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A CASE STUDY

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Studies on engineering properties of raw and roasted pulses

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SUMMARY :

The physico-chemical properties of various raw and roasted pulses (bengal gram: JG-11, green gram: LGG-460, horse gram: PHG2, yellow pea: AP3) were investigated. The physical properties (length, breadth, thickness, geometric mean diameter, aspect ratio, sphericity, surface area), gravimetric properties (bulk density, true density and porosity), frictional properties (angle of repose and static co-efficient of friction), and optical properties (L, a*, b*, ΔE) were studied for some of the varieties of pulses and compared between roasted and unroasted pulses. The engineering properties were determined in compliance with ASAE Standard 5352.1 (1984). Results obtained showed a bulk density ranging from 998.46 in yellow pea (*Pisum Satirum*) seed to 616.86 kg/m^3 in horse gram (*Dolichos biflorus*) seed, both roasted and unroasted pulses. Bulk density of raw pulses showed a increasing trend than the roasted pulses. The relation between length, breadth, thickness, arithmetic mean, geometric mean, volume, sphericity, bulk and true density, porosity, surface and specific surface follow a strict pattern which enables the reliable correlation of geometrical dimensions to the unit mass. Angle of repose of studied pulses varied from 72.42 to 76.84 degrees. Angle of repose of roasted pulses recorded higher values than the raw grains. The correlations could be used for sorting, conveying and hopping. The engineering and mechanical properties of various pulses vary considerably. The correlation found in this study is useful for handling, sorting and conveying purpose.

KEY WORDS : Engineering properties, Physical properties, Pulses, India

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The engineering properties of pulse grains are important in the process design and manufacture of food products. Some of the optical, mechanical, structural, geometric and food powder properties of pulses are studied. These properties indicate changes in chemical composition and structural organization of foods ranging from molecular to macroscopic level. This provides information about the macro-structural effects of the processing conditions in fresh and manufactured pulses. Data found in published list of engineering properties of pulses can be considered as approximate values. These tabular values are still useful since a safety factor is added to almost all calculations or designs or food processes or operations (Mohsenin, 1970; Tiwari and Singh, 2012).

Optical properties are related to consumer judgment on food appearance and produce some kind of visual effect. The hunter system in all three-dimensional system using parameters L*, a* and b*; L is the lightness (non-linear), a* is redness or greenness and b* is yellowness or blueness. Combination of L*, a* and b* can be converted to a single colour. Optical properties are used to perform quality control and continuous inspection during processing operation.

The mechanical properties mainly results from the structure, physical state and rheology. They are sub-divided into structural and geometrical properties including mass-volume-area related properties (density, shrinkage porosity), and morphological properties (surface area, roundness and sphericity). These properties are needed for process design, estimating other properties, characterizing food and quality determination. Size, shape, sphericity, volume, surface area, density and porosity are important physical characteristics of many grains in handling and processing operations (Oke *et al.*, 1985).

EXPERIMENTAL METHODS

The present study was carried out at varieties of pulses including Bengal Gram:

Raw materials :

Pulses :

Varieties of pulses including bengal gram (Chickpea) (*Cicer arietinum*): JG-11, green gram (*Vigna radiate*): LGG-460, horse gram (Kulthi) (*Dolichos biflorus*): PHG2 and yellow pea (*Pisum Satirum*): AP3 were procured from various organizations of the country. The obtained varieties were cleaned manually to remove the stones, dust particles and other impurities for further use. After cleaning, the grains were stored under refrigerated condition at 8° C. The stored grain was kept outside to equilibrate to room temperature for subsequent roasting.

Processing methods :

Roasting :

The derived varieties of pulses (bengal gram (*Cicer arietinum*): JG-11, green gram (*Vigna radiate*): LGG-460, horse gram (*Dolichos biflorus*): PHG2, yellow pea (*Pisum Satirum*): AP3) were subjected to roasting at a temperature of 280 ± 5° C for 30 seconds and then were used for subsequent analysis. Unroasted and roasted pulses are presented in Fig. A.

Fig. A : Raw and roasted pulses

Physical properties of pulse grains :

Dimensional properties :

The dimensional parameter of the grain included length, breadth, thickness, geometric mean diameter, aspect ratio, surface area, and sphericity. Length, breadth and thickness of the grain were measured using Grain meter (Singh and Prasad, 2013)

The geometric mean diameter (dg) was obtained using the formula :

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

where: a, b and c represent the length, breadth and thickness of the grain, respectively.

The sphericity (ϕ) of the grains was obtained using the formula :

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

where: a, b and c represent the length, breadth and thickness of the grain, respectively.

The surface area of bulk sample was found by analogy with a sphere of the same Geometric Mean Diameter, using the following relationship (Adhoo *et al.,* 1976; Altuntas and Demirtola, 2007) :

$$S = \pi D_g^2$$

where; S is the surface area (mm^2)

Gravimetric properties :

The gravimetric properties of the grain involved bulk density, true density and porosity. Bulk density was calculated from the mass of bulk material divided by volume containing the mass. The true density,defined as the ratio between the mass and the true volume of the bulk material (grains), was determined using the toluene (C_7H_8) displacement method while porosity of bulk materials was calculated from bulk and true densities using the relationship (Mohsenin, 1980), as follows :

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right)100$$

where: ε is the porosity (%); ρ_b is the bulk density (kg / m^3); and ρ_t is the true density (kg /m^3) (Prasad *et al.*, 2010).

Frictional properties :

The obtained frictional properties of the grain included angle of repose, co-efficient of friction on glass, galvanized iron sheet and plywood horizontal and vertical. The angle of repose was determined by using an open ended cylinder. The cylinder was placed at the centre of a plate and filled with grains. The cylinder was raised slowly until it formed a cone on the plate.

The height of the cone was recorded by using a movable pointer fixed on a stand having a scale of 0.1 cm precision. The angle of repose (θ) was calculated using the formula:

$$\theta = \tan^{-1}\left(\frac{2H}{d}\right)$$

where: *H* is the height of the cone (cm) and *d* is the diameter of cone (cm).

Colour characteristics of raw and roasted pulses :

The colour characteristics of raw and roasted grains were assessed using a Colour Spectrophotometer (Gretag Macbeth model No 15, USA) to determine L value (Light- dark), a value (red- green) and b value (Yellow- Blue), which is shown by Hunter Lab colour space rate (Fig. B). The colorimeter was calibrated with white standard L, a and b measurement were evaluated from three samples and the values were averaged. Colour was also evaluated as the total colour difference (ΔE).

$$aE = Ě(L_0-L)^2 + (a_0-a)^2 + (b_0-b)^2$$

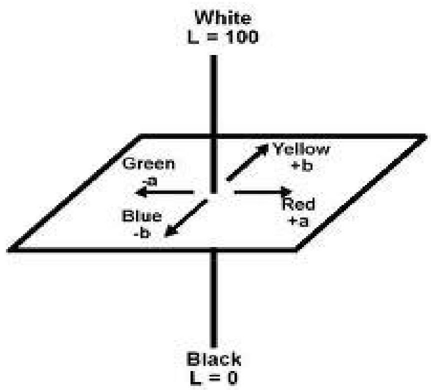

Fig. B : Hunter lab colour space

where;

L_0, b_0 and a_0 represented the reading at time zero and L, a and b represented the instantaneous individual reading during baking.

EXPERIMENTAL FINDINGS AND ANALYSIS

The data related to dimensional parameters, gravimetric properties, frictional characteristics and optical properties of chickpea seed (JG-11) and green gram seed (LGG-460) are presented in Table 1. Table 2 contains the physical and optical properties of horse gram seed (PHG2) and yellow pea seed (AP3).

The dimensional properties of various pulses has been recorded and presented under respective grains. The dimensional properties of different grains are variety and species specific. The obtained results are very well in agreement with earlier studies. Engineering properties of pulse grains provide essential data required for: grain handling and design of aeration and storage structure, e.g. bulk density and porosity, design and control of operations such as mechanical separation, drying and processing, e.g. bulk density, co-efficient of friction, angle of repose, grain dimension during dehulling (Nimkar and Chattopadhya, 2001). Grain density (bulk and true) is useful for designing hopper for dehulling, storage facilities and grinding. (Nimkar *et al.*, 2005; Konak *et al.*, 2002).

Table 1: Physical properties of chick pea seed and green gram seed values are (Mean ± S.D.) of three replicates

Sr. No.	Attributes	Chick pea seed (JG-11)		Green gram seed (LGG-460)	
		Raw	Roasted	Raw	Roasted
1.	Length (L), mm	6.96± 0.56	7.36 ± 1.02	4.97±0.81	4.82 ± 0.44
2.	Breadth (B), mm	4.88 ± 0.20	5.50 ± 0.46	3.83±0.45	3.92 ± 0.32
3.	Thickness (T), mm	4.83 ± 0.45	5.13 ± 0.88	3.83±0.45	3.92 ± 0.32
4.	Geometric mean diameter (GMD), mm	5.37 ± 0.29	5.77 ± 0.27	4.11 ± 0.49	4.13 ± 0.31
5.	Aspect Ratio (AR)	70.53 ± 6.14	76.63 ± 16.46	77.84 ± 8.24	81.71 ± 6.30
6.	Sphericity (SPH)	0.77 ± 0.04	0.79 ± 0.11	0.82 ± 0.05	0.85 ± 0.04
7.	Surface area (SA), mm²	91.01 ± 9.97	104.73 ± 10.13	53.73 ± 13.11	53.99 ± 8.07
8.	Bulk density (BD), kg/m³	995.6 ± 6.02	665.02 ± 5.91	862.4 ± 26.8	661.06 ± 19.9
9.	True density (TD), kg/m³	1298.3 ± 21.82	1102.8 ± 10.56	1243.06 ± 6.00	1027.06 ± 13.10
10.	Porosity (POR), %	23.24 ± 1.12	39.92 ± 1.13	31.66 ± 2.46	36.21 ± 2.23
11.	Angle of repose (AOR), degree	72.59 ± 1.06	74.22 ± 0.23	72.42 ± 0.60	76.84 ± 0.13
12.	Co-efficient of friction on				
12a.	Glass (CFG)	0.42 ± 0.01	0.31 ± 0.008	0.31 ± 0.01	0.24 ± 0.008
12b.	Galvanized iron sheet (CFGI)	0.38 ± 0.008	0.31 ± 0.005	0.32 ± 0.008	0.31 ± 0.01
12c.	Plywood horizontal (CFPH)	0.27 ± 0.01	0.32 ± 0.004	0.23 ± 0.01	0.28 ± 0.02
12d.	Plywood vertical (CFPV)	0.35 ± 0.01	0.35 ± 0.02	0.24 ± 0.008	0.32 ± 0.005
13.	Degree of lightness to darkness (L*)	45.86 ± 0.89	47.87 ± 0.32	46.44 ± 1.27	46.52 ± 0.33
14.	Degree of redness to greenness (a*)	9.07 ± 0.37	8.87 ± 0.48	1.59 ± 0.35	3.45 ± 0.27
15.	Degree of yellowness to blueness (b*)	10.77 ± 0.84	12.68 ± 0.95	12.10 ± 0.31	11.73 ± 0.75
16.	Colour difference (ΔE)	35.67 ± 1.00	36.76 ± 0.68	34.64 ± 1.24	33.85 ± 0.50

Table 2 : Physical properties of horse gram seed and yellow pea seed values are (Mean ± S.D.) of three replicates

Sr. No.	Attributes	Horse gram seed (PHG2)		Yellow pea seed (AP3)	
		Raw	Roasted	Raw	Roasted
1.	Length (L), mm	5.02 ± 0.28	4.90 ± 0.90	6.00 ± 0.45	6.71 ± 0.32
2.	Breadth (B), mm	3.52 ± 0.20	3.37 ± 0.56	6.00 ± 0.45	6.71 ± 0.32
3.	Thickness (T), mm	1.8 ± 0.08	2.42 ± 0.30	6.00 ± 0.45	6.71 ± 0.32
4.	Geometric mean diameter (GMD), mm	3.12 ± 0.14	3.35 ± 0.40	5.89 ± 0.44	6.58 ± 0.31
5.	Aspect ratio (AR)	70.17 ± 3.94	70.19 ± 14.25	100 ± 0	102 ± 0
6.	Sphericity (SPH)	0.61 ± 0.02	0.69 ± 0.08	0.98±0.02	0.97 ± 0.003
7.	Surface area (SA), mm²	30.76 ± 2.84	35.86 ± 7.94	109.57 ± 16.63	136.35 ± 12.96
8.	Bulk density (BD), kg/m³	822.8 ± 31.2	616.86 ± 29.08	998.46 ± 3.44	637.12 ± 7.17
9.	True density (TD), kg/m³	1192.06 ± 6.87	1133 ± 36.60	1291.42 ± 7.44	1167.5 ± 12.12
10.	Porosity (POR), %	31.28 ± 2.98	45.15 ± 4.29	22.75 ± 0.40	45.56 ± 0.54
11.	Angle of repose (AOR), degree	72.61 ± 0.80	76.09 ± 0.18	73.59 ± 0.57	74.63 ± 0.21
12.	Co-efficient of friction on				
12a.	Glass (CFG)	0.35 ± 0.01	0.32 ± 0.01	0.35 ± 0.01	0.29 ± 0.008
12b.	Galvanized iron sheet (CFGI)	0.36 ± 0.01	0.31 ± 0.01	0.28 ± 0.01	0.32 ± 0.008
12c.	Plywood horizontal (CFPH)	0.29 ± 0.008	0.37 ± 0.008	0.25 ± 0.02	0.38 ± 0.008
12d.	Plywood vertical (CFPV)	0.34 ± 0.01	0.32 ± 0.008	0.26 ± 0.01	0.38 ± 0.01
13.	Degree of lightness to darkness (L*)	55.08 ± 1.61	48.93 ± 0.76	63.79 ± 0.88	61.15 ± 1.04
14.	Degree of redness to greenness (a*)	6.80 ± 0.23	9.70 ± 0.45	10.08 ± 0.12	9.45 ± 0.17
15.	Degree of yellowness to blueness (b*)	14.36 ± 0.18	13.32 ± 0.68	19.91 ± 0.10	20.75 ± 0.62
16.	Colour difference (ΔE)	26.78 ± 1.56	34.52 ± 0.36	21.85 ± 0.67	33.06 ± 0.93

The gravimetric and frictional properties for bulk, true density, porosity of grain size information is presented in Table 1 and 2. The data reflects the dependency of porosity and density. The decrease in porosity value increased the densities (Carman, 1996).

The static co-efficient of friction was studied on four different surfaces. The static co-efficient of friction was found least for galvanized iron followed by plywood and glass. The angle of repose of studied pulses varied from 72.42 to 76.84 indicating that the information can be used in development of hopper construction during storage, conveying, processing, handling and transportation equipments (Altuntas and Demirtola, 2007).

The degree of lightness to darkness (L) value showed the unroasted grains tended to darkness when roasted. Different pulses had different "L" value. The optical parameters may be considered to identify different pulses and their variety and between roasted and unroasted. On optical method, even online process can be applied in sorting of different pulses and between roasted and unroasted seeds (Yalein *et al.*, 2007).

Conclusion:

Engineering properties determined include bulk density, porosity, true density, angle of repose and coefficient of friction. Least true density was noticed in green gram seed while chickpea seed showed highest true density. A significant difference was noticed in the porosity of different pulses. The co-efficient of friction on plywood showed the least values while glass showed more friction. The information on co-efficient of friction can be very well utilized for hopper construction to enable the grains slide and roll down easily.

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