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Full Research Article

Studies on Engineering Properties of Pelleted Carrot (*Daucus carota* L.) Seeds

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Abstract

Carrot (*Daucus carota* L.) commonly known as *Gajar*. Certain limitations associated with the production, processing and effective utilization of small seeds. Carrot seeds are small in size and difficult to handle for sowing purpose. For the development of a mechanism for carrot seed sowing the study of engineering properties of carrot seeds is of utmost importance. The biometric properties of seeds play an important role in designing seed metering device. Physical and engineering properties of carrot seed both un-pelleted and pelleted were evaluated in the laboratory. Therefore, the physical properties of the carrot seeds such as size, shape, thousand grain weight, and angle of repose, bulk density and coefficient of static friction are important from engineering view point and were studied for cultivars of carrot i.e. deshi red pelleted were compared with un-pelleted carrot seeds. The geometric mean diameter (GMD) was 2.03, 2.19, 2.39 and 2.70 mm for deshi red carrot seeds, respectively. The average values of angle of repose for the cultivars under study as observed in the laboratory was 32.79°, 30.37°, 28.87° and 28.00° respectively for deshi red carrot seeds. The values of porosity are decreased gradually in seeds whereas the porosity for seed having GMD 2.70 mm was 50.84% and is the lowest amongst the other cultivars. The porosity of un-pelleted seed was the highest (64.96%).

1. Introduction

Carrot (*Daucus carota* L.) 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 Haryana and Punjab, this crop has gained the importance crop rather than as a vegetable crop because of its very high export potential. In India, Haryana is a leading carrot growing state followed by Punjab, Telangana, Karnataka, Bihar Assam and Tamilnadu. The productivity of carrot is the highest in Tamilnadu (32.88 t ha^{-1}) followed by Jammu and Kashmir, Uttar Pradesh and Punjab (24.69, 24.09 and 20.54 t ha^{-1}) (Anonymous, 2015).

In Punjab carrot is sown over an area in 2013–14 of about 6.16 mha having production of 126.54 thousand t (Anonymous, 2015). Generally, the carrot 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 (Anonymous, 2013). During carrot 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 carrot cultivation is low and can be increased by mechanization of this crop.

Singh et al. (2006) reported that carrots are also beneficial for the heart, blood circulation, eye sight, skin and lungs. Seed, the biological material often considered as the basic, critical and vital input for enhancing agricultural productivity. Certain limitations associated with the production, processing and effective utilization of small seeds. Many vegetable seeds are small, light and irregular in shape; therefore it is difficult to plant them precisely (Tuna and Zeybek, 2009). Sowing of such tiny size, light weight and irregular shaped seeds are generally accomplished manually using broadcasting method. There is little control over the seed placement, spacing, line sowing, the plant stand is uneven and requires good management. A large amount of costly seed may get wasted because of uneven seed placement, thinning, damage by seed metering mechanism, damage by birds. Seed pelleting is an essential component of seed technology and plays vital role in making the seed bolder, safer in handling and in field emergence. The pelleting is designed basically to facilitate accurate precise sowing, to protect the seed against soaking injury to excess soil moisture in condition when it is spare and to give at least as good seedling emergence as does raw seed (Powell and Mathews, 1988). Thereby it enhances the farm revenue (Vanangamudi et al., 2003).

The area under carrot cultivation can be increased by mechanization of the sowing method. For the development of a mechanism for carrot seed sowing the study of engineering properties of carrot seeds is of utmost importance. Therefore, the physical properties of the carrot 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 onion seed (Chhina and Sharma, 2011); Arigo seeds (Davies, 2010); coriander seed (Coskuner and Karababa, 2007); millet (Baryeh, 2002); quiona seed (Vilche et al., 2003) and almond nut and kernel (Aydin, 2003).

2. Materials and Methods

2.1. Selection of the varieties

The variety of the Carrot seed is Deshi red, were selected for the study. Deshi red 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.

2.2. Sample preparation

Moisture content of the samples was determined according to AOAC approved vacuum oven method (AOAC, 1990). The seed moisture content ranged from 3.40–8.82% (db.) since transportation, storage and handling operations of the seeds are performed in this moisture range. All the experiments were replicated five times and the average values were reported.

2.3. Size and shape of the seed

Olympus BX 61 microscope was used to measure the size of carrot seeds. Olympus BX 61 microscope consisted of control box, motorized microscope, hand switch, data logger and a monitor. 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 in equation 1 and 2 (Mohsenin, 1970).

$$Dp = (\sqrt[3]{LWT}) \quad (1)$$

Where,

L=Length, mm

W=Width, mm

T=Thickness, mm

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

$$\Psi=(\sqrt[3]{LWT/L}) \quad (2)$$

2.4. Roundness

To measure roundness 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. Measuring roundness with callipers is slow and tedious. Seed property analyser calculate roundness with equation (3),

$$Roundness=(W/L+T/L+T/W)/3 \quad (3)$$

2.5. 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.

2.6. 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 carrot 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 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 carrot seed was computed using equation (4) (Bart-Plange and Baryeh, 2003; Mohsenin, 1980)

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

2.7. 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 hectolitre^{-1} 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 carrot 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. Five replicates were conducted for each carrot seed (Un-pelleted and Pelleted 1:1, 1:2, 1:3). True density was calculated using the following equation (5).

$$TD=(W/V) \qquad (5)$$

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 equation (6).

$$Porosity=(TD-BD)/TD \qquad (6)$$

2.8. Coefficient of static friction

The coefficient of static friction of carrot seed was determined on mild steel (MS) surface. A table top arrangement was used (Jha and Prasad, 1993; Jha, 1999; Sethi, 1998). The arrangement consists of a wooden box having dimensions of 10.5×10.5×5 cm^3, 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 (10.5×10.5×5 cm^3) was so selected to ensure that the total contact area of carrot 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 carrot 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 equation (7).

$$\mu=(W_2-W_1)/W \qquad (7)$$

3. Results and Discussion

3.1. Size and shape

The range of major, intermediate and minor dimensions of the carrot seeds of cultivars T_0, T_1, T_2 and T_3 and for the T_3 carrot seeds are given in (Table 1). For T_0 carrot seed the

Table 1: Size of carrot seeds of various cultivars studied

Treatment		T_0	T_1	T_2	T_3
Major dimension	Range (mm)	2.68–4.78	1.8–4.90	2.75–4.96	3.05–5.04
	Mean (mm)	4.21	4.35	4.81	4.95
	SD	0.79	1.15	0.91	0.73
Intermediate dimension	Range (mm)	1.15–2.23	1.2–3	1.18–2.57	1.6–3.15
	Mean (mm)	1.83	1.85	1.95	2.31
	SD	0.36	0.53	0.38	0.48
Minor dimension	Range (mm)	0.66–1.74	0.68–2.21	1.03–2.32	1.04–2.56
	Mean (mm)	1.10	1.34	1.46	1.74
	SD	0.36	0.42	0.43	0.47

major dimension varied from 2.68–4.78 mm, intermediate dimension 1.15–2.23 mm, and the minor dimension 0.66–1.74 mm having mean values of 4.21, 1.83 and 1.10 mm, respectively (Figure 1). These values show that the carrot seeds are not spherical. Microscopic view of the T_0 and pelleted (T_1, T_2 and T_3) carrot seed used for the study is shown in (Figure

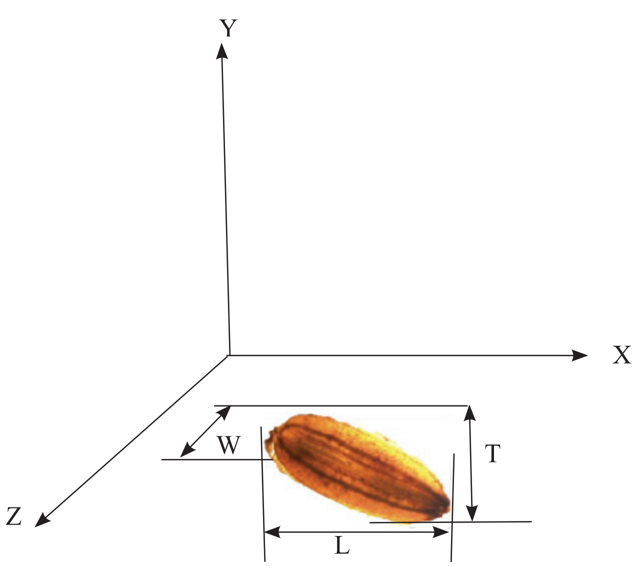

Figure 1: Characteristics dimensions of carrot

2). The geometric mean diameter as calculated from these dimensions and found to be 2.03, 2.19, 2.39 and 2.70 for T_0, T_1, T_2 and T_3 carrot seeds respectively (Table 2). The value of geometric mean diameter for T_3 carrot seeds was highest 2.70 mm and for the T_0 it was least amongst the cultivars. The Spherecity as calculated using eq. 2 and it came out to be 0.47, 0.52, 0.49, and 0.54 respectively for T_0, T_1, T_2 and T_3 of carrot seeds. The higher value of Spherecity in case of T_3 seeds shows that these are nearly spherical in shape.

3.2. Test weight

The test weight of carrot seeds of the cultivars under study are given in (Table 3). Thus, there is considerable variation in the test weight of different cultivars. The average value of thousand grain weight was highest for the T_1, T_2 and T_3 carrot seeds are 2.46, 5.95 and 6.70 g, as compared to the T_0 seeds is 1.37. Amongst the pelleted seeds the T_3 has the highest thousand grain weight (6.70 g), followed by T_2 (5.95 g) and T_1 (2.46 g).

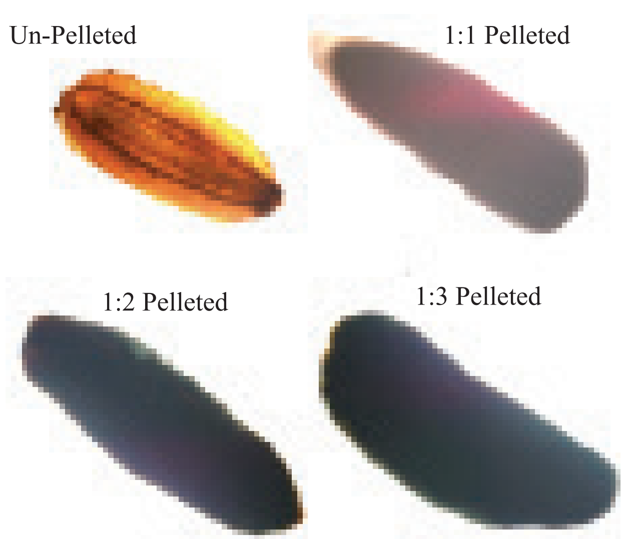

Figure 2: Microscopic view of non-pelleted and pelleted carrot seed

Table 2: Geometric mean diameter and spherecity of carrot seeds of various cultivars studied

Treatment		T_0	T_1	T_2	T_3
Geometric mean diameter	Range	1.29 – 2.68	1.29 – 3.23	1.50 – 3.02	1.72 – 3.53
	Mean	2.03	2.19	2.39	2.70
	SD	0.44	0.56	0.48	0.47
Spherecity	Range	0.40 – 0.59	0.38 – 0.72	0.43 – 0.62	0.44 – 0.64
	Mean	0.47	0.49	0.52	0.54
	SD	0.057	0.09	0.06	0.062

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

Treatment	T_0	T_1	T_2	T_3
Moisture content (%)	8.82	5.06	3.52	3.40
Test weight (g)	1.37	2.46	5.95	6.70
Attached material on seed (g)	-	1.09	4.58	5.33
Attached material on seed g^{-1}	-	1.80	4.34	4.89
Angle of repose (degree)	32.79°	30.37°	28.87°	28.00°
Bulk density (kg m^{-3})	357	544	596	654
True density (kg m^{-3})	1020	1170	1250	1330
Porosity	64.96	52.34	53.71	50.84
Roundness value	0.431	0.462	0.491	0.521
Coefficient of static friction	0.86	0.83	0.79	0.66

3.3. Angle of repose

The average values of angle of repose for the treatment under study as observed in the laboratory were 30.37°, 28.87°, 28.00° and 32.79° for Pelleted (T_1, T_2 and T_3) carrot seed and un-pelleted (T_0) carrot seeds respectively. The lowest value of angle of repose was 28.00° for T_3 seeds confirm near Sphere city of the pelleted seeds. The other seeds have nearly equal value of angle of repose. The pelletization of carrot seed had significant effect on angle of repose.

3.4. Bulk density and true density

The average value of bulk density was observed to be 357, 544, 596 and 654 kg m^{-3} for the seeds of T_0, T_1, T_2 and T_3 carrot seeds respectively. Analysis of variance indicated that the bulk density differs significantly among the different seeds studied. The average values of true density were 1020, 1170, 1250 and 1330 kg m^{-3} respectively for T_0, T_1, T_2 and T_3 carrot seeds. The values of porosity were 64.96, 52.34, 53.71 and 50.84 for the T_0, T_1, T_2 and T_3 seeds whereas the porosity for T_0 seed was 53.3 and is the highest amongst the other cultivars.

3.5. Coefficient of static friction

The values for static friction for T_0, T_1, T_2 and T_3 carrot seeds were 0.86, 0.83, 0.79 and 0.66 respectively. The minimum value of coefficient of friction for T_3 carrot seeds confirms the near roundness of the pelleted seeds. From the study it can be concluded that the range of GMD for the seeds of carrot cultivars under study was 2.03 to 2.70 mm, the Spherecity ranges from 0.47 to 0.54, the test weight ranged from 1.37 to 6.70 g, angle of repose from 32.79° to 28.00°, bulk density range from 357 to 654 kg m^{-3}, true density from 1020 to 1330 kg m^{-3} and the porosity ranged from 64.96 to 50.84. The coefficient of static friction ranges from 0.66 to 0.86. The Spherecity ranged from 0.47 to 0.54. The pelleting of seeds no doubt improves the Spherecity of the seeds and hence the flow ability of seeds but at the same time increases the bulk density as well as true density of the seeds.

4. Conclusion

The average major, intermediate and minor dimension and geometric mean diameter of carrot seeds increased and length values of carrot seeds also increased with the increase of pelleted material ratio of seeds. The pelleting of carrot seeds no doubt improved the spherecity of the seeds and hence the flow-ability of seeds but at the same time increased the bulk density as well as true density of the seeds.

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