

PROTECTED CULTIVATION AND POST HARVEST TECHNOLOGY (ASAE3204)

ENGINEERING PROPERTIES-
(Physical And Thermal Properties)

Physical Characteristics

1. Size
2. Shape
3. Weight
4. Volume
5. Density
6. Porosity
7. Specific Gravity
8. Surface area

APPLICATION

- ✓ In design of specific machine or analysis of product behaviour during handling and processing operations.
- ✓ Separation of seeds and grains from undesirable material.
- ✓ Fruits and vegetables are usually graded depending on size, shape, and density. Impurities in food materials are separated by density differences between impurities and foods.
- ✓ Conveying of solid materials (density, size, shape).

- ✓ Knowledge of the bulk density of food materials is necessary to estimate floor space during storage and transportation.
- ✓ Sorting, grading and for capacity determination of machines and during storage.
- ✓ When mixing, transportation, storing and packaging particulate matter, it is important to know the properties of bulk material

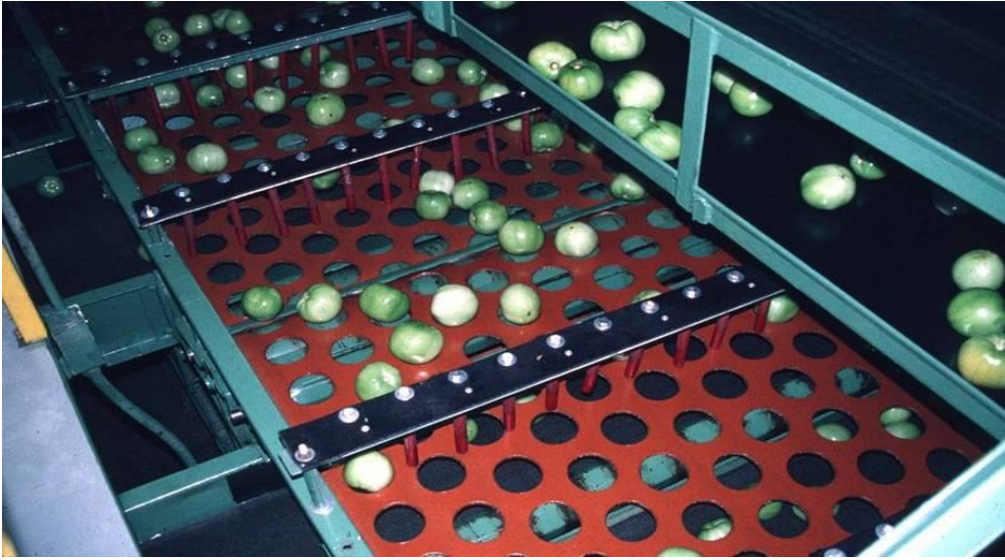


Fig1. shows a sorting machine that separates on the basis of shape and size.



Fig2. shows a cartoon that is used for storage and transportation

SIZE

- ✓ It relates to dimension of the commodity.
- ✓ It is used in screening solids to separate foreign materials, grading and sorting of food materials.
- ✓ It helps in assigning market and price differentials of large and small produce, to match consumer preferences and to allow pattern packing
- ✓ Mandatory for modern or on-line fruit/ vegetables/ grain/spices density sorting, for which two size-related parameters, volume and weight, are required.

Methods of measurement

- 1. Projected method:** Photographic enlarger
- 2. Micrometer method:** Micrometer and slide calipers
- 3. Electronic devices:** Image analysis (Precise method)

- ✓ The size of spherical particles like peas is easily defined by a **single characteristic** such as its diameter.
- ✓ The size of non-spherical objects like wheat kernels, pears may be described by **multiple length** measurements.
- ✓ SI units for particle size are micrometers (or microns) or millimeters depending on the size range
- ✓ For a particulate material to be considered powder, its **approximate median size should be less than 1 mm.**

SHAPE

- **Shape** describes the object in terms of a geometrical body.
- The shape of a food material is usually expressed in:
 - ✓ **Roundness**
 - ✓ **Sphericity**
 - ✓ **Aspect ratio**
 - ✓ **Ellipsoid ratio and**
 - ✓ **Slenderness ratio**

➤ **Roundness** is a measure of the sharpness of the corners of the solid.

- **Roundness** = A_p/A_c

- where: A_p = largest projected area of object in natural rest position
- A_c = area of smallest circumscribing circle

➤ **Sphericity** expresses the characteristic shape of a solid object relative to that of a sphere of the same volume .

Sphericity = D_e/D_c

- **Sphericity** = $(V_o / V_c)^{1/3} = \{(lwt)^{1/3} / 1\}$ (For triaxial Ellipsoid)
i.e. Ratio of Geometric mean diameter to major diameter
- V_o = Volume of object
- V_c = Volume of smallest circumscribed sphere

where: D_e = diameter of a sphere of the same volume as the object

D_c = diameter of smallest circumscribed circle

➤ **Slenderness ratio** = Ratio of length of rice to width of rice. usually used for grading of rice.

➤ **Aspect ratio** = The **aspect ratio** of a geometric shape is the ratio of its sizes in different dimensions.

➤ **Ellipsoid ratio** = *Major diameter : minor diameter*

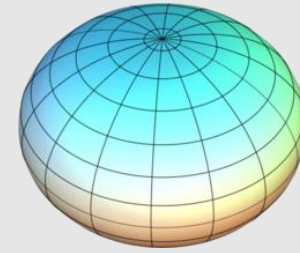
➤ **Prolate spheroid** which is formed when an ellipse rotates about its major axis.

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

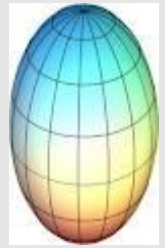
➤ **Oblate spheroid** is formed when an ellipse rotates about its minor axis.

- An oblate spheroid is a rotationally symmetric ellipsoid having a polar axis shorter than the diameter of the equatorial circle **e.g. Orange, pumpkin, lentil (masur dal)**

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



Oblate



Prolate



VOLUME AND SURFACE AREA OF DIFFERENT SHAPE

Sphere

$$V = \frac{4}{3}\pi r^3 \quad \text{and} \quad A = 4\pi r^2$$

Cylinder

$$V = \pi r^2 L \quad \text{and} \quad A = 2\pi r^2 + 2\pi rL$$

Cube

$$V = a^3 \quad \text{and} \quad A = 6a^2$$

Brick

$$V = abc \quad \text{and} \quad A = 2(ab + bc + ca)$$

Prolate spheroid

$$V = \frac{4}{3}(\pi ab^2) \quad \text{and} \quad A = 2\pi b^2 + \frac{2\pi ab}{e} \sin^{-1}e$$

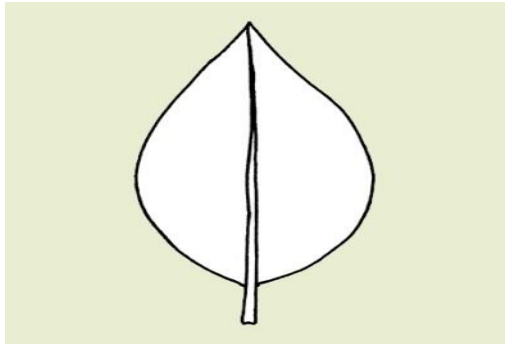
Oblate spheroid

$$V = \frac{4}{3}(\pi a^2 b) \quad \text{and} \quad A = 2\pi a^2 + \frac{\pi b^2}{e} \ln\left(\frac{1+e}{1-e}\right)$$

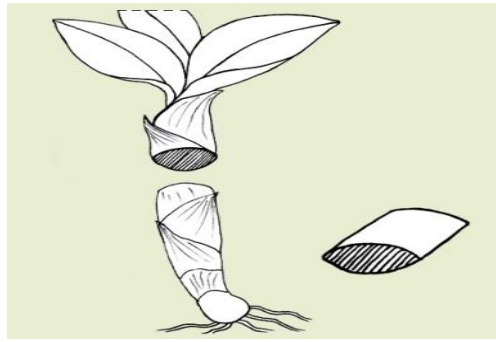
Frustum right cone

$$V = \frac{\pi}{3} L (r_1^2 + r_1 r_2 + r_2^2) \quad \text{and} \quad A = \pi (r_1 + r_2) \sqrt{L^2 + (r_1 - r_2)^2}$$

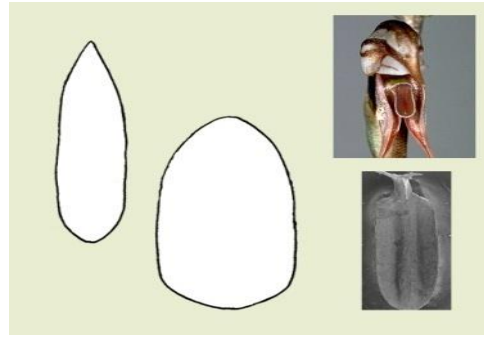
- * Where a and b , respectively, are major and minor semi-axes of the ellipse of rotation, e is the eccentricity given by $e = \sqrt{1 - (b/a)^2}$, r_1 and r_2 , respectively, are the radii of base and top, and L is the altitude.
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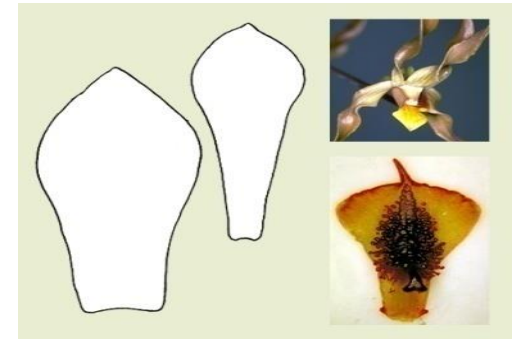
Ovate



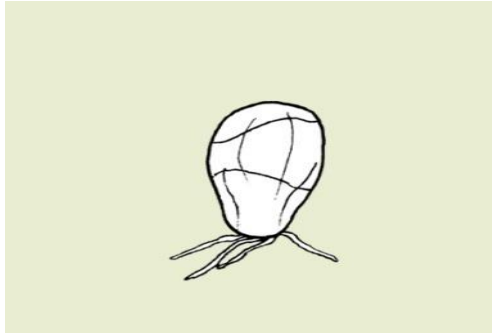
ellipsoid



Oblong



obovate



obovoid



Elliptical



Prolate



Oblique



Conic



Truncate

VOLUME

- **Volume** is defined as the amount of three-dimensional space occupied by an object. In the SI system, the unit of volume is m^3 .
- 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).
- Particle volume: This volume is the actual volume of the solid granular material, which is devoid of intergranular spaces.
- Solid volume :is the volume of the solid material (including water) excluding any interior pores that are filled with air.
- It can be determined by the gas displacement method in which the gas is capable of penetrating all open pores up to the diameter of the gas molecule.

- **SHRINKAGE**: This is the reduction in volume or geometric dimensions during processing.
- **EXPANSION**: It happens when post-processing volume is larger than initial volume.

DENSITY

It of two types:

Bulk density and Particle density

POROSITY

- It is the percentage of air (pore space) between the particles compared to a unit bulk volume of particles.

$$\text{Porosity} = [(PD - BD) * 100] / PD$$

- **Porosity depends on**: Shape ,Dimension/ Size, Roughness of grain surface

NOTE:

- Beds with low porosity are more resistant to fluid flow and more difficult to dry, or cool.
- With high porosity, drying/cooling is faster, and power required is low.

SPECIFIC GRAVITY

- It is a ratio, expressed decimally, of the weight of a substance to the weight of an equal volume of a substance chosen as a standard, both substances at the same temperature.
- Water is used as the standard for the specific gravities of liquids and solids.
- The most useful standard for gases is hydrogen, although sometimes air is used

SURFACE AREA

1. Using planimeter,
2. Coating method,
3. Wrapping
4. Peeling method,
5. By image analysis

For fruits and vegetables:

- a. Peeling
- b. Coating
- c. Wrapping

THERMAL PROPERTIES

METHODS OF HEAT TRANSFER

- **Conduction:** is heat transfer between part of the same material or different material which are adjacent to one another.
 - **Convection:** is heat transfer from one material to another via a medium, such as air or water.
 - **Radiation:** is heat transfer without any medium and through electromagnetic waves, such as between the Sun and the Earth.
- In food processing, heat transfer is usually a combination of conduction and convection.

IMPORTANT THERMAL PROPERTIES

1. Heat capacity
2. Specific heat
3. Thermal conductivity
4. Thermal diffusivity
5. Surface heat transfer co-efficient
6. Latent heat of fusion and vapourization
7. Heat of respiration
8. Co-efficient of thermal expansion
9. Thermal Emissivity

Heat capacity

Heat capacity may be defined as the thermal capacity, is the amount of heat required to change a substance's temperature by one degree. In SI units, heat capacity (C) is expressed in (J) per kelvin (K).

It is the Ratio of heat supplied (Q) to the corresponding temp rise (Δt)

$$C = Q / \Delta t$$

Specific heat

Specific heat (c_p) or mass heat capacity is the heat required to increase the temperature of one unit of mass by one degree.

The specific heat is expressed in kJ/(kg-K).

$$Q = m(t_2 - t_1)c_p$$

THERMAL CONDUCTIVITY

- Thermal conductivity is a measure of the ease with which heat flows through a material. It is defined as the “heat flow through the material per unit of time (Q), the cross sectional area of the material through which the heat flows (A), and the temperature difference per unit thickness of the conducting material (dT/dx)”.

$$Q = k A (dT/dx)$$

ENTHALPY

- Total heat content of a material per unit mass.
- Enthalpy change is defined by the following equation:

$$H_2 - H_1 = m c_p (T_2 - T_1) + m X_w L$$

Where:

- $H_2 - H_1$ = Enthalpy difference, m = Mass of product
- X_w = Water fraction
- $T_2 - T_1$ = Temperature difference, L = Latent heat

THERMAL DIFFUSIVITY

- In transient heat transfer, where temperature varies with time and location, the relevant thermal property is thermal diffusivity.
- Thermal diffusivity (α , m²/s) is a combination of three basic thermal properties, defined as “The rate at which heat is diffused out of the material.
- This is a quantity derived from conductivity, which is a measure of its ability to exchange thermal energy with its surroundings”.
- Mathematically ,
- Thermal diffusivity = Thermal conductivity/(density \times specific heat)

or

$$\alpha = k / \rho C_p$$

CONVECTIVE HEAT TRANSFER COEFFICIENT

- The thermal property associated with convection heat transfer is the convective heat transfer coefficient (h); it also goes by the names surface heat transfer coefficient, unit surface conductance or film coefficient.
- It is defined as the “Rate of heat transfer per degree of temp difference across the solid fluid interface per unit of the solid’s surface area”.

$$Q = h A \Delta T$$

Latent heat (L)

- It is the heat that is exchanged with a material during a phase change, when the heat exchanged does not result in a change in the temperature of the material.
- The units for latent heat are kJ/kg. Latent heat is usually subdivided into latent heat of freezing and latent heat of vaporization.

Latent heat of freezing

- It is the **335 kJ** that 1 kg of water releases while maintaining its temperature at 0°C when changing from the liquid to the solid state.

Latent heat of vaporization

- It is represented by the **2257 kJ** that 1 kg of water must absorb while temperature remains constant at 100 °C to evaporate from liquid into vapor.

HEAT OF RESPIRATION

- Fruit and vegetable products are living organisms. To maintain their life processes, they must consume energy. They do this by a “combustion” process that “burns” sugar to produce CO₂ and heat.
- The heat produced by this process is commonly called the heat of respiration.

COEFFICIENT OF THERMAL EXPANSION

- When a material is heated, it leads to density difference. Solids mostly expand in response to heating and contract on cooling.
- This response to temperature change is expressed as its coefficient of thermal expansion.

$$B = \Delta V / (V * \Delta T)$$

ΔV Change in volume,

ΔT : Change in Temp

THERMAL EMISSIVITY

- The emissivity coefficient (ϵ) is the ratio of total emissive power of any body to the total emissive power of a black body at the same temperature.
- If an hot object is radiating energy to its cooler surroundings the net radiation heat loss rate can be expressed as :
- Where:

Q = rate heat transfer

A = surface area

$\epsilon = 1$ (black body) and < 1 (real object)

σ = Stefan Boltzmann constant

T_h & T_c = Absolute temperature of hot and cold body respectively

$$Q = A \epsilon \sigma (T_h^4 - T_c^4)$$

ASSIGNMENT NO. 8

- a. Liquid displacement method
- b. Gas displacement method
- c. Application of thermal properties