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Research Paper

DESIGN RELATED PHYSICAL PROPERTIES OF MAJOR CEREALS

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INTRODUCTION

Basic information on physical properties of cereals plays major role in machine and structural design and process engineering. Cereals may pose special problem in determining their physical properties because of their diversity in shape, size, and moisture content and maturity levels. So efforts have directed towards evaluation of physical properties of major cereals and their utilities. Physical properties such as shape, size, weight, density, porosity, surface area, angle of repose and angle of internal friction of major cereals i.e rice, wheat and maize were determined with standard procedure and compared with literature and developed relationships between properties. Although the recent scientific development have improved the handling and processing of biomaterials through mechanical, thermal, electrical, optical, and other techniques, little is known about the basic physical characteristics of these materials. Such basic information is important not only to engineers, but also to food scientists and processors, plant, and animal breeders and other scientists who may find new uses (Mohsenin, 1980). In developing tropical countries like India, there is lot of scope to develop machinery for agricultural processing, for this purpose basic information on physical properties of agricultural products is necessary. Needless to say, the evaluation of the physical properties of these agricultural materials should therefore be undertaken on an urgent basis to enhance the handling and processing of these products. In this study the design-related physical properties of major cereals are established.

MATERIALS AND METHODS

Sample Preparation

The sun dried cereal grains i.e maize, rice and wheat kernels used in the present study were obtained from the local market at IIT Kharagpur in India. The grains were cleaned manually and foreign matter such as stones, straw and dirt were removed. The moisture content of the grains was determined using a moisture meter and the average moisture content was 8±1% (w.b.).

Determination of Physical Properties

To determine the size of cereal grain, a sample of hundred kernels was randomly selected. The three major perpendicular dimensions of the kernels namely length (L), width (W), and thickness (T) were measured using a digital calliper reading to 0.01. The geometric mean diameter Dg of the seed was calculated by using the following relationship (Mohsenin, 1980):

$$\text{Dg} = (LWT)^{1/3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where L is the length, W is the width and T is the thickness in mm. The sphericity index value (ϕ) of grain kernels is calculated using the following formula(Mohsenin, 1980):

$$\phi = \frac{(LWT)^{1/3}}{L} \text{X } 100 \ldots\ldots\ldots\ldots(2)$$

Jain and Bal, 1997 have stated kernel volume, V and kernel surface area, S may be given by:

$$V = \frac{\pi B^2 L^2}{6(2L-B)}. \qquad \ldots\ldots\ldots(3)$$

$$S = \frac{\pi B L^2}{2L-B} \qquad \ldots\ldots\ldots\ldots\ldots(4)$$

Where $B=(WT)^{0.5}$

The aspect ratio (Ra) was calculated by (Maduako and Faborode, 1990)

$$Ra = \frac{W}{L} \qquad \ldots\ldots(5)$$

Thousand kernels weight (W) was determined by counting 100 kernels and weighing them in an electronic balance and then multiplied by 10 to give the mass of 1000 kernels. The bulk density is the ratio of the mass sample of the kernels to its total volume. It was determined by filling a 1000 ml container with kernels from a height of about 15 cm, striking the top level and then weighing the contents (Gupta and Das, 1997).
Apparent density defined as the ratio of mass of the sample to its kernel volume, was determined using the water displacement method. Five hundred milliliter of water was placed in a 1000 ml graduated measuring cylinder and 25 g seeds were immersed in that water. Owing to the short duration of the experiment and the nature of the skin of the kernel, which did not allow water to be absorbed easily, the kernels were not coated to prevent moisture adsorption. The amount of displaced water was recorded from the graduated scale of the cylinder. The ratio of weight of seeds to the volume of displaced water gave the kernel apparent density (Amin et al. 2004).
Bulk porosity of bulk kernel was computed from the values of kernel apparent density and bulk density using the relationship given by Mohsenin, 1980 as follows:

$$\varepsilon = (1 - \frac{\rho_b}{\rho_a})\text{X } 100 \ldots\ldots\ldots\ldots\ldots(6)$$

where ρ_b is the bulk density and ρ_a is the apparent density. The coefficient of static friction was determined with respect to three surfaces: plywood (μp), galvanized iron sheet (μg) and aluminum sheet (μa). These are common materials used for handling and processing of grains and construction of storage and drying bins. A hollow metal cylinder 50 mm diameter and 50 mm high and open at both ends was filled with the seeds at the desired moisture content and placed on an adjustable tilting table such that the metal cylinder does not touch the table surface. The tilting surface was raised gradually by means of a screw device until the cylinder just starts to slide down. The angle of the surface was read from a scale and the static coefficient of friction was taken as the tangent of this angle. Other researchers have used this method for other grains and seeds (Dutta et al. 1998).

To determine the dynamic angle of repose (ɵ), a plywood box measuring 300 mm× 300 mm ×300 mm, having a removable front panel was used. The box was filled with the seeds at the desired moisture content, and the front panel was quickly removed, allowing the seeds to flow to their natural slope. The angle of repose was calculated from measurements of seed free surface depths at the end of the box and midway along the sloped surface and horizontal distance from the end of the box to this midpoint. This method has been used by other researchers (Suthar and Das, 1996: Jain and Bal, 1997). The angle of repose may also be determined from the diameter and height of a heap of seeds on a circular plate (Visvanathan et al. 1996). All the experiments were replicated 5 times for each grain samples, and the average values were reported.

RESULTS AND DISCUSSIONS

A summary of the physical properties of major cereals is shown in Table 1. The average maize length, width and thickness were found to be 9.87, 7.41, and 3.25 mm, respectively, while 8.45, 2.60, and 1.86mm were obtained for rice and 7.08, 3.27, and 2.98mm for wheat. Seeds graded uniformly, according to size, provide uniform germination and usually give increased harvesting yield. Effective grading according to width, through sieves with round holes, occurs when the particles lie along the axis perpendicular to the surface of the sieve. For this, the sieve must be vibrating vertically. When the length of the particle is no more than twice the width, the grading is satisfactory even on sieves which vibrate horizontally (Klenin et al., 1986). The equivalent diameters for maize, rice and wheat were 6.9, 3.44 and 4.10 mm, respectively. Based on statistical analysis, a significant difference at the 5% level probability was observed between them. There were marked differences in the sphericity values among the cereals. The sphericity of maize, rice and wheat were observed in the range of 62.76%, 40.76% and 57.93%, respectively. The sphericity values of raw rice fall within the range of 0.32–0.41 reported by Mohsenin (1986) for most agricultural materials. The results for sphericity agreed with this suggestion. The grain volume values for maize, rice and wheat were 90.30, 20.27 and 31.20mm^3, respectively. Surface area values for maize, rice and wheat were observed mean value of 120.02, 20,27 and 31.20mm^2 respectively. The separation of the grain mix in an air stream depends on not only the ratio between the air velocity and the terminal velocity of the particles but also on the quantity of particles entrained per unit volume of the air flow. The rate of heat transfer to the material also significantly depends on the heat transfer surface. The smaller the volume of material per unit surface, the better its condition for rapid heat transfer. The effects of size and surface area on drying rates of particulate materials can also be characterized by using the surface to volume ratio. When diffusion of water within the particle limits drying rate, larger particles dry more slowly than smaller particles of the same shape. Also, the ratio of surface area to volume affects drying time and energy requirements (Stroshine and Hamann, 1994). Bulk density values showed significant differences between the cereals at the 5% probability level. In precision agriculture, diverse approaches are used to determine the volume of the existing grain in a combine hopper. To determine the weight of product in the hopper, a knowledge of bulk density is necessary. The mean value for bulk density of maize, rice and wheat were 765, 471 and 650 kg/m3, respectively. The bulk density of grains is useful in the design of silos and storage bins (Nalladulai et al., 2002). Since the bulk density of rice is less than that of maize and wheat, maize and wheat would require a larger silo compared to rice with the same weight. The true density of maize, rice and wheat were found to be 1315, 1193 and 1150 kg/m3, respectively. Pneumatic sorting tables are used to separate seeds of cereal crops by true density. Seeds of various impurities such as centourea, rye grass, field mustard and wild oats greatly differ in true density from the seeds of cereal crops. The true density of grain mixtures is determined either in solution or in suspension (Klenin et al., 1986). The porosity values of maize, rice and wheat showed significant differences. The corresponding values for maize, rice and wheat were 62.76, 40.76 and 57.93%, respectively. During convective drying with forced draft, when the air or air and combustion product mixture is blown through the grain mass layer of high porosity, the resistance offered to the air combustion product mixture is low, resulting in faster drying compared to the cases in which porosity is low. Difference among cereals in terms of true and bulk density and porosity may be due to characteristics of cereal type. Aspect ratio values of grains present significant differences at the 1% probability level among the cereals. The aspect ratio for maize, rice and wheat were 0.75, 0.31 and 0.46 respectively. In the case of the static coefficient of friction, as shown in Table 1, there were significant differences between the studied cereals and among surfaces at the 1% level probability. For maize, the average value of the static coefficient of friction against plywood, aluminium sheet and galvanized iron sheet, were 0.68, 0.53, and 0.6, respectively, while 0.42, 0.28, and 0.38 were obtained for rice and 0.38, 0.31and 0.33 for wheat respectively. For the same surfaces, Brooker et al. (1992) (cited by Fotana, 1986), determined a friction coefficient value range of 0.4–0.45, 0.45–0.6 and 0.4–0.5 for wood, concrete and steel, respectively. It was observed that in order to establish comparisons between the results from differences of the wall material roughness, measurements of average roughness were needed. There were no marked differences in the angle of repose values between the maize, rice and wheat. Thousand grain weight values of maize, rice and wheat were 220.64, 21.64 and 30.20 g, respectively.

Table 1. Some Physical properties of major cereals

Property	**Maize**	**Rice**	**Wheat**
Moisture Content, (%db)	9.12	9.70	8.40
Length, mm	9.87	8.45	7.08
Width, mm	7.41	2.60	3.27
Thickness, mm	3.25	1.86	2.98
Geometrical mean diameter, mm	6.19	3.44	4.10
Sphericity, %	62.76	40.76	57.93
Aspect ratio	0.75	0.31	0.46
Surface area,mm^2	120.02	20.27	31.20
volume,mm^3	90.30	30.76	40.45
True density, Kg/m^3	1315.00	1193.00	1150.00
Bulk density, Kg/m^3	765.00	471.00	650.00
Porosity, %	41.83	60.52	43.48
1000 kernel weight	220.00	21.64	30.00
Angle of repose	30.20	37.50	36.20
Static coefficient of friction			
Plywood	0.68	0.42	0.38
Aluminium sheet	0.53	0.28	0.31
GI sheet	0.60	0.38	0.33
Grain to grain	0.60	0.40	0.37

CONCLUSIONS

This paper concludes with information on engineering properties of maize, rice and wheat which may be useful for designing much of the equipment used for cereal processing. It is recommended that other engineering properties such as mechanical, thermal, and rheological properties be measured or calculated to provide fairly comprehensive information on design parameters involved in cereal processing. Also, it is recommended that the effect of grain moisture content on physical properties should be investigated.

REFERENCES

Amin M N; Hossain M A; Roy K C. 2004. Effects of Moisture Content on Some Physical Properties of Lentil Seeds. J. Food Eng., 65, 83–87.

Brooker D B; Bakker-Arkema F W; Hall C W. 1992. Drying and Storage of Grains and Oilseeds. The AVI Publishing Company,Westport, 450pp.

Dutta S K; Nema V K; Bhardwaj R K. 1998. Physical Properties of Gram. J. Agric. Eng. Res., 39, 259–268.

Gupta R K; Das S K. 1997. Physical Properties of Sunflower Seeds. J. Agric. Eng. Res., 66, 1-8.

Jain R K; Bal S. 1997. Properties of Pearl Millet. J. Agric. Eng. Res. 66, 85–91.

Klenin N I; Popov I F; Sakun V A. 1986. Agricultural Machines, Theory of Operation, Computation of Controlling Parameters and the Conditions of Operation, first ed. Reka Printers Private Limited, NewDelhi.

Maduako J N; Faborode M O. 1990. Some physical properties of cocoa pods in relation to primary processing. Ife Journal of Technology 2, 1–7.

Mohsenin N N. 1986. Physical Properties of Plant and Animal Materials, second ed. Gordon and Breach Science Publishers, New York.

Nalladulai K; Alagusundaram K; Gayathri P. 2002. Airflow resistance of paddy and its byproducts. Biosystems Engineering 831, 67–75.

Stroshine R; Hamann D D. 1994. Physical Properties of Agricultural Materials and Food Products. Course manual, Purdue University,USA.

Suthar S H; Das S K. 1996. Some Physical Properties of Karingda Seeds. J. Agric. Eng. Res., **1996**, 65, 15–22.