countable objects such as individual items available as units for sale, or a material not countable as individual items.

19.1.1What is sampling?

"A procedure used to draw inferences about a lot (population) from results obtained from a sample"

"To collect a representative sample to obtain information on its status"

Sampling involves the selection of a certain portion, number of container and product units from a particular lot of the same food. It must be as representative as possible of the whole consignment or from lot.

An act of obtaining a sample is called **sampling**, which can be done by a person or automatically. Samples of material can be taken or provided for testing, analysis, inspection, investigation, demonstration, or trial use.

19.1.2 Objective:

Samples are usually collected from a lot of food for random surveillance, collection of data for a specific purpose, or monitoring/and to determine whether the food is unsatisfactory for any reason.

19.1.3. Importance of Sample Collection

The reliability of analytical data thus obtained depends on several factors, sampling being the major factor. Current analytical methods require only few grams of food sample to analyze. Thus, it is necessary that a sample be as representative of the population as possible.

19.2 Foods sampling

19.2.1 Food sample:

Food samples of biological origin (liquid or solid) have been divided generally into the five categories described in Table 19.1. This coarse division is important when considering the choice of isolation technique, extraction solvent, and sample clean-up method during an analytical procedure.

Moisture content is an important consideration during sampling procedures, in part because it affects the extent of sample heterogeneity. Virtually all foods are heterogeneous, and the analyst should be familiar with their variability in composition and structure. In general, fresh foods of plant origin are more variable in composition than fresh foods of animal origin. The analyst should be also aware of the postmortem or postharvest physiological changes that can occur after a fresh food is sampled and which can affect sample heterogeneity. A combination of cold storage and chemical preservation may be required to maintain sample integrity in the event of prolonged storage.

Table 19.1: General classification of food samples according to their content

Sample	Character	Typical analytes
Milk	Aqueous, proteins, lipids	Veterinary drugs, toxic elements, pesticides, industrial contaminants
Eggs	High lipids and albumin content	Veterinary drugs , pesticides, industrial contaminants
Other samples of animal origin (liver, fat)	Various fat, proteins, or water	Drugs, pesticides, industrial contaminants
Plant materials (fruits, vegetables)	Various water, plant pigments, proteins, lipids, essential oil, waxes	toxic elements, pesticides, industrial contaminants
Food (meat, milk, cereals, wines, juices, plants oils, sugar	Various fat, oils, lipids, proteins, sugar, starch, water, or pigments	pesticides, industrial contaminants, synthetic colorants, additives, synthetic sweeteners, antioxidants

Although the chemical and physical properties of foods are inherently variable, even between samples that originate from the same breed or strain, the variability in composition of a single food sample can be minimized with proper sampling and sample pretreatment techniques. Two approaches can be used for sampling a food mass that is larger than the

amount required for analysis in the laboratory. Many minute increments of a solid material can be collected and blended to represent the entire foodstuff, or a quantity of material that is large enough to be compositionally representative of the whole can be collected and then reduced to a fine mixture before being sub-sampled. The first approach is usually avoided, since it is difficult to obtain a statistically representative sample and the sampling time can also be very long. The latter approach is more practical, accurate, and reproducible.

Since virtually no food material can be analyzed in its entirety, careful sampling techniques are required to obtain representative, laboratory-sized primary samples, in addition to subsequent subsamples, or secondary samples. The amount of subsample required for an analytical procedure usually varies from a fraction of a gram to several grams.

19.2.2 Sample Size

The required sample size is defined in part by the nature of the target compound, that is, to what extent the analyte is retained in the matrix. Xenobiotics are generally present at trace levels. A sufficiently large amount of sample must be collected and analyzed in order to be able to measure minute quantities of the compound of interest and to satisfy the method's limit of detection. Conversely, relatively small samples may be collected for the macro analysis of gross food components, i.e., to measure crude fat, crude protein, crude fiber, or ash. Although proximate analysis of these food components is sometimes sufficient, more exact analyses are usually required.

The sample size is also dependent on the relationship that exists between the mass required to adequately represent a sample and the characteristics of that sample. If a foodstuff consists of some mixture of different-sized particles, enough sample mass needs to be collected in order to adequately represent all of the particles. Because large particles are more difficult to represent than smaller ones, a mass that is large enough to represent the larger particles will also be representative of the smaller ones. The segregation of finer, denser particles to the bottom of the sample container must be recognized during the sampling process to ensure that all particles are represented and to avoid large sampling errors.

19.3 Sampling Steps

19.3.1 Sample collection

- Containers
- Sampling devices
- Sampling procedures: aseptic technique
- Sample labeling

Techniques:

Food lots are sampled in either a manual or continuous manner in order to obtain a representative specimen. Containers holding loose foodstuffs can be sampled manually with devices that trap the material in a compartment such as a probe or tube. Slots or openings

placed at intervals in the tube allow for simultaneous sampling at different depths of the product. When employing this technique, however, the analyst must consider the segregation effect and ensure that all particle sizes are accessible. The foodstuff may ultimately need to be removed from the sample-container and poured onto a flat surface. The amount of material may then be reduced with a coning-and-quartering method, and a subsample collected in multiple random increments. No particle size should be excluded during the sampling process. Since food components or contaminants that collect in certain-sized particles might be omitted from the final analysis, thereby resulting in an increase in sampling error.

Large mixtures may also be reduced with a riffle cutter, which is a box-like device that has equally spaced dividers to divide the sample stream. The sample may be further cut or quartered by passing it through successive riffles. Other proportional dividers are available for reducing a sample, such as the straightline sampler and the spinning riffle sample divider.

Uniformly solid or liquid products are perhaps the most straightforward to sample. Drill-type devices are used to obtain a core from solid products such as cheese or frozen foods. Liquid samples are thoroughly mixed before a subsample is removed with a syringe-type sampler or by submerging a container under the liquid's surface (a so-called "grab" sample). For obvious reasons, 'many complex foods such as vegetables, fruit, or animal tissues may require blending prior to being sampled.

Throughout the sample preparation procedure, it is essential for the analyst to recognize the necessity of utilizing methods that satisfy statistical sampling and analysis requirements. The inherent variability in the composition of raw materials, basic ingredients, and processed foods requires the use of statistical methods for obtaining representative and replicate samples, and for estimating the error involved in sampling.

19.4 Food pretreatment:

19.4.1. Removal of extraneous matter:

Before sample blending is done, it is often necessary to wash, remove, or drain irrelevant extraneous matter. Soil or sand that adheres to fresh fruit or vegetables can be removed by washing or wiping the surface of the produce; however, excessive washing should be avoided to prevent the leaching of soluble solids.

Depending on the objective of the analysis, fresh produce may be separated into the core and the outer and inner tissues. Shells are usually separated from nut kernels and pits from stone fruits. Large fish are cleaned, scaled, and eviscerated, while small fish can be blended whole. Shellfish are shucked, eggs are broken to isolate the liquid interior, and meat is removed as completely as possible from bone. Canned fruit and vegetable products may be drained through screens if it is not necessary to analyze the composite sample.

19.4.2. Sample reduction

Once a food sample has been collected using the sampling techniques a suitable method is required to make the material less heterogeneous. Various approaches may be utilized for reducing the particle weight and size in a primary sample, so that smaller subsamples can be

taken for a representative analysis of the whole. Finely divided materials also dissolve faster and are easier to extract because of their greater surface area.

Methods for reducing solid or semi-solid foods include mechanical grinding, mixing, rolling, agitating, stirring, chopping, crushing, macerating, mincing, pressing, pulverizing, or any other reasonable means of cornminuting the sample.

Sample reduction can also be achieved with a Wiley or ball mill, mortar and pestle, mechanical high-speed beaters or blenders (for soft or wet foods), and meat grinders.

19.4.3. Sample handling

- Transportation
- Reception

19.4.4. Sample analysis

- Withdrawing analytical units
- Homogenization of analytical units/ Analysis using appropriate methods and instruments

19.5 Types of Sampling

19.5.1 Bulk sampling

It involves the selection of a sample from a lot of material that does not consist of discrete, identifiable or constant units. Sampling may be performed in static or dynamic situations. Bulk sampling poses special problems requiring certain decisions to be made: the number of increments to be taken, the size of the increments, from where in the pile or stream they should be drawn, the sampling device to be used, and how to reduce the increments taken to a reasonable size of ample for delivery in the laboratory.

19.5.2 Acceptance sampling

It differs from the bulk sampling and involves the application of predetermined plan to decide whether a lot of goods meet defined criteria for acceptance. The risks of accepting ―bad‖ or rejecting "good‖ lots are stated in conjunction with one or more parameters. Statistical plans can be designed to regulate the probabilities of rejecting good lots or accepting bad lots.

Sampling Plan

The particular choice of sampling procedure to determine the minimum number of food units that will provide a high degree of certainty about the quality of a food lot.

Sample units (n)

1. Large enough to represent the population

2. Small enough to be economically feasible

Sample characteristics

The material may be solid, liquid, gas, material of some intermediate characteristics such as gel, tissue, organisms, or a combination of these. Even if a material sample is not countable as individual items, the quantity of the sample may still be describable in terms of its volume, mass, size, or other such dimensions. A solid sample can come in one or a few discrete pieces, or can be fragmented, granular, or powdered.

19.6 Solid food sampling:

19.6.1 Samplers for general usage:

Sampling from bulk: Use appropriate apparatus for obtaining increments from static bulk (example, hand- held spears, mechanical or air-assisted apparatus).

Sampling from bags: Use sack type spears**.**

Mixing and dividing: Use shovels and dividing apparatus or automatic random dividing apparatus**.**

19.6.2 Sampling from silos, bins or warehouses:

Increments shall be taken throughout the whole depth of the lot. Suitable instruments must be used to achieve this requirement. If the depth of the lot does not permit use of this method, sampling should be carried out from the flowing cereal in accordance with ISO 6644.

Take the square root of the tonnage in the static bulk. Divide by two and round up to the next whole number. This is the minimum number of increments that is to be obtained.

Example: Number of increments for bulk grain of more than 500 t

tonnage	500	1000	2000	4000	6000	8000	10000
Square root	22.4	31.6	44.7	63.2	77.4	89.4	100
Number of increments	12	16	23	32	39	45	50

Sampling from bags: Unless otherwise specified in the contract or unless the practice at the port or elsewhere requires otherwise, increments shall be taken from different part of a bag (for eg. Top, middle, bottom) by means of a sack/ bag spear from the number of bags specified in table

Number of bags in consignment	Number of bags to be sampled
Up to 10 10 to 100 More than 100	Each bag 10, taken at random Square root (approx.) of total number,

Sampling Scheme for consignment of more than 100 bags.

The consignment shall be dividing into (n-1) groups containing n or (n-1) bags: the remaining bags constitute a group.

Examples:

A consignment comprising 200 bags.

The square root of 200=14.142, therefore n=14: ---makeup 14 group of 14 bags (i.e. total of 196 bags); ---Draw up a list from 1 to 14; cross out one number, for e.g. 7; ---Sample the seventh bag from each group of 14 bags; ---the remaining group (i.e. 4) is smaller than 14 bags, so sample one bag from this group at random. A total of 15 bags have thereof been selected.

A consignment comprising 2000 bags

The square root of 2000=44.721, therefore n=45: ---make up 44 groups of 45 bags (i.e. total of 1980 bags); ---draw up a list from 1 to 45; ---cross out one number, for example 20; ---sample the 20th bag from each group of 45 bags; ---the remaining group (i.e. 20) is smaller than 45 bags, so sample one bag from this group at random. A total of 45 bags ha therefore been selected.

Reduction of the Sample to Analytical Size

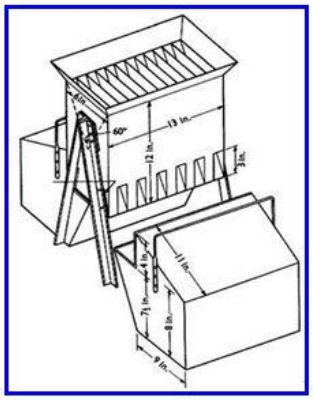


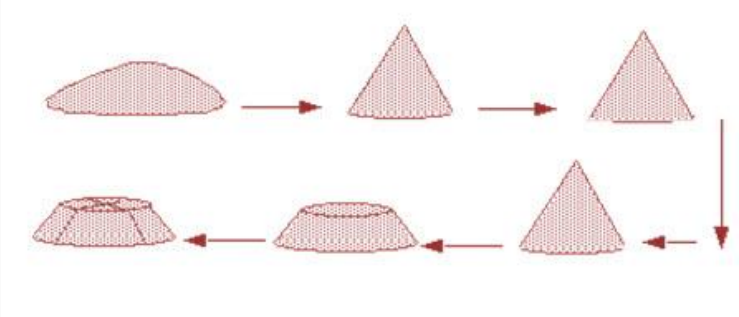
Fig. Riffle

The two common methods of reducing bulk samples to a practical size are riffling and quartering. The sample is fed onto the top of the riffle and as it falls through the device the sample is divided equally into two bins. When the operation is complete, the contents of one bin is discarded and the other passed through the riffle again. In this way the sample is progressively and randomly halved until its bulk is reduced to that required for laboratory

work up. The riffle, due to its design is extremely difficult to clean and therefore it is practical to arrange for an individual riffle should be permanently kept for use with a specific material.

Sample Quartering:

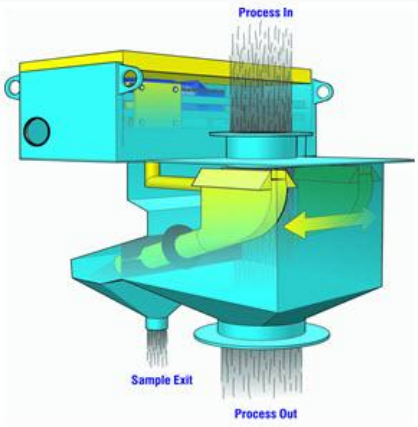
The total sample is placed on a clean impervious surface and formed into a cone by shoveling. Each shovel full is placed on the top of the last so that the material runs down the side of the pile and is thereby distributed around the sides of the pile as evenly as possible (if larger pieces of material roll away from the base of the cone they must be pushed back to the edge). From the first cone two successive cones are sequentially made in the same manner (this is to mix the sample well). The third cone is then flattened to a uniform thickness and then quartered along two diameters. One diagonal pair of quarters is rejected. These four stages are repeated until a sample of the required size is obtained. If the initial bulk sample is very course then the average particle diameter made need to be reduced by grinding between each quartering procedure.



19. 7. Instruments for different types of product and storage states.

Sample dividers:

Ideal for Free Flowing Powders Suitable for use with powder chemicals, food stuff, feed and similar granular materials These hand held sample dividers will subdivide material samples into smaller portions by single or multiple passes. The important feature of Endecotts sample dividers is that each subdivision retains the characteristics of the original sample.



Sample Scoops

These Heavy Duty Sample Scoops are produced to the highest quality, are crevice free to minimise contamination and easy to clean.

Sleeve Sampler :

Ideal for Free Flowing Powders Suitable for use with powder chemicals, food stuff, feed and similar granular materials Ideal for sampling large volumes at great depths. At the required depth pull up the sampler slightly. This will force the sleeve down so that the product can fall into the sample chamber

The Sampling Spear

Powder, Granules or Crystals:

Samples of powders granules or crystals are usually taken with a 'spear The spear is thrust at an angle into the material (the opening underneath) rotated two or three times and then carefully withdrawn with the opening uppermost. The contents are then discharged into the sample container.

Lesson 20. Liquid Food Samples And Extraction Techniques

20.0 Sample preparation

The analyses of liquid food samples have an advantage over those associated with solid samples or gaseous samples in that they usually require one less pretreatment step, due to their liquid form or a dissolution or extraction step is not needed. In some cases, very little sample preparation may be required if the liquid is sufficiently free of matrix interferences. For liquid samples the removal of interferences, concentration / dilution of the samples and compatibility with the final analytical techniques are the most important features. Typical approaches for liquids include: solid-phase extraction (SPE), LLE, dilution, evaporation, distillation, microdialysis and lyophilization.

20.1 Pretreatments:

20.1.1 Removal of extraneous material:

Suspended matter or sediment present in liquids such as beer, wine, juice, or cooking oil is removed by filtration or separated by centrifugation.

Sample reduction:

Liquid samples can be mixed using magnetic stirrers or sonic oscillators. There are several other factors to consider when reducing a food sample. Food choppers, blenders, and mixers should be constructed of metal alloys that resist corrosion or erosion, and that are inert enough to prevent contamination of the product. Aeration of the product during the blending process should be avoided since this can result in appreciable changes in oxidizable components. It is also important to avoid heating the material during the grinding step since this can accelerate chemical changes in the foodstuff. The surfaces of all mixing equipment should be clean and dry, since changes in sample moisture content can change the chemical and physical nature of the foodstuff. Care should also be taken to prevent the release of volatile constituents during grinding, if this is of concern.

20.2 Extraction methods:

20.2.1 Solid Phase Extraction (SPE)

In SPE a liquid is passed through a solid phase, which selectively retains the analyte. Thereafter, the analyte can be eluted with a strong solvent. In some cases interferences are retained and analytes allowed passing through solid phase unretained. The mechanism of SPE is comparable with LC. The advantages of SPE are that a wide variety of sorbents is available for the selective removal of inorganic, organic, and biological analytes. The good selectivity and efficiency of SPE can be explained by the fact that various modes like reversed-phase (RP), normal-phase (NP), ion-exchange (IE), restricted-access (RAM), Immunoaffinity (IA) and molecular-imprinting (MIP) can be applied. Techniques like SPME

and stir bar sorption extraction (SBSE) are relatively new developments approaches to perform extraction procedures without the need for using organic solvents. Furthermore, a number of different sampling formats (e.g., packed syringes and cartridges, disks, pipette tips and 96-well plates) allowing off-line, at-line, on-line and in-line sampling procedures. This means that SPE can be considered to be the most versatile sampling and sample manipulation approach.

20.2.2 Liquid-liquid Extraction (LLE)

Still the most popular technique is LLE. In this case the sample is partitioned between two immiscible phases. The extraction solvent and extraction conditions are chosen in such a way that a maximum difference in solubility is obtained. In order to obtain reliable results one should beware of the formation of emulsions. Possibilities to break them are heat, addition of salt; change of the KD value by using different solvents or chemicals affecting the equilibrium (such as buffers for pH adjustment, salts for ionic strength, complexing agents, ion-pairing agents, etc.). LLE can be performed manually by using a separatory funnel in case a relatively small number of samples must be analyzed or in an automated way by using packed cartridges or 96-well plates in case larger number of samples must be analyzed.

20.2.3. Dilution

An additional technique is dilution in which the sample is diluted with a solvent compatible with the eluent of the separation system (e.g. LC) to avoid system overloading or to be in linear range of detector. For example, to avoid band broadening the solvent should not be too strong for the LC eluent and should be miscible with LC eluent; "dilute and shoot" is a typical ST method for simple liquid samples such as pharmaceutical formulations.

20.2.4. Evaporation

In evaporation the liquid is removed by gentle heating at atmospheric pressure with flowing air or inert gas or under vacuum. Evaporation should not be performed too quickly and bumping can result in sample losses. Sample losses can also occur on the wall of the container. Evaporation should be done at moderate temperatures, by using an inert gas (e.g. N2) by using a rotary evaporator or an automated system (e.g. Turbovap).

20.2.5. Distillation

In distillation a sample is heated to the boiling point of the solvent, and volatile analytes are concentrated in the vapor phase, condensed, and collected. This approach is mainly used for samples that can easily be volatilized. Problems are that a sample can decompose if heated too high. This means that vacuum distillation can be used for low-vapor-pressure compounds, while steam distillation is rather gentle since maximum temperature is 1000C.

20.2.6. Microdialysis

Microdialysis is a technique in which a semipermeable membrane is placed between two aqueous liquid phases and low-molecular weight molecules transfer from one liquid to the other based on a concentration difference over the membrane. Enrichment techniques such as SPE are required to concentrate the dialysate. Microdialysis is used, for example, for the

examination of extracellular chemicals in living plant and animal tissue and in fermentation broths. It has been used on-line with LC. Dialysis with MWCO membranes can also be used for on-line deproteination of samples.

20.2.7. Lyophilization (freeze-drying)

In lyophilization (freeze-drying) an aqueous sample is frozen and water removed by sublimation under vacuum. This technique can be used for nonvolatile organics, the concentration of inorganics and large sample volume can be handled. A potential problem can be the loss of volatile analytes.

20.2.8.Water sampling

In the case of water sampling it is important that collection containers are pretreated before the sample can be collected. In principle, only polyethylene or PTFE containers should be used and they should be washed and stored in 10% of HNO3 for 2 days and rinsed with double distilled deionised water. Following collection, acidification of the sample (normally with 2 mL of 10% HNO3 or 5 M HCl) will reduce or eliminate trace element adsorption and hydrolysis.

Depending on the type of water precautions must be taken. For the collection of tap water, the first water running from the tap must be avoided because there will be a high concentration of trace elements from the pipes, soldering and welds. Normally, sampling is performed by running the tap for 5 – 30 min, before the actual sample is taken.

Most water samples require filtration immediately after collection to remove bacteria, algae and particulate matter. In most cases 0.5 mm membrane filters are used. Stabilizing agents like nitric, hydrochloric and sulphuric acids are frequently added to lower the pH to about 1 – 3.5. Before storage all sample containers should be completely full, because the presence of air may chemically or biologically alter the sample. Water samples shouldbestored in the dark, either by refrigeration (40C) or by deep-freezing (-200C).

The most important problem during the sampling of surface water is that, in principle, no samples may be taken from a stagnant water source because in those cases contaminants from valves, connectors, pipes, lubricants, etc. can be dissolved in the water. The system must therefore always be flushed for a while before taking the sample. The material of the container, used for storage, normally is not critical. However, the container must be carefully closed using aluminum or PTFE cap to avoid that pollutants fro the cap will pollute the sample. It is important that the sampling is performed at the same temperature as the surroundings. Using pressurized systems the sample must be done at flow rates of 500 mL/min or higher.

20.2.9 Microextraction techniques

Two equilibrium-based microextraction techniques serve as alternatives to classical solid-phase extraction: solid-phase microextraction (SPME) and stir-bar sorptive extraction (SBSE). Stir bar sorptive extraction is a similar equilibrium technique that requires submersion of a stir bar (that is encapsulated in a glass jacket and coated with a solid-phase) into the liquid sample. In this case, the solid-phase is usually a relatively high amount (25-125 ,ul) of

polydimethylsiloxane (PDMS) polymer. The stir bar is then thermally desorbed on-line in the heated injector of a gas chromatograph. The advantage to utilizing SBSE for sampling liquid samples or extracts that are amenable to the PDMS solid-phase technique is that a 500-fold increase in enrichment, and therefore sensitivity, can be achieved compared with a 100 pm PDMS SPME fiber.

20.2.10. Membrane techniques

Membrane extraction methodologies encompass both the non-porous techniques of supported liquid membrane extraction (SLM), microporous membrane liquid-liquid extraction (MMLLE), polymeric membrane extraction (PME), and membrane-extraction with a sorbent interface (MESI), in addition to the porous membrane technique of dialysis. Variations of the latter are microdialysis and electrodialysis. Unlike the non-porous membrane methodologies, the porosity-based techniques are not characterized by analyte enrichment. There is no discrimination between small-sized molecules that are similar in size to the analyte, and only partial sample clean-up is achieved by membrane separation of lower molecular weight species from higher molecular weight matrix components. A dialysis clean-up step is therefore often combined with a subsequent enrichment technique, for example on an automated trace enrichment of dialysates system, also known as ASTED.

20.2.11. Microwave-assisted extraction

Microwave-assisted extraction (MAE) is one of several techniques that have

been developed in response to the increased demand for techniques that have a

shortened extraction time and reduced solvent consumption. One of the primary benefits of MAE is the ability to directly heat the sample with the application of microwaves. This type of heating is fast and temperature gradients are kept to a minimum. A drawback to the technique is the requirement for an extraction solvent that is able to absorb microwaves. In addition, a subsequent clean-up step is usually required once the microwave vessel has cooled sufficiently for handling.

Microwave techniques have been applied to biological and food samples quite extensively.

20.2.12. Pressurized liquid extraction

Pressurized liquid extraction (PLE) methods frequently utilize the Accelerated Solvent Extraction (ASE) system, or any other system that performs static or dynamic solvent extractions at elevated temperatures and pressures. The advantage to performing extractions under pressurized conditions is that the upper extraction temperature is not limited by the boiling point of the solvent, as is the case with the traditional Soxhlet system. A flow-through system such as the ASE is also particularly beneficial in food analysis. Static extractions are performed inside steel extraction vessels that have ample capacity for food samples, from 11-100 ml. The static extraction period is followed by elution of the extraction solvent into a collection vial.

20.2.13. Supercritical fluid extraction

Super critical fluid such as super critical carbon dioxide (SC- CO_2), super critical water are used for extraction as the solubility of materials at supercritical stage increases. SC-CO_2 continues to be the fluid of choice, since its critical parameters (31.1"C, 72.8 bar) are easily achieved with high pressure instrumentation. Further, it is non-toxic and easy to obtain. Some of the SF-based methodologies utilize suitable modifiers to enhance analyte recovery.

Module- 7 Sensory quality

Lesson 21. Importance of Sensory Attributes

21.1 Introduction

Sensory evaluation can be defined as a scientific discipline used to evoke, measure, analyze and interpret results of those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch and hearing.

21.2 Importance

Physical, chemical, microbiological and sensory evaluations are the main procedures to examine foods for their quality attributes. For a product, sensory evaluation plays very important role for the following reasons:

- What consumers like and why
- Improve testing methodology
- Ensures a cost-efficient new products
- People can sometimes detect odorants at levels lower than what can be detected by an instrument.
- Instruments can not measure liking
- Monitor formulation changes.
- Monitor processing changes.
- Quality attributes can be measured quickly in quantifiable manner
- A particular defect that cannot be detected by other analytical techniques can be evaluated by sensory evaluation

21.3 Applications

Inspection of Raw Materials: Quality of foods related to colour, appearance, aroma and taste can be quickly detected on the reception dock by the senses of smell, taste and sight.

New Product Development or Improvement of Existing Product: New products developed result into failure mainly because of poor sensory attributes and adoption of appropriate sensory methods during new product development helps to overcome such problems.

Cost Reduction: The use of low cost or alterative ingredients and simultaneously maintaining same sensory qualities will help in reducing cost of product .

Quality Control: Quality Control involves sensory evaluation at all stages of product. The changes in product quality in terms of colour, flavour and texture during processing and storage can be regularly monitored using sensory techniques.

Selection of Packaging Material: The newer types of packaging materials, particularly in forms of flexible films/pouches/laminates are being extensively used. The suitability of these films for packaging a food product can to be examined adopting sensory analysis along with some chemical/ instrumental method.

Shelf Life Studies: Food products during storage undergo many types of changes, for example, chemical, bacterial, enzymatic, physical, etc. All these alter the sensory properties, such as taste, colour, flavour, texture and appearance. Application of sensory evaluation monitors these changes and expiry date can be determined by using chemical and sensory techniques together.

Establishing Analytical/ Instrumental/ Sensory Relationships: Quick evaluation of the product quality can be established, for example, the titratable acidity of fresh milk ranges between 0.14 to 0.16%, and at 0.17% and above it may impart sour flavour. Relationship between sensory textural attributes, hardness, stickiness, chewiness, gumminess and elasticity/ sponginess with that measured by an instrument can also be established.

22.4 Relationship Senses with Sensory Attributes

The sensory attributes of any food are:

- Appearance
- Odor/aroma/fragrance
- Consistency and texture
- Flavor (aromatics, chemical feelings, taste)

However, in the process of perception, most or all of the attributes overlap and without training he or she will not be able to provide an independent evaluation of each. Flavor is the combined impression perceived via the chemical senses from a product in the mouth, i.e., it does not include appearance and texture. The term "aromatics" is used to indicate those volatile constituents that originate from food in the mouth and are perceived by the olfactory system via the posterior nares.

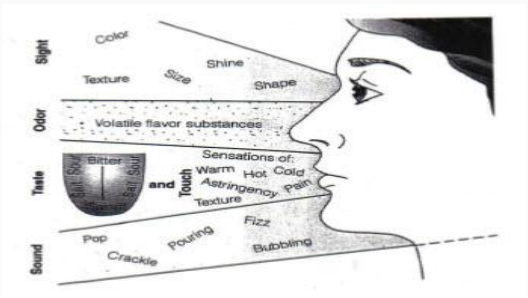


Fig: Role of five senses in sensory evaluation.

21.4.1 Appearance

The characteristics of a food product that can be evaluated by sense of sight are: style, neatness and cleanliness of package exterior, attractiveness of product finish, package closures, colour, consistency, body and texture and overall appearance. Colour and appearance aspects of products should not be overlooked because these features may render the product acceptable / unacceptable. The appearance is an attribute which a decision is taken to purchase or consume.

Color: A phenomenon that involves both physical and psychological components: the perception by the visual system of light of wavelengths 400 to 500 nm (blue), 500 to 600 nm (green and yellow), and 600 to 800 nm (red), commonly expressed in terms of the hue, value, and chroma of the Munsell color system. Deterioration of food is often accompanied by a color change.

Size and shape: Length, thickness, width, particle size, geometric shape (square, circular, etc.), distribution of pieces, e.g., of vegetables, pasta, prepared foods, etc.; size and shape are indications of quality of products.

Surface texture The dullness or shininess of a surface, the roughness, evenness; surface characteristics i.e wet, dry, soft, hard, crisp, tough are indicators of quality.

Clarity The haze or opacity of transparent liquids or solids, the presence or absence of particles of visible size are important indicators of quality.

21.4.2 Odour/ Aroma/ Fragrance

This sense plays paramount role in evaluation of quality of food products. The role of olfactory perception is greater in overall flavour than the taste. Food products are smelled for aroma perception immediately after the opening of closure/ package and earlier than the taste.

The odor of a product is detected when its volatiles enter the nasal passage and are perceived by the olfactory system. We talk of odor when the volatiles are sniffed through the nose (voluntarily or otherwise). Aroma is the odor of a food product, and fragrance is the odor of a perfume or cosmetic.

Aromatics, are the volatiles perceived by the olfactory system from a substance in the mouth. The amount of volatiles that escape from a product is affected by the temperature and by the nature of the compounds.

Volatility is also influenced by the condition of a surface: at a given temperature, more volatiles escape from a soft, porous, and humid surface than from a hard, smooth, and dry one.

Many odors are released only when an enzymatic reaction takes place at a freshly cut surface (e.g., the smell of an onion). Odorous molecules must be transmitted by a gas, which can be the atmosphere, water vapor, or an industrial gas, and the intensity of the perceived odor is

determined by the proportion of such gas which comes into contact with the observer's olfactory receptors .

21.4.3 Consistency and Texture

Tactual and mouth feel play an important role in examining the body and texture characteristics. The pressure between the teeth and jaws determine the hardness, chewiness and gumminess. The fingertips and ball of the thump help in determining other textural attributes, notably stickiness, elasticity/ sponginess and brittleness

The other set of attributes to be considered are those perceived by sensors in the mouth

- Viscosity (for homogeneous Newtonian liquids)
- Consistency (for non-Newtonian or heterogeneous liquids and semisolids)
- Texture (for solids or semisolids)

Viscosity" refers to the rate of flow of liquids under some force, such as gravity. It can be accurately measured and varies from a low of approximately 1 cP (centipoise) for water or beer to 1000s of cP for jelly-like products.

Texture" is much more complex, can be defined as the sensory manifestation of the structure or inner makeup of products in terms of their reaction to stress, measured as mechanical properties (such as hardness/firmness, adhesiveness, cohesiveness, gumminess, springiness/resilience, viscosity) by the kinesthetic sense in the muscles of the hand, fingers, tongue, jaw, or lips.

Tactile feel properties, measured as geometrical particles (grainy, gritty, crystalline, flaky) or moisture properties (wetness, oiliness, moistness, dryness) by the tactile nerves in the surface of the skin of the hand, lips, or tongue.

21.4.4 Flavour

It is a companion sense with aroma in establishing the overall flavour of food products. In some of the products, particularly frozen foods where volatile compounds are not perceived by sense of smell at very low temperature, the sense of taste plays deciding role for evaluating the flavour.

Flavor, as an attribute of foods, beverages, and seasonings, has been defined as the sum of perceptions resulting from stimulation of the sense ends that are grouped together at the entrance of the alimentary and respiratory tracts:

- The aromatics, i.e., olfactory perceptions caused by volatile substances released from a product in the mouth via the posterior nares.
- The tastes, i.e., gustatory perceptions (salty, sweet, sour, bitter) caused by soluble substances in the mouth.

- The chemical feeling factors, which stimulate nerve ends in the soft membranes of the buccal and nasal cavities (astringency, spice heat, cooling, bite, metallic flavor, umami taste).

21.4.4.1 Chemical / Trigeminal Factors

Chemical irritants such as ammonia, ginger, horseradish, onion, chili peppers, menthol, etc. stimulate the trigeminal nerve ends , causing perceptions of burn, heat, cold, pungency, etc. in the mucosa of the eyes, nose, and mouth.

Trigeminal effects assume practical significance: (a) when the olfactory or gustatory threshold is high, e.g., for short-chain compounds such as formic acid and (b) when the trigeminal threshold is low, e.g., for capsaicin.

The trigeminal response to mild irritants (such as carbonation, mouth burn caused by high concentrations of sucrose and salt in confections and snacks, the heat of peppers and other spices) may contribute to, rather than distract from, acceptance of a product.

21.4.4.2 Gustation

Like olfaction, gustation is a chemical sense. It involves the detection of stimuli dissolved in water, oil, or saliva by the taste buds which are located primarily on the surface of the tongue as well as in the mucosa of the palate and areas of the throat. Compared with olfaction, the contact between a solution and the taste epithelium on the tongue and walls of the mouth is more regular in that every receptor is immersed for at least some seconds.

The gustatory sensors are bathed in a complex solution, the saliva, which contains water, amino acids, proteins, sugars, organic acids, salts, etc. and they are fed and maintained by a second solution, the blood. Hence, we can only taste differences in the concentration of many substances, not absolute concentrations.

21.4.5 Noise

Vibrations in the local medium, usually air, cause the eardrum to vibrate. The vibrations are transmitted via the small bones in the middle ear to create hydraulic motion in the fluid of the inner ear, the cochlea, a spiral canal covered in hair cells which when agitated send neural impulses to the brain.

The noise produced during mastication of foods is a minor but not negligible sensory attribute. It is common to measure the pitch, loudness, and persistence of sounds produced by foods. The pitch and loudness of the sound contribute to the overall sensory impression. Differences in pitch of some rupturing foods (crispy, crunchy, brittle) provide sensory input, which we use in the assessment of freshness/staleness.

Common Noise Characteristics of Foods,

Pitch: frequency of sound, Crispy, Crunchy, Squeak

Loudness: intensity of sound

Persistence: endurance of sound over time, Perceived sounds (pitch, loudness, persistence) and auditory measurement

21.5. Other Properties

The Components of Texture

Hardness: force to attain a given deformation **:** Firmness(compression) Hardness (bite)

Cohesiveness: degree to which sample deforms (rather than ruptures)

Adhesiveness: force required to remove sample from a given surface Sticky (tooth/palate)

Denseness: compactness of cross-section Dense/heavy Airy/puffy/light

Springiness: rate of return to original shape after some deformation Springy/rubbery Cushy

Geometrical Properties: perception of particles (size, shape, orientation) measured by tactile means

- ***Smoothness:*** absence of all particles
- ***Gritty:*** small, hard particles
- ***Grainy:*** small particles
- ***Chalky/powdery:*** fine particles (film)
- ***Fibrous:*** long, stringy particles (fuzzy fabric)
- ***Lumpy/bumpy:*** large, even pieces or protrusions

Moisture Properties: perception of water, oil, fat, measured by tactile means

Moistness: amount of wetness/oiliness present, when not certain whether oil and/or water

Moisture release: amount of wetness/oiliness exuded/ Juicy

Oily: amount of liquid fat

Greasy: amount of solid fat

21.6 ISO Standards for Sensory Analysis

Note: There are also corresponding British Standards

ISO 3591-1977 Sensory analysis - Apparatus - Wine-tasting glass

ISO 3972-1991 Sensory analysis - Methodology - Method of investigating sensitivity of taste

ISO 4120-1983 Sensory analysis - Methodology - Triangular test

ISO 4121-1987 Sensory analysis - Methodology - Evaluation of food products by methods using scales

ISO 5492-1992 Sensory analysis — Vocabulary

ISO 5494-1978 Sensory analysis - Apparatus - Tasting glass for liquid products

ISO 5495-1983 Sensory analysis - Methodology - Paired comparison test

ISO 5496-1992 Sensory analysis - Methodology - Initiation and training

ISO 5497-1982 Sensory analysis - Methodology - Guidelines for the preparation of samples for which direct sensory analysis is not feasible

ISO 6564-1985 Sensory analysis - Methodology - Flavour profile methods

ISO 6658-1985 Sensory analysis - Methodology - General guidance

ISO 8586.1-1993 Sensory analysis - General guidance for the selection, training and monitoring of assessors - Part 1: Selected assessors

ISO 8586.2-1994 Sensory analysis - General guidance for the selection, training and monitoring of assessors - Part 2: Experts

ISO 8587-1988 Sensory analysis - Methodology — Ranking

ISO 8588-1987 Sensory analysis - Methodology - "A" - "not A"

ISO 8589-1988 Sensory analysis - General guidance for the design of test rooms

ISO 10399-1991 Sensory analysis - Methodology - Duo-trio test

ISO 11035-1994 Sensory analysis - Identification and selection of descriptors for establishing a sensory profile by a multidimensional approach

ISO 11036-1994 Sensory analysis - Methodology - Texture profile

ISO 11037-1999 Sensory analysis - General guidance and test method for assessment of the colour of foods

ISO 11056-1999 Sensory analysis - Methodology - Magnitude estimation method

Lesson 22. Controls for Test Room And Factors Effecting Sensory Evaluation

22.1 Introduction:

Sensory tests should be conducted in well integrated manner. Overall plan for effective evaluation is required with adequate facilities. A successful implementation of sensory evaluation program requires three major components:

- Proper laboratory facilities
- Sensory panels/evaluators, and panelist criteria
- Rigorous training programme

22.2 Sensory Evaluation Laboratory

Many designs of the sensory evaluation laboratory are available. Generally sensory laboratory should include a briefing room, an office, testing booths and sample preparation room. The most important considerations for a sensory laboratory are location, ventilation, lighting, traffic pattern, sample preparation and presentation and experimental comfort.

22.2.1 Briefing Room: All the sensory evaluators are first assembled here. They are briefed by the organizer about the objective of the sensory work, scorecard and its use and give other instructions. This room should be adjoining to testing booths and have facilities for comfortable sittings.

22.2.2 Testing Booths/Area: This is the area where panel members carry out actual sensory evaluation of food products. Testing area should be located separately but in the immediate vicinity of the preparation area. This area is normally divided in to small booths (number of booths between 5 to 10) so that each panel member can independently evaluate the product.

22.2.2.1 Points to be considered:

- The temperature and relative humidity shall be constant, controllable and comfortable for evaluators. A temperature of about 20^{o}C and 62% relative humidity are considered to be optimum.
- Noise level shall be kept to a minimum during the tests. The movement of persons shall also be restricted in the area.
- The testing area shall keep free from odours. A slight positive pressure may be created in the testing area to reduce inflow of odorous air from other area.
- Lighting particularly in testing booths shall be uniform, shadow free, controllable and of sufficient intensity to permit effective evaluation of the colour and appearance of samples. In most cases, 110 candle foot light is desirable. In order to mask differences

in colour and other appearance characteristics special lighting devices, such as a dimmer device, colored lamps/filters or sodium vapour lamps, may be provided.

- The size of each testing booth shall be sufficiently large to accommodate the samples, utensils, sink, rinsing agents and score sheet/card. An area of 0.9 m wide and 0.6 m deep is considered optimum for this purpose. The height of working space in the booth should be appropriate to allow comfort to the evaluator.
- A counter on the serving/distribution area side shall be provided. Openings, covered by sliding doors, of convenient size may be provided for supplying samples into the booths from the serving counter. A system, such as light bulb on the counter side, is devised for evaluator to signal to the operator when he is ready for a sample.

22.2.3 Preparation Room: A laboratory for the preparation of samples shall be located adjacent to the testing area. Its location shall be such that the evaluators do not have to pass through testing area. The preparation area shall be well ventilated so that odours emanating from the samples preparation are removed. The type of equipment required in this area depends on the range of products, which will be processed here. The main components of the preparation room for food products are: working space, sink, cooking range, oven, refrigerator, deep freezer, blender, scoops, knives, balance, dishes, spoons, and cleaning and storage facilities. Utensils and cutlery used in sample preparation and presentation shall be of the materials, which do not impart any odour or taste to the product.

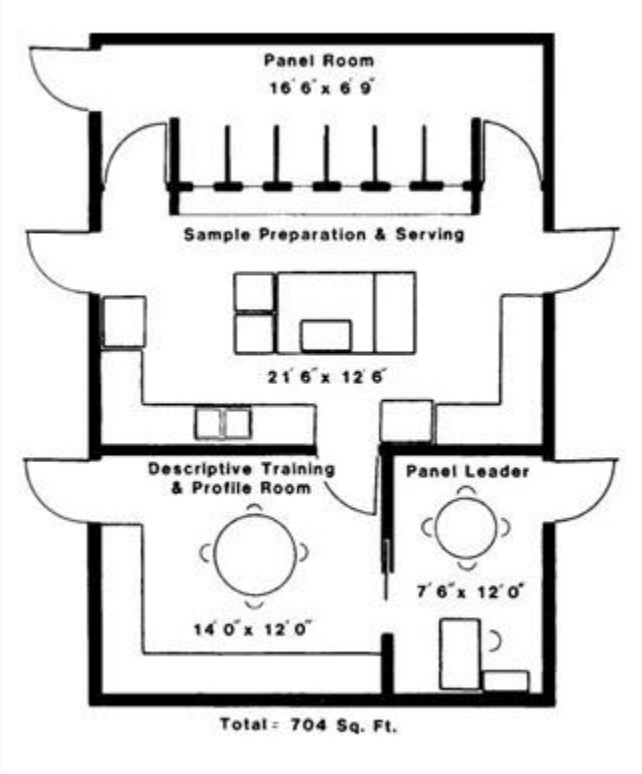


Figure: Sensory evaluation laboratory layout.

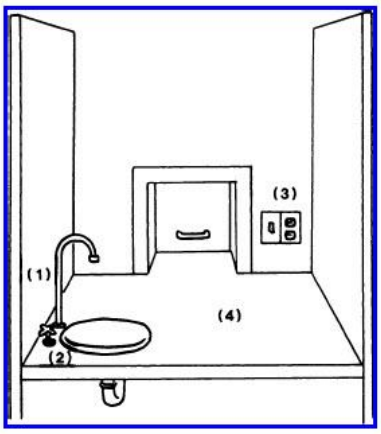


Fig: Sensory evaluation booth with hatch, tap water, small sink, easy access to clean table.

Limitations of sensory evaluation

1. The result may be highly variable

2. People with colds or other health problems temporarily lose their maximum effectiveness.

3. Emotional burdens may influence an individual's ability.

22.3 Sensory Panel

Trained panel members: The sensory qualities, particularly the flavour attributes are essentially to be measured subjectively. From early times this judging has been the preserve of experts who used to evaluate tea, coffee and wine. With the development of sensory evaluation techniques on scientific lines, the experts are being replaced by panels whose sensitivity and consistency have been established by training and repeated tests. The panel members analyse food products through properly planned experiments and their judgements are quantified by appropriate statistical analysis.

22.3.1 Selection of panel of judges: Actually one extremely discriminating pains taking and unbiased individual would suffice for tasting. Further one individual may not be able to discriminate different aspects of food quality. Hence a panel of judges may be used. Members of the panel should be carefully selected and trained to find out difference in specific quality characteristics between different stimuli and also direction and intensity of difference. The requirements for an ideal panel member are as follows.

- He should be able to discriminate easily between samples and should be able to
- distinguish appreciable differences in taste and smell.
- He should have good health. If he is suffering from cold his sensitivity may be affected. A sick patient cannot judge the food correctly he should not be habituated to chewing pan

- He should be experienced in the particular field.
- He should have high personal integrity. He should not be prejudiced.
- He should be able to evaluate objectively.
- Willingness to spend time for the sensory evaluation work is required.
- He should have interest in sensory analysis of samples and intellectual curiosity.
- He should have ability to concentrate and derive proper conclusion.
- He should be available and willing to submit to periodic test to get consistent results.

22.3.2. Different types of panels:

Trained panel: Laboratory panels must then be carefully trained for specific products or purposes. These tests aim at finding differences in specific quality characteristics between different stimuli and also direction and/ or intensity of the difference. Periodically the panel is given refresher training and tests. The number of members in the trained panel should be small varying from 5 to 10.

Discriminative, communicative or semi-trained panels: These panels are constituted of technical people and their families, who are normally familiar with the qualities of different types of food. They are capable, with few preliminary test runs, of following instructions for tests given, discriminating differences and communicating their reactions. Such panels of 25-30 are used to find the acceptability or preference of final experimental products prior to large scale consumer trials.

Consumer panels: Such panels are made up of untrained people chosen at random to represent a cross-section of the population for which the product is intended. The greater the number, the greater is the dependability of the result. A group of not less than 100 is considered the minimum.

22.4 Factors Influencing Sensory Verdicts

22.4.1 Physiological Factors

1. Adaptation

Adaptation is a decrease in or change in sensitivity to a given stimulus as a result of continued exposure to that stimulus or a similar one. In sensory testing this effect is an important unwanted source of variability.

2. Enhancement or Suppression

Enhancement — The effect of the presence of one substance increasing the perceived intensity of a second substance.

Synergy — The effect of the presence of one substance increasing the perceived combined intensity of two substances, such that the perceived intensity of the mixture is greater than the sum of the intensities of the components.

Suppression — The effect of the presence of one substance decreasing the perceived intensity of a mixture of two or more substances.

22.4.2 Psychological Factors

1.Expectation Error

Information given with the sample may trigger preconceived ideas. Panel usually find what they expect to find. A panelist who hears that a food product has been returned to the plant will have a tendency to detect aged flavors in the samples. Expectation errors can influence the validity of a test and must be avoided by keeping the source of samples a secret. Samples should be coded and the order of presentation should be random among the participants.

2.Habituation Error

This error results from a tendency to continue to give the same response when a series of slowly increasing or decreasing stimuli are presented, for example, in quality control from day to day. The panelist tends to repeat the same scores and hence to miss any developing trend or even accept an occasional defective sample. Habituation is common and must be counteracted by varying the types of product or presenting doctored samples.

3.Stimulus Error

This error is caused when irrelevant criteria, such as the style or color of the container, influence the observer. If the criteria suggest differences, the panelist will find them even when they do not exist. Samples served late in a test may be rated more flavorful because panelists know that the panel leader will present light-flavored samples first in order to minimize fatigue. To overcome such error avoid leaving irrelevant cues, schedule panel sessions regularly.

4.Logical Error

Logical errors occur when two or more characteristics of the samples are associated in the minds of the assessors. Knowledge that a darker beer tends to be more flavorful causes the observer to modify his verdict, thus disregarding his own perceptions. Logical errors must be minimized by keeping the samples uniform and by masking differences with the aid of colored glasses, colored lights, etc. With trained panelists the leader may attempt to break the logical association by occasionally doctoring a sample with quinine in order to produce high bitterness combined with low hop aroma.

5.Lack of Motivation

It is the responsibility of the panel leader to create an atmosphere in which assessors feel comfortable and do a good job. An interested panelist is always more efficient. Panelists should be made to feel that the panels are an important activity.

6. Impulsiveness Vs. Timidity

Some people tend to use the extremes of any scale, thereby exerting more than their share of influence over the panel's results. Others tend to stick to the central part of the scale and to minimize differences between samples. In order to obtain reproducible, meaningful results, the panel leader should monitor panelists scores on a daily basis, giving guidance in the form of typical samples already evaluated by the panel and, if necessary, using doctored samples.

7. Poor Physical Condition

Panelists should be excused from sessions:

- if they suffer from fever or the common cold, in the case of tasters, and if they suffer from skin or nervous system disorders in the case of a tactile panel;
- if they suffer from poor dental hygiene or gingivitis;
- in the case of emotional upset or heavy pressure of work which prevents them from concentrating.
- Smokers can be good tasters but should refrain from smoking for 30 to 60 min before a panel.
- Strong coffee paralyzes the palate for up to an hour.
- Tasting should not take place the first 2 h after a major meal. The optimal time for panel work (for persons on the day shift) is between 10 a.m. and lunch. Generally the best time for an individual panelist depends on his biorhythm: it is that time of the day when one is most awake and one's mental powers are at their peak.

22.5 Factors affecting Sensory Evaluation

i) Health of Evaluator: The evaluator should be physically and mentally in good health. The sensitivity for evaluator in respect of sense of smell and taste should be normal. He/she should not be suffering from anosmia and ageusia.

ii) Age: Evaluators should preferably be in the age group of 18-50 years. Persons of younger age are unable to properly interpret and communicate the sensory results, whereas at older age the memory decreases. Sharp memory of evaluator is considered highly useful in judging of food products, particularly for quality control applications.

iii) Interest and Motivation: Sensory evaluation work is very time consuming and sometimes fatigue also. The evaluator should, therefore, have interest and be motivated.

iv) Adaptation: Continuous exposure of evaluator to a particular stimulus, particularly at high concentration for long time, leads to decrease in his sensitivity (also called as fatigue). It is therefore desirable either to give sufficient time between the samples or use taste sanitizers, such as brine solutions, fruits and mild acids. The taste sanitizers improve the taste sensitivity or bring it back to normal level.

v) Sampling: The sample should be representative of the lot. Care shall be taken that no loss of flavour occurs and no foreign tastes or odours are imparted during the sample presentation. The sample should be drawn from a bulk lot in such a way that body and texture characteristics are not changed.

vi) Sample Numbers and Quantity: For economic efficiency of sensory testing, larger the number of samples per session, the better it will be. Normally 5-8 samples with average intensity of flavour for each sitting are optimum. The amount of each sample should be about 25-50 ml or gm, which is sufficient for one full sip or bite.

vii) Score Card: The evaluation card should be simple, brief, easy to follow and all important sensory attributes included in it. It should be clearly printed and the matter should be arranged in logical sequence. Terminology used shall be clear and understandable.

viii) Miscellaneous Factors: The temperature of serving should be close to that recommended for each product . The test should be carried out preferably one hour before or after lunch. Use of materials, which are likely to vitiate results, such as smoking, chewing pan and taking intoxicants by the evaluator should have a time lapse of at least 30 minutes before the test.

Lesson 23. Methods of Sensory Evaluation

23.1 Introduction

Instruments can be set for values and calibration points. Sensory attributes are complex and hence, a more varies approach is required. Sensory responses can be measured by various ways and sensory data usually fall under one these categories.

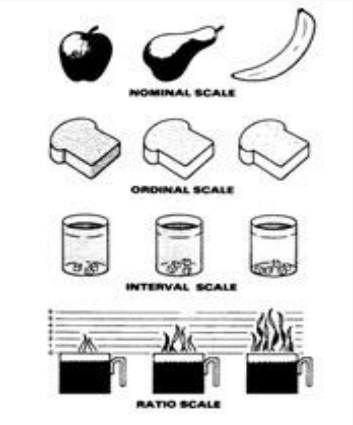
Nominal data: the items examined are placed in two or more groups which differ in name but do not obey any particular order or any quantitative relationship; example: the numbers carried by sports players.

Ordinal data: the panelist places the items examined into two or more groups which belong to an ordered series; example: slight, moderate, strong.

Interval data: panelists place the items into numbered groups separated by a constant interval; example: three, four, five, six.

Ratio data: Panelists use numbers which indicate how many times the stimulus in question is stronger (or saltier, or more irritating) than a reference stimulus presented earlier.

Nominal data contain the least information. Ordinal data carry more information and can be analyzed by most nonparametric statistical tests. Interval and ratio data are even better because they can be analyzed by all nonparametric and often by parametric methods. Ratio data are preferred by some because they are free from end-of-scale distortions.



23.2 Methods of Measuring Responses

23.2.1 Classification:

In classification tests, the subjects are asked to select an attribute or attributes which describe the stimulus. In a beverage test, for example, subjects place a mark next to the term(s) which best describe(s) the sample:

No attempt is made to standardize the terms, and the results are reported as the number of check marks for each term. Such data are nominal: no numbers are used, and there is no increasing or decreasing series expressed in the data. For example, the apples in a lot may be characterized by predominant color (red, green, yellow). Selection of the terms for classification must be based on actual product characteristics. This in turn requires pre examination of the samples by a well-trained panel to make sure that all appropriate attributes are listed.

Grading: Various commodities can be segregated on the basis of specified qualities with the help of expert graders. Coffee, Tea, Spices, Fish, Meat etc are graded on the basis of overall attributes giving a grade : Extra, Regular, Reject etc.

Ranking: Ranking tests are rapid and can be performed with relatively little training and familiarization with the attribute under test. Ranking tests have wide application, but with sample sets above three they do not discriminate well compared to scaling tests.

Scaling: Scaling techniques involve the use of numbers or words to express the intensity of a perceived attribute (sweetness, hardness, smoothness) or a reaction to such attribute (e.g., too soft, just right, too hard). If words are used, the analyst may assign numerical values to the words (e.g., like extremely = 9, dislike extremely = 1) so that the data can be treated statistically. Compared with difference testing, scaling is a more informative and therefore a more useful form of recording the intensity of perception. As with ranking, the results are critically dependent on how well the panelists have been familiarized with the attribute under test and with the scale being used.

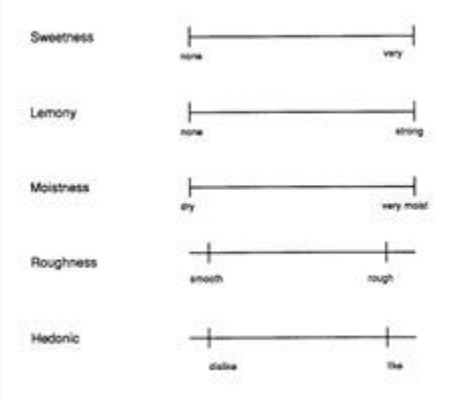


Fig: Line Scale

23.2.2. EVALUATION CARD

The questionnaire or score card should be prepared carefully for each test. The card should be clearly typed or printed. It should be simple and use unambiguous terms and directions in the desired sequence of action as a guide to the evaluation.

The design of score cards for sensory evaluation is challenging and difficult because the key characteristics of the product need to be evaluated on paper in a way that permits the judges to transmit their assessments of the samples accurately to the researcher. A score card with

too much detail and clutter may discourage careful judgement too brief a form may fail to obtain some important information.

A score card may be as simple as indicating which sample is different as is done when duo-trio or triangle testing is the mode being used. A sheet for indicating rank order for a single characteristic also is extremely simple. It is in the descriptive tests that the score card becomes a critical part of the planning for an experiment.

A table utilising the hedonic ratings ranging from unacceptable to very acceptable is relatively easy to construct. No single score card fits all experiments. Instead, the score card needs to be developed for the specific experiment. All score cards should contain the date and name of the judge.

23.3 Sensory Methods:

Following sensory tests are used on different conditions.

1. Difference or Discriminative tests
2. Scoring
3. Ranking
4. Hedonic scale
5. Descriptive analysis
6. Acceptance and preference test

23.3.1 Difference or Discriminative Testing.

Difference test is one of the most useful sensory tests. It is generally used for selection and training of sensory panelists. Difference test is designed to discriminate difference between two or more samples. Within this general class are a variety of specific methods, viz., paired comparison, duo-trio, triangle and multiple sample tests. The main features of these difference tests are .

a) Paired Comparison Test: It is a two products (A & B) test, and the panelist's job is to compare these and identify whether the samples are similar of different. If different, which attribute, such as sweetness, acidity, hardness, colour etc. is responsible for this difference. This part of the test is called as directional difference test. The test can be further extended and the preference component of the panelist can be included. The paired comparison test is relatively easy to organize and implement. The two coded samples in order of AA, BB, AB, BA are served simultaneously, and panelist has to decide if there is any difference or not. Paired comparison is typically used in comparing new and old processing techniques, change of ingredients in a product, preference testing at the consumer level, etc.

b) Duo-trio Test: This test is a modified paired comparison test. One sample identified as the reference (R) is first given to the panelists for evaluation. Subsequently two coded samples, one of which is identical to reference, are presented. The panelist is asked to indicate, which

of the two samples is the same as 'R'. The test is suitable for products that have relatively intense odour, taste and/or kinesthetic effects such that sensitivity of evaluator is significantly reduced. ***c) Triangle Test***: Triangle test is most well known and more frequently used out of the three difference tests. As its name implies, it is a three product test in which all the samples are coded and the panelist's task is to determine which two are most similar or which one is most different from the other two. Triangle test is more difficult test because the panelist must recall the sensory characteristics of two products before evaluating the third and then make a decision.

Triangle Test

Name _____ Date _____

Type of Sample _____

Instructions

Taste samples from left to right. Two are identical; determine which is the odd sample.

If no difference is apparent, you must guess.

Sets of three samples	Which is the odd sample?	Comments
___ ___ ___	_____	_____
___ ___ ___	_____	_____
___ ___ ___	_____	_____

d) Multiple Sample Test: Test involving more than 3 stimuli are classified as multiple sample tests. They may have equal (symmetrical) or unequal (asymmetrical) numbers of each stimulus. When they are applied as true difference tests, the judge is required to separate the sample into two groups of like samples. When they are applied as directional tests, the judge is asked to identify the groups of higher or lower intensity of a given criterion.

23.3.2. Scoring:

Certain score is given to each sensory attribute arranged in logical order on a score sheet in this method. The weightage is given on the basis of importance of the attribute. For example, flavour is considered to be most important and highest score is allotted to this attribute. The scoring method is most extensively used by the dairy industry. Score cards wherein 10 to 100 total points have been allotted to different quality attributes are in use for dairy and food products. Scoring method is most frequently used because of its diversity, simplicity and ease of statistical analysis. The most attractive feature of this method is that rigorous training is not required for panelists as information on defects and scoring guide is also provided on the scorecard.

23.3.3. Ranking

In ranking method two or more samples are provided to the panelists who are asked to arrange them in an ascending or descending order of intensity of a specific attribute, e.g. sweetness. Ranking is often used for screening inferior from superior samples in product development. This method is also suited for comparison of market samples of different

brands. Samples may be ranked in order of degree of acceptability or in order of general quality or by a specific attribute.

23.3.4 Hedonic Rating

Hedonic relates to the psychology of pleasurable and non pleasant states of consciousness. In hedonic method, psychological states of like and dislike are measured on a rating scale. Normally rating scale has been categorized into five forms, viz. numerical, graphic, standard, cumulated points and forced choice forms. The Nine points numerical scale as given below has been most extensively used for new product development and consumer studies.

SCORE CARD – HEDONIC SCALE
Name of the Judge:_____ Date: _____
Product Name_____ Attribute: _____

Degree of Preference	Sample 1	Sample 2
Like Very much		
Like much		
Like moderately		
Like slightly		
Neither like nor dislike		
Dislike slightly		
Dislike moderately		
Dislike much		
Dislike very much		
Comments		

The above scale can be modified by assigning a numerical value of 0 to the indifferent category, with positive integers above and negative integers below this point. The use of positive and negative type of scoring can be effectively used by only trained panel. The hedonic scale provides following advantages:

- evaluators can respond to the queries without previous experience
- data can be handled statistically, and
- indicates general level of preference or liking for the samples

The only requirement for use of hedonic method is that large number of evaluators are needed to provide reliable responses or results.

23.3.5. Descriptive Analysis

Descriptive method of sensory evaluation provides quantitative descriptions of a sensory attributes of a product taking into account all sensation that are perceived: visual, auditory, olfactory, gustatory, kinesthetic and so on. A descriptive method enables us to relate specific process variables to specific changes in some of the sensory attributes of a product, for example, the flavour changes in milk at high temperature processing. A descriptive test involves relatively few judges, who have been screened, selected and trained for the particular product category. Training of this group is primarily focused on development of descriptive language, which is used as a basis for scoring a new product, developing a definition of each attribute and familiarizing the judges with scoring procedures. There are numerous applications for descriptive analysis including monitoring competitions, storage stability/shelf life, product development, quality control, establishing physical/chemical and sensory correlation. Some of the popularly used descriptive method are flavour profile, texture profile etc.

23.3.6. Acceptance/Preference Testing

Affective or acceptance testing is a sensory technique, usually performed at consumer's levels. It refers to measuring liking or preference for a product. Preference can be measured directly by comparison of two or more products with each other. Indirect measurement of preference is achieved by determining which product has scored significantly higher rating than another product in a multi product test. The two methods most frequently used to directly measure preference and acceptance are the paired comparison test and a 9-points hedonic scale.

Lesson 24. Interpretation of Sensory Results And Statistical Analysis

24.0 Introduction:

Statistical quality control (SQC) is the term used to describe the set of statistical tools used by quality professionals. SQC employs statistical principles and methods which have been developed to assess the magnitude of chance cause variation and to detect assignable cause variation. It indicates the limits beyond which these variations in the product should not go without correction.

SQC encompasses three broad categories :

- **Descriptive statistics** (e.g.the mean, standard deviation, and range)
- **Statistical process control(SPC)**
    - Quality characteristics are measured and charted
    - helpful in identifying in-process variations
- **Acceptance sampling** used to randomly inspect a batch of goods to determine acceptance/rejection Does not help to catch in-process problems

Sources of Variation:

Variation exists in all processes. Variation can be categorized as :

- Common or random causes of variation, or Random causes that
- we cannot identify,
- unavoidable,
- Eg. Slight difference in process variables lie diameter, weight, service time, temperature
- assignable causes of variation:
    - causes can be identified and eliminated,
    - eg poor employee training, worn tool, machine needing repair

24.1 Traditional statistical tool:

24.1.1. Descriptive statistics include

- **The mean**: measure of central tendency

$$\bar X=\frac{\sum\nolimits_{i=1}^n{X_i}}{n}$$

- **The range**: difference between largest/ smallest observations in a set of data.
- **Standard deviation**: measures the amount of data dispersion around mean.

$$\sigma=\sqrt{\frac{\sum\nolimits_{i=1}^n{\left({X_i}-\bar X\right)}^2}}{n-1}}$$

- **Distribution of data shape**
- Normal or bell shape
- Skewed

24.1.2. Distribution of Data

24.2 Statistical Process Control (SPC)

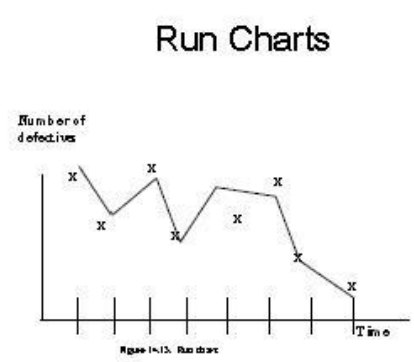
- A method of inspection by which it can be determined whether a process is in control
- Differs from Acceptance Sampling in that SPC does not make judgements about the quality of the item processed.
- Key tool is the Control Chart of which several types exist.

24.2.1 SPC Defined

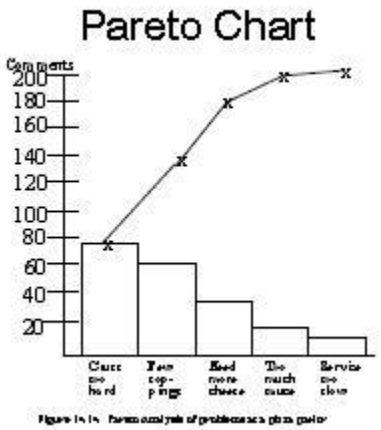
- All processes are affected by multiple factors and, therefore, SPC can be applied to any process.
- There is inherent variation in any process which can be measured and "controlled."
- SPC does not eliminate variation, but it does allow the user to track special cause variation.
- "SPC is a statistical method of separating variation resulting from special causes from natural variation and to establish and maintain consistency in the process, enabling process improvement".

24.2.2The Seven Tools of Quality

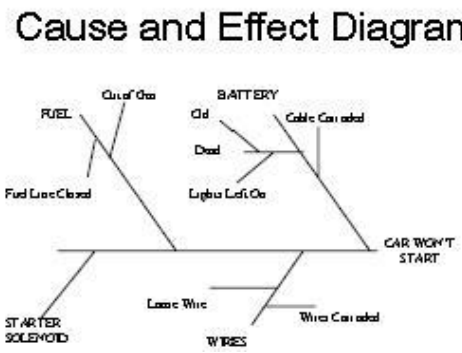
- Control chart
- Run chart



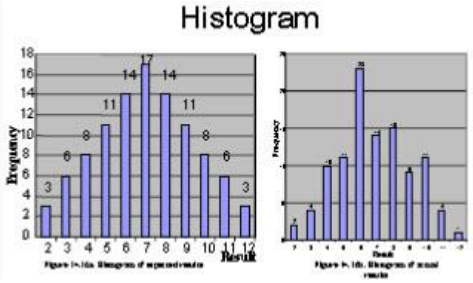
- Pareto chart



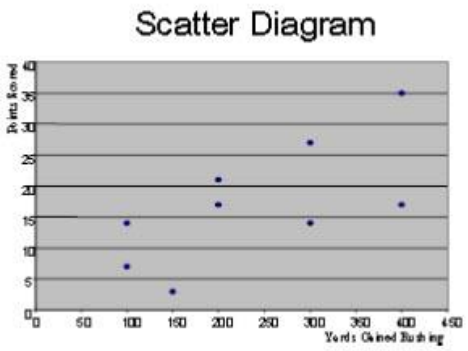
- Flow chart
- Cause and effect diagram



- Histogram



- Scatter diagram



24.2.3 Variation in Processes

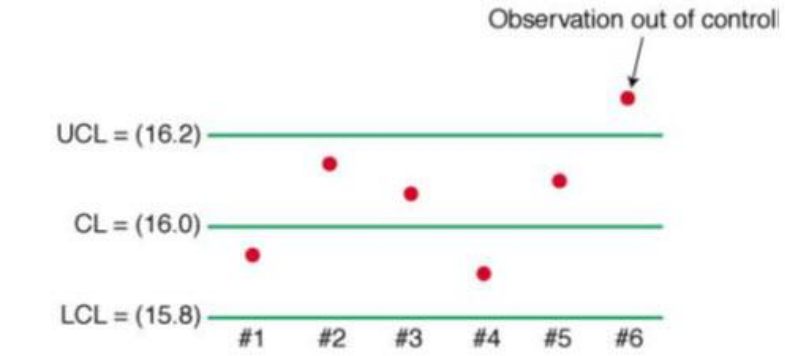
- Common Cause variation - the variation which in inherent in the process itself; when sampled, a normal distribution is found; a process is said to be in statistical control when only common cause variation exists.
- Special (or Assignable) Cause variation – the variation in process output that might be traced to a specific cause; the process is said to be out of control when a special cause variation exists.

24.2.4 Rationale for SPC

- Control of Variation
- Continuous Improvement
- Predictability of Processes
- Elimination of Waste
- Product Inspection

24.2.5. SPC Methods-Control Charts

- Control Charts show sample data plotted on a graph with CL, UCL, and LCL
- Control chart for variables are used to monitor characteristics that can be measured, e.g. length, weight, diameter, time
- Control charts for attributes are used to monitor characteristics that have discrete values and can be counted, e.g. % defective, number of flaws in a shirt, number of broken eggs in a box11



24.2.6 Creating Control Charts

- All control charts rely on the periodic sampling and measurement of items.
- The data collected will allow the calculation of a centerline, and upper and lower control limits.
- The centerline is the mean of all samples, whereas the control limits are, conceptually, the mean +/- three standard deviations.

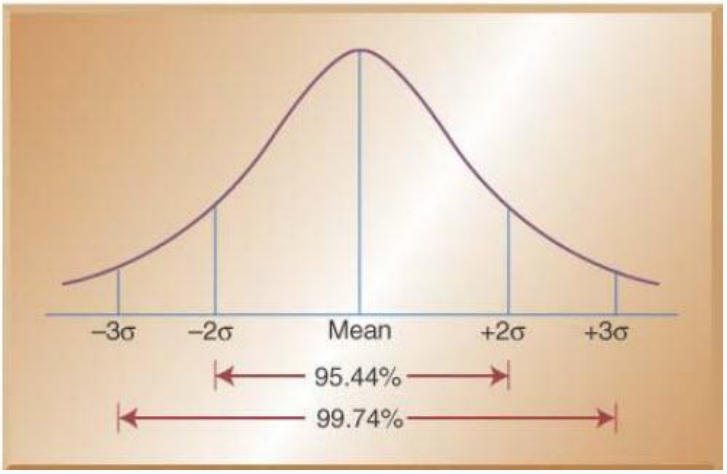
Interpreting Control Charts

SPC is based upon the Central Limit Theorem which tells us, in effect, that the samples will follow a normal distribution regardless of the shape of the parent distribution.

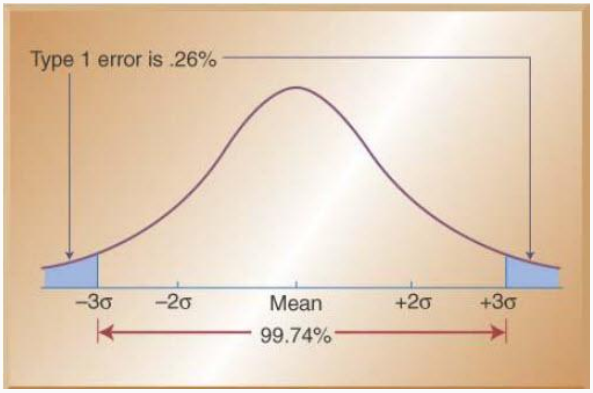
Interpreting control charts is, then, all about probabilities – if the observations aren't probable, then there must be a special cause variation.

24.2.7. Setting Control Limits

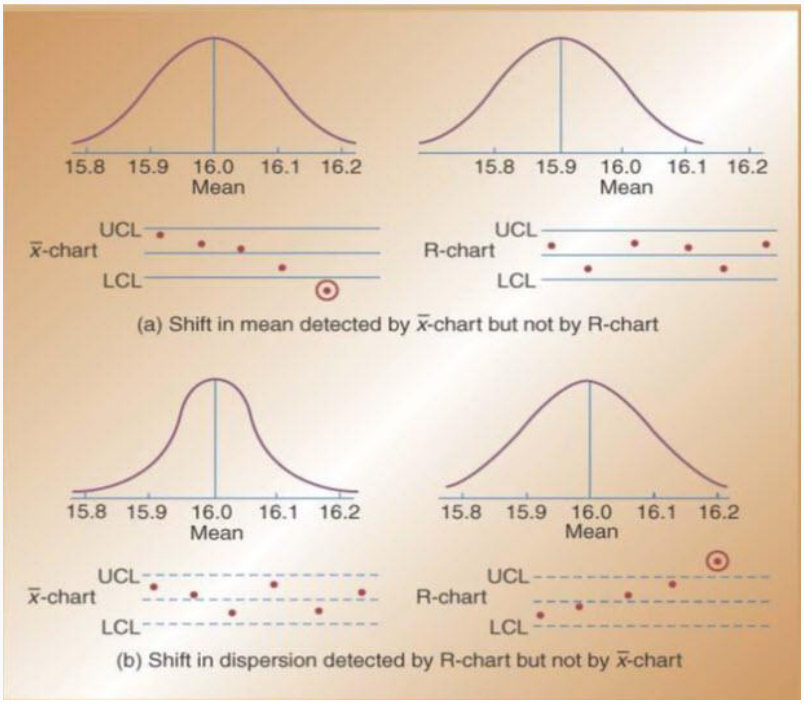
Percentage of values under normal curve



Control limits balance risks like Type I error

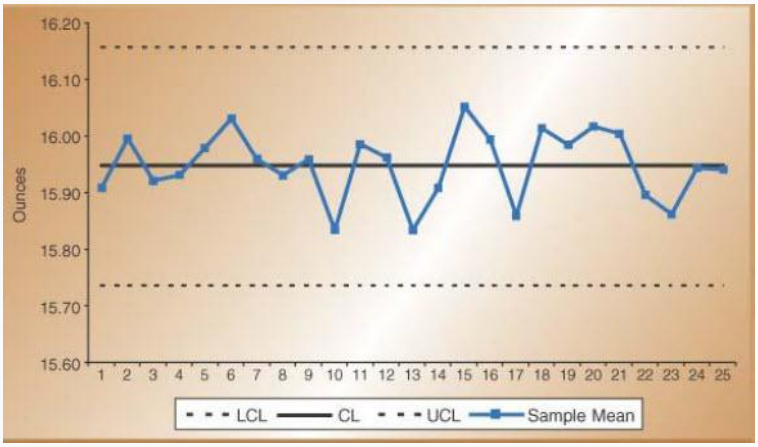


Control Charts for Variables

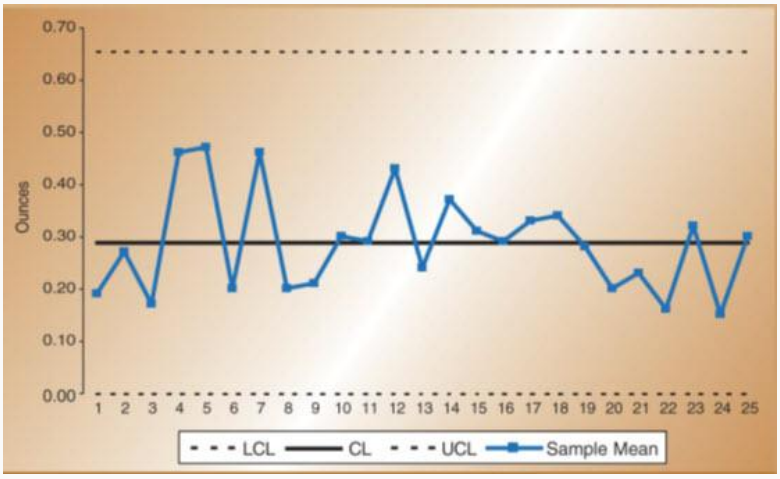


- Use x-bar and R-bar charts together
- Used to monitor different variables
- X-bar& R-bar Charts reveal different problems
- In statistical control on one chart, out of control on the other chart? OK?
- Use x-bar charts to monitor the changes in the mean of a process (central tendencies)
- Use R-bar charts to monitor the dispersion or variability of the process
- System can show acceptable central tendencies but unacceptable variability
- System can show acceptable variability but unacceptable central tendencies

X-Bar Control Chart



R-Bar Control Chart



Control Charts for Attributes –P-Charts & C-Charts

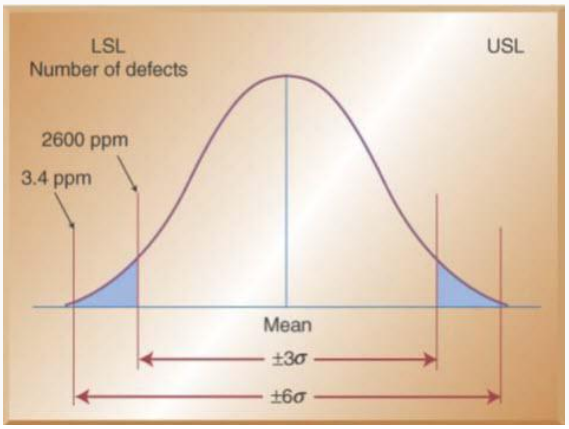
Attributes are discrete events; yes/no, pass/fail

- Use P-Charts for quality characteristics that are discrete and involve yes/no or good/bad decisions
- Number of leaking caulking tubes in a box of 48
- Number of broken eggs in a carton
- Use C-Charts for discrete defects when there can be more than one defect per unit
- Number of flaws or stains in a carpet sample cut from a production run
- Number of complaints per customer at a hotel

±6 Sigma versus ±3 Sigma

Motorola coined "six-sigma"to describe their higher quality efforts back in 1980's.

PPM Defective for ±3σ versus ±6σ quality.



- Six-sigma quality standard is now a benchmark in many industries
- Before design, marketing ensures customer product characteristics
- Operations ensures that product design characteristics can be met by controlling materials and processes to 6σlevels
- Other functions like finance and accounting use 6σconcepts to control all of their processes

Special Cause Variation is assumed to exist if:

1. Any point falls outside the control limits.

2. Nine consecutive observations fall on one side of the mean.

3. Six consecutive observations are increasing (or decreasing.)

4. 14 observations alternate above and below the mean.

5. Two of three consecutive points fall in zone C in one-half of the chart.

6. Four of five consecutive points fall in zone B in one-half of the chart.

Risks of SPC

- SPC has the same Type I and Type II risks as acceptance sampling
- If the process if in fact in control but we conclude that it is out of control, we have committed a Type I error.
- If the process if in fact out of control but we conclude that it is in control, we have committed a Type II error.

Common control charts for variables and attributes

Data category	Chart type	Statistical quality
Variables data	X-bar and R	Mean and range
	X-tilde and	Median and range
	X-Rs	Individual data
Attributes data	P- chart	Percent defects
	Np -chart	Number of defectives
	c-chart	Number of defects
	u-chart	Number of defects per unit (length, area, time etc.)

What SPC does not do

- SPC only determines whether a process is in statistical control NOT whether the process is producing within specifications nor whether the process is even capable of producing within specifications.
- We must rely on another measure AFTER we have assured that the process is in control using SPC.

24.3 Acceptance Sampling

Definition: The third branch of SQC refers to the process of randomly inspecting a certain number of items from a lot or batch in order to decide whether to accept or reject the entire batch.

Different from SPC because acceptance sampling is performed either before or after the process rather than during

Sampling before typically is done to supplier material

Sampling after involves sampling finished items before shipment or finished components prior to assembly

Used where inspection is expensive, volume is high, or inspection is destructive

Module 8. Quality Control and Management

Lesson 25. Total Quality Management

25.1 Introduction:

The quality control discipline is constantly developing with growing importance of the quality aspects in food processing operation. Earlier the quality control was primarily concerned with maintaining the quality standards. The need to produce and sell high quality products and increase the efficiency of the production process, has led to the development of quality assurance systems and then total quality management systems.

25.1.1 Quality control is the evaluation of a final product prior to its marketing, i.e. it is based on quality checks at the end of a production chain for maintenance of prescribed standards . Since, at the end of the production chain, there is no way to correct production failures or upgrade the quality of the final product, the non-marketable products have to be discarded. Thus, quality control has only a limited potential to increase the quality and efficiency of a multi-step production procedure.

25.1.2 Quality Assurance: In contrast to quality control, the quality assurance includes the planning and surveillance of everything to do with the quality throughout the company. It is the implementation of quality checks and procedures to immediately correct any failure and mistake that is able to reduce the quality of the interim products at every production step.

25.1.3 Total Quality Management (TQM) The management approach to long-term success through customer satisfaction, based on the participation of all members of an organization (suppliers and distributors included) in improving processes, products, services and the working culture.

25.2 History of Total Quality Management

Quality control had its beginnings in the factory system in the 1850s. At that time, production methods were rudimentary. Products were made from non standardized materials using non standardized processes, resulting in products of varying quality. The only standards used were measures of dimensions, weight, and in some instances, purity.

In 20th century, quality consciousness increased at a tremendous rate, with much interest in the application of statistical quality control. Centralized inspection departments were organized to check for quality. In the beginning of the century, methods of statistical quality control were added.

Modern quality management was initiated with the works of Walter A. Shewhart, Joseph Juran, and W. Edwards Deming at Bell Telephone Laboratories in the 1920s. After World War II, modern quality concepts emerged leading to Total Quality Management.

25.2.1 The Pioneers of Scientific Quality Management

Frederick Taylor: A highly regarded consultant whose name was synonymous with "scientific management,". He proposed the reduction of waste through careful study.

Walter A. Shewhart: Introduced production process into a state of statistical control to manage a process economically.

W. Edwards Deming: Deming defined quality as a predictable degree of uniformity and dependability, at low costs and suited to the market. He produced his 14 Points for management in order to help people understand and implement for transformation in industry. **Joseph M. Juran:** Ddefines quality as "fitness for use" in terms of design, conformance, availability, safety, and field use.,

Philip B. Crosby Coined the word Quality Is Free He stated that quality is free because the small costs of prevention will always be lower than the costs of detection, correction, and failure. Crosby's name is perhaps best known in relation to the concepts of "Do It Right the First Time" and "Zero Defects."

25.3 Total Quality Management

TQM is a management philosophy, a paradigm, a continuous improvement approach to doing business through a new management model. TQM expands beyond statistical process control to embrace a wider scope of management activities of how we manage people and organizations by focusing on the entire process, not just simple measurements.

TQM is a comprehensive management system which:

- Focuses on meeting customers' needs by providing quality services at a cost that provides value to the customers
- Is driven by the quest for continuous improvement in all operations
- Recognizes that everyone in the organization has owners/customers who are either internal or external
- Views an organization as an internal system with a common aim rather than as individual departments acting to maximize their own performances
- Focuses on the way tasks are accomplished rather than simply what tasks are accomplished
- Emphasizes teamwork and a high level of participation by all employees

25.3.1 Need of implementing TQM

Organization Reality

Industrial disputes, climate of distress

Increased competition – domestic / International

Conservative management

Monopoly situation

Organization Self Evaluation

Where are we as an organization

Where do we want to go

How do we get there

How TQM help to get there

How will we know when we get there

Immediate Objectives

Trust and hormany

Awareness of organization reality

Waste identification

Team building

Success measures

Approach Steps

25.4. Implementation Process

1. Obtain CEO Commitment
2. Educate Upper-Level Management
3. Create Steering Committee
4. Outline the Vision Statement, Mission Statement, & Guiding Principles
5. Prepare a Flow Diagram of Company Processes
6. Focus on the Owner/Customer (External) & Surveys

7. Consider the Employee as an Internal Owner/customer
8. Provide a Quality Training Program
9. Establish Quality Improvement Teams
10. Implement Process Improvements
11. Use the Tools of TQM
12. Know the Benefits of TQM

1 Obtain CEO Commitment, and

2 Educate Upper-Level Management

The first step in implementing TQM is to obtain the total commitment, involvement, and leadership of the CEO and upper-level management.

The second step is to teach the CEO and upper-level management how to conduct the following:

- Undergo quality training
- Commit to TQM and provide the necessary resources of time and money to permit improvement
- Assist in the development of the corporate vision statement, mission statement, guiding principles, and objectives

3 Create a Steering Committee

Upon completion of upper management's commitment and training, a steering committee to be created to guide the company through the process of implementing TQM. The role of the steering committee would be .

- Review and evaluate customer surveys.
- Determine processes to be improved, based on customer and employee recommendations, surveys, and a knowledge of existing problems.
- Monitor process improvement.
- Oversee employee recognition for quality improvement.
- Communicate successes and progress.

4 Outline the Vision Statement, Mission Statement, & Guiding Principles

In developing the fourth step, important principles to consider including in the company's vision statement, mission statement, and guiding principles are

- Reputation as the best in the field
- customer Satisfaction
- Improved Safety
- Elimination of errors and defects Continuous Improvement
- Employee Empowerment

5 Prepare a Flow Diagram of Company Processes

Prepare a TQM flow diagram illustrating in the figure to implement quality processes within the company.

6 Focus on the Customer (External) & Surveys

The best ways of accomplishing quality improvement is by focusing on customers' concerns, and by learning what those concerns are through customer surveys. Several areas to survey, and to take care to provide are

Safe operating procedures Accident experience Attitude Professional competence of the project manager, superintendent, and project engineers Technical competence of the work force Overall responsiveness to owner/customer requests	Degree of communications Planning Administrative procedures Appearance and conduct of the work force Condition of equipment Coordination and supervision of subcontractors Appearance of the jobsite Timeliness

7 **Consider the Employee as an Internal Owner/Customer**

In order to conduct an analysis of the internal processes within the company, the following steps should be applied to the internal processes within a company.

- List several of your internal owners/customers within your company
- Choose one of these owners/customers to focus on for the application of this technique
- Determine the Outputs (products, services, information) that must be provided to this internal owner/customer
- Determine the work Processes your company uses to produce these Outputs
- Learn how your customer's expectations are met and how satisfaction is measured

8 Provide a Quality Training Program

The training program must begin with upper management, then training must be provided for the remaining management, and the in-house trainers and facilitators.

- Upper Management
- Remaining Management
- In-House Trainers & Facilitators
- Front-Line Supervisors
- Non-Supervisory Employees
- Team Training
- Training of Subcontractors & Suppliers

9 Establish quality improvement teams

In establishing quality improvement teams, a smaller company might assign one quality improvement team. Larger firms might assign several, possibly with one quality lead team as a guide for the other teams. Areas where quality improvement teams could begin investigating for possible improvement are:

- Increased Employee Value
- Technical Training
- Quality Training
- Employee Suggestions
- Employee Participation
- Personal Development

A quality improvement team (QIT) meets on a regular basis, once per week for 3 to 5 hours. After the TQM implementation plan is complete and underway, the QIT should meet once or twice per month.

10 Implement Process Improvements

- Identification of areas needing improvement
- Cooperative attitude between elements of the company
- Viewing every person who is on the receiving end of a process as a customer
- Fear driven from the company

- A system for selecting processes to be improved
- Training for all employees in quality awareness
- Improved communications outside the company

11 Use the Tools of TQM

Seven classical tools of quality and process improvement, plus one, are presented below.

1.Flowchart 2.Control Chart 3. Cause and Effect Diagram 4. Histogram 5. Check Sheet 6. Pareto Diagram 7.Scatter Diagram

12 What are the benefits of TQM?

- Improve competitiveness
- Reduce Operational costs
- Increase sales
- Enhance customer satisfaction
- Reduce wastes
- Improve efficiency
- Improve human relations
- Improve internal and external customer relation
- Integrates with ISO

Lesson 26. The 7 Qc Tools For Quality Improvement

26.1 Introduction:

The 7 QC Tools are simple statistical tools used for problem solving. These tools were either developed in Japan or introduced to Japan by the Quality Gurus such as Deming and Juran. These tools have been the foundation of Japan's astonishing industrial resurgence after the second war. In terms of importance, these are the most useful in industries. Kaoru Ishikawa has stated that these 7 tools can be used to solve 95 percent of all problems..

The following are the 7 QC Tools :

1. Check Sheets

2. Histogram

3. Scatter Diagrams

4. Graphs

5. Control Charts

6. Pareto Diagram

7. Cause & Effect Diagram

26.2 Check Sheets

As measurement and collection of data forms the basis for any analysis, this activity needs to be planned in such a way that the information collected is both relevant and comprehensive. Check sheets are tools for collecting data. They are designed specific to the type of data to be collected. Some examples of check sheets are daily maintenance check sheets, attendance records, production log books, etc.

Stratification

Data collected using check sheets needs to be meaningfully classified. Meaningful classification of data is called stratification. Stratification may be by group, location, type, origin, symptom, etc. for Example :

a) Data on rejected product may be classified either machine wise or operator wise or shift wise.

b) Data of production of food grains may be classified nation wise, state wise or district wise, etc.

Fig. 1 Example

Typing test analysis Date: 12th Oct

Typist: Kelly Hall Test: R324

Examiner: Jay Brown

Type of error	Count	Score
Reversed letters	𝍸	5
Missing letters	𝍸 |||	8
Extra letters	𝍸	5
Wrong letters	𝍸 𝍸	10
	Total errors:	28

26.3 Histogram

Histograms or Frequency Distribution Diagrams are bar charts showing the distribution pattern of observations grouped in convenient class intervals and arranged in order of magnitude. Histograms are useful in studying patterns of distribution and in drawing conclusions about the process based on the pattern.

The Procedure to prepare a Histogram consists of the following steps :

1. Collect data (preferably 50 or more observations of an item).

2. Arrange all values in an ascending order.

3. Divide the entire range of values into a convenient number of groups each representing an equal class interval. It is customary to have number of groups equal to or less than the square root of the number of observations. However one should not be too rigid about this.

4. Note the number of observations or frequency in each group.

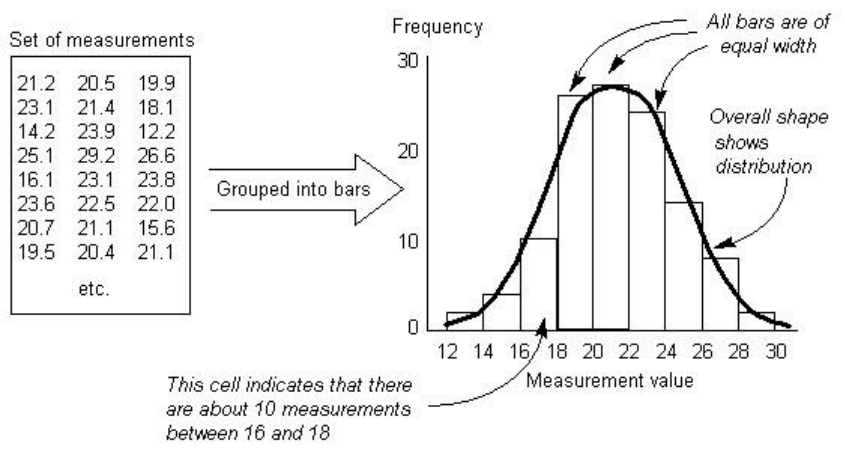
5. Draw X-axis and Y-axis and decide appropriate scales for the groups on X-axis and the number of observations or the frequency on Y-axis.

6. Draw bars representing the frequency for each of the groups.

7. Provide a suitable title to the Histogram.

8. Study the pattern of distribution and draw conclusion.

HISTOGRAM

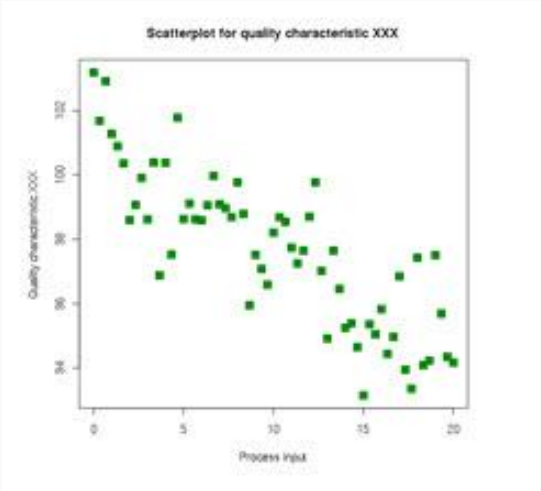


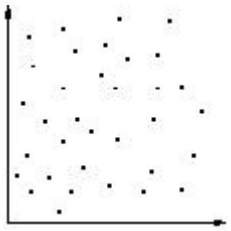
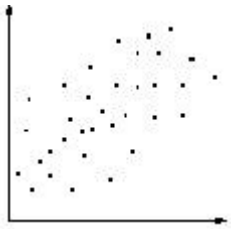
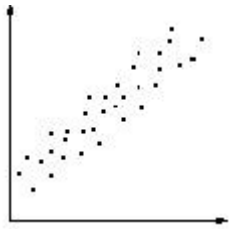
26.4 Scatter diagram

When solving a problem or analysing a situation one needs to know the relationship between two variables. A relationship may or may not exist between two variables. If a relationship exists, it may be positive or negative, it may be strong or weak and may be simple or complex. A tool to study the relationship between two variables is known as Scatter Diagram.

It consists of plotting a series of points representing several observations on a graph in which one variable is on X-axis and the other variable in on Y-axis. The way the points lie scattered in the quadrant gives a good indication of the relationship between the two variables.

Figure shows various types of distributions and relationship between the variables.



Scatter Diagram	Degree of correlation	Interpretation
	None	No relationship can be seen. The y variable is not related to the x variable in any way.
	Low	A vague relationship is seen. There is a low positive correlation between the x variable and the y variable. There might be some connection between the two, but it is not clear.
	High	The points are grouped into a clear linear shape. The two variables are clearly related in some way. Given one, you can predict a moderate range in which the other will be found.
	Perfect	All points lie on a line (which is usually straight). The variables are deterministically related, and given one you can predict the other with accuracy.

26.5 Graphs

Graphs of various types are used for pictoral representation of data. Pictoral representation enables the user or viewer to quickly grasp the meaning of the data. Different graphical representation of data are chosen depending on the purpose of the analysis and preference of the audience. The different types of graphs used are as given below :

1. Bar Graph To compare sizes of data

2. Line Graph To represent changes of data

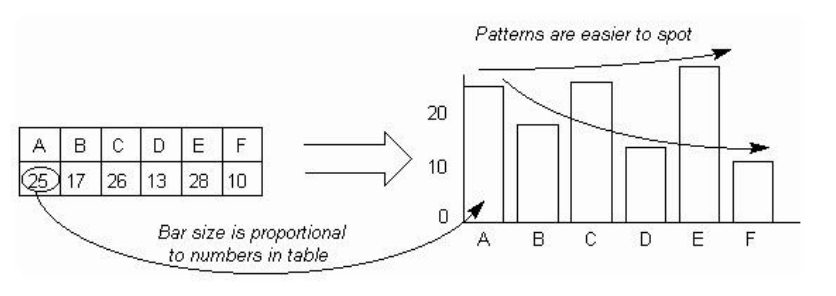
3. Gantt Chart To plan and schedule

4. Radar Chart To represent changes in data (before and after)

5. Band Graph Same as above

6. Pie Chart Used to indicate comparative weights

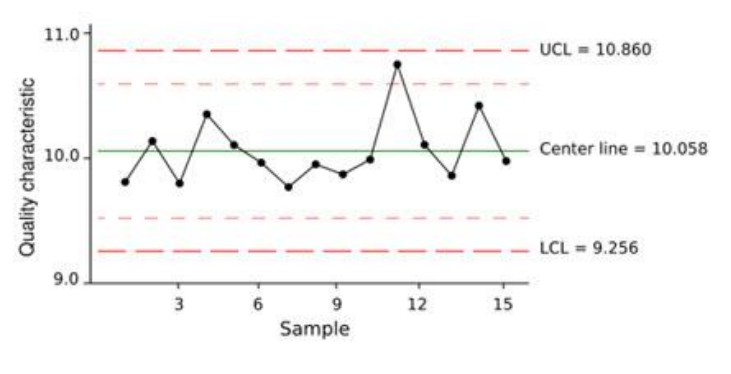
Example: Bar chart



26.6 Control Charts

Control charts was developed by Dr. Walter A. Shewhart during 1920's while he was with Bell Telephone Laboratories.

Control chart makes possible the diagnosis and correction of many production troubles and brings substantial improvements in the quality of the products and reduction of spoilage and rework. It tells us when to leave a process alone as well as when to take action to correct trouble.



26.7 Pareto Diagram

Pareto Diagram is a tool that arranges items in the order of the magnitude of their contribution, thereby identifying a few items exerting maximum influence. The origin of the tool lies in the observation by an Italian economist Vilfredo Pareto that a large portion of wealth was in the hands of a few people. He observed that such distribution pattern was common in most fields. Pareto principle also known as the 80/20 rule is used in the field of materials management etc

Procedure : The steps in the preparation of a Pareto Diagram are :

1. From the available data calculate the contribution of each individual item.

2. Arrange the items in descending order of their individual contributions. If there are too many items contributing a small percentage of the contribution, group them together as

"others". It is obvious that "others" will contribute more than a few single individual items. Still it is kept last in the new order of items.

3. Tabulate the items, their contributions in absolute number as well as in percent of total and cumulative contribution of the items.

4. Draw X and Y axes. Various items are represented on the X-axis. Unlike other graphs Pareto Diagrams have two Y-axes - one on the left representing numbers and the one on right representing the percent contributions. The scale for X-axis is selected in such a manner that all the items including others are accommodated between the two Y axes. The scales for the Y-axes are so selected that the total number of items on the left side and 100% on the right side occupy the same height.

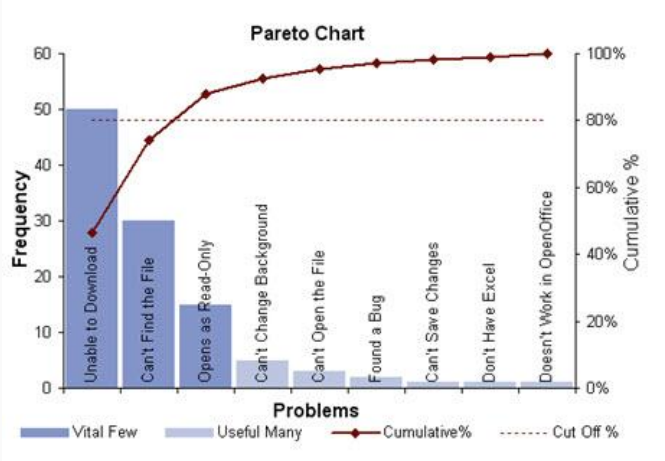
5. Draw bars representing the contributions of each item.

6. Plot points for cumulative contributions at the end of each item. A simple way to do this is to draw the bars for the second and each subsequent item at their normal place on the X-axis as well as at a level where the previous bar ends. This bar at the higher level is drawn in dotted lines. Drawing the second bar is not normally recommended in the texts.

7. Connect the points. If additional bars as suggested in step 6 are drawn this becomes simple. All one needs to do is - connect the diagonals of the bars to the origin.

8. The chart is now ready for interpretation. The slope of the chart suddenly changes at some point. This point separates the 'vital few' from the 'useful many' like the A,B and C class items in materials management.

An example of a Pareto Chart



26.8 Cause & Effect Diagram

A Cause-and Effect Diagram is a tool that shows systematic relationship between a result or a symptom or an effect and its possible causes. It is an effective tool to systematically generate ideas about causes for problems and to present these in a structured form. This tool

was devised by Dr. Kouro Ishikawa and as mentioned earlier is also known as Ishikawa Diagram.

Structure

Another name for the tool, as we have seen earlier, is Fish-Bone Diagram due to the shape of the completed structure. The symptom or result or effect for which one wants to find causes is put in the dark box on the right. The lighter boxes at the end of the large bones are main groups in which the ideas are classified. Usually four to six such groups are identified. In a typical manufacturing problem, the groups may consist of five Ms - Men, Machines, Materials, Method and Measurement. The six M Money may be added if it is relevant. Important subgroups in each of these main groups are represented on the middle bones and these branch off further into subsidiary causes represented as small bones. The arrows indicate the direction of the path from the cause to the effect.

Procedure

The steps in the procedure to prepare a cause-and-effect diagram are :

1. Agree on the definition of the 'Effect' for which causes are to be found. Place the effect in the dark box at the right. Draw the spine or the backbone as a dark line leading to the box for the effect.

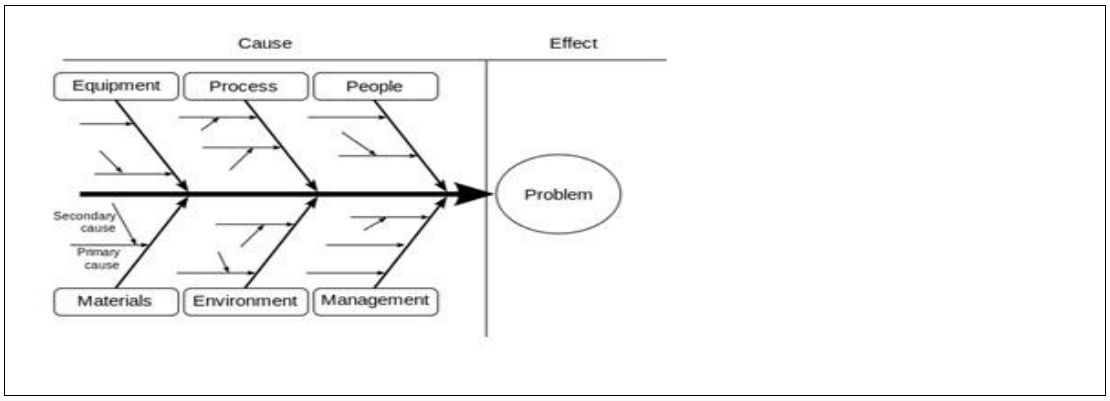
2. Determine the main groups or categories of causes. Place them in boxes and connect them through large bones to the backbone.

3. Brainstorm to find possible causes and subsidiary causes under each of the main groups. Make sure that the route from the cause to the effect is correctly depicted. The path must start from a root cause and end in the effect.

4. After completing all the main groups, brainstorm for more causes that may have escaped earlier.

5. Once the diagram is complete, discuss relative importance of the causes. Short list the important root causes.

An example of a cause and effect diagram



Module 9. Food Laws

Lesson 27. FOOD LAWS-I (FSSAI, Weights & Measures Act, Essential Commodities Act and other Regulatory Agencies)

27.1 Introduction

To protect health and safety of consumers, an effective food control systems are essential. This will facilitate countries to assure the safety and quality of their foods for global trade. The global environment for food trade has stringent norms on both importing and exporting countries. The governments have greater responsibility for food safety and consumer protection. Responsibility for food control in our country is shared between different agencies or ministries through various food laws for protecting public health.

27.2 National level agencies

27.2.1 Food Safety and Standard Act 2006:

The act has been enacted to consolidate the laws related to food and to establish the Food safety and standards Authority of India for laying down science based standards for articles of food and to regulate their manufacture, storage distribution sale and import to ensure availability of safe and whole some food for human consumption

27.2.1.1 Salient Features Of FSSAI Act, 2006: Some of the salient features of the Act are:

- Movement from multi-level and multi-department control to a single line of command.
- FSSAI as a single reference point for all matters relating to Food Safety and Standards, Regulations and Enforcement.
- Integrated response to strategic issues like Novel foods, Health Foods, Nutraceuticals, GM foods, international trade etc.
- Adequate information dissemination on food to enable consumer to make informed choices.
- Compounding and Adjudication of cases – to reduce Court's workload and expedite the disposal of cases.
- Graded penalty depending upon the gravity of offences.
- Adequate representation of government, industry organizations, consumers, farmers, technical experts, retailers etc.
- Enforcement of the legislation by the State Governments/ UTs through the state Commissioner for Food Safety, his officers and Panchayati Raj/Municipal bodies.

The Act, incorporates the salient provisions of the Prevention of Food Adulteration Act, 1954 and is based on international legislations and instrumentalities. Act takes care of international practices and envisages a overreaching policy framework and provision of single window to guide and regulate persons engaged in manufacture, marketing, processing, handling, transportation, import and sale of food..

27.2.1.2 Provisions in the Act

- Covering Health Foods, supplements, nutraceuticals
- Issuing Licenses within a time frame of 2 months
- Provision of Notice by Designated Officers
- Prosecution, if to be launched, should be within 1 year time frame
- Special Courts for summary trials
- Compensation to Victims (for any case of Injury/ Grievous injury/ Death)
- Reward to informer (informing about the violators – adulteration etc.) by State Govt.
- One composite license for unit(s) falling under one area

Important definitions and features of the act:

Adulterant

Any material which is or could be employed for making the food unsafe or sub-standard or mis-branded or containing extraneous matter;

Misbranded

1. Means an article of food with false, misbranding or deceptive claims either on the label of the package, or through advertisement,
2. If the article is sold as an imitation of, or is a substitute for, or is likely to deceive, or
3. The package bears statement, design or device regarding the ingredients or the substances contained therein, which is false or misleading or
4. Manufacturers name and address is false or
5. Contains any artificial flavouring, colouring or chemical preservative and is not labelled properly as per the requirements of the law.

Unsafe

Means an article of food which is injurious to health:-

1. by the article itself, or its package thereof, or
2. consists wholly or in part, any filthy, putrid, rotten, decomposed or diseased animal substance or vegetable substance; or
3. is processed unhygienically or the article of food has harmful substance in it or is infected or infested with worms, weevils or insects; or
4. has been substituted by inferior or cheaper substance whether wholly or in part; or
5. uses a substance directly or as an ingredient or as additive which is not allowed under the law; or
6. by virtue of its being prepared, packed or kept under unsanitary conditions; or
7. by virtue of its being mis-branded or sub-standard or food containing extraneous matter; or
8. by virtue of containing pesticides and other contaminants in excess of quantities specified by regulations.

Food

Any substance, whether processed, partially processed or unprocessed, which is intended for human consumption and includes primary food i.e. all raw produce except those in hands of the grower, farmer, fisherman etc., genetically modified or engineered food or food containing such ingredients, infant food, packaged drinking water, alcoholic drink, chewing gum, and any substance, including water used into the food during its manufacture, preparation or treatment but does not include any animal feed, live animals unless they are prepared or processed for placing on the market for human consumption, plants prior to harvesting, drugs and medical products, cosmetics, narcotic or psychotropic substances: Provided that the Central Government may declare, by notification in the Official Gazette, any other article as food for the purposes of this Act having regards to its use, nature, substance or quality;

27.2.2 The Standards of Weights and Measures Act, 1976

The Standards of Weights and Measures, 1956 enforces uniform standards of weights and measures, based on the metric system. Based on the suggestions of General Conference of Weights and Measures (CGPM), International Organization of Legal Metrology (OIML), the 1956 act was replaced by a comprehensive legislation, The Standards of Weights and Measures, are administered by the ministry of Consumer affairs, Food and Public Distribution.

All weights or measures must be recorded in metric units and certain commodities can only be packed in specified quantities (weight, measure or number). These include baby and

weaning food, biscuits, bread, butter, coffee, tea, vegetable oils, milk powder, wheat and rice flour etc.

27.2.2.1 Salient features of this Act :

- Establishment of weights and measures based on SI units, as adopted by the CGPM and recognized by OIML
- Provide to prescribe specification of measuring instruments used in commercial transaction, industrial production.
- Regulation of pre-packed commodities sold or intended to be sold in the course of inter-state and commerce.
- Approval of models of weights and measuring instruments intended to be manufactured.
- Control and regulation of export and import of weights and measures and commodities in packed form.
- Inspection of weighing and measuring instruments during their use to prevent fraudulent practices.
- Powers of inspectors to search , seize and forfeiture of non-standard weight or measure.

27.2.3 Essential Commodities Act, 1955

To ensure availability of essential commodities to the consumers and to protect them from exploitation by unscrupulous traders, the Government of India made law on Essential Commodities Act, 1955 and the Prevention of Black marketing and Maintenance of Supplies of Essential Commodities Act, 1980 . The act provides for the regulation and control of production, distribution and pricing of commodities which are declared as essential for maintaining or increasing supplies or for securing their equitable distribution and availability at fair prices. The enforcement/ implementation of the provisions of the Essential Commodities Act, 1955 lies with the State Governments and UT Administrations. This act is under the Legislative Department, Ministry of Law, Justice and Company Affairs.

The essential commodities mean any of the following classes of commodities:

- Cattle fodder including oil cakes and other concentrates
- Coal including coke and other derivatives
- Component parts and accessories of automobiles
- Cotton and woolen textiles
- drugs

- Food stuffs including edible oilseeds and oils
- Iron and steel including manufactured products of iron and steel
- Paper including newsprint, paper board and straw board
- Petroleum and petroleum products
- Raw cotton whether ginned or un-ginned and cotton seed
- Raw jute
- Any other class of commodity which the Central Government by notified order declares to be essential commodity.

27.3 Other Regulatory and Voluntary Laws:

Milk and Milk Products Order, 1992: The Milk and milk products order (MMPO) 1992 is exercised under the essential commodities Act and is regulated by the ministry of Agriculture through the department of Animal husbandry and Dairying and fisheries. According to this order, any dairy unit having processing capacity more than 10,000 liters of milk per day or handle more than 500 tones of milk solids per annum is required to take license. The production, collection, transportation, distribution and supply of milk and milk products are controlled by the Milk and Milk Products Order, 1992. The order sets sanitary requirements for dairies, machinery and premises and includes quality control, certification, packing, marking and labeling standards for milk and milk products. The standards specified in the order also apply to imported products.

The Edible Oils Packing (Regulation) Order, 1998: The order came into force in 1998 and is regulated by the Department of Sugar and Edible oil under Ministry of Food and Consumer affairs. "Edible oil" means vegetable oils and fats but does not include any margarine, vanaspati, bakery shortening and fat spread as specified in PFA and rules made there under, for human consumption.

Vegetable Oils Products (Regulation Order) 1998: It controls the manufacture, trade and distribution of vegetable oils..

Solvent Extracted Oils, De-Oiled Meal and Edible Flour Control Order 1967: It applies for oils and fats and deals with the licensing manufacture distribution and trade of solvent extracted edible oils and quality and operated by Directorate of vanaspati, vegetable oil and fats. This order provides for compulsory licensing of manufacturing units. The specifications of the edible oils produced by solvent extraction method have been laid down under the said order.

Edible Oil Packaging (Development and regulation) Order, 1998: This order is regulated by the Department of sugar and edible oil under ministry of food and consumer affairs.

Meat Food Products Order Regulation for the production of meat products are covered by the Meat Food Products Order, 1973. The Directorate of Marketing and Inspection at the ministry of Agriculture is the regulatory for the order, which is equally applicable to

domestic processors and importers of meat products. Provision of MFPO requires on four stages of inspection by qualified veterinary doctors for hygienic production of meat products

Environment Protection Act 1986: It implements rules for the manufacture, use/ import and storage of hazardous microorganisms/ genetically engineered organisms or cells.

The Export Inspection Council of India (EIC): Established in 1963, it notifies commodities, establishes standards of quality control and/ or inspection and prohibit the export of a notified commodity. Through its network of laboratories it inspect and issue certificate of export.

Agricultural and Processed Food Products Export Development Authority (APEDA): Under the Ministry of Commerce and Industry, APEDA puts it quality logo on the products to be exported. This logo is a mark of pride and reliability. The products in the APEDA purview are fruits, vegetables, meat products, dairy products, confectionery and bakery products, beverages, cereals rice etc.

Marine Product Export Development Authority: Constituted in 1972 through Act, specifies standards for fisheries of all kinds.

ISO 9000 Quality Management System

A quality system is a mechanism by which a company can organize and manage its resources to achieve, sustain and improve quality economically.

ISO 14000 Quality Management Systems

ISO 14000 is designed to provide a structure for the management of environmental compliance. The most familiar standard in the 14000 series is ISO 14001, entitled "Environmental Management Systems, Specification with Guidance for Use." Like ISO 9000, ISO 14000 is neither industry- nor product-specific.

Codex Alimentarius Commission

Codex Alimentarius Commission was established in 1962. The Commission develops food standards, guidelines and related texts such as codes of practice under the joint FAO/WHO food standards program. It is also called Codex harmonized international standards due to involvement of both FAO and WHO.

The objectives of the Codex Alimentarius commission are to protect the health of consumers and to facilitate the international trade. It brings all the interested parties like scientists, technical experts, governments, consumers and industry representatives to help develop standards for food manufacturing and trade. These standards, guidelines and recommendations are recognized worldwide for their vital role in protecting the consumers and facilitating international trade.

The codex contract point in India is the Directorate General of Health Services (DGHS) in the ministry of Health; however the ministry of food processing industries is closely associated with the activities of Codex Alimentarius.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Lesson 28. NATIONAL FOOD LAWS (BIS, AGMARK, FPO, Consumer Protection Act)

28.1 Introduction

Food may be contaminated or adulterated and may injurious to health due to various reasons. It is essential to set the minimum limits of the desirable characteristics required and the maximum limits of the undesirable components.

Food Laws are for the following reasons:

- To maintain the quality of the food produced in the country.
- To prevent exploitation of the consumers by the sellers.
- To safeguard the health of the consumers.
- To establish criteria for quality of the food products

Most common standards are :

Legal Standards: These are established by federal, central, state or municipal agencies and are generally mandatory. These are set up by the law or through regulation. They generally concerned with freedom from adulteration.

Company or Voluntary Standards: These are established by various segments of the food industry. These standards generally represent consumer image and become symbol of product quality. These are used by private firms or supermarkets.

Industry Standards: These standards are established by an organizational group to maintain the quality of the given commodity. These standards become effective by pressure where other legal standards are not involved.

Consumer or Grade Standards: These standards represent consumer's requirements of the product and generally based on the experience of the industry for consumers.

28.2 Bureau of Indian Standards (BIS):

BIS certification scheme is voluntary and aims at providing quality, safety and dependability to the ultimate consumer. Presence of certification mark known as Standard Mark on a product is an assurance of conformity to specifications The activities of Bureau of Indian Standards (BIS) are formation of Indian Standards in the processed food sector and the implementation of standards through promotion, voluntary and third party certification systems. In general these standards cover raw materials and their quality parameters, hygienic conditions under which products are manufactured and packaging and labeling requirements. Manufacturers complying with standards laid down by the BIS can obtain the

ISI Mark that can be exhibited on product packages. These standards have higher quality specifications than those prescribed under AGMARK and FSSAI.

The BIS has laid down specification for mineral water and packaged drinking water and is the licensing authority for the manufacture of mineral water and packaged drinking water in India. IS Standards have been laid down for fruit and vegetable products, spices and condiments, animal products and processed foods. The products are checked for quality by the BIS in their own network of testing laboratories or in several public and private laboratories recognized by them. Under BIS many of the standards are laid down based upon ISO (International Organization for Standardization) standards which is a worldwide federation of National Standard Bodies.

28.2.1 Constitution of the Bureau: The Bureau consist members such as the Minister in charge of the Ministry, Minister of State, the Director-General of the Bureau, persons representing the Ministries, state Governments, recognized consumer organizations, farmers, industry and trade, research institutions, technical, educational and professional organizations etc.

28.2.2 Powers and Functions of the Bureau

28.2.2.1 Establishment, Publication and Promotion of Indian Standards : For the purpose of formulation of Indian Standards in respect of articles or processes, technical committees of experts are constituted. Such committees may include Division Councils, Sectional Committees, Sub-committees and Panels and each of these councils have specified functions .

28.2.2.2 Procedure for Establishment of Indian Standards: Any Ministry of Central or State Government, consumer organizations, industrial units, industry-associations, professional bodies, can submit proposals to the Bureau for establishing a standard or for revising, amending, a standard by making a request in writing. Division Council concerned will assign the task of formulating the standard to an appropriate Technical Committee. Later a draft standard prepared and duly approved by a Committee shall be issued and widely circulated for a period of not less than one month amongst the various interests concerned for critical review and suggestions for improvement. The appropriate Technical Committee shall thereafter finalize the draft standard giving due consideration to the comments that may be received. The draft standard shall be submitted to the Chairman of the Division Council concerned for adoption. All established standards shall be reviewed periodically, at least once in five years, to determine the need for revision or withdrawal. Standards which there is need to revise or amendment shall be reaffirmed.

28.2.2.3 Grant of License: Manufacturing units can apply for BIS license on a prescribed form along with application fee and other documents such as location map of factory list of manufacturing and testing equipments, flow charts of the process, details of the technical staff etc. BIS office will do a preliminary inspection verify all documents and process. The product samples are drawn and sent for analysis at BIS certified lab. After satisfactory inspection and sample report of the product, license is granted 1 to 2 years which can renewed periodically.

28.2.2.4 Inspection : The certified units are inspected by inspecting officers. The may be done at manufacturing place, dispatch place or at the place where it is used. At manufacturing place the inspection will also be for the QA systems, verification and validation. The Bureau shall designate such of the officers of the Bureau as Inspecting Officers

28.2.2.5 STOP Marking: If there is evidence that the product is not as per the conforming standards and agreed clauses, the licensee will be directed to stop marking. The reasons can be Non conformance of products at manufacturing place or at market place, Non implementation of Scheme of Testing of the products, Non availability of testing staff , Significant modification of plant and machinery with out informing BIS, Relocation of plant and machinery, Prolonged closure of the unit, Marking non conformed product, Marking standard mark other than that are included in the license. The licensee can resume only after re inspection and satisfactory compliance.

LIST OF STANDARDS UNDER MANDATORY CERTIFICATION

Sl No.	Parent Act	Rules/ QC Order	Notification	Implementing Authority
I	Food Safety & Standards Act, 2006	Food Safety & Standards (Prohibition & Restriction on sales) Regulations 2011	*Ministry of Health and Family Welfare, Dept of Health, Notification dated : 1 Aug 2011* Date of Implementation: *5 Aug 2011*	*Food (Health) Authority of the State*
1.	IS 1165	Milk powder		
2.	IS 1166	Condensed milk, partly skimmed and skimmed condensed milk		
3.	IS 1656	Milk-cereal based weaning foods		
4.	IS 11536	Processed cereal based complementary foods for infants		
5.	IS 12176	Sweetened ultra high temperature treated condensed milk		
6.	IS 13334(Part 1)	Skimmed milk powder, standard grade		
7.	IS 13334(Part 2)	Skimmed milk powder, extra grade		
8.	IS 14542	Partly skimmed milk powder		
9.	IS 14433	Infant milk substitute, Milk protein based		
10.	IS 13428	Packaged Natural Mineral Water		
11.	IS 14543	Packaged Drinking Water (Other than Packaged Natural Mineral Water)		
12.	IS 15757	Follow –up – formula- Complimentary Food-Specification		

28.3 AGMARK

The word Agmark is derived from Agricultural Marketing. The DMI under the Department of Agriculture and Co-operation in the Ministry of Agriculture enforces the Agricultural Products (Grading and Marketing) Act 1937. Under this Act Grade standards are prescribed for agricultural and allied commodities. Agmark grading means grading of an article in accordance with grade/standards prescribed under the provisions of the act. These are known as AGMARK standards. Grading under the provision of this Act is voluntary. Any person or body of persons desirous of being authorized to grade and mark an article under the provisions of the act shall apply to the agricultural marketing advisor or any other officer of the Central Government or State Government authorized by Agricultural Marketing Advisor. Manufacturers who comply with standard laid down by DMI are allowed to use "AGMARK" labels on their products

The grade designation marks shall be applied only to the articles mentioned in the certificate of authorization during the validity period. The certificate of authorization is issued by agricultural marketing advisor or any other officer of the central or state government authorized by the Agricultural Marketing Advisor. The grade designation characteristics vary from product to product. The quality of the product is determined with reference to the size, variety, weight, color, moisture, fat content and other factors are taken in to account. It covers quality assurances of unprocessed, semi processed and processed agricultural

commodities. Blended edible vegetable oils and fat spread are compulsorily required to be certified under Agmark.

The inspecting officer shall analyze the sample for quality factors as laid down in grading and marketing rules of the specific commodity in respect of produce. The inspecting officer shall also ensure that all the food article graded and certified under Agmark shall satisfy the mandatory requirements laid down under PFA rules. The rules for affixation of AGMARK labels, method of packing and marking, check sampling and certificate of grading rules are also given under this act.

28.3.1 Salient features of Agmark standard:

(1) Quality standards for Agricultural commodities are framed based on their intrinsic quality.

(2) Food safety factors are being incorporated in the standards to compete in world trade.

(3) Standards are being harmonized with international standards keeping in view the WTO requirements.

(4) Check is kept on the quality of certified products through 23 laboratories and 43 offices spread all over the country

The grades incorporated are grades 1, 2, 3 and 4 or special, good, fair and ordinary.

Agmark products are subjected to continuous inspection. The certificate of "Authorization" is granted only to those in the trade having adequate experience and standing in the market. The staff of the DMI or of the state Government is generally present at the time of selection of goods, their processing, grading and packing before applying the appropriate AGMARK labels.

Products available under AGMARK are pulses, wheat products, vegetable oils, ground spices, whole spices, milk products, honey, compounded asafetida, rice, tapioca sago, seedless tamarind and gram flour; grading of these commodities is voluntary. On the other hand grading of commodities like tobacco, walnut, spices, basmati rice, essential oils, onion, potatoes are meant for export is compulsory under AGMARK.

The Directorate of marketing and inspection of central government has 21 laboratories and 50 sub offices spread all over the country. The central AGMARK laboratory at Nagpur continuously carries out research and development works in this field.

28.4 FRUIT PRODUCTS ORDER (FPO) 1955

Constituted under Essential Commodities Act it is mandatory for all manufacturers of Fruit and Vegetable Products to obtain a licence under FPO. The act is implemented by the Food

Safety and Standards Authority of India through Directorate of Fruit & Veg. Processing at its Regional Offices.

The Fruit Product Order (FPO) lays down statutory minimum standards in respect of the quality of various fruits and vegetable products and processing facilities at manufacture, storage and sale. The Agricultural marketing Advisor is authorized by law to issue a license for manufacturing fruits and vegetable products, after due inspection of the factory for hygiene, sanitation and quality of formulation. Periodic inspection by Government inspectors in establishments is carried out to ensure conformity of standards by processors. Licenser is empowered to put the FPO specification mark on the product. The products covered in FPO include, fruit juice, pulp concentrate, squashes, cordials, crush, fruit syrups, nectar, aerated water containing fruit juice or pulp and read to serve beverages etc., Depending on their quality the products are grade in four categories as ordinary, fair, good and special. The FPO specifications cover list of constituents, a method of presentation permissible colors in the preparation and also minimum quality requirement of the product. An expert committee known as the Central Food Product Advisory Committee deals with all matters relating to the FPO.

FPO also lays down specific requirements in regard to the following:

- Containers and labeling requirement
- Limits of poisonous metals in fruit products
- List of permissible harmless food colors
- Limits for permitted preservatives in fruit products
- Other permitted additives

28.5 Consumer Protection Act 1986:

Government of India has accorded a very high priority to the consumer protection programme. Ministry of food and Consumer Affairs, Department of Consumer Affairs has been designated as the Nodal Department to deal with the area of consumer protection. Since 1986, the department is taking a number of measures to promote a strong and broad based consumer movement in the country. The main objective of this Act is to provide better protection for the consumer in terms of quality of the product he buys. Unlike the existing laws which are preventive in nature, the provisions of this Act are compensatory in nature. This Act is intended to provide simple, speedy and inexpensive redressal to the consumer's grievance and relief of specific nature. The act has been amended in 1993 both to extend its coverage and scope and to enhance the powers of redressal machinery.

Module 10. Standards and regulations in food quality management

Lesson 29. HACCP

29.1 Introduction:

HACCP stands for Hazard Analysis and Critical Control Point. Hazard is a biological, chemical or physical agent that is reasonably likely to cause illness or injury in the absence of its control. Hazards can be harmful microorganisms or chemical and/or physical contaminants. To ensure safe food, HACCP system is designed to identify hazards, establish controls and monitor these controls. HACCP is a preventive system of hazard control rather than a reactive one. Food processors can use it to ensure safer food products for consumers..

The Pillsbury Co. pioneered the application of the HACCP concept to food production during its efforts to supply food for the U.S. space program in the early 1960s.. It is not a zero-risk system, but it is designed to minimize the risk of food-safety hazards. In an assessment of the effectiveness of food regulation in the United States, the National Academy of Sciences (NAS) recommended in 1985 that the HACCP approach be adopted by all regulatory agencies and that it be mandatory for food processors Since then globally this system has been adopted to ensure safety of foods.

HACCP is a preventive system for ensuring food safety, but it is not a stand-alone system. HACCP must be built upon current food-safety programs such as Good Manufacturing Practices (GMPs) and others to make it work.

29.2 HACCP Plan:

To perform a hazard analysis for the development of a HACCP plan, food processors must gain a working knowledge of potential hazards. The HACCP plan is designed to control all reasonably likely food-safety hazards. Such hazards are categorized into three classes: biological, chemical and physical.

Biological Hazards

These hazards can come from raw materials or from food-processing steps used to make the final product. Microorganisms live everywhere: air, dirt, fresh and salt water, skin, hair, animal fur and plants. Microorganisms are classified into various groups. A few groups important in foods include yeasts, molds, bacteria, viruses and protozoa. Although thousands of kinds of microorganisms exist, only a few pose hazards to humans. Without adequate food, water and temperature, microorganisms stop growing and multiplying. Some die and others stop functioning until they get the elements they need. Some preservation methods, such as drying or smoking, control of water or nutrients in food, make these essential elements unavailable to microorganisms.

Chemical Hazards

Chemical contamination can happen at any stage in food production and processing. Chemicals can be helpful and are purposefully used with some foods, such as preservatives. The presence of a chemical may not always represent a hazard. The amount of the chemical may determine whether it is a hazard or not. Some may require exposure over prolonged periods to have a toxic effect. Regulatory limits are set for some of those contaminants.

Chemical hazards can be separated into three categories:

- Naturally occurring chemicals.
- Intentionally added chemicals.
- Unintentionally or incidentally added chemicals.

Physical Hazards

Physical hazards include any potentially harmful extraneous matter not normally found in food. When a consumer mistakenly eats the foreign material or object, it is likely to cause choking, injury or other adverse health effects. The source of the hazard is often easy to identify.

29.3 Guidelines for the Application of the HACCP System

Prior to application of HACCP to any sector of the food chain, that sector should be operating according to the Codex General Principles of Food Hygiene, the appropriate Codex Codes of Practice and appropriate food safety legislation like FSSAI. Management commitment is necessary for implementation of an effective HACCP system.

During hazard identification, evaluation and subsequent operations in designing and applying HACCP systems, consideration must be given to the impact of raw materials, ingredients, food manufacturing practices, role of manufacturing processes to control hazards, likely end-use of the product, categories of consumers of concern, and epidemiological evidence relative to food safety.

29.3.1 Application

The application of HACCP principles consists of the following tasks as the Logic Sequence for Application of HACCP

29.3.2 Principles

The HACCP system consists of the following seven principles:

Principle 1 : Conduct a hazard analysis.

Principle 2 : Determine the Critical Control Points (CCPs).

Principle 3 : Establish critical limit(s).

Principle 4 : Establish a system to monitor control of the CCP.

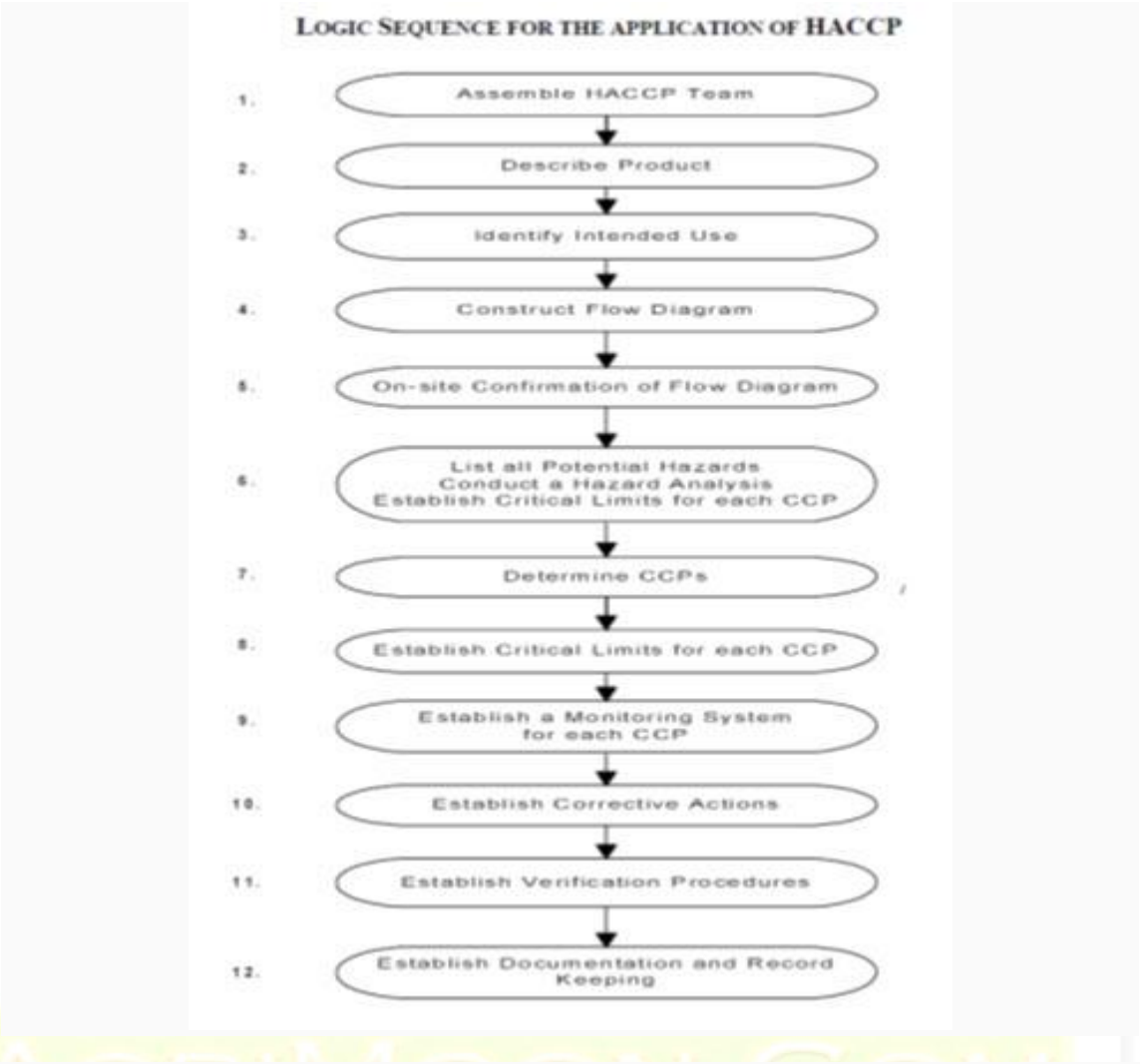
Principle 5 : Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control.

Principle 6 : Establish procedures for verification to confirm that the HACCP system is working effectively.

Principle 7 : Establish documentation concerning all procedures and records appropriate to these principles and their application.

29.3.3 Logic Sequence for Application of HACCP

1. Assemble the HACCP Team
2. Describe the Product
3. Identify Intended Use
4. Construct Flow Diagram
5. On-site Confirmation of Flow Diagram
6. List All Potential Hazards Conduct a Hazard Analysis Determine Control Measures
7. Determine CCPs
8. Establish Critical Limit for Each CCP
9. Establish a Monitoring System for Each CCP
10. Establish Corrective Action for Deviations that May Occur
11. Establish Verification Procedures
12. Establish Documentation and Record Keeping



29.3.3.1 Assemble HACCP team

The food operation should assure that the appropriate product specific knowledge and expertise is available for the development of an effective HACCP plan. This is accomplished by assembling a multidisciplinary team consisting production, QA, engineering, marketing, purchase, HR personnel. The scope should describe which segment of the food chain is involved and the general classes of hazards to be addressed.

29.3.3.2. Describe product

A full description of the product should be drawn up, including relevant safety information such as: composition, physical/chemical structure (including aw, pH, etc.), microcidal / static treatments (e.g. heat-treatment, freezing, brining, smoking, etc.), packaging, durability and storage conditions and method of distribution.

29.3.3.3. Identify intended use

The intended use should be based on the expected uses of the product by the end user or consumer. In specific cases, vulnerable groups of the population, e.g. institutional feeding may have to be considered.

29.3.3.4. Construct flow diagram

The flow diagram should be constructed by the HACCP team. The flow diagram should cover all steps in the operation. When applying HACCP to a given operation, consideration should be given to steps preceding and following the specified operation.

29.3.3.5. On-site confirmation of flow diagram

The HACCP team should confirm the processing operation against the flow diagram during all stages and hours of operation and amend the flow diagram where appropriate.

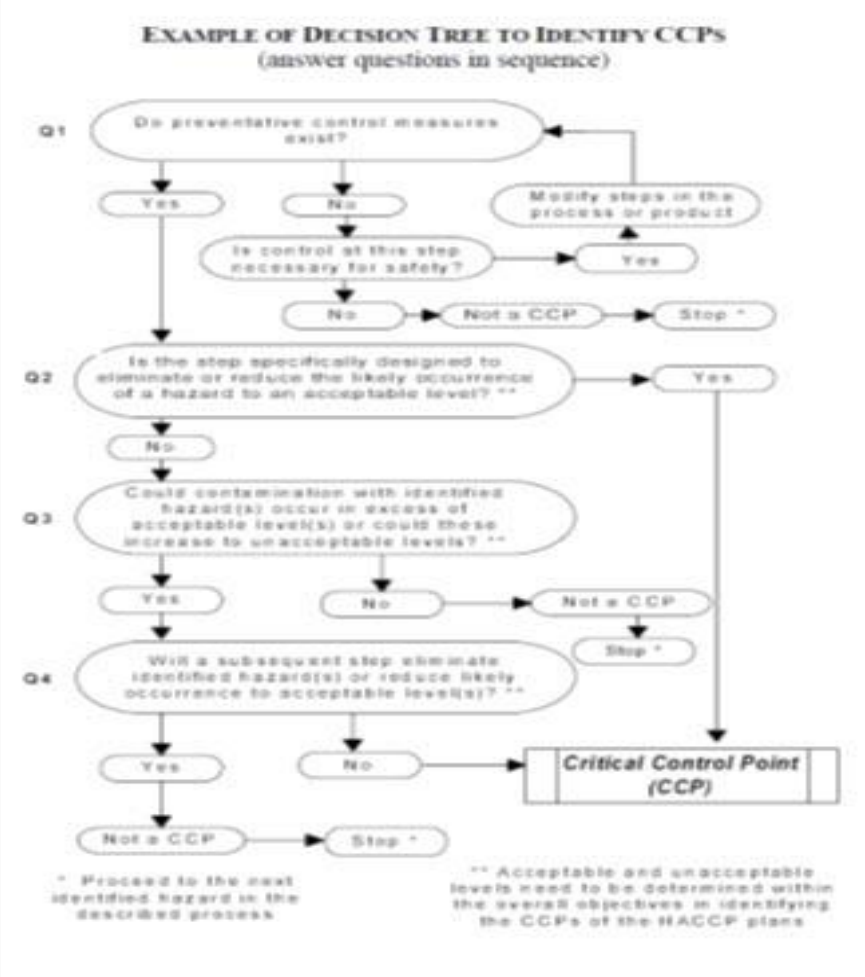
29.3.3.6. List all potential hazards associated with each step, conduct a hazard analysis and consider any measures to control identified hazards

The HACCP team should list all of the hazards that may be reasonably expected to occur at each step from primary production, processing, manufacture, and distribution until the point of consumption.

The HACCP team should conduct a hazard analysis to identify for the HACCP plan which hazards are of such a nature that their elimination or reduction to acceptable levels is essential to the production of a safe food. The team must then consider what control measures, if any, exist which can be applied for each hazard.

29.3.3.7. Determine Critical Control Points

There may be more than one CCP at which control is applied to address the same hazard. The determination of a CCP in the HACCP system can be facilitated by the application of a decision tree which indicates a logic reasoning approach. Application of a decision tree should be flexible, given whether the operation is for production, slaughter, processing, storage, distribution or other. It should be used for guidance when determining CCPs.



29.3.3.8. Establish Critical Limits for each CCP

Critical limits must be specified and validated if possible for each critical control point. In some cases more than one critical limit will be elaborated at a particular step. Criteria often used include measurements of temperature, time, moisture level, pH, Aw, available chlorine and sensory parameters such as visual appearance and texture.

29.3.3.9. Establish a Monitoring System for each CCP

Monitoring is the scheduled measurement of a CCP relative to its critical limits. The monitoring procedures must be able to detect loss of control at the CCP. Data derived from monitoring must be evaluated by a designated person with knowledge and authority to carry out corrective actions when indicated. Physical and chemical measurements are often preferred to microbiological testing because they may be done rapidly and can often indicate the microbiological control of the product. All records and documents associated with monitoring CCPs must be signed by the person doing the monitoring and by a responsible reviewing official of the company.

29.3.3.10. Establish a Corrective Actions

Specific corrective actions must be developed for each CCP in the HACCP system in order to deal with deviations when they occur. The actions must ensure that the CCP has been brought under control. Actions taken must also include proper disposition of the affected product. Deviation and product disposition procedures must be documented in the HACCP record keeping.

29.3.3.11. Establish a Verification Procedures

Verification and auditing methods, procedures and tests, including random sampling and analysis, can be used to determine if the HACCP system is working correctly. Examples of verification activities include:

- Review of the HACCP system and its records
- Review of deviations and product dispositions
- Confirmation that CCPs are kept under control

29.3.3.12. Establish a Documentation and Record Keeping

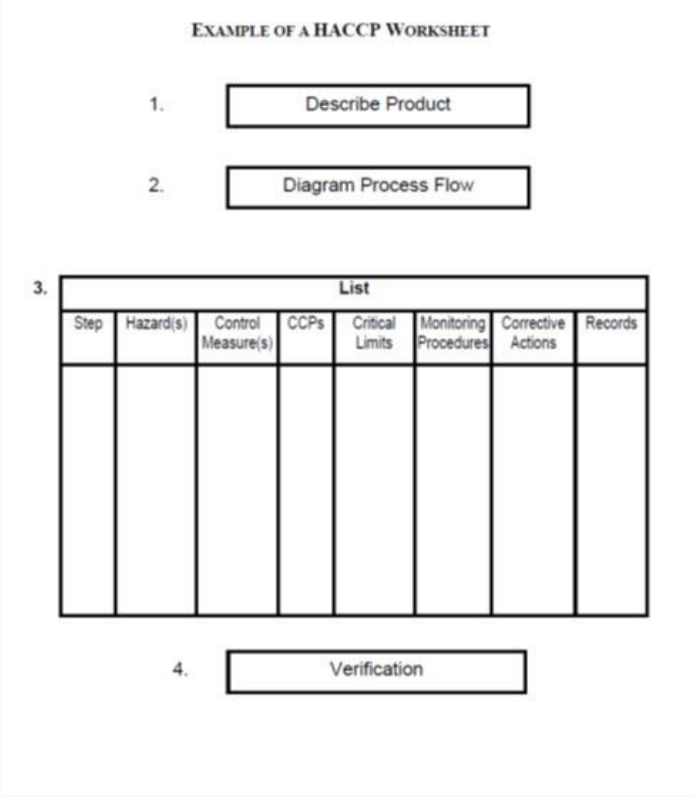
Efficient and accurate record keeping is essential to the application of a HACCP system. HACCP procedures should be documented. Documentation and record keeping should be appropriate to the nature and size of the operation.

The HACCP system is to focus control at Critical Control Points (CCP). Redesign of the operation should be considered if a hazard which must be controlled is identified but no CCPs are found. HACCP should be applied to each specific operation separately. The HACCP application should be reviewed and necessary changes should be made when any modification is made in the product, process, or any step.

29.4 Terminology

Control (verb):	To take all necessary actions to ensure and maintain compliance with criteria established in the HACCP plan.
Control Measure:	Any action and activity that can be used to prevent or eliminate a food safety hazard or reduce it to an acceptable level.
Corrective Action:	Any action to be taken when the results of monitoring at the CCP indicate a loss of control.
Critical Control Point (CCP):	A step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level.
Critical Limit:	A criterion which separates acceptability from unacceptability.
Deviation:	Failure to meet a critical limit.

HACCP:	A system which identifies, evaluates, and controls hazards which are significant for food safety.
HACCP Plan:	A document prepared in accordance with the principles of HACCP to ensure control of hazards which are significant for food safety in the segment of the food chain under consideration.
Hazard:	A biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect.
Hazard Analysis:	The process of collecting and evaluating information on hazards and conditions leading to their presence to decide which are significant for food safety and therefore should be addressed in the HACCP plan.
Monitor:	The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a CCP is under control.
Validation:	Obtaining evidence that the elements of the HACCP plan are effective.
Verification:	The application of methods, procedures, tests and other evaluations, in addition to monitoring to determine compliance with the HACCP plan.



Lesson 30. Good Manufacturing and Hygienic Practices

30.1 Introduction:

The food processing industry is one of the largest industries in India having huge potential for uplifting agricultural economy, creation of large scale processed food manufacturing and food chain facilities. Food processing covers a spectrum of products from sub-sector comprising agriculture, horticulture, plantation, animal husbandry and fisheries. Essentially, the food industry involves the commercial movement of food from field to fork. To meet the global food safety norms, good manufacturing and good hygienic practices are essential at various stages of food chain. Following guidelines are given by national and international agencies for efficient GMP and GHP practices.

30.2 Good Manufacturing Practices (GMP) & Good Hygiene Practices (GHP) for Food Businesses.

30.2.1 Primary Production

The Food establishment shall exercise control contamination of food produce / materials from air, soil, water, feedstuffs, pests, fertilizers, pesticides, veterinary drugs during production, handling, storage and transport, as appropriate. Plant and animal health are controlled so that it does not pose a threat to human health through food consumption

30.2.2 Location and Surroundings

Food establishment shall be located away from environmentally polluted areas and industrial activities which produce disagreeable or obnoxious odour, fumes, excessive soot, dust, smoke, chemical or biological emissions and pollutants which pose a serious threat of contaminating food; areas subject to flooding; areas prone to infestations of pests; and areas where wastes, either solid or liquid, cannot be removed effectively.

30.2.3 Layout and Design of Food Establishment Premises

The layout of the food establishment shall ensure a forward food preparation / manufacturing process flow such that cross-contamination from earlier steps in the process is avoided in the later steps.

30.2.3.1 Equipment

Equipment and containers that come in contact with food and used for food handling, storage, preparation, processing, packaging and serving shall be made of materials, which do not impart any toxicity to the food material.

Containers used to hold cleaning chemicals and other dangerous substances shall be identified and where appropriate, be lockable to prevent accidental contamination of food.

30.2.3.2 Facilities

Water supply

Only potable water which meets the requirements of specifications of drinking water, with appropriate facilities for its storage, distribution and temperature control, shall be used, if required as an ingredient and also for food handling, washing, processing and cooking. Water storage tanks shall be cleaned periodically and records of the same shall be maintained.

Ice and steam

Ice and steam used in direct contact with food shall be made from potable water and complying with requirements specified. Ice and steam shall be produced, handled and stored to protect them from any contamination.

Drainage and waste disposal

The disposal of sewage and effluents (solid, liquid and gas) shall be in conformity with requirements of Environment Pollution Control Board. Adequate drainage, waste disposal systems and facilities shall be provided. They shall be designed and constructed so that the risk of contaminating food or the potable water supply is eliminated. Waste storage shall be located in such place that it does not contaminate the food process, storage areas, the environment inside and outside the food establishment. Waste shall be kept in covered containers and shall not be allowed to accumulate in food handling, food storage, and other working areas.

Personnel facilities and toilets

Personnel facilities shall include adequate means of hygienically washing and drying hands, including wash basins and a supply of hot and /or cold water; separate lavatories of appropriate hygienic design for males and females; and adequate changing facilities for personnel. Such facilities shall be suitably located so that they do not open directly into food process areas. Rest and refreshments rooms shall be separate from food process and service areas. These areas shall not lead directly to food production, service and storage areas.

Air quality and ventilation

Ventilation systems, natural or mechanical, including air filters, wherever required, shall be designed and constructed so that air does not flow from contaminated areas to clean areas; minimize air-borne contamination of food; control odours; control ambient temperatures and humidity, where necessary, to ensure the safety and suitability of food.

Lighting

Adequate natural or artificial lighting shall be provided to enable the undertaking to operate in a hygienic manner. Lighting fixtures should, where appropriate, be protected to ensure that food is not contaminated by breakages.

30.2.4 Food Operations and Controls

30.2.4.1 Procurement of raw materials

No raw material or ingredient shall be accepted by an establishment if it is known to contain parasites, undesirable micro-organisms, pesticides, veterinary drugs or toxic, decomposed or extraneous substances, which would not be reduced to an acceptable level by normal sorting and/or processing.

30.2.4.2 Storage of raw materials and food

Food storage facilities shall be designed and constructed to enable food to be effectively protected from contamination during storage; permit adequate maintenance and cleaning; and avoid pest access and harbourage.

30.2.4.3 Food Processing ,Packaging and Distribution , Temperature control

The Food establishment shall develop and maintain system to ensure that time and temperature is controlled effectively where it is critical to the safety and suitability of food. Such controls shall include time and temperature of receiving, processing, cooking, cooling, storage, packaging, distribution and food service up to the consumer, as applicable.

Precautions against contaminants and cross-contamination

Systems shall be in place to prevent contamination of food materials and foods by physical, chemical and microbiological contaminants. Microbiological and chemical analysis, suitable detection devices for foreign objects shall be used, where necessary. Access to food preparation / processing / manufacturing facility shall be controlled. Further, staff from raw processing areas shall not be allowed to go to forward process areas.

Food Packaging

Packaging materials shall provide adequate protection for processed food products to prevent contamination, damage and accommodate proper labelling. Packaging materials or gases where used shall be non-toxic and not pose a threat to the safety and suitability of food under the specified conditions of storage and use.

Food Distribution / Service

Processed, packaged / ready-to-eat food shall be adequately protected during transport and service. Temperatures and humidity necessary for sustaining food safety and quality shall be maintained during transport and service. The conveyances /containers shall be designed, constructed and maintained such that they can effectively maintain the requisite temperature, humidity, atmosphere and other conditions necessary to protect food.

30.2.5 Management and Supervision

The Food establishment shall ensure that managers and supervisors have appropriate qualifications, adequate knowledge and skills of food hygiene principles and practices to be able to ensure food safety and quality of its products, judge food hazards, take appropriate

preventive and corrective action, and ensure that effective monitoring and supervision takes place.

30.2.6 Documentation and Records

Appropriate records of food processing / preparation, production / cooking, storage, distribution, service, food quality assurance, cleaning and sanitation, pest control and product recall shall be kept and retained for a period that exceeds one year or the shelf-life of the product, which ever is more.

30.2.7 Traceability and Food Products Recall

The Food Business shall ensure that effective traceability procedures are in place from raw material to finished product and to the consumer so as to deal with any food safety hazard and to enable the complete, rapid recall of any implicated lot of the food product from the market.

30.3. 3 Sanitation and Maintenance of Establishment Premises

30.3. 3.1 Cleaning and maintenance

Food premises shall be kept clean and where possible dry, maintained in good repair and condition and have an adequate supply of hot and cold water. Work surfaces and surfaces of equipment in contact with food shall be maintained in a sound condition, cleaned and, where necessary, disinfected at frequent intervals.

30.3. 3.2 Pest Control Systems

Food establishment shall be kept in good repair and condition to prevent pest access and to eliminate potential breeding sites. Holes, drains and other places where pests are likely to gain access shall be kept sealed or fitted with mesh / grills / claddings as required. Animals and pets shall not be allowed into the food establishment premises. Records of pesticides / insecticides used shall be maintained.

30.3. 3.3 Personal Hygiene

Health Status

Personnel known, or suspected, to be suffering from, or to be a carrier of a disease or illness likely to be transmitted through food, shall not be allowed to enter any food handling area if there is a likelihood of their contaminating food. The Food establishment shall develop system whereby any person so affected shall immediately report illness or symptoms of illness to the management. Medical examination of a food handlers shall be carried out if clinically or epidemiologically indicated.

Personal Cleanliness

Food handlers shall maintain a high degree of personal cleanliness. The Food establishment shall provide to all food handlers adequate and suitable, clean protective clothing, head

covering and footwear. The Food operators shall ensure that the food handlers at work wear only clean protective clothes, head covering and footwear every day.

Personal Behaviour

Food handlers engaged in food handling activities shall refrain from smoking; spitting; chewing or eating; sneezing or coughing over unprotected food and eating in food preparation and food service areas Food handlers shall not wear any personal effects such as rings, bangles, jewellery, watches, pins and other items that pose a threat to the safety and suitability of food.

Visitors

The Food establishment shall ensure that visitors to its food manufacturing, cooking, preparation, storage or handling areas should, where appropriate, wear protective clothing and adhere to the other personal hygiene provisions in this section.

30.3.4 Product Information and Consumer Awareness

All packaged food products shall carry a label and requisite information as specified under regulatory bodies so as to ensure that adequate and accessible information is available to the next person in the food chain to enable them to handle, store, process, prepare and display the food products safely and correctly and that the lot or batch can be easily traced and recalled if necessary.

30.3. 5 Training

The Food establishment shall ensure that all food handlers are aware of their role and responsibility in protecting food from contamination or deterioration. Food handlers shall have the necessary knowledge and skills relevant to the food processed / manufactured, packed, stored and served so as to ensure the food safety and food quality.

Lesson 31. Food Safety Management System-Iso 22000:2005

31.1 Introduction:

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is carried out through ISO technical committees.

Food safety is related to the presence of food-borne hazards in food at the point of consumption. As the food safety hazards can occur at any stage of the food chain, adequate control throughout the food chain is essential. Thus, food safety is ensured through the combined efforts of all the parties participating in the food chain.

The International Standard ISO 22000:2005 specifies the requirements for a food safety management system that combines the following generally recognized key elements to ensure food safety along the food chain, up to the point of final consumption:

The International Standard integrates the principles of the Hazard Analysis and Critical Control Point (HACCP) system and application steps developed by the Codex Alimentarius Commission. By means of auditable requirements, it combines the HACCP plan with prerequisite programmes (PRPs). Hazard analysis is the key to an effective food safety management system, since conducting a hazard analysis assists in organizing the knowledge required to establish an effective combination of control measures.

Since ISO 22000 is a generic food safety management standard, it can be used by any organization directly or indirectly involved in the food chain. It applies to all organizations in the food chain. It doesn't matter how complex the organization is or what size it is, ISO 22000 can help ensure the safety of its food products.

The food chain consists of the entire sequence of stages and operations involved in the creation and consumption of food products. This includes every step from initial production to final consumption. More precisely, it includes the production, processing, distribution, storage, and handling of all food and food ingredients.

The food chain also includes organizations that do not directly handle food. These include organizations that produce feed for animals. It also includes organizations that produce materials that will eventually come into contact with food or food ingredients.

31.1.1 Advantages of ISO 22000: 2005

ISO 22000 will help you to achieve the following objectives:

a) To establish a food safety management system (FSMS).

b) To ensure that products do not cause adverse health effects.

c) To demonstrate compliance with external safety requirements.

d) To evaluate customers' food safety requirements.

e) To provide safe products and enhance customer satisfaction.

f) To export food products and penetrate international markets.

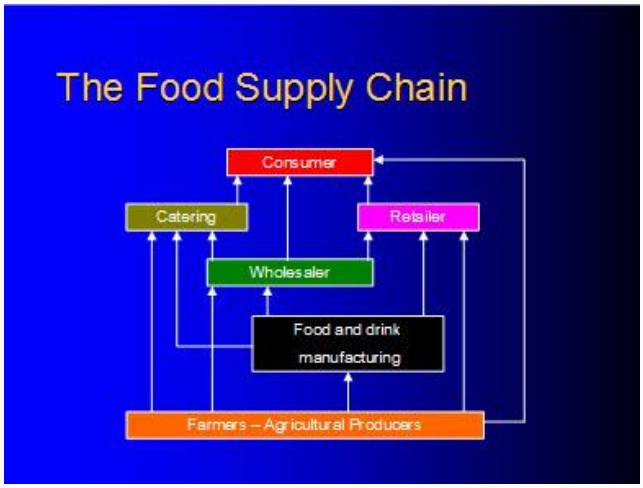
g) To communicate safety issues throughout the food chain.

h) To ensure compliance with company's food safety policy

31.2 Key Elements of ISO 22000:

- **Interactive communication**: Communication is essential along the food chain to ensure all relevant food safety hazards are identified and adequately controlled at each step within the food supply chain. This implies for both upstream and down steam in organizations.
- **System Management**: The most effective food safety systems are to be designed, operated within the framework of structured management system then and incorporated into the overall management activities of the organization.
- **Prerequisite Program**: The prerequisite programmes are classified into 2 subcategories. The Infrastructure and Maintenance programs which cover permanent features in food safety. The Operational prerequisite programs are designed to reduce the risk of hazards in the product or processing environment.
- **HACCP Principles**: The HACCP plan is used to manage the critical control points determined to eliminate, prevent or reduce specific food safety hazard from the product, as determined during hazard analysis.

Interactive Communication



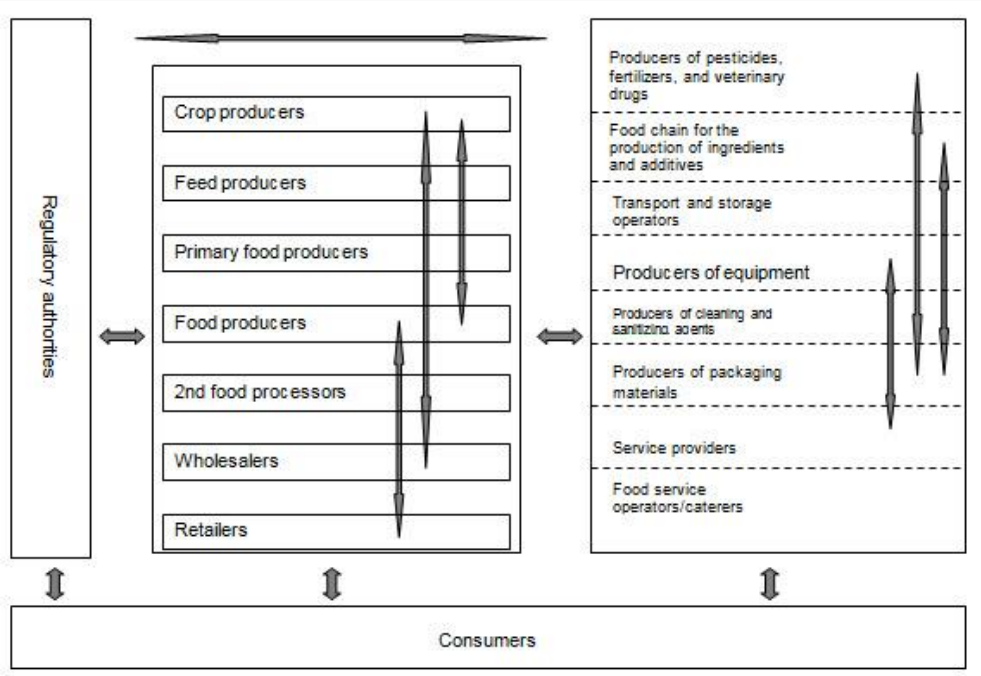
ISO 22000 requires that interactive communication (i.e. proactive, open, continuous

dialogue with the stake holders to ensure that:

a) all relevant food safety hazards are identified and adequately controlled at each step within the food chain through communication to all parties in the food chain.

b) Communication with customers and suppliers, based on the information

generated through systematic hazard analysis is maintained to establish customer and supplier requirements in terms of feasibility, need and impact on the end product.



31.3 Prerequisite Programme

Prerequisite programs (PRPs) are the conditions that must be established throughout the food chain and the activities and practices that must be performed in order to establish and maintain a hygienic environment. PRPs are also referred to as good hygienic practices, good agricultural practices, good production practices, good manufacturing practices, good distribution practices, and good trading practices.

Operational prerequisite programs (OPRPs) are prerequisite programs (PRPs) that are essential. They are essential because a hazard analysis has shown that they are necessary in order to control specific food safety hazards.

31.4HACCP Principles

ISO 22000 integrates the HACCP 7 principles developed by the Codex Alimentarius Commission and dynamically combine it with PRPs necessary to control and reduce any food safety hazards identified for the end products delivered to the next step in the food chain to acceptable levels.

HACCP PRINCIPLES

1. Conduct a hazard analysis;

2. Determine the Critical Control Points (CCP's);

3. Establish critical limit(s);

4. Establish a system to monitor control of the CCP;

5. Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control;

6. Establish procedures for verification to confirm that the HACCP system is working effectively; and

7. Establish documentation concerning all procedures and records appropriate to these principles and their applications

31.5 ISO 22000 Food Safety Management System

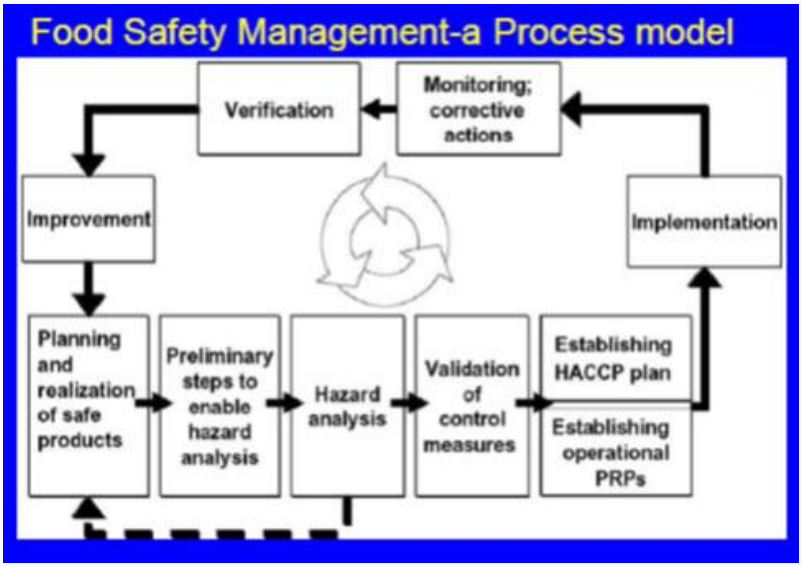
FSMS is a set of interrelated to establish policy and objectives and to achieve those objectives used to direct and control an organization with regard to food safety.

An effective FSMS should be well-established, documented, implemented, maintained and continually improved / updated and has its products / services that actually meet its intended usage and are safe and is proactive and innovative, scientific, risk-avoiding and prevention-oriented

Model of the ISO 22000

The ISO 22000 model is a continuous improvement process-based FSMS with systematic approach to developing, planning, validating, establishing, implementing, monitoring, verifying and improving the FSMS.

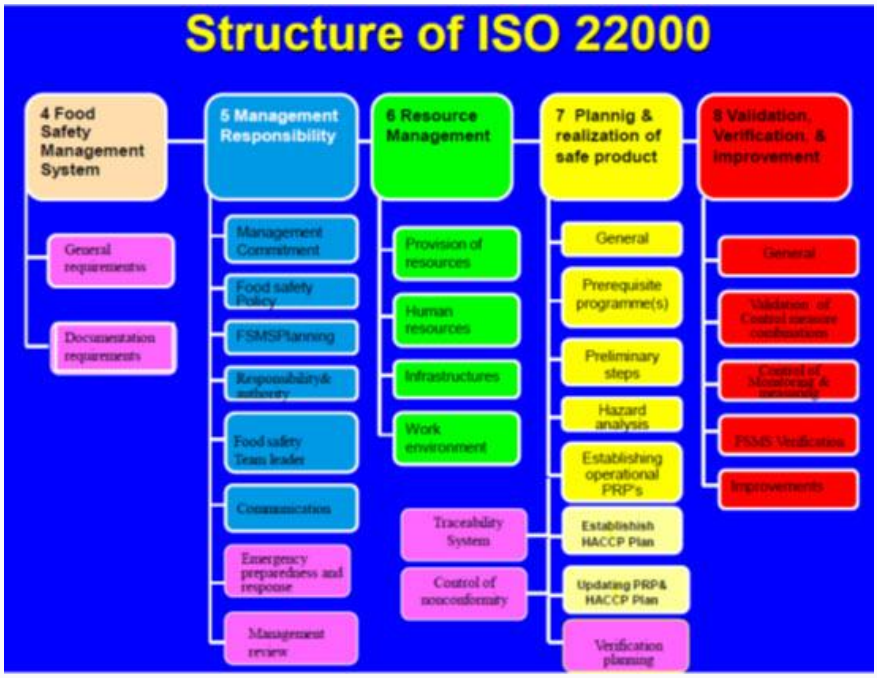
Fig Food Safety Management-a Process model



Key Requirements of the ISO 22000: 2005

The ISO 22000 standard is a management system standard that sets requirements for results without setting requirements for resources. This standard sets out specific requirements for the five areas shown in the fig.08).

Clause wise requirements of ISO 22000



Implementation model for food safety control measures

ISO 22000 requires that organizations to plan and develop processes needed for realization of safe product, implement, operate and ensure effectiveness of planned activities. This includes PRP's, Operational PRP's and/or HACCP plan.The organization uses a dynamic and systematic process approach to develop the food safety management system. This is achieved through effective development, implementation, monitoring of planned activities, maintenance and verification of control measures, updating the food processes and process environment, and through appropriate actions in the event of the production of nonconformities.

ISO 22000 groups control measures into three groups(See Fig 10):

i) Prerequisite programmes (PRPs) that manage the basic conditions and activities; the PRPs are not selected for the purpose of controlling specific identified hazards but for the purpose of maintaining a hygienic production, processing and/or handling environment;

ii) Operational prerequisite programmes (OPRPs) that manage those control measures that the hazard analysis identifies as necessary to control identified hazards to acceptable levels, and which are not otherwise managed by the HACCP plan; and

iii) HACCP plan to manage those control measures that the hazard analysis identifies as necessary to control identified hazards to acceptable levels, and which are applied at critical control points (CCP's).

FOOD SAFETY MANAGENT SYSTEM PLAN

CONSTITUTION OF A MULTIDISCIPLINARY FOOD SAFETY TEAM

Gathering information for prerequisites

Gathering information for hazard analysis

1. Recommended International Code of Practice General Principles of FoodHygiene(Codex)

1. Product characteristics

a) Raw materials, ingredients and product-contact materials

b) Characteristics of end products

2. Industry specific guidelines /codes

2. Intended use

3. Statutory & regulatory requirements in that specific area

3. Flow diagrams, onsite verification.

Process steps and control measures

ISO 22000 Certification

ISO 22000 is designed to be used for certification/registration purposes. In other words, once company has established a FSMS that meets ISO's requirements, it can apply for certification to a certification agency to audit the system. If certification agency find after audit that the implemented system meets the ISO 22000 requirements, it will issue an official certificate that states that company's FSMS meets the food safety requirements.

However, it is not mandatory to go for certification. A company can be in compliance without being formally certified by an accredited certification agency. It can self assess the system implemented and declare ISO 22000 compliant company. But company customers and business partners are not likely to accept that the company has an effective FSMS if it is not certified.

Benefits of ISO 22000 for users

Organizations implementing the standard will benefit from:

- Organized and targeted communication among trade partners ;
- Optimization of resources (internally and along the food chain);
- Improved documentation;
- Better planning, less post process verification;

- More efficient and dynamic control of food safety hazards;
- All control measures subjected to hazard analysis;
- Systematic management of prerequisite programmes;
- Wide application because it is focused on end results;
- Valid basis for taking decisions;
- Increased due diligence;
- Control focused on what is necessary, and
- Saving resources by reducing overlapping system audits

Lesson 32. Sanitation in food industry

Lesson 32.Cleaning And Sanitizing

32.0 CLEANING AND SANITIZING

Cleaning and sanitizing procedures must be part of the standard operating procedures that make up your food safety program. Improperly cleaned and sanitized surfaces allow harmful microorganisms to be transferred from one food to other foods.

32.1 Cleaning

Cleaning is the process of removing food and other types of soil from a surface, such as a dish, glass, or cutting board. Cleaning is done with a cleaning agent that removes food, soil, or other substances. The right cleaning agent must be selected because not all cleaning agents can be used on food-contact surfaces. (A food-contact surface is the surface of equipment or utensil that food normally comes into contact.) For example, glass cleaners, some metal cleaners, and most bathroom cleaners cannot be used because they might leave an unsafe residue on the food contact surface. The label should indicate if the product can be used on a food-contact surface.The right cleaning agent must also be selected to make cleaning easy. Cleaning agents are divided into four categories:

- **Detergents –** Use detergents to routinely wash tableware, surfaces, and equipment. Detergents can penetrate soil quickly and soften it. Examples include dishwashing detergent and automatic dishwasher detergents.
- **Solvent cleaners –** Use periodically on surfaces where grease has burned on. Solvent cleaners are often called degreasers.
- **Acid cleaners** -- Use periodically on mineral deposits and other soils that detergents cannot remove. These cleaners are often used to remove scale in warewashing machines and steam tables.
- **Abrasive cleaners** -- Use these cleaners to remove heavy accumulations of soil that are difficult to remove with detergents. Some abrasive cleaners also disinfect.

Clean food-contact surfaces that are used to prepare potentially hazardous foods as needed throughout the day but no less than every four hours. If they are not properly cleaned, food that comes into contact with these surfaces could become contaminated.

32.2 Sanitizing

Sanitizing is done using heat, radiation, or chemicals. Heat and chemicals are commonly used as a method for sanitizing in a restaurant; radiation rarely is. The item to be sanitized must first be washed properly before it can be properly sanitized. Some chemical sanitizers, such as chlorine and iodine, react with food and soil and so will be less effective on a surface that has not been properly cleaned.

32.2.1 Sanitizing Methods

- **Heat.** There are three methods of using heat to sanitize surfaces – steam, hot water, and hot air. Hot water is the most common method used in restaurants. If hot water is used in the third compartment of a three-compartment sink, it must be at least 171oF (77oC). If a high-temperature warewashing machine is used to sanitize cleaned dishes, the final sanitizing rinse must be at least 180oF (82oC). For stationary rack, single temperature machines, it must be at least 165oF (74oC). Cleaned items must be exposed to these temperatures for at least 30 seconds.
- **Chemicals.** Chemicals that are approved sanitizers are chlorine, iodine, and quaternary ammonium.

Chemical Sanitizers

Different factors influence the effectiveness of chemical sanitizers. The three factors that must be considered are:

- **Concentration** -- The presence of too little sanitizer will result in an inadequate reduction of harmful microorganisms. Too much can be toxic.
- **Temperature** -- Generally chemical sanitizers work best in water that is between 55oF (13oC) and 120oF (49oC).
- **Contact time** -- In order for the sanitizer to kill harmful microorganisms, the cleaned item must be in contact with the sanitizer (either heat or approved chemical) for the recommended length of time.

32.2.2 Sanitizer Testing

Every restaurant must have the appropriate testing kit to measure chemical sanitizer concentrations. To accurately test the strength of a sanitizing solution, one must first determine which chemical is being used -- chlorine, iodine, or quaternary ammonium. Test kits are not interchangeable so check with your chemical supplier to be certain that you are using the correct kit. The appropriate test kit must then be used throughout the day to measure chemical sanitizer concentrations.

32.2.3Machine Warewashing

Most tableware, utensils, and other equipment can be cleaned and sanitized in a warewashing machine. Warewashing machines sanitize by using either hot water or a chemical sanitizing solution.

- Check the machine for cleanliness at least once a day.
- Make sure all detergent and sanitizer dispensers are properly filled.
- Scrape, rinse, or soak items before loading them into the machine.
- Load racks correctly and use racks designed for the items being washed.

- Check temperatures and pressure at least once a day.
- Check each rack as it comes out of the machine for soiled items.
- Air-dry all items.
- Keep your warewashing machine in good repair.

32.2.4 Cleaning and Sanitizing in a Three-Compartment Sink

1. Rinse, scrape, or soak all items before washing them in a three-compartment sink.

2. Wash items in the first sink in a detergent solution that is at least 110oF (43oC).

3. Immerse or spray rinse items in the second sink using water that is at least 110oF (43oC).

4. Immerse items in the third sink in hot water or a properly prepared chemical sanitizing solution.

5. Air-dry all cleaned and sanitized items before storing them.

32.2.5 Cleaning In Place Equipment

1. Turn off and unplug equipment before cleaning.

2. Remove food and soil from under and around equipment.

3. Remove detachable parts and manually wash, rinse, and sanitize them or run through awarewashing machine.

4. Wash and rinse all other food-contact surfaces that you cannot remove, then wipe or spray them with a properly prepared chemical sanitizing solution.

5. Keep cloths used for food-contact and non-food-contact surfaces in separate properly marked containers of sanitizing solution.

6. Air-dry all parts, then reassemble.

7. Resanitize food-contact surfaces handled during reassembly.

32.3. Storing Utensils, Tableware, and Equipment

Improperly storing cleaned and sanitized equipment, utensils, and linens could allow them to become contaminated before they are used again. Contamination can be caused by moisture from flooding, drips, or splash. Food debris, toxic materials, litter, dust, and other substances might also cause it.

32.3.1. Using Chemicals

Separate chemicals from food, equipment, utensils, linens, and single-use items. If chemicals are stored directly above or next to any of these items, they could spill onto the item and

contaminate it. Only buy chemicals approved for use in a restaurant or food establishment. Store chemicals in their original container away from food storage and food preparation areas. If a chemical is transferred to a new container, label the container with the chemical name, manufacturer's name and address, and potential hazards of the chemical.Material Safety Data Sheets (MSDS) are one way that chemical manufacturers provide hazard information to users, such as foodservice workers.

32.4. Sanitary Facility Design

A general understanding of process and facility sanitation is important for the successful manufacturing of food products. When a new facility or process is designed, sanitation standards can be built-in. Good sanitation practices will improve product quality, minimize maintenance efforts, please inspectors and delight clients.

32.4.1 Building Exterior

Design and construct the establishment so that the internal environment is protected from external contaminants. Ensure the establishment (e.g. walls, roof) is of a sound construction and is maintained in good repair (e.g. no evidence of damage). Take steps to prevent or minimize the entrance and harbourage of pests, insects and contaminants (e.g. no holes or unprotected openings, weather stripping on exterior doors). Cover air intakes and openings or equip them with appropriate screens.

32.4.2.Cross-contamination Control

Separate operations that have the potential to cause cross contamination by physical partition, by work area designation, by designated equipment or by other effective means.

32.4.3. Personnel Facilities

Washrooms, change rooms and lunch and break areas(s) are provided and maintained to ensure that personal hygiene can be maintained to protect the safety and suitability of food. Washrooms are equipped with adequate lighting and an adequate number of flush toilets and hand-washing stations; are free of condensation, excess moisture or odours; and are designed to prevent or minimize contamination.

32.4.4. Internal Structures and Fittings

Internal rooms, structures and fittings are suitable and are maintained for the operations taking place within. Floors, walls, ceilings, overheads, doors, windows, stairs and other structures are cleanable, properly maintained, exhibit no evidence of degradation that would cause contamination and are suitable for the activities in each area. The condition of internal rooms, structures and fittings protects the safety and suitability of food.

32.4.5. Lighting:

Ensure lighting levels are adequate to properly complete the tasks performed in each area (e.g. product inspection, sanitation, maintenance, visual examination of rooms). Ensure light

sources do not alter the natural colour or appearance of food where food assessments are performed.

32.4.6. Lighting Fixtures:

Light bulbs and lighting fixtures in areas of exposed food, ingredients, packaging materials or food contact surfaces are equipped with shatterproof bulbs or breakage shields to prevent or minimize contamination of food if breakage occurs.

32.4.7.Air Quality and Ventilation

The establishment has and uses ventilation to keep rooms free of excessive heat, humidity, steam, vapours, smoke, particulates and condensation. Ventilation openings have screens or filters that can be easily cleaned or changed. Ventilation systems do not permit air to flow from contaminated areas to clean areas.

32.4.8. Drainage and Sewage Systems

The establishment has and uses drainage and liquid waste disposal systems that are maintained to protect the safety and suitability of food and the potable water supply. Drainage and liquid disposal systems are equipped with back-flow preventers and no cross-connections exist with drainage or waste systems and potable water lines. Pooling of water and liquids is prevented or addressed.

32.4.9. Equipment Design, Construction and Installation

Equipment and utensils that may impact on food safety are constructed of nontoxic materials, exhibit no signs of degradation that could contaminate food, and are easy to clean, sanitize and maintain. Equipment design, location, construction and installation promote effective assessment, maintenance, and cleaning and sanitizing activities. Adequate equipment or facilities are available for the activities conducted to protect the safety and suitability of food. Equipment functions in accordance with its intended use.

32.4.10. Waste Containers and Utensils

Containers and utensils used for collection and holding of waste and inedible or hazardous substances are clearly identified, function properly, exhibit no signs of degradation that could lead to the contamination of food and can be cleaned and maintained. Containers and utensils are cleaned prior to entering food processing, handling or storage areas.

32.5. Pest Control and Sanitation

Control of pests and use of pesticides are particularly critical in places where food is prepared, served or packaged. Most industries and institutions (such as schools and hospitals) are inspected for sanitation by one or more state, federal or local agencies. To assure food has been prepared, packed and held under sanitary conditions, The Federal Food, Drug and Cosmetic Act of the Food and Drug Administration (FDA) states the following: “Sec. 402. A food shall be deemed to be adulterated ... (a) (3) if it consists in whole or in part of any filthy, putrid, or decomposed substance, or if it is otherwise unfit for food; or

(4) if it has been prepared, packed, or held under unsanitary conditions whereby it may have become contaminated with filth, or whereby it may have been rendered injurious to health; ..."

32.5.1. Importance of Pest Control

Pests are attracted to food premises since they are an ideal habitat in which to live and reproduce. Since pests pose a significant health risk, pest control is extremely important. Inadequate control can lead to pest infestation and serious consequences to consumer health.Besides potential health risks, pest infestation will inevitably lead to significant waste and, therefore, commercial loss. The loss caused by pest infestation of raw materials or the finished product can be large.

32.5.2.Hazards Posed by Pests

Food products are at a high risk of contamination if control measures are not in place. Pests are carriers of food poisoning microorganisms and viruses that pose major hazards to consumer health. In addition to the contamination by microorganisms and viruses, pests can also contaminate food with

- hair
- fur
- droppings/urine
- eggs
- dead bodies.

Certain pests, rodents in particular, can also cause significant damage to a factory by, for example, chewing through electrical wires and causing fires.

32.5.3Types of Pests

There are many different types of pests that can pose a risk to human health or the commercial viability of your company. These include

- rats
- mice
- insects – cockroaches, flies, ants
- stored product pests – larder beetles, weevils, flour moths
- reptiles – lizards
- birds

32.5.4. Habitats of Pests

Pests require certain conditions to survive and reproduce:

- security
- shelter
- food
- water

As a food safety manager, you must understand what conditions allow pests to survive and reproduce. If you aren't fully aware of what these circumstances are, you business will suffer contamination and loss that may make the business no longer sustainable.

32.5.5.Prevention

Once pests have entered your factory, it is difficult to control and totally eliminate them, particularly if there is an infestation. You must prevent their invading your factory or facility!

Preventing any and all ingression of pests will be commercially more cost-effective than continually eliminating pest infestation.

The control of prevention of ingression of pests requires

- proofing the premises
- monitoring for signs of infestation
- practicing good hygiene.

32.6. Conditions to Minimise the Risk of Pest Ingression

Effective proofing of your factory premises is the preferred method for control of pests. Doors and windows pose the highest risk of ingression; thus a door and window closure policy should be introduced. Other methods may need to be considered: fine mesh screens for windows and doors, self-closing mechanisms on doors, and plastic curtains on internal and external door openings. Rodents can enter a factory through the smallest of openings, so any gap under doors should be covered with a metal plate. To prevent flying insects, reptiles, or birds, any holes or openings in the fabrication of the factory must be filled with mortar or covered with metal/plastic sheets or mesh.

32.6.1. Awareness of Infestation

As the food safety manager, you must make sure all staff members are aware of signs of pest infestation and possible entry points. They should also be aware of the importance of reporting the presence of any possible infestation right away. Signs to look for are

- live animals
- dead animals
- droppings
- damaged packaging
- smell
- smears/discolouration of walls
- larvae/pupae
- eggs
- webbing
- piles of debris
- holes in fabrication.

32.6.2. Good Hygiene Practices

Denying pests food and shelter in your facility is another way of preventing infestation. This can be achieved by practicing good hygiene practices, effective cleaning, and proper waste disposal.

By using good hygiene practices, your staff is removing the food and shelter pests need to survive. All staff should be aware of these good hygiene practices:

- Keep the factory clean.
- Have proper waste control.
- Be sure food in preparation areas is kept covered.
- Clean spillages quickly and effectively.
- Be sure no food is left outside the facility.
- Keep food stored off the floor and away from walls.
- Be sure raw materials are checked upon intake and during storage.
- Be sure food is stored in pest-proof containers.

- Keep drains clean and screened.
- Allow no external shelter.

32.6.3. Control of Pests

Prevention methods should protect you from the ingression of pests; however it is a good practice to ensure there are control measures in place to minimise the risk of pest infestation in your factory.

As a food safety manager, you have a responsibility to ensure control measures are in place.

There are two types of pest control:

- Physical
- Chemical

Both types are designed to control specific types of pests, but by their very nature they should be correctly used since they themselves could pose a risk to your product or staff.

Physical Control

Physical means of control is usually the preferred option. By their very nature, however, physical means of control are not always 100% effective, a point that should be very seriously considered. In the event of a significant infestation, physical controls cannot cope with the numbers of pests, so alternative methods of elimination must be considered.

Typical physical control methods include

- electric fly killers
- rodent traps
- sticky fly strips
- curtains
- bird screens
- pheromone traps.

Since several of these methods will actually kill pests, you should consider the location and placement of control mechanisms such as electric fly killers and sticky fly traps in order to avoid possible product contamination.

Chemical Control

Chemical control measures are much more effective than physical control methods: however, chemical substances do pose possible risks to staff, so their use should be frequently and carefully controlled and monitored. Chemical substances also pose a risk to food contamination, so they should also be used only under controlled and monitored conditions.

Because of the risks involved, it is good practice to employ a professional to carry out chemical pest control.

Chemical controls include

- rodenticides
- insecticides
- fumigates.

Conclusion

Proper sanitation practices will contribute to improved product quality and wholesomeness and the "bottom line" of the companyAll sanitation practices must be individually developed to suit the particular facility and process of concern. Maintenance and development of sanitary conditions are an ongoing process, to be continually evaluated an improved.

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