A comparative study of various physical properties of five indigenous rice varieties of Dinajpur districts of India and Bangladesh

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Abstract: Due to the green revolution in agricultural field, the acceptability of the indigenous rice variety is decreasing now –a- days. The high yielding varieties (HYV's) has importance in recent perspective. In this paper, we have studied some geometrical and gravimetrical properties of five indigenous rice varieties collected from different parts of Dinajpur districts of West Bengal, India and Bangladesh. The data of axial dimension showed, there was no horizontal vibration of rice variety that is very important for rice processing. According to the shape and size of the rice variety fall in slender, bold and fine to super–fine in quality. We have calculated the angle of repose θ value and it was seen that all the varieties are free–flowing (30–38°). We have seen from the data that aspect ratio R_a is proportional to sphericity φ. The examined five indigenous rice varieties in this study are not spherical in nature. The surface area of S and the volume of V are the highest and lowest for Kalonunia (BD) and Begun Bichi (Ind) respectively. The surface area/volume ratio was observed as maximum for Begun Bichi (Ind) i.e. 1.959, might be responded by the easy heat transfer.

Keywords: Indigenous rice varieties, High yielding varieties, geometrical properties, gravimetrical properties, free-flowing, sphericity

1. Introduction

Rice *(Oryza Sativa L.)* is a plant of grass species, Gramineae (Poaceae) and it is one of the main food crops in the world. Traditionally, India has a verse record of rice farming internationally. First, India stands in the rice cultivation region and secondly in the rice production [1]. The physical and engineering property of agricultural equipment is significant as the best having in the mind of mechanism for planting, harvesting, storing and processing operations. Furthermore, thrashing, managing, dusting and drying. The main axial dimension of rice grain is used for selecting sieve for separating during rice milling operation [2]. These properties are evaluated as a function of the moisture content and dry weight basis of rice grain. The granules are examined for sphericity, bulk density, true density, porosity and angle of repose by dry weight basis. Rice quality can be measured by some physical and mechanical properties i.e. sphericity, densities (bulk density and true density), porosity, and the angle of repose; aromatic, dietary, cooking and eating value; ageing properties, milling quality and degree of milling (DOM) [3]. The axial dimension (length, width and thickness) of a rice grain is useful for choosing sieve for separating and calculating the essential control for rice milling procedure. The axial dimension can also be used in determining the aspect ratio, surface area and volume of the grain, that are significant for modelling of aeration kinetics including heating, cooling and drying. Absorbent mode of grain bulk allows the airflow to pass through and approach to almost all individual kernels. Its value is in relation to the power of drying system [4]. Comparative studies of various black rice and rice starch were investigated by many research groups. [5,6]. Two districts of West Bengal in India *viz.* North Dinajpur and South Dinajpur and the Dinajpur District of Bangladesh are traditionally rice–growing areas, and the variation in micro–climate across these two districts have resulted in the evolution of a huge number of landraces rice cultivars were not found anywhere else in the world. With the advent of green revolution, the high yielding varieties (HYV's) of rice were introduced. The HYV's of rice though somehow meet the goal for achieving the high production of rice still it has some disadvantages to

produce high quality of rice with desired food values. Generally the rice cultivars suited to upland and deep–water paddy farms slowly have started disappearing. [7] Though green revolution greatly helped in maximizing the production capacity however, continuous application of chemicals has caused serious threats to the soil, ecology, environment and human health. To minimize such kind of drawbacks, government should implement the indigenous rice varieties again to cope with all environmental hazards. But there is little or no data existence in scientific literature on the physical proprieties and processing characteristic of indigenous rice varieties cultivated in Dinajpur District in Bangladesh and the North Dinajpur District in India. The current study, therefore, is intended and conducted to find out some of the physical and processing properties of rice including linear dimensions (Length, Width, and Thickness), 1000 grains weight, surface area, volume, geometric mean diameter, sphericity, aspect ratio, percentage hull and milling performance of some popular rice varieties grown in aforementioned regions as a strategy to create scientific data for the improvement of technical system rice processing operation for the general improvement of the competitiveness of locally milled rice. The main objective of our research work is to determine some of the physical and mechanical properties of five indigenous rice varieties of India and Bangladesh that can help to the design of handling, processing, and packaging machinery for rice production.

2. Materials and Methods

The rice grains used in this study were collected from local rice cultivators in Dinajpur District in Bangladesh and in Raiganj, North Dinajpur, West Bengal, India. Rough rice grains of Begun Bichi (collected from Raiganj, North Dinajpur, India) and Kalojeera cultivars (collected from Raiganj, North Dinajpur, India) are short and medium grain in size. On the other hand, the variety of Begun Bichi (Collected from Dinajpur, Bangladesh) is short grain and Kalonunia and Vough (Collected from Dinajpur, Bangladesh) are medium grains in size.

The collected rice grain varieties were cleaned physically and separate all foreign matters for example dust, sand and, broken rice and drying them about on a dry weight basis. 100 rice grains were selected randomly from each rice sample to determine the main axis length (L), intermediate axis width (W), and the simple axis thickness (T) of the raw rice interior by using a vernier calliper to an accuracy of 0.01 mm.
Toluene was purchased from Merck and it used to determine the true density. All rice kernels were weighed by K. Roy microbalance, India (model BW203) with accuracy of 0.01mg.

2.1. Geometrical properties:
The aspect ratio (Ra), equivalent diameter (Dp), volume (V), sphericity (φ) and surface area (S) can be determined by the following equations [4,8–10]. Where L is the length (mm), W is the width (mm), and T is the thickness (T) of a rice grain and B is calculated by the equation $B = \sqrt{WT}$. The values of mean, maximum, minimum, and standard deviations were calculated by Microsoft Excel (2007).

2.1.1. Equivalent diameter (Dp):
The grains Equivalent Diameter (D_p) determined by the following equation [10]:
$$D_p = [4L(\tfrac{W+T}{4})^2]^{1/3} \text{———————} (1)$$

2.1.2. Volume (V)
The grains Volume (V) determined by the following equation [4]:
$$V = 0.25[\left(\tfrac{\pi}{6}\right)L(W+T)^2] \text{———————} (2)$$

2.1.3. Surface Area (S)
The surface area of a rice grain was determined by the following equation [4, 11, 12]:
$$S = \tfrac{\pi B L^2}{2L-B} \text{—————} (3)$$

2.1.4. Sphericity (φ)
The shape of a paddy can be expressed in the term of sphericity (φ). It is defined as the ratio or the surface area of sphere having the same value of the paddy and was followed by this equation [4].

$$\varphi = \tfrac{(LTW)^{1/3}}{L} \text{—————} (4)$$

2.1.5. Aspect ratio (Ra)
The aspect Ratio (Ra) of the rice grains was determined by the following equation [13].
$$R_a = \tfrac{w}{L} \text{—————} (5)$$

2.1.6. Size and shape

Size is one of the important physical parameters and it is used to describe the object. Size dimension was analysed by the behaviour of a rice grain during handling, processing, storage and designing the machinery [14]. The Size was determined by the following formula [14].

$$Size = (Length \times Width \times Thickness)^{\frac{1}{3}} \quad (6)$$

Shape is defined as the ratio of Length (The principal axial dimension) to width. The shape of a grain is influenced by volume and weight. Slender type rice varieties take on more volume than round type rice varieties [14].

$$Shape = \frac{Length}{Width} \quad (7)$$

2.2. Gravimetrical properties:

The weight of one thousand rice grains was taken from the each test sample and the weight was measured by a digital electronic balance.

2.2.1. Bulk Density

Bulk density, ρ_b in kgm^{-3} is the ratio of the weight of the sample to its entire volume. To determine the bulk density, a cylindrical container with a height of 0.3 meters and a diameter of 0.2 meters is filled with grains of 0.15 meters high from the top surface of the container and the upper level without separate or additional manual compression was performed.

$$\rho_b = \frac{M}{V} \quad (8)$$

Where: ρ_b= bulk density; M= mass of the rice granule; V= volume of the Cylinder.

2.2.2. True density

The true density, ρ_t in kgm^{-3} defined as the ratio of weight the sample to its true volume (rice grain volume) was determined by liquid displacement method employing toluene (C_7H_8) [9, 10, 15]. Toluene was used in the place of water because of rice absorbing toluene to a lesser extent than water.

3. Results and Discussions

3.1. Axial dimensions

The geometrical properties of the collected five rice varieties were investigated in this study, shown in the **table 1**. The axial dimensions of 100 grains of each rice varieties were determined. The length 5.957 mm, width 2.052 mm and the thickness 1.469 mm were found for Begun Bichi (Ind). Kalojeera

$$\rho_t = \frac{M}{v} \quad (9)$$

V = volume of the rice and $v = (V_1 – V_2)$
V_1 = total volume of the cylinder and V_2 is the volume of toluene.

2.2.3. Porosity

Porosity (ε) is defined as the percentage of free space in bulk grain that is not occupied by grain. The mean, minimum, maximum, and standard deviations were calculated by Microsoft Excel (2007). It was determined by following relationship [4].

$$\varepsilon = \frac{(\rho_t - \rho_b)}{\rho_t} \times 100 \quad (10)$$

Where ε = Porosity, ρ_t = True Density and ρ_b = Bulk Density of collected indigenous rice varieties.

2.2.4. Angle of Repose

According to Shi Hu the angle of repose to a grain is the steepest angle of decrease comparative to the horizontal flat surface to a material can be piled without sliding. The angle of repose is one of the main characteristic of granular materials that reflects inter–particulate resistance and to characterize their flow ability [16]. The angle of repose is a good determinant which commonly used for the evaluation of antiparticle forces, flow behaviour of granular materials and is significant for the design of processing, storage and conveying systems of particular materials. When the grains are smooth and rounded, the angle of repose is low. For very fine and sticky materials the angle of repose is high. The angle of repose was measured by fixed funnel method [17].

The Angle of repose was measured by the following formula [18].

$$\theta = tan^- (\frac{h}{r}) \quad (11)$$

Where θ the Angle of Repose, h is the height and r is the radius of the cone.

(Ind) has the length 7.248 mm, width 2.164 mm, and thickness 1.474 mm. Begun Bichi (BD)

has the length 6.179 mm, width 2.047 mm, and thickness 1.484 mm. For the variety of Kalonunia (BD) the length, width, and thickness were found as 7.460 mm, 2.305 mm and 1.650 mm respectively. Whereas, the length, width, and thickness were appeared as 7.242 mm, 2.001 mm

and 1.532 mm respectively for Vough (BD) variety. We found that the Kalonunia (BD) has the highest length and Begun Bichi (Ind) has the minimum. The Kalonunia (BD) has the highest width and minimum was for Vough (BD) whereas the Kalonunia (BD) has the highest thickness and Begun Bichi (Ind) has the minimum. There was no such a significant difference of lengths among all other varieties. Similarly, the width and the thickness of all other varieties have no such a significant difference. Axial dimension is essential to determining the size of apertures and mode of reciprocating motion in designing grain handling machinery [13, 19].

The width using sieves with round holes occur while the sieves vibrate vertically. When the length of the grain is less than twice of width, then the grading would be acceptable even on sieves which vibrate horizontally [13]. According to **table 1**, no indigenous varieties studied in this paper have shown horizontal vibration.

According to the standard evaluation system (SES) for rice, the length of Begun Bichi (Ind) variety was appeared as medium (5.51 to 6 mm) and the other varieties as long (6.6 to 7.5 mm). The width of the variety of Begun Bichi (Ind), Begun Bichi (BD) and Vough (BD) was very narrow (<2.0 mm) and the variety of Kalojeera (Ind) and Kalonunia (BD) was found as narrow (2.1–2.5 mm) [20]. We determined the size of 100 grains of each indigenous rice variety and the values are represented in the **table 1**. The size for various rice varieties was observed as 2.615 mm for Begun

Bichi (Ind), 2.846 mm for Kalojeera (Ind), 2.654 mm for Begun Bichi (BD), 3.023 mm for Kalonunia (BD) and 2.808 mm for the variety of Vough (BD). It has been found that the Kalonunia (BD) has the highest value of size and the lowest was observed for Begun Bichi (Ind). The size is known as the geometric mean dimension (De), which is significant in itself as it is correlated with three major axial dimensions of the grain (L, W and T) [21].

We also determined the shape of each collected rice varieties. The values of shapes were observed as 2.918, 3.363, 3.033, 3.270 and 3.628 for Begun Bichi (Ind), Kalojeera (Ind), Begun Bichi (BD), Kalonunia (BD) and Vough (BD) respectively. We observed that Vough has the highest value of shape and lowest was for Begun Bichi (Ind). The values of length to width ratio were used to classify the shape of the individual rice grain. The rice grains were classified as considering the length to width ratio; round (ratio>2.0), bold (ratio 2–3) and slender (ratio>3.0) [22]. Rice is also classified in three groups as considering the ratio of length to width; rice is super fine if the ratio is >3, fine if the ratio is >2.5, and common if the ratio is <2.5 [23].

According to the results, Kalojeera (Ind), Kalonunia (BD) and Vough (BD) rice varieties are slender type and super fine in quality. Other two varieties i.e. Begun Bichi of India and Bangladesh are Bold and fine in quality. The digital image of five indigenous varieties of rice kernels is given in the **figure 1**. The data shown in the **table 1** are represented graphically in the **figure 2**.

Figure 1. Digital images of five indigenous rice kernels

Table 1: Axial dimensions, shape and size of five indigenous rice varieties

Variety	Value	Axial dimensions (mm)			Shape	Size (mm)
		Length	**Width**	**Thickness**		
Begun Bichi (Ind)	Mean	5.957	2.052	1.469	2.918	2.615
	Max	6.800	2.500	1.700	3.529	2.924
	Min	5.100	1.700	1.300	2.360	2.412
	SD	0.209	0.157	0.091	0.222	0.094
Kalojeera (Ind)	Mean	7.248	2.164	1.474	3.363	2.846
	Max	7.700	2.500	1.800	4.052	3.198
	Min	6.900	1.900	1.000	2.800	2.487
	SD	0.214	0.156	0.099	0.222	0.116
Begun Bichi (BD)	Mean	6.179	2.047	1.484	3.033	2.654
	Max	7.000	2.400	1.700	3.555	2.866
	Min	5.800	1.800	1.400	2.458	2.458
	SD	0.270	0.150	0.080	0.250	0.097
Kalonunia (BD)	Mean	7.460	2.305	1.650	3.270	3.023
	Max	8.000	2.600	1.900	4.315	3.319
	Min	6.900	2.000	1.500	2.760	2.696
	SD	0.303	0.171	0.095	0.292	0.133
Vough (BD)	Mean	7.242	2.001	1.532	3.628	2.808
	Max	7.900	2.300	1.800	4.166	3.091

Min	6.700	1.800	1.300	3.181	2.598
SD	0.268	0.108	0.104	0.213	0.098
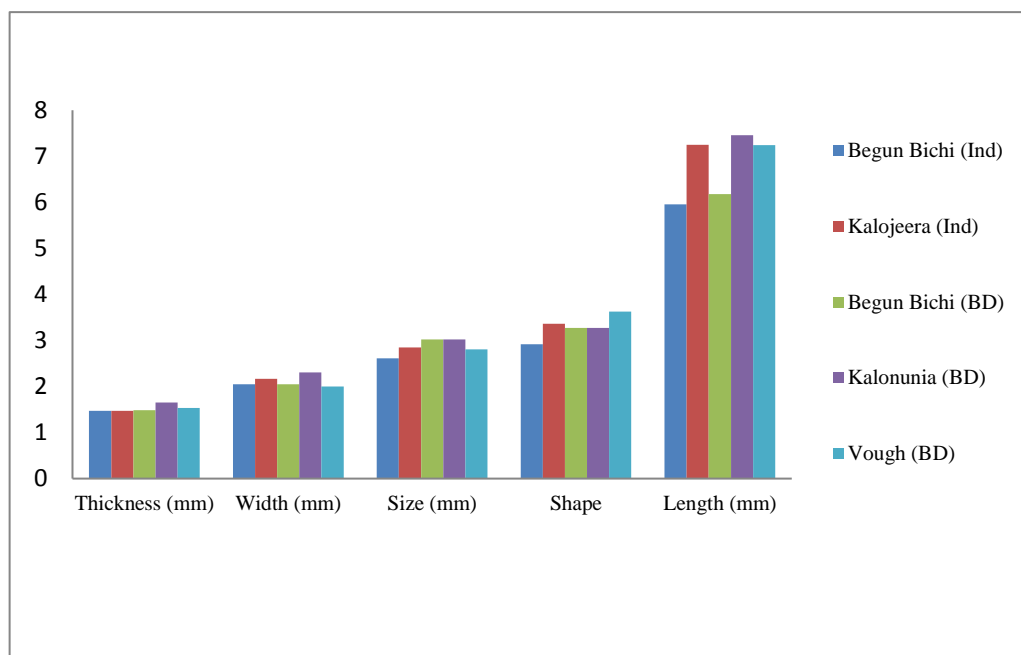
Figure 2. The graphical representation of axial dimensions, shape and size of five indigenous rice varieties

3.2. Weight of thousand grain

The weight of thousand grains of rice and the value of bulk density, true density and porosity were shown in the **table 2, figures 3 and 4**. The different weights of thousand grains of Begun Bichi (Ind), Kalojeera (Ind), Begun Bichi (BD), Kalonunia (BD) and Vough (BD) were 10.766×10^{-3}, 13.737×10^{-3}, 12.455×10^{-3}, 14.677×10^{-3} and 14.722×10^{-3} kg respectively. The weight of thousand grains showed a significant difference among all the indigenous rice varieties. The maximum weight of thousand grains (14.776×10^{-3} kg) was obtained for Vough (BD) variety and the minimum value (10.766×10^{-3} kg) belongs to the variety of Begun Bichi (Ind).

3.3. Bulk Density, True Density and Porosity

The value of bulk densities were appeared as 591.558, 501.528, 571.419, 597.068 and 513.150 kgm^{-3} respectively for the varieties of Begun Bichi (Ind), Kalojeera, Begun Bichi (BD), Kalonunia (BD) and Vough (BD) respectively. The bulk density was highest for Kalonunia (597.06 kgm^{-3}) and lowest for Kalojeera (501.528 kgm^{-3}).

The true densities of Begun Bichi (Ind), Kalojeera (Ind), Begun Bichi (BD), Kalonunia (BD) and Vough (BD) were 1171.322, 1127.173, 1177.222, 1289.892 and 1103.573 kgm^{-3} respectively for the varieties. Begun Bichi collected from Bangladesh and India has no such significant difference in true density. Kalonunia (1289.8 kgm^{-3}) had maximum and Vough (BD) (1103.5 kgm^{-3}) had minimum values of true density.

The value of porosity for Begun Bichi (Ind), Kalojeera (Ind), Begun Bichi (BD), Kalonunia (BD) and the Vough (BD) were 49.473%, 55.476%, 51.385%, 53.633% and 53.474%, respectively. The range of porosity values for all varieties was found as 49.473% to 55.476%. The porosity value of most cereal grains ranges between 35 and 55% [24], which were corroborated to our research work.

True and bulk densities demonstrate density of only material substance and density of the bulk consisting of the material substance and inter–granular spaces, respectively. The bulk density of an individual grain is always lower than its true density. Measuring densities helps to estimate the breakage susceptibility and hardness of cereal grains [13]. In this study, the bulk density of Kalojeera (Ind) variety was lowest among the other varieties (**table 2**); according the results of the table the true density of the collected rice varieties is

increase when the bulk density is increase. It would require a larger silo with the same weight compared to others. The highest bulk density belonged to Kalonunia (BD) 597.068 kgm^{-3}. Begun Bichi from both India and Bangladesh had not any significant difference in true density and the value was almost the same. True density is a proficient part for removing impurities from the cereals by the aeration process [2]. Porosity is defined as a ratio of inter–granular empty space to total space held by bulk grains [13, 25]. Kalonunia (BD) had maximum and Vough (BD) had minimum value of true density and the values were found to be 1289.892 and 1103.573 kgm^{-3} respectively.

Physical properties such as length and porosity have significant influences on increasing degree of milling (DOM) in rice and as a result of the loss of selenium while producing white rice from brown rice. In a similar milling time, long–grain rice has revealed a higher DOM than the grains with shorter length [26, 27]. When brown rice is hulled from rough rice it lost to its total weight 8-10% it also lost some important nutrient components such as proteins, lipids, vitamins, minerals, dietary fibers, iron, and selenium [27]. Liu *et al*. expressed that width, thickness, sphericity and bulk density had a significantly negative relation with DOM; on the other side, the length and the porosity increased DOM. According to the drying process, higher porosity improves aeration quality and subsequently increases water vaporization [19, 27]. The highest porosity value was found as 55.476% for Kalojeera (Ind), and indicated that the water vaporization increases for this variety and could be easily dried under the aeration process. We have drawn a relation between the bulk density, the true density and the porosity among the studied varieties

in this work. It can be shown from the **table 2** and **figure 3** that if the bulk density has higher value then the true density and porosity will be lower one in most of the cases.
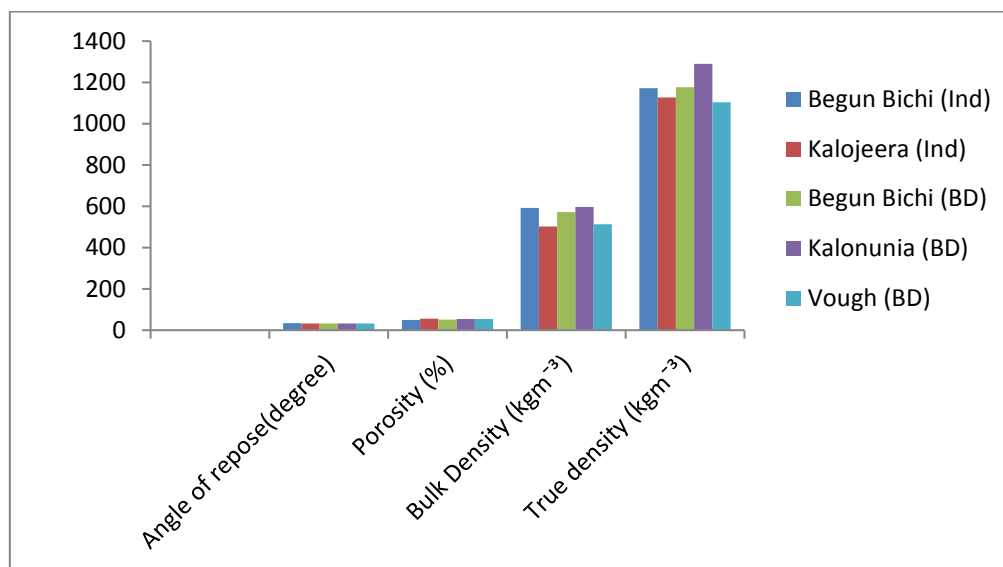
3.4. Angle of repose

The result of the angle of repose is shown in **table 2**. It was shown that the values of all the rice varieties are almost the same. The angle of repose values of the five indigenous rice varieties, Begun Bichi (Ind), Kalojeera (Ind), Begun Bichi (BD), Kalonunia (BD) and the Vough (BD) were 33.377°, 33.070°, 31.944°, 31.853° and 32.139° respectively. It was also shown that the values of angle of repose of collected five examined rice varieties ranged between 31.853–33.377°. Generally the lower values of angle of repose means the grains are flowing easily [13]. The angle of repose was affected by the grain size and relatively the rough surface of the grain prevents the easy slide of grains on each other [28]. In the agricultural field, the angle of repose is broadly used to design and dimensioning of silos and tanks, hoppers to determine the capability and required volume of the stored and transported seeds, wheat, rice, flour, *etc*. [29]. There is a concrete affiliation between the angle of repose and the porosity; as the angle of repose increases, the granular porosity increases and the granular porosity of the granules decrease when the angle of repose is decreased [3]. The grains with the angle of repose ranging 25–30° are- very free flowing, 30–38°, free flowing, 38–45°, fair flowing, 45–55°, cohesive or non–easy flowing and more than 55° can be considered very cohesive materials [4,28]. According to the data, all the indigenous varieties used herein are regarded as free flowing [28].

Table 2. Weight of 1000 grain, bulk density, true density, and porosity of five indigenous rice varieties

Variety	Weight of 1000 grains (10^{-3} kg)	Angle of repose (degree)	Porosity (%)	Bulk Density (kgm^{-3})	True Density (kgm^{-3})
Begun Bichi (Ind)	10.766	33.377	49.47	591.558	1171.322
Kalojeera (Ind)	13.737	33.070	55.47	501.528	1127.173
Begun Bichi (BD)	12.454	31.944	51.38	571.419	1177.222
Kalonunia (BD)	14.677	31.853	53.63	597.068	1289.892

Vough (BD)	14.776	32.139	53.47	513.15	1103.573

Figure 3. The graphical representation of angle of repose, porosity, bulk density and true density of five indigenous rice varieties
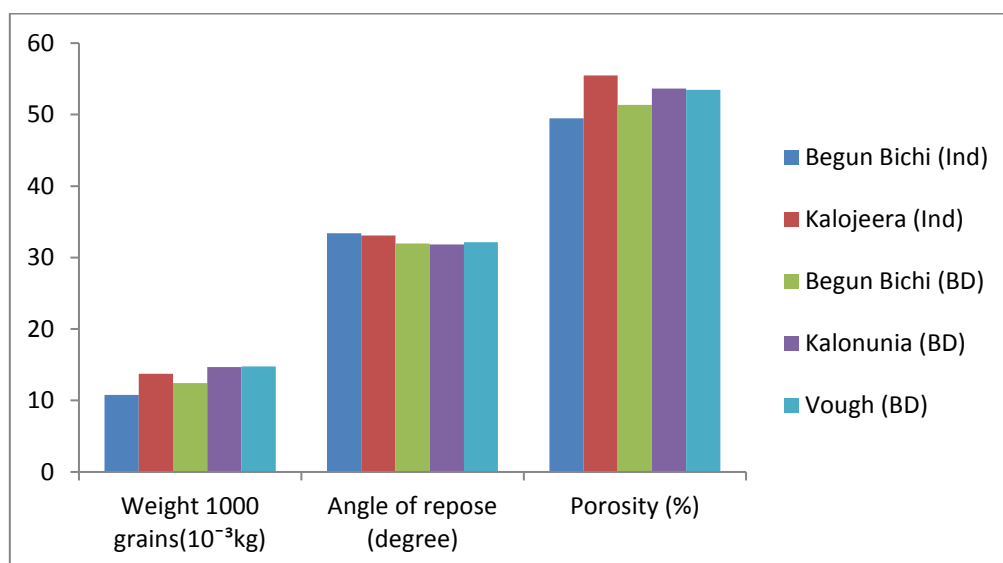
Figure 4. The graphical comparison among the weight 1000 grain, angle of repose and porosity of five indigenous rice varieties

3.5. Aspect ratio

The various geometrical properties like aspect ratio, equivalent diameter, volume, sphericity, and surface area were shown in **table 3 and figure 6**. We had determined these properties of 100 grains of each rice variety. The aspect ratio was determined by the equation 5 as mentioned in the materials and method section. Aspect ratio is an important parameter for determining the grains which may slide or roll on their flat surfaces or not. Higher length to width ratio or lower width to length ratio means that the grains slide more than roll on a surface [16]. The values of aspect ratio for the variety Begun Bichi (Ind), Kalojeera (Ind), Begun Bichi (BD), Kalonunia (BD) and Vough (BD) were 0.3446, 0.2985, 0.3318, 0.3093 and

0.2765 respectively. The value of aspect ratio was almost the same for all of the collected indigenous rice varieties. The highest value of aspect ratio was assigned for Begun Bichi (Ind) and the lowest value for the Vough (BD) variety.

3.6. Sphericity

The sphericity was determined by equation 4. The value of sphericity for Begun Bichi (Ind), Kalojeera (Ind), Begun Bichi (BD), Kalonunia (BD) and Vough (BD) were found as 0.4329, 0.3926, 0.4301, 0.4065 and 0.3879 respectively. The range of the sphericity for most of the agricultural products is 0.32 to 1 [9]. Similarly, the aspect ratio and the values of sphericity express whether the grains would slip or roll on their surface. The result of the sphericity and the aspect ratio in this study approves the mentioned reality. According to **table 3**, the lower and the higher values of the aspect ratio belonged to the varieties with the lower and the higher values of the sphericity. The sphericity of a grain is more than 0.7 classified as spherical [30]. According to the obtained results, none of the examined varieties are classified as spherical kernels.

3.7. Equivalent diameter

The equivalent diameter was determined by equation 1. The values of equivalent diameter for the variety of Begun Bichi (Ind), Kalojeera (Ind), Begun Bichi (BD), Kalonunia (BD) and Vough (BD) were 2.6422, 2.8830, 2.6792, 3.0771 and 2.8265 mm respectively. There is no significant difference among these values. The highest and the lowest values of the equivalent diameter were obtained for Kalonunia (BD) and Begun Bichi (Ind) respectively.

3.8. Surface area

We used equation 3 as mentioned in the materials and method section to determine the surface area. The range of this value was found between 19.0047 mm^2 to 26.2603 mm^2. The values of the surface area for Begun Bichi (Ind), Kalojeera (Ind)¸ Begun Bichi (BD), Kalonunia (BD) and Vough (BD) were 19.0047, 23.1868, 19.6873, 26.2603 and 22.6501 mm^2 respectively. Kalonunia (BD) has the highest value of the surface area as we have seen from the **table 3 and figure 5**. The values of the equivalent diameter and the surface area depend on the axial dimensions and these parameters are helpful for the modelling of drying kinetics, heating, cooling and aeration systems [31].
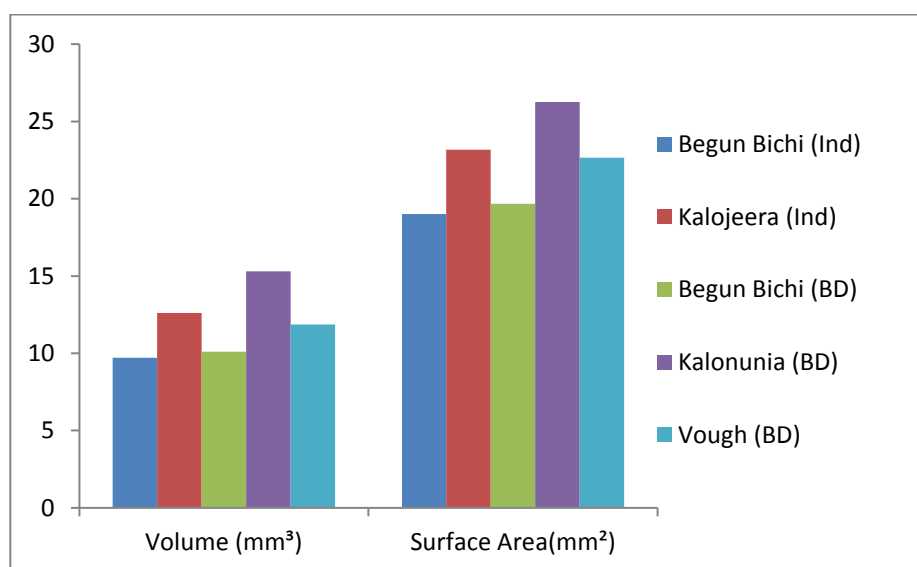
3.9. Volume

To determine the volume, we used equation 2 in the materials and method section. The value of the volume for Begun Bichi (Ind) has 9.7006 mm^3, Kalojeera (Ind) has 12.6116 mm^3, Begun Bichi (BD) has 10.1138 mm^3, Kalonunia (BD) has 15.3094 mm^3, and the Vough (BD) has 11.8670 mm^3. Kalonunia (BD) has the highest value of the volume and Begun Bichi (Ind) has the lowest shown in **table 3 and figure 5**. These findings indicate that the length, the aspect ratio and the porosity are noteworthy for optimizing the milling process in order to accomplish a required degree of milling (DOM) at the same time retaining the higher levels of selenium. The rate of heat transfer is a crucial factor for estimating aeration period and energy desires and significantly depends on the ratio of surface area to volume. The higher is the surface of a material per unit of volume; the better is the condition for heat transport [13]. According to the results in **table 3**, the surface area and volume ratio are the highest for Begun Bichi (Ind) i.e. 1.959. We assume that, Begun Bichi (Ind) variety will easily dry due to ease of heat transfer.
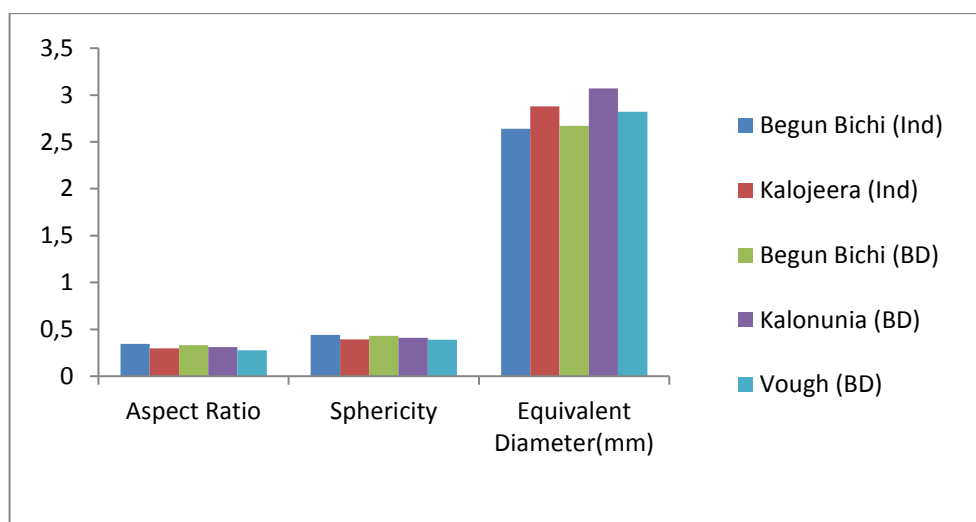
Table 3. Aspect ratio, equivalent diameter, sphericity, surface area, and volume of five indigenous rice varieties

Variety	Value	Aspect Ratio	Equivalent Diameter (mm)	Sphericity	Surface Area (mm²)	Volume (mm³)
Begun Bichi (Ind)	Mean	0.3446	2.6422	0.4392	19.0047	9.7006
	Max	0.4237	2.9570	0.4867	23.8554	13.5387
	Min	0.2833	2.4337	0.4005	16.5235	7.5476
	SD	0.0264	0.1001	0.0149	1.3185	1.1206
Kalojeera (Ind)	Mean	0.2985	2.8830	0.3926	23.1868	12.6116
	Max	0.3571	3.2382	0.4245	28.7886	17.7798

	Min	0.2467	2.6168	0.3554	18.2417	9.3829
	SD	0.0193	0.1190	0.0121	1.7548	1.5761
Begun Bichi (BD)	Mean	0.3318	2.6792	0.4301	19.6873	10.1138
	Max	0.4067	2.9129	0.4824	22.6850	12.9414
	Min	0.2812	2.4718	0.3851	16.9981	7.9084
	SD	0.0277	0.1025	0.0183	1.3771	1.1737
Kalonunia (BD)	Mean	0.3093	3.0771	0.4087	26.2603	15.3094
	Max	0.3623	3.3036	0.4508	30.0814	18.8786
	Min	0.2500	2.8440	0.3684	22.8260	12.0448
	SD	0.0252	0.1051	0.0158	1.6192	1.5581
Vough (BD)	Mean	0.2765	2.8265	0.3879	22.6501	11.8670
	Max	0.3142	3.1086	0.4172	27.3455	15.7288
	Min	0.2400	2.6292	0.3611	19.709	9.5169
	SD	0.0162	0.0981	0.0121	1.5345	1.2510

Figure 5. The graphical representation of volume and surface area of five indigenous rice varieties

Figure 6. The graphical representation of aspect ratio, sphericity and equivalent diameter of five indigenous

rice varieties

4. Conclusions

The finding that appeared in this study that there were not significant statistical differences among all of the five collected indigenous rice varieties in the case of geometrical and gravimetrical properties. There was no horizontal vibration of rice kernels were seen for all varieties. According to standard evaluation system (SES), Begun Bichi (Ind) was designated as medium and other varieties as long. Slender and bold types of varieties were seen as per data and the quality of rice was assigned as fine and super fine. The bulk density, true density and the porosity were measured.

Similarly, the other values such as angle of repose, aspect ratio, sphericity, surface area, equivalent diameter were also measures according to standard method and the values were evaluated as per standard equations as mentioned in the manuscript (literature given). It is possible to get the value of rate of heat transfer by means of surface area to volume ratio. It was found that the highest value of this ratio was seen for Begun Bichi (Ind). These data could be useful for designing of the tools to handle, transport, progress, store the rice grains and investigation of behaviour of products for the period of post–harvest processing.

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