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Studies on physical properties of pelleted radish (*Raphanus sativus*) seeds

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Abstract: Radish (Raphanus sativus) is one of the major vegetable crop grown throughout the country. It is widely grown in different parts of the country mainly by small and marginal farmers. The planting operation of the radish crop is not mechanized in India, with most of the area cultivated by line sowing and broadcasting operation. However, problem of flow of material are experienced. Pelletizing of the radish seed by providing a seed coat, helps in changing the physical characteristics of the seed. The biometric properties of seeds play an important role in designing seed metering device. Physical and engineering properties of radish seed both un-pelleted and pelleted (T_0, T_1, T_2 and T_3) were evaluated in the laboratory. The average major and intermittent dimension of T_0, T_1, T_2 and T_3 seed were 3.31 mm, 3.75 mm, 4.27 mm, 4.35 mm and 2.72 mm, 3.11 mm, 3.64 mm, 3.84 mm, respectively.T_3 enhanced the major and intermittent dimension of seeds. Roundness value and sphericity of T_0, T_1, T_2 and T_3 seed were 0.70, 0.79. 0.82, 0.90 and 0.78, 0.84, 0.85, 0.91 respectively. The geometric mean diameter was maximum for T_3 radish seed (3.94 mm) followed by T_2 (3.65 mm), T_1 (3.14 mm) and T_0 (2.58 mm) radish seed. Thousand seed weight, W 1,000 of T_0, T_1, T_2 and T_3 was 11.74 g, 23.43 g, 32.86 g and 46.05 g respectively. Angle of repose and static coefficient of friction for mild steel surface were 28.81°, 25.09°, 23.70°, 23.16° and 0.82, 0.69, 0.65, 0.54 for T_0, T_1, T_2 and T_3 radish seed respectively. The values of porosity are decreased in gradually T_0, T_1, T_2 and T_3 seeds whereas the porosity for T_3 seed was 44.51% and is the lowest amongst the other treatments. The porosity of T_0 seed was the highest (47.78%).

Key words: Angle of repose, Radish, Physical properties, Pelleted Seed, Small seed, Test weight

Introduction

Radish (*Raphanus sativus*) is an edible root vegetable of the Brassicaceae family that was domesticated in Europe in pre-roman Times. Radishes are grown and consumed throughout the world, being mostly eaten raw as a crunchy salad vegetable. They have numerous varieties, varying in size, flavor, colour and the length of time they take to mature. Radishes of spicy varieties owe their sharp flavor to the various chemical compounds produced by the plants, including glucosinolate, myrosinase, and isothiocyanate. They are sometimes grow as companion plants and suffer from few pests and diseases. They germinate quickly and grow rapidly, smaller varieties being ready for consumption within a month, while larger daikon varieties taking several months. Some radishes are grown for their seeds: daikon, for instance, may be grown for oil production. Others are used for sprouting and both roots and leaves are sometimes served cooked (Dixon, 2007). Radish (*Raphanus sativus*) is one of the major vegetable crop grown throughout the country. It is widely grown in different parts of the country mainly by small and marginal farmers. In West Bengal and Haryana, this crop has gained the importance crop rather than as a vegetable crop because of its very high export potential. In India, West Bengal is a leading radish growing state followed by Haryana, Assam, Bihar, Odisha, Punjab and Chhattisgarh. The productivity of radish is the highest in Punjab (20.52 t/ha) followed by Chhattisgarh, Bihar, Haryana and West Bengal (18.3, 15.76, 15.23 and 12.25 t/ha) (Anon., 2015).

In Punjab radish is sown over an area in 2013-14 of about 12.33 thousand hectare having production of 253.07 thousand tonnes (Anon., 2015). Generally, the radish seeds are sown manually for small scale maintain spacing 30 to 45 cm row to row and 7.5 cm plant to plant by hand and for large scale production, broad casting method generally used by the farmers. During radish cultivation of seedlings, thinning, weeding and harvesting are the most labour intensive operations that are presently done manually in India. Because of high requirement and shortage of labour, the area under radish cultivation is low and can be increased by mechanization of this crop in India. Higher productivity with low input cost is one of the success keys in messing benefits of vegetables production. In Europe and USA precision seed planters are used, which cut down the input cost. However, these precision planters are very expensive and may not suit to the budget of our Indian farmers. Further, these are usually preferred for large scale cultivation and may not be convenient and economical for small holdings in India. No such specialized equipment's are available in India for direct planting.

Small and irregular shaped seeds lead to variation and placement of the seeds when existing planters are used. Due to this many times farmers resort to broadcasting of the seed. There is lack of mechanization in cultural practices in the areas where seed is broadcast. In areas where seed is broadcasted, there are issues of crop maintenance and management. This negatively affects the yield and cost of production. Therefore, increasing the yield and

expanding the usage of mechanization in planting areas is a necessity, because of its uniform size and shape, pelleted seed is less likely to become stuck in mechanical planters, allowing growers to plant accurately and efficiently direct seeded crops. Accurate seeding and seed spacing makes thinning stands, at a later stage, easier or even unnecessary, leading to less seed waste and lower labor costs. Seed pelleting is the process of encapsulating a seed with small quantity of inert material just large enough to produce globular unit of standard size to facilitate precision planting. The inert material creates natural water holding media and provides small amount of nutrients to young seedlings (Roos 1979, Scott 1989 and Krishnasamy, 2003). For the development of a mechanism for radish seed sowing the study of engineering properties of radish seeds is of utmost importance. Therefore, the physical properties of the radish seeds such as size, shape, test weight, angle of repose, bulk density and coefficient of static friction were studied. In recent years, physical properties have been studied for various crops such as locust bean seed (Ogunjimi *et al.,* 2002); millet (Baryeh, 2002); quiona seed (Vilche *et al.,* 2003) and almond nut and kernel (Aydin, 2003).

Material and Methods

Selection of the varieties: The varieties of the radish seed is Pusa Chetki, were selected for the study. Pusa Chetki was procured from the Director Seeds, Punjab Agricultural University, Ludhiana, India. Seeds were pelletized in different ratio according to seed weight and denoted by 1:1, 1:2 and 1:3 pelleted respectively. To study its properties and comparison between un-pelleted (T_0) seed to 1:1 pelleted (T_1), 1:2 pelleted (T_2) and 1:3 pelleted (T_3) seeds.

Sample preparation: Moisture content of the samples was determined according to AOAC approved vacuum oven method (AOAC, 1990). The seed moisture content ranged from 5.90–2.78% (d.b.) since transportation, storage and handling operations of the seeds are performed in this moisture range. All the experiments were replicated ten times and the average values were reported.

Size and shape of the seed: Olympus BX 61 microscope was used to measure the size of radish seeds. Olympus BX 61 microscope consisted of control box, motorized microscope, hand switch, data logger and a monitor. "Cell" imaging software for life science microscopy was used to measure the three principal axis of the seed. In order to acquire the image of the seed, the seed was placed in rest (horizontal) position over the glass slide and placed under the microscope. The image was focused sharply and clicked "snapshot" to obtain stationary image. Thereafter, the cell software was used to measure the two axis and thereafter the seed was rotated by 90° and the third axis was measured by repeating the same procedure. The dimensions of the randomly selected fifty seeds were measured for each variety. Further, geometric mean diameter (Dp) of the seeds were calculated using the following relationship (Mohsenin, 1970).

$$Dp = (\sqrt[2]{LWT}) \quad \text{..... (1)}$$

Where: L = Length (mm), W = width (mm), T = thickness (mm)

The Spherecity (ψ) was calculated using the following equation (Mohsenin, 1970).

$$\psi = (\sqrt[2]{LWT/L}) \quad \text{..... (2)}$$

Roundness: Roundness was measured by the trace of the seed is done on the graph paper and the area under the trace is measured by measuring the squares within it. The area of the closest circle in the seed area is also computed. The ratio of these two gives the roundness. Seed property analyser calculate Roundness with following relationship.

$$Roundness = (W/L + T/L + T/W)/3 \quad \text{..... (3)}$$

Test weight: Test weight was determined for five random samples of each variety on an electronic balance having least count of 0.001 g. One thousand seeds were counted manually and thereafter weighed on an electronic balance.

Angle of repose: The angle of repose can be measured by measuring the height of the heap and the diameter of heap formed by the seeds (Kaleemullah and Gunasekar, 2002). For the determination of angle of repose of radish seed, a plastic cylinder (inner diameter 70 mm and height 270 mm) was kept vertically on horizontal wooden surface and filled with sample. Tapping during filling was done to obtain uniform packing and to minimize the wall effect, if any. The cylinder was slowly raised above so that whole

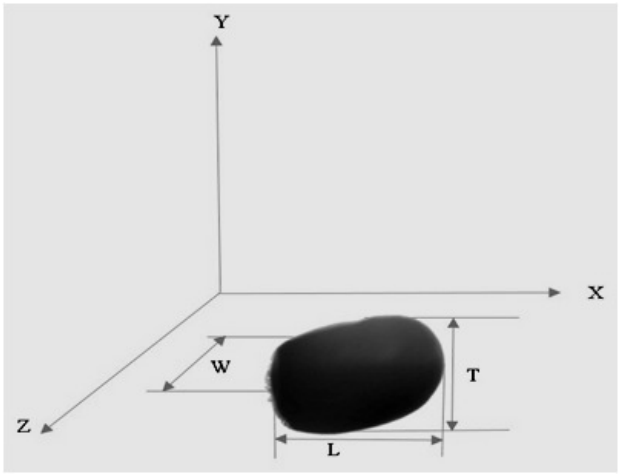

Fig. 1: Characteristics dimensions of radish

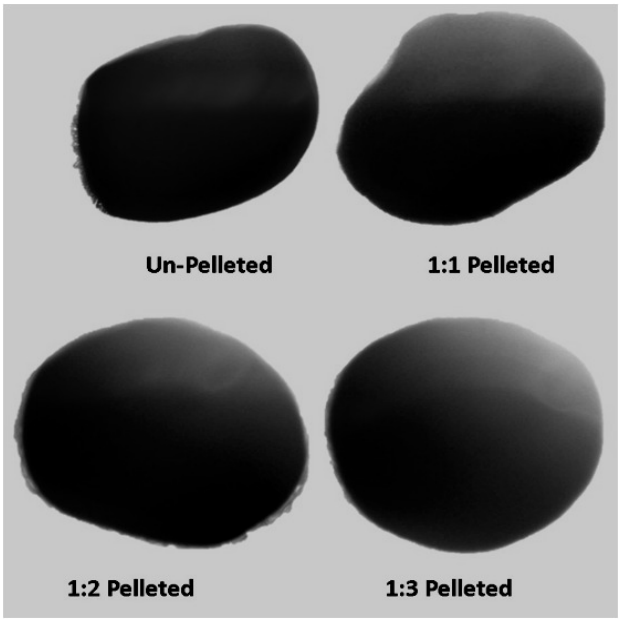

Fig. 2: Microscopic view of non-pelleted and pelleted radish seed

Table-1: Size of radish seeds of various cultivars studied

Treatment		Un-Pelleted	Pelleted 1:1	Pelleted 1:2	Pelleted 1:3
Major Dimension	Range	2.54-4.09	2.73-4.69	3.25-5.8	3.05-6.69
	Mean	3.31	3.75	4.27	4.35
	SD	0.57	0.78	0.81	1.01
	C V %	17.34	20.88	19.07	23.32
Intermediate Dimension	Range	1.79-3.70	2.15-4.39	2.71-4.9	2.6-5.37
	Mean	2.72	3.11	3.64	3.84
	SD	0.61	0.59	0.74	0.85
	C V %	22.43	18.93	20.46	22.18
Minor Dimension	Range	1.32-2.42	1.92-4.02	2.2-4.76	2.71-5.42
	Mean	1.92	2.66	3.13	3.69
	SD	0.31	0.64	0.82	0.87
	C V %	16.32	24.73	26.17	23.70

Table-2: Geometric mean diameter and Spherecity of radish seeds of various cultivars studied

Treatment		Un-Pelleted	Pelleted 1:1	Pelleted 1:2	Pelleted 1:3
Geometric Mean Diameter	Range	1.82-3.22	2.29-4.59	2.69-5.13	2.78-5.43
	Mean	2.58	3.14	3.65	3.94
	SD	0.42	0.63	0.78	0.86
	C V %	16.48	20.13	21.48	21.88
Spherecity	Range	0.68-0.85	0.71-1.01	0.79-0.94	0.78-1.14
	Mean	0.78	0.84	0.85	0.91
	SD	0.055	0.07	0.044	.09
	C V %	7.09	8.43	5.20	9.97

material could slide freely to form a heap. The height of the heap (H) and the diameter of the heap (D) were measured with the help of measuring scale and the angle of repose (Φ) of radish seed was computed using following relationship ((Bart-Plange and Baryeh, 2003; Mohsenin, 1980)

$$\Phi = \tan^{-1} (2H/ D) \quad \text{..... (4)}$$

Bulk density, true density and porosity: The bulk density is the ratio of the mass of a sample of a seed to its total volume and it was determined with a weight per hektolitre tester which was calibrated in kg/m^3 (Deshpande *et al*., 1993; Mohsenin, 1970). The porosity of bulk seed was calculated from bulk and kernel densities using the relationship given by Mohsenin (1970). A graduated measuring cylinder having an inner diameter 70 mm and height of 150 mm was filled with the prepared sample of radish seeds to a known volume. The filled sample was weighed using electronic weighing balance and the bulk density of the material filling the cylinder was computed. The kernel density of a seed is defined as the ratio of the mass of a sample of a seed to the solid volume occupied by the sample (Deshpande *et al*., 1993). The seed volume and its kernel density were determined using the liquid displacement method (Mohsenin, 1970; Sitkei, 1976). Toluene (C_7H_8) was used in place of water, because it is absorbed by seeds to a lesser extent and its surface tension is low, so that it fills even shallow dips in a seed and its dissolution power is low (Ogut, 1998). Then the known weight of the sample was poured in the graduated cylinder and displaced volume was noted. Ten replicates were conducted for each radish seed (t_0 and t_1, t_2, t_3). True density was calculated using the following equation.

Table 3: Physical properties of radish seeds of various cultivars studied

Treatment	Un-Pelleted	Pelleted 1:1	Pelleted 1:2	Pelleted 1:3
Moisture content (%)	5.90	3.87	3.43	2.78
Test Weight(g) 11.74	23.43	32.86	46.05	
Attached material on seed (g)	-	11.69	21.12	34.31
Attached material on seed/g	-	2.00	2.80	3.92
Angle of repose (degree)	28.81°	25.09°	23.70°	23.16°
Bulk density (kgm^{-3})	600	664	722	788
True density (kgm^{-3})	1050	1250	1330	1420
Porosity 47.78	46.88	45.69	44.51	
Roundness value	0.70	0.79	0.82	0.90
Coefficient of static friction	0.82	0.69	0.65	0.54

$$TD = (W / V) \quad \text{..... (5)}$$

Where: TD = true density (g/cm^3), W = Weight of sample (g), V = Displaced volume (cm^3)

The porosity is the measure of unconsolidated mass of material. It was calculated by using the using the following relation.

$$\text{Porosity} = (TD - BD) / TD \quad \text{..... (6)}$$

Coefficient of static friction: The coefficient of static friction of radish seed was determined on mild steel (MS) surface. A table top arrangement was used (Jha and Prasad, 1993; Jha, 1999). The arrangement consists of a wooden box having dimensions of 10.5 cm x 10.5 cm x 5 cm, connected to a hanging weight carrier (pan) by means of string (having negligible mass) which passed over pulley of negligible friction fixed on one end of the table. The dimensions of the box (10.5 cm x 10.5 cm x 5 cm) was so selected to ensure that the total contact area of radish seed, with a horizontal surface is large enough to resist the force applied tangentially by sliding the whole mass rather than rolling should be sufficient to be measured easily. The wooden box was positioned on a horizontal MS surface. The weights were put into the pan until the box just started to slide. The total weight (W_1) was noted. The wooden box was then filled with radish seeds and was slightly raised above the floor to eliminate the effect of the rim of the wooden box in the value of static friction. Weights were again added to the hanging pan in small amounts until the box filled with seed began to just slide on the MS surface. The total weight (W_2) required to slide the box on the selected surface was recorded. The weight of the sample (W) was also noted and the coefficient of static friction was computed by the following expression.

$$\mu = (W_2 - W_1) / W \quad \text{..... (7)}$$

Results and Discussion

Size and shape: The range of major, intermediate and minor dimensions of the radish seeds of four treatments T_0, T_1, T_2 and for T_3 radish seeds are given in table-1. For T_0 radish seed the major dimension varied from 2.54-4.09 mm, intermediate dimension 1.79 – 3.70 mm, and the minor dimension 1.32 – 2.42 mm having mean values of 3.31, 2.72 and 1.92 mm, respectively. These values show that the radish seeds are not spherical. Microscopic view of the non-pelleted and pelleted radish seed used for the study is shown in Fig. 1. The t_3 radish seed gave highest ranges of major, intermediate and minor dimensions is shown in Table 1. The geometric mean diameter as calculated from these dimensions and found to be 2.58, 3.14, 3.65 and 3.94 for T_0, T_1, T_2 and t_3 radish seeds respectively (Table-2).

The value of geometric mean diameter for t_3 radish seeds was highest 3.94 and for the T_0 2.58 was least amongst the treatments.

The shape of the seed in terms of roundness and sphericity was studied. There was increment in roundness and sphericity of radish seeds due to coating of material by weight (Table-2 and 3). The roundness of radish seeds were0.70, 0.79, 0.82 and 0.90 for four treatment of radish seeds viz. T_0, T_1, T_2 and T_3 respectively. The sphericity of radish seeds T_0, T_1, T_2 and T_3 were 0.78, 0.84, 0.85 and 0.91 respectively. The radish seeds even pelleting from roundness and gave clue to use round shape of cells over seed plate periphery. The coefficients of variation for roundness and sphericity of four forms of seeds were more than 10 percent. The roundness and sphericity observed in case of radish seed in different treatments were such that shape of the radish seed could assumed to be spherical. Therefore, the shape of the cell for seed plates, could be semi-circular, slant type with characteristic dimensions greater than or equal to the major, intermediate and mean diameter of seed.

Test Weight: The test weight of radish seeds of the treatments under study are given in table-3 Thus, there is considerable variation in the test weight of different treatments. The average value of thousand grain weight was highest for the T_1, T_2 and T_3 radish seeds is 23.43, 32.86 and 46.05 g, as compared to the T_0 seeds is 11.74 gm. Amongst the pelleted seeds T_3 has the highest thousand grain weight (46.05 g), followed by the T_2 (32.86 g) and T_1 (23.43 g).

Bulk density, true density and porosity: Average bulk density of radish seeds T_0, T_1, T_2, and T_3 were 600, 664, 722 and 788 kgm^{-3}, whereas true density 1050, 1250, 1330 and 1420.0 kgm^{-3}, respectively (Table-3). The bulk density and true density were highest for T_3 seed as 788 $kgm^{-3}$and 1420 kgm^{-3}, respectively. The values of porosity were 47.78, 46.88, 45.69 and 44.51 for the T_0, T_1, T_2, and T_3 seeds whereas the porosity for T_0 seed was 47.78 and is the highest amongst the other treatments. The increase in the bulk density of T_1, T_2, and T_3 was due to higher thousand seed weights W 1,000 than volume of seeds. The true density of seed 1000 to 1420 kg m^{-3} as it was coated with three layers of coated material; this was due to the increase in single seed volume.

Angle of repose and coefficient of static friction: Average value of angle of repose for the radish seeds T_0, T_1, T_2, and T_3 were respectively. The maximum value of angle of repose was 28.81°, 25.09°, 23.70° and 23.16° for seed T_3. The coefficients of variation in all cases were greater than 10 percent. The mean values of coefficient of friction of seed for mild steel surface were 0.82, 0.69, 0.65 and 0.54 for T_0, T_1, T_2, and T_3 respectively. The maximum value for coefficient of static friction was recorded for mild steel surface for seed T_0, became rougher which diminished sliding ability.

The following conclusions are revealed from the investigation of some physical properties of radish seed for moisture content range of 5.90-2.78 % (d.b.). The average width, thickness, arithmetic mean diameter, and geometric mean diameter of radish seeds increased and length values of radish seeds also increased with increase of pelleted material ratio of seeds. Sphericity, seed volume and seed surface area increased with increase of seed ratio. One thousand seeds weight increased with increase of seed pelleted material ratio. True density was higher than bulk density at all seed kernel seed ratio studied. The true density varied with seed ratio from 1050 to 1420 kgm^{-3} while bulk density 600 to 788 kgm^{-3} in the range of seed ratio between T_0 to T_3. In addition, porosity values of radish seeds varied from 47.78 to 44.51. The static coefficients of friction was highest 0.82 for T_0 seed and lowest 0.54 for 1:3 seed. Angle of repose from 28.81°to 23.10°, from seed of T_0 to T_3. The pelleting of seeds no doubt improve the Spherecity of the seeds and hence the flow ability of seeds but at the same time increase the bulk density as well as true density of the seeds.

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