Physical Attributes

Size, Shape, Volume, Density, Porosity and Particle Size Distribution

Agricultural and food materials have varying physical attributes

Size:

10 – 150 μm for powdered milk

0.5 m for watermelons

Shape:

Spherical – canned peas

Ellipsoidal – orange, grapefruit

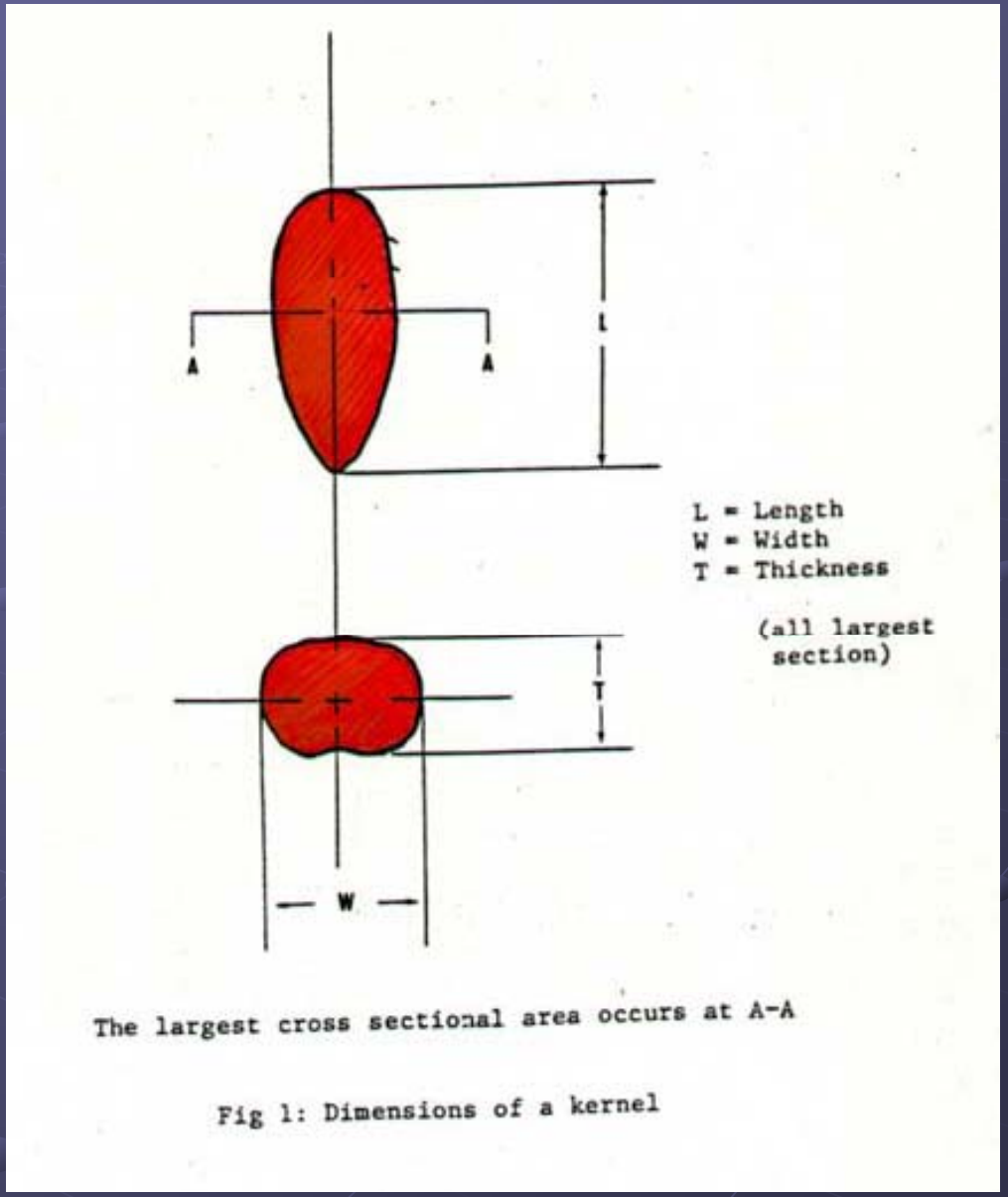
Long/narrow – oats

Square fruit

Size and Shape

Size described by dimensions of projected area

length, width and thickness used for grains and seeds



The largest cross sectional area occurs at A-A

Fig 1: Dimensions of a kernel

3 characteristic dimensions

1) Major diameter (a) – longest dimension of the maximum projected area

2) Intermediate diameter (b) – min. dimension of the maximum projected area or longest dimension of the min. projected area

3) Minor diameter (c) – shortest dimension of the minimum projected area

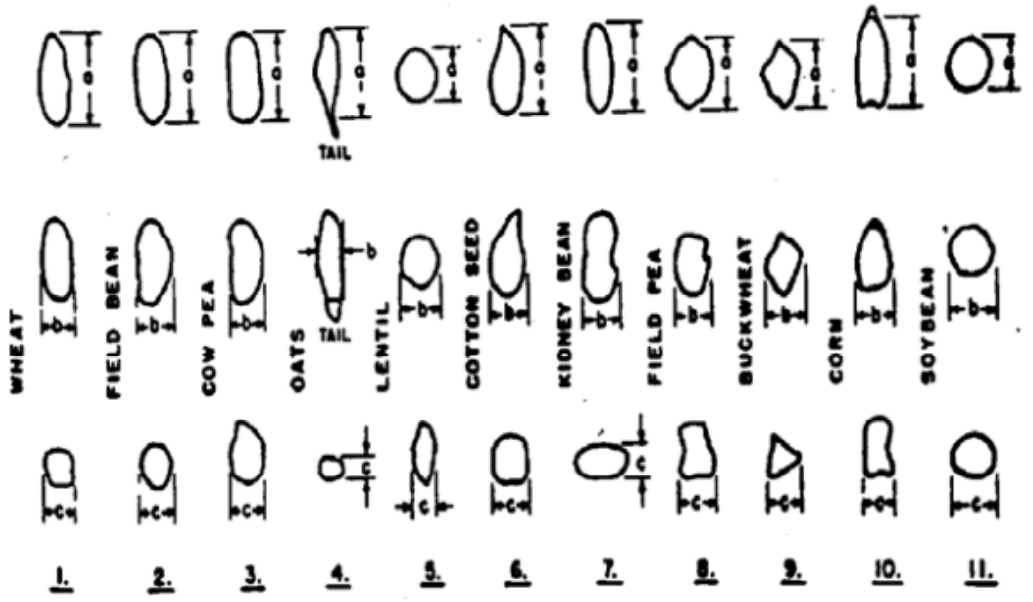


FIGURE 12 - TRACINGS OF SHAPE AND DESIGNATION OF THE THREE INTERCEPTS FOR SEEDS AND GRAINS OBTAINED BY A PHOTOGRAPHIC ENLARGER.

METHODS

- ✓Micrometer
- ✓Caliper
- ✓Overhead

✓Machine Vision

Table 2.1 Dimensions of Grains, Fruits and Vegetables.

Product	Major Diameter (mm)		Intermediate Diameter (mm)		Minor (mm)	
	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.
Grains[a]						
Corn	12.01	1.52	8.15	0.71	5.18	1.00
Wheat	6.02	0.41	2.79	0.37	2.54	0.08
Soybeans	7.29	0.66	6.43	0.51	5.38	0.20
Oats	10.84	1.65	2.67	0.36	2.03	0.33
Barley	8.76	1.19	3.15	0.38	2.51	0.38
Rye	6.65	0.69	2.21	0.25	2.11	0.25
Fruits and Vegetables[b]						
Apples (Gldn. Delicious)	70.1	-	67.6	-	56.4	-
Apples (Red Delicious)	76.7	-	71.6	-	63.5	-
Blueberry	11.7	-	11.4	-	8.6	-
Cherry (Napolean)[c]	22.6	0.864	22.5	1.19	19.8	0.864
Peach (Red Haven)	58.2	-	57.2	-	54.9	-
Pear (Maxine)	83.6	-	73.2	-	68.1	-
Plum	46.0	-	44.7	-	40.9	-
Potato (Norchip)[d]	70.	-	62.	-	53.	-
Tomato	63.8	-	59.2	-	47.2	-

Characterizing size by single dimension

Mean diameter

$$d_m = \frac{(a+b+c)}{3}$$

Equivalent diameter (geometric mean diameter)

$$d_e = (abc)^{1/3}$$

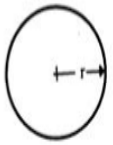
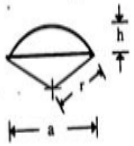
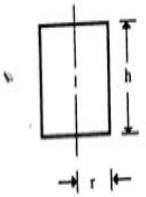
Equivalent diameter of an object: measure V and calculated

$$d_e = 2r = 2[\frac{3v}{4\pi}]^{\frac{1}{3}}$$

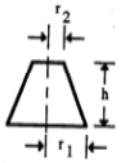
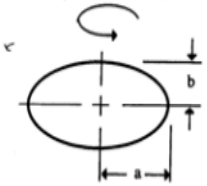
Shape used to describe agricultural & biological materials

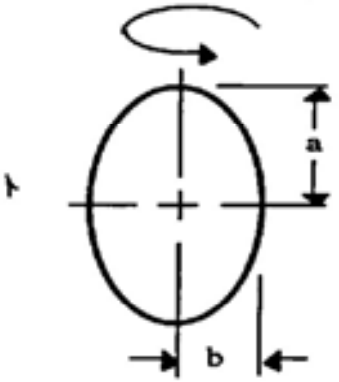
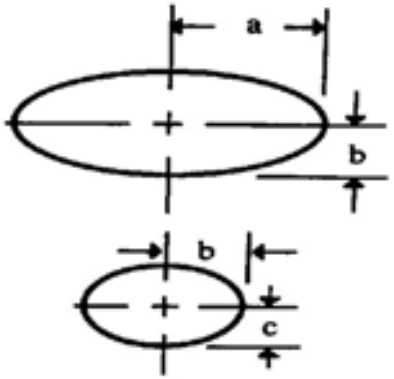
- Describes processed food
- Shape can be characterized by using similarity to geometric solids such as:
  - Sphere
  - Prolate spheroid (بیضی دوران کرده حول محور بزرگ)
  - Oblate spheroid (بیضی دوران کرده حول محور بزرگ)
  - Triaxial ellipsoid
  - Truncated cone

Appendix C
Formulas for Surface Areas and Volumes of Geometric Solids

SHAPE	SURFACE AREA	VOLUME
Sphere 	$S = 4\pi r^2$	$V = \frac{4}{3}\pi r^3$
Hemispere 	$S = 3\pi r^2$ (not including circular bottom)	$V = \frac{2}{3}\pi r^3$
Spherical Segment 	$S = 2\pi r h$ (not including circular bottom)	$V = \frac{1}{3}\pi h^2 (3r - h)$ where $r = \frac{h}{2} + \frac{a^2}{8h}$
Right Circular Cylinder: 	$S = 2\pi r(h + r)$ (including circular bottom and top)	$V = \pi r^2 h$

Back

SHAPE	SURFACE AREA	VOLUME
Right Circular Cone 	$S = \pi r \sqrt{r^2 + h^2}$ (not including circular bottom)	$V = \frac{1}{3} \pi r^2 h$
Truncated Right Circular Cone 	Area of curved surface (top and bottom excluded) $S = \pi (r_1 + r_2) \sqrt{h^2 + (r_1 - r_2)^2}$	$V = \frac{\pi h}{3} (r_1^2 + r_1 r_2 + \frac{2}{2})$
Pyramid : 	$S = a L + b L$ (bottom excluded)	$V = \frac{1}{3} a b h$
Oblate Spheroid (rotation around minor axis) : 	$S = 2 \pi a^2 + \frac{\pi b^2}{e} \ln \left(\frac{1+e}{1+e} \right)$ where $e = \left(1 - \left(\frac{b}{a} \right)^2 \right)^{\frac{1}{2}}$	$V = \frac{4 \pi}{3} a^2 b$

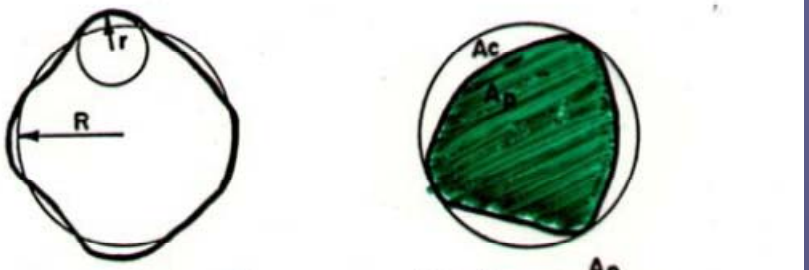
SHAPE	SURFACE AREA	VOLUME
Prolate Spheroid (rotation about major axis): 	$S = 2\pi b^2 + \frac{2\pi a b}{e}\sin^{-1}(e)$ where $e = \left(1 - \left(\frac{b}{a}\right)^2\right)^{\frac{1}{2}}$ and $\sin^{-1}(e)$ is expressed in radians, 1 radian = 57.2988°	$V = \frac{4\pi}{3} a b^2$
Triaxial Ellipsoid all three perpendicular sections are ellipses): 		$V = \frac{4}{3}\pi a b c$

Technique to quantify differences in shape of agricultural materials:

- Spherecity – ratio of volume of triaxial ellipsoid with equivalent diameters to the volume of sphere which circumscribes the object

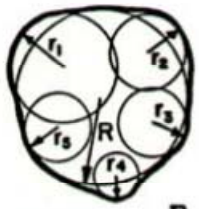
$$\text{Spherecity} = \frac{\frac{4}{3}\pi abc}{\frac{4}{3}\pi r^3} \qquad r = a$$

$$\text{Spherecity} = \frac{(abc)^{1/3}}{a}$$



Roundness Ratio = $\frac{r}{R}$

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



Roundness = $\frac{\Sigma r}{NR}$

Sphericity = $\frac{d_i}{d_c}$

FIGURE 1~~5~~.1 - ROUNDNESS AND SPHERICITY AS DEFINED BY GEOLOGISTS TO DESCRIBE SHAPE OF GRAINS AND PEBBLES (Curray, 1951).

Number of seed; At least 100

Table1: Size and distribution of three types chickpea at initial moisture content (w.b.)

Type	Physical attributes	Size category*			
		Ungraded	Small	Medium	Large
kabuli			<10(mm)	10-11(mm)	>11(mm)
	Percent of sample				
	By number	100	24	50	26
	By mass	100	24	44	32
	Average dimensions				
	Major (a), mm	10.42±0.04	9.76 ± 0.03	10.47 ± 0.03	11.28 ± 0.07
	Intermediate (b), mm	8.35±0.03	8.14 ± 0.04	8.38 ± 0.03	8.55 ± 0.09
	Minor (c), mm	8.25±0.03	8.1±0.04	8.27 ± 0.03	8.45 ± 0.08
	projected area (A), mm^2	66.09±0.39	60.87 ± 0.47	66.48 ± 0.32	72.84 ± 1.10
	Unit mass (M), g	0.507±0.007	0.451 ± 0.005	0.508 ± 0.003	0.566 ± 0.006
	Unit volume (V), mm^3	392±6.1	356 ± 9.3	401 ± 4.7	426 ± 13.8
Chico			<8(mm)	8-9(mm)	>9(mm)
	Percent of sample				
	By number	100	37.33	38.67	24
	By mass	100	19.07	40.99	39.94
	Average dimensions				
	Major (a), mm	8.53±0.05	7.69 ± 0.04	8.51 ± 0.03	9.35 ± 0.04
	Intermediate (b), mm	7.06±0.03	6.73 ± 0.07	7.12 ± 0.04	7.26 ± 0.06
	Minor (c), mm	6.81±0.03	6.49 ± 0.06	6.84 ± 0.04	7.06 ± 0.06
	Major projected area (A), mm^2	46.21±0.48	39.32 ± .0.57	46.38 ± 0.43	52.24 ± 0.58
	Unit mass (M), g	0.215±0.004	0.160 ± 0.01	0.210± 0.002	0.243 ± 0.004
	Unit volume (V), mm^3	170±5.4	147±8.4	165±8.1	195±7.5
Desi			<7.5(mm)	7.5-8.5(mm)	>8.5(mm)
	Percent of sample				
	By number	100	16.67	56.66	26.67
	By mass	100	28	44	28
	Average dimensions				
	Major (a), mm	8.08±0.05	7.25 ± 0.04	8.00 ± 0.03	8.79 ± 0.03
	Intermediate (b), mm	6.46±0.04	6.38 ± 0.48	6.42 ± 0.05	6.61 ± 0.06
	Minor (c), mm	5.89± 0.11	5.74 ± 0.08	5.95 ± 0.17	5.88 ± 0.36
	Major projected area (A), mm^2	38.28 ± 0.33	34.66 ± 0.56	37.41 ± 0.33	42.39 ± 0.47
	Unit mass (M), g	0.279±0.006	0.224 ± 0.006	0.276± 0.003	0.324±0.006
	Unit volume (V), mm^3	206±4.5	170±4.8	207±0.003	242± 4.7

* Based on major dimension.

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