PROCESSING TECHNOLOGY OF CEREALS ASFE 2201

SUDIPTA BEHERA

ASSISTANT PROFESSOR, SoABE

Physico - chemical properties of cereals, major and minor millets

IMPORTANCE OF PHYSICO – CHEMICAL PROPERTIES

- Design of equipment for handling, aeration, and storage as well as processing cereal grains and other agricultural materials.
- Basic thermal and moisture transport properties are also required for simulating heat and moisture transport phenomena during drying and storage.
- Providing basic data for food engineering and unit operations.
- Predicting behavior of new food materials.

CLASSIFICATION OF ENGINEERING PROPERTIES

A. Physical Characteristics

1. Shape	5. Surface area	9. Appearance
2. Size	6. Density	10. Center of gravity
3. Weight	7. Porosity	
4. Volume	8. Color	

B. Mechanical Properties

B1. Mechanical Properties

1. Hardness
2. Compressive strength
3. Tensile strength

B2. Frictional properties

1. Sliding coefficient of friction
2. Static coefficient of friction
3. Coefficient of internal friction

B3. Aero and Hydro dynamic properties

1. Drag coefficient
2. Terminal velocity

B4. Rheological properties

1. Shear resistance
2. Compressibility
3. Elasticity
4. Plasticity
5. Bending strength

C. Thermal Properties

1. Specific heat	4. Thermal conductivity	7. Emmisivity
2. Thermal capacity	5. Surface conductance	8. Transmissivity
3. Thermal diffusivity	6. Absorptivity	

D. Electrical Properties

1. Conductance	4. Dielectric properties
2. Resistance	5. Reaction to electromagnetic radiation
3. Capacitance	6. Conductivity— (ability of seeds to hold a surface charge)

E. Optical Properties

1. Light transmittance	3. Light absorptance	5. Contrast
2. Light reflectance	4. Color	6. Intensity

SORTING AND GRADING

APPLICATIONS

- **Physical Characteristics**

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

SIZE

- 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, bananas, pears, or potatoes may be described by **multiple length** measurements.

- The longest diameter (major) and shorter diameter/s (minor) will adequately describe the size of an **ellipsoidal object such as grain kernel or potato**. The two/three dimensions are usually measured perpendicular to one another.

- The size of pear-shaped objects such as pears, carrots, or beets can be expressed by **diameter or circumference of the largest part and an overall length in the direction of the stem.**

- The size of irregular-shaped materials like **bananas, okra** requires more extensive considerations. May be given **only in overall length**.

- **Methods of measurement**

- ✓ Projected method: Photographic enlarger
- ✓ Micrometer method: Micrometer and slide calipers
- ✓ Electronic devices: Image analysis (**Precise method)**

- **Precise methods** incorporating optical, light, or lasers in machine vision systems exist to define shape and size of irregular-shape objects.

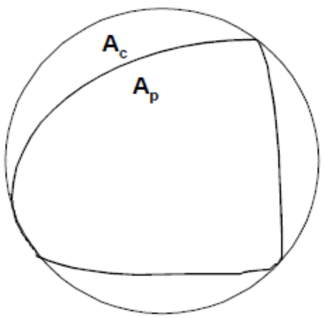
- These systems are costly; their use is warranted in applications of **high value** materials more commonly found in highly processed, final products rather than raw, unprocessed materials.

- **1000-Grain weight:**
- In handling and processing of grains, it is customary to know the weight of 1000 grain kernels. The 1000 grain weight is a good indicator of the grain size, which can vary relative to growing conditions and maturity, even for the same variety of a given crop. When compared with other crops at the same moisture level, the 1000 kernel weight will also provide an idea of relative size of the kernel for handling purposes. Generally, this is measured directly by taking the weight of 1000 grain kernels.

- The shape of a food material is usually expressed in terms of its

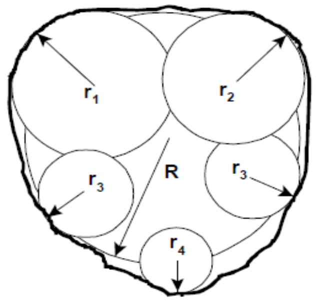
- ✓ **Roundness,**
- ✓ **Sphericity,**
- ✓ **Aspect ratio,**
- ✓ **Ellipsoid ratio and**
- ✓ **Slenderness ratio**

- **<u>Roundness</u> is a measure of the sharpness of the corners of th solid.**



- **1. Roundness** = Ap/Ac
- where: *Ap* = largest projected area of object in natural rest positi
- *Ac* = area of smallest circumscribing circle

2. Roundness = Σr / NRi

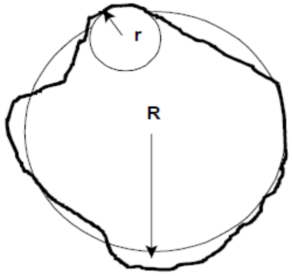


- where: *r* = radius of curvature as defined in figure
- *Ri* = radius of maximum inscribed circle
- *N* = total number of corners summed in numerator

3. Roundness Ratio = <u>Radius of curvature of the sharpest corner</u>

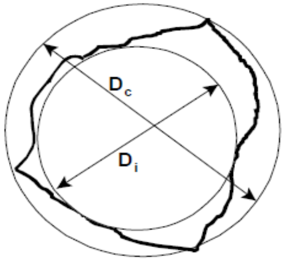
Mean radius of the particle

$= r/R_m$, where $R_m = \sum r/n$



- The use of the radius of curvature of a single corner determines
- the roundness or flatness of an object

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



Sphericity = D_i / D_c

- 1. **Sphericity** = *De/Dc*
- 2. **Sphericity** = *Di/Dc*

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

Di = diameter of largest inscribed circle

Dc = diameter of smallest circumscribed circle

3. Sphericity = $(Vo / Vc)^{1/3}$ = $(lwt)^{1/3} / l$ (For triaxial Ellipsoid)

i.e. Ratio of Geometric mean diameter to major diameter

Vo= Volume of object

Vc= Volume of smallest circumscribed sphere

l = longest intercept

w = longest intercept normal to l

t = longest intercept normal to a and w

Note: $Vo = [(\pi/6)\ lwt]$ and $Vc = [(\pi/6)\ l^3]$

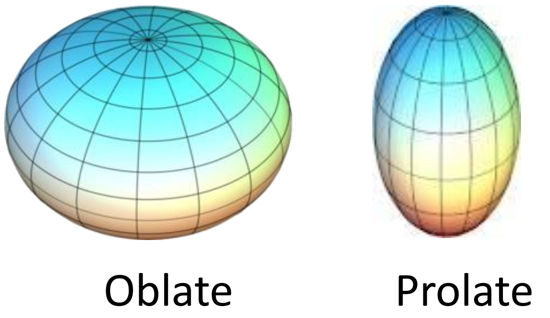
- **Slenderness ratio=** Ratio of length to width
- **Aspect ratio=** The **aspect ratio** of a geometric shape is the ratio of its sizes in different dimensions.
- Rectangle is the ratio of its longer side to its shorter side
- Ellipse, the ratio of the major axis to the minor axis.

- **Ellipsoid ratio = Major diameter : minor diameter**
- **Right circular cone or cylinders** is formed when a frustum rotates about its axis e.g. carrot and okra.

- **Flattening** (**oblateness**)is a measure of the compression of a circle or sphere along a diameter to form an ellipse or an ellipsoid of revolution**.**
- It is the ratio of difference of the major and minor semi-axes to major semi axis

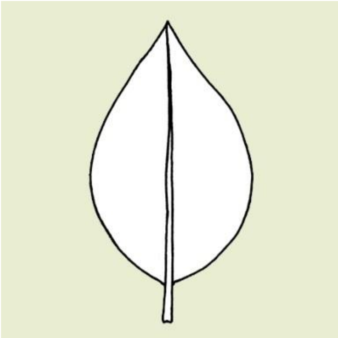
- **Prolate spheroid** which is formed when an ellipse rotates about its major axis. A prolate spheroid is a spheroid in which the polar axis is greater than the equatorial diameter. e.g. lemon, lime, grape.

- **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)

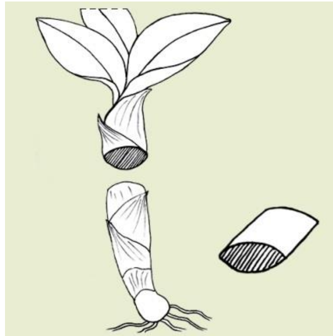


COMMON SHAPES OF BIOMATERIALS

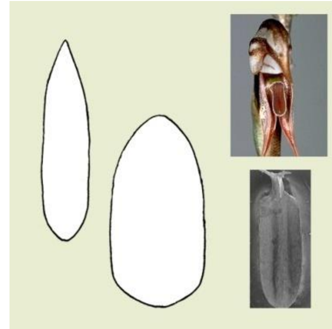
Shape	**Description**	**Examples**
Round	Approaching Spheroid	sapota, cherry tomato, pea
Oblate	Flattened at the stem end and apex	orange, pumpkin
Prolate	Elongated along a line	Lemon, grape
Oblong	Vertical diameter greater than horizontal diameter	some apple varieties, capsicum, brinjal, rice, wheat
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



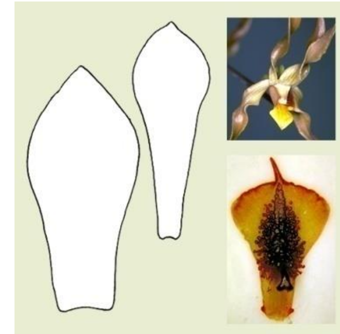
Ovate



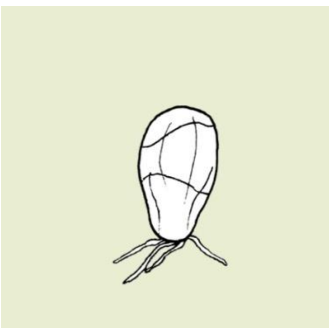
ellipsoid



Oblong



obovate



obovoid

Oblate

Prolate

Oblique

Conic

Regular

Truncate

Ribbed

Unequal

Elliptical

Volume

- SI unit of volume is m^3
- The most common definitions of volume:
  - Solid volume/True volume (V_s) – volume of the solid material (including water) excluding any interior pores that are filled with air.
  - Apparent volume (V_{app})– Volume of a substance including all pores within the material (internal pores).
  - Bulk volume (V_{bulk}) – is the volume of a material when packed or stacked in bulk.
- Volume of solids can be determined experimentally by liquid, gas or solid displacement

- **Liquid Displacement Method.**

1. The volume of a sample can be measured by direct measurement of volume of liquid displaced. The difference between the initial volume of the liquid in a measuring cylinder and the volume of the liquid plus **immersed material (coated)** is the volume of the material. Coating is necessary so that liquid does not penetrate in the pores.

2. A **nonwetting fluid** such as mercury is better to use for displacement since in this case samples do not need coating.

3. The use of a specific gravity bottle (Pycnometer, small necked) and toluene has been practiced for many years

- **Toluene has many advantages when used as reference liquid** (Mohsenin, 1986):

- 1. Little tendency to soak on the sample
- 2. Smooth flow over the surface due to surface tension
- 3. Low solvent action on constituents, especially fats and oils
- 4. Fairly high boiling point
- 5. Stable specific gravity and viscosity when exposed to the atmosphere
- 6. Low specific gravity

VOLUME AND SURFACE AREA OF SOME COMMON SHAPES

Sphere

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

Cylinder

$$V = \pi r^2 L \quad and \quad A = 2\pi r^2 + 2\pi r L$$

Cube

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

Brick

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

Prolate spheroid

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

Oblate spheroid

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

Frustam right cone

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

* Where a and b, respectively, are major and minor semiaxes 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.

- **Density** of a material is the amount of that material occupying a certain space and is expressed in units of mass per unit volume.
- **Particle density** is the mass divided by the volume of the particle alone. Particle density is the density of a particle, which includes the volume of all closed pores but not the externally connected pores. For the determination of kernel density of an average grain, two methods have been suggested: one involved the displacement of a gas, whereas the other used displacement of a liquid. In both methods, Archimedes' principle of fluid displacement is used to determine the volume.
- **Bulk density** is the mass of a group of individual particles divided by the space occupied by the entire mass, including the air space. Density of food materials is useful in mathematical conversion of mass to volume. Bulk density is the density of a material when packed or stacked in bulk.

- **Porosity** is the percentage of air between the particles compared to a unit volume of particles.
- Porosity = [(PD – BD) * 100] / PD
- The porosity of grain is an important parameter that affects the
- kernel hardness, breakage susceptibility, milling, drying rate, and resistance to fungal development.
- Porosity depends on (a) shape, (b) dimensions and (c) roughness of the grain surface.
- Porosity (P) is a property of grain that depends on its bulk and kernel densities.
- The grain porosity can be measured with the help of an air comparison pycnometer or by the mercury displacement method.

- The **specific gravity** is defined as the ratio of the mass of that product to the mass of an equal volume of water at 4°C, the temperature at which water density is greatest.
- A reference temperature other than 4°C may be used if that temperature is explicitly specified with the specific gravity value. Specific gravity may be calculated from the following expression:
- Specific gravity = (mass in air × specific gravity of water) / mass of displaced water
- Surface area of Fruits & Vegetables can be known by Peeling the surface area and measuring the tracing of the peeled by planimeter.

Specific gravity by Pycnometer method:

Specific gravity of tolune = weight of tolune / weight of water

Specific gravity of grain = (specific gravity of tolune x weight of grain) / (weight of tolune displaced by the grain)

= specific gravity of tolune x weight of grain / [(weight of sample) – ((weight of tolune+sample+bottle) – (weight of tolune+bottle))]

Procedure:

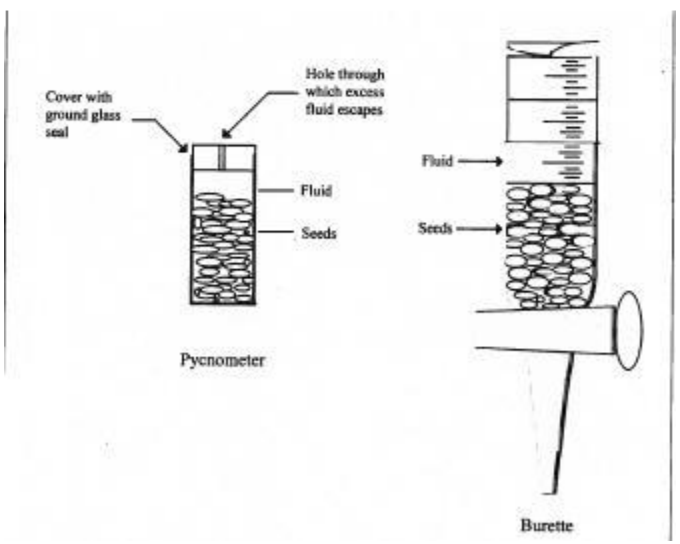
1. *Determine the exact capacity of the pycnomeer by weighing it when empty and likewise when filled with distilled water at 20 deg C and tolune separately*
2. *Determine specific gravity of tolune*
3. *Around 10 g of solid specimen are placed in the pycnometer with sufficient tolune to coverthe sample*
4. *Gradually exhaust the air from the bottle by a vacuum pump to promote escape of the air trapped under the surface hairs and in the creases of the seeds or kernels*
5. *When air bubbles cease to be given off afer several cycles of vacuuming and releasing the vacuum, fill the bottle with tolune and allow the temperature to reach 20 deg C*
6. *Weigh the bottle and calculate specific gravity of the seeds as given above.*

$$V_s = \frac{\text{Weight of the liquid displaced by solid}}{\text{Density of liquid}}$$

$$= \frac{(W_{pl} - W_p) - (W_{pls} - W_{ps})}{\rho_l}$$

where

V_s = volume of the solid (m^3),
W_{pl} = weight of the pycnometer filled with liquid (kg),
W_p = weight of the empty pycnometer (kg),
W_{pls} = weight of the pycnometer containing the solid sample and filled with liquid (kg),
W_{ps} = weight of the pycnometer containing solid sample with no liquid (kg),
ρ_l = density of the liquid (kg/m^3).



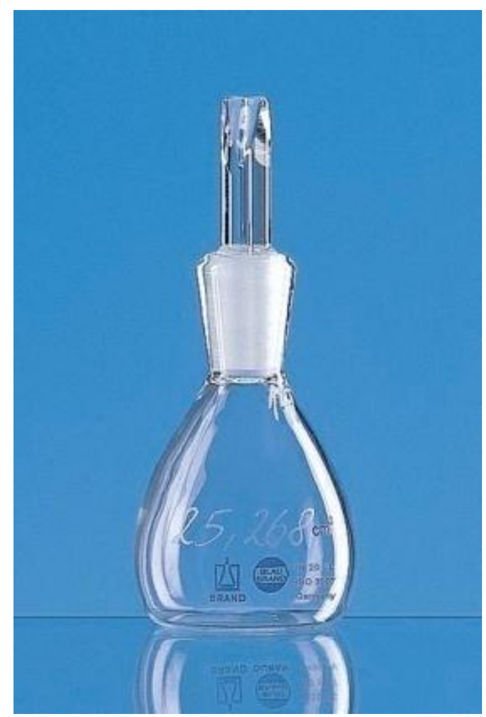


Table 4.3: Some physical and mechanical properties of the grains

Grains	Moisture content (%, wb)	Bulk Density (Kg/m^3)	True Density (Kg/m^3)	Porosity	Angle of repose (Degree)	Friction coefficient on sheet metal
Wheat	8-14	790-700	1390-1400	40	26-28	0.40
Rice	9-11	610-580	1200-1240	54	27-30	0.48
Corn	10	820	1393	41	26-28	0.23
Soya bean	10-11	680	1180	42	24-25	0.34
Pigeon pea	9-10	815	1330	39	19	0.29
Gram	8-9	815	1340	39	17	0.35

Source: Engg. properties of Food material (1980) CIAR Publication /80/15