Indian Journal of Agricultural Sciences **89** (10): 1693–7, October 2019/Article
https://doi.org/10.56093/ijas.v89i10.94630

Study of engineering properties of selected vegetable seeds

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Received: 15 February 2019; Accepted: 09 April 2019

ABSTRACT

Quality seed is the foundation block of vegetable production system. Proper post-harvest processing of seed is important to maximize yield, longevity, vigour, and overall quality. The engineering properties determination is the first and foremost step for the design of any seed processing, storage and handling machine or equipment. Engineering properties like geometric, gravimetric, frictional and aerodynamic properties of bottle gourd, sponge gourd, garden pea, and radish seeds have been determined at different levels of moisture content (7.5 % to 19 % dry basis). Results revealed a quadratic increase in all properties with moisture content except for gravimetric properties. The properties like sphericity (0.83), bulk density (710.61 kg/m^3), true density (1109.79 kg/m^3), angle of repose (26.41°), terminal velocity (10.13 m/s) and drag coefficient (0.92) were highest for garden pea seeds. Whereas, bottle gourd seeds exhibited maximum values for size (7.17 mm), projected area (115.68 mm$^{2)}$, porosity (53.4%) and coefficient of friction (0.727).

Key words: Aerodynamics, Frictional properties, Geometric properties, Gravimetric properties, Vegetable seeds

India is the second largest producer of vegetables (175 million tonnes, NHB-2017) with 2.8% of the total cropped area under vegetables. Various agronomic and non-agronomic benefits that vegetable offers are high yield, short duration, nutritional richness, economic viability and ability to generate on-farm and off-farm employment (Vanitha *et al.* 2013). Quality seed is the foundation block of the vegetable production system. Seed quality in terms of viability and vigour depends mainly on harvesting, extraction, cleaning, transportation, and storage conditions (McCormack 2004). Seed processing plays an important role in maintaining its quality until consumption. The engineering properties of seed are of utmost importance in designing any seed processing and handling machine or equipment. The physical and frictional properties of seeds are linked with moisture content and significantly influences the storage structure design. Geometric properties like size, sphericity, projected area, geometric mean diameter, etc. are important for the design of separating, harvesting, grinding machines (Altuntas and Demirtola 2007). Gravimetric properties like bulk density, porosity, etc. are important in the design of storage equipment, conveying and handling equipment and for separation of seeds (Pradhan *et al.* 2013). Frictional properties like the coefficient of friction and angle of repose are important in determining the lateral pressure in storage structures, also used for the design of conveyors, elevators, hoppers, etc. Aerodynamic properties such as terminal velocity and drag coefficient are important in determining the pneumatic cleaning machines, winnowing, air screen cleaners, pneumatic conveyors, etc. (Sahay and Singh 2001). All the properties of seeds are intensively allied with moisture content as well as seed quality. However, very little information is available about bottle gourd, sponge gourd, garden pea, and radish with respect to relationship between engineering properties and moisture content levels. Moisture content from 7.5 % to 19 % (d.b.) was considered for the study that generally prevails for processing and storage of the seed.

MATERIALS AND METHODS

Sample preparation

The study was conducted at Division of Agricultural Engineering, ICAR-IARI, New Delhi in the year 2015. Raw materials were collected from Seed Processing Unit (SPU), ICAR-IARI, New Delhi. Four types of seeds were taken *i.e.* bottle gourd (*Pusa Naveen*), sponge gourd (*Pusa Sneha*), garden pea (*Pusa Pragati*) and radish (*Pusa Chetki*). Moisture content was determined using a standard hot air oven method. Samples of 10 g each for bottle gourd, sponge gourd, garden pea, and radish seeds were taken in moisture dishes. It was dried for 17 h at 105°C (Pradhan

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et al. 2013), 6 h at 130°C (Ogunsina *et al.* 2010), 24 h at 105°C (Altuntas and Demirtola 2007) and 1 h at 130°C (Çetin *et al.* 2010), respectively in hot air oven. The bone dried samples were weighed using electronic balance having an accuracy of 0.001 g. Averages of three replications were taken as moisture content.

The seeds were dried in a hot air oven at 40-45°C or sprayed and mixed with a pre-calculated amount of water to get the desired moisture level. These samples were kept in sealed polyethene bags in a refrigerator at 5°C for some period of time for even distribution of moisture. Before conducting experiment required amount of seeds were taken out and equilibrated to room temperature. The properties of the seeds were determined at four levels of moisture content i.e. 7.5, 11.1, 14.9 and 19 % d.b.

Geometric Properties

Size, sphericity and projected area: The major, intermediate and minor dimensions of the seed were measured by using a digital vernier calliper. The dimensions of randomly selected 50 seeds were measured in three replications. Further, the geometric mean diameter (GMD) of the seeds were calculated by using the relationship given by Pradhan *et al.* (2013). The sphericity (φ) and projected area (A_p) were also computed by the relationship as suggested by Mohsenin (1986).

Gravimetric Properties

Bulk density (ρb): Samples were randomly selected from the bulk. Seeds were dropped from a funnel which had an opening of 32 mm to a wooden box. The bottom of the funnel was 52 mm above the box. The excess seed from the box was removed by passing a wooden stick across the top surface using 5 zig-zag motions (Altuntas and Demirtola 2007). The box volume was 125 cm^3. The weight of contained material in the box, as well as an empty box, was measured using a precision balance with a least count of 0.001 g. Three replications were made at each moisture level.

True density (ρt): The true density of the samples were determined using the liquid (toluene: C_7H_8) displacement method (Coskuner and Karababa 2007). A sample of 100 seeds was weighed. The weighed amount of sample was poured into a measuring flask containing 50 ml of toluene. Change in volume level in the measuring flask was recorded. Average of three replications were taken for true density

Porosity (ε): The porosity (F) of bulk seed was computed from the values of true density and bulk density using the relationship given by Pradhan *et al.* (2013).

Frictional Properties

Angle of repose (θ): The angle of repose of seeds was determined using emptying method (Pradhan *et al.* 2013). An open-ended cylinder of 6 cm diameter and 10 cm height was placed at the centre of a circular plate having a diameter of 35 cm and was filled with seeds. The cylinder was gradually raised until it formed a cone on the circular plate. The height and diameter of the cone were recorded by using a special arrangement.

Coefficient of friction (μ): The coefficient of friction of seeds was determined using an inclined plane method (Çetin *et al.* 2010). An open-ended plastic cylinder having 60 mm diameter and 50 mm height was filled with seeds and placed on the adjustable tilting surface. The cylinder was raised slightly so as not to touch the surface. The structural surface with the cylinder resting on it was inclined gradually with a screw device until the cylinder just started to slide down and the angle of tilt was read from a graduated scale for mild steel sheet as tilting surface at different moisture level in five replications.

Aerodynamic Properties

Terminal velocity (Vt): Terminal velocity of the seeds was measured using an air column method (Çetin *et al.* 2010). The selected seeds were dropped from the top of a 1 m long plexiglass tube with 75 mm diameter. The air was blown upwards in the tube while its velocity was adjusted by using an inverter type motor speed control until the major fraction of the sample remains suspended in the air stream. The air velocity near the location of the suspension of the samples was measured by hot-wire anemometer having an accuracy of 0.1 m/s.

Drag coefficient (Cd): The drag coefficient of the seeds was determined using the standard method described by Gupta *et al.* (2007).

RESULTS AND DISCUSSION

All engineering properties had been determined at different levels of moisture content (7.5–19% d.b.) and it was observed that all properties had exhibited a close relationship with moisture content except sphericity (Table 1). The trends were found to be quadratic for all properties except for the angle of repose of bottle gourd seeds and a drag coefficient of radish seeds which showed a linear trend (Table 2).

Effect of moisture content on geometric properties: On scanning the compiled data of geometric properties of the selected seed, it was found that all the geometric properties had an increasing quadratic trend with an increase in moisture content, except sphericity; irrespective of the cultivar (Table 2). The geometric mean diameter of garden pea seed increased rapidly compared to bottle gourd, sponge gourd, and radish seed with an increase in moisture content. It might be a consequence of moisture absorption. Sphericity value was observed to be highest (0.83) for garden pea and lowest (0.46) for bottle gourd seeds as bottle gourd seed is flat and garden pea is round.

The projected area had also expressed a positive relationship with moisture content irrespective of the crop type. It was found to be highest for bottle gourd seeds, followed by a sponge gourd, garden pea, and radish seeds (Table 1). Similar effects of moisture content on geometric properties were reported by Aydin (2007), Calisir *et al.* (2005), and Altuntaş and Yildiz (2007) for peanut, Turkey

Table 1 Engineering properties of seeds at different levels of moisture content

Moisture Content (% d.b.)	GMD (mm)	Sphericity	Projected Area (mm^2)	Bulk Density (kg/m^3)	True Density (kg/m^3)	Porosity (%)	Coefficient of Friction for Mild Steel	Angle of Repose (°)	Terminal Velocity (m/s)	Drag Coefficient
Bottle Gourd										
7.53	6.73 ± 0.30	0.46 ± 0.02	102.65 ± 9.87	458.53 ± 5.68	853.30 ± 22.27	46.26 ± 0.8	0.328 ± 0.023	21.44 ± 2.12	5.53 ± 0.28	0.08 ± 0.064
11.11	6.93 ± 0.31	0.46 ± 0.02	108.24 ± 10.63	442.95 ± 6.34	830.99 ± 17.19	46.70 ± 1.9	0.475 ± 0.027	21.84 ± 1.37	6.44 ± 0.13	0.06 ± 0.016
14.94	6.95 ± 0.24	0.46 ± 0.02	108.98 ± 7.57	441.53 ± 2.08	815.91 ± 17.99	45.88 ± 1.3	0.412 ± 0.027	22.57 ± 1.48	6.97 ± 0.13	0.05 ± 0.003
19.04	7.17 ± 0.19	0.49 ± 0.02	115.68 ± 7.13	365.30 ± 3.21	783.89 ± 30.97	53.40 ± 1.7	0.727 ± 0.047	23.67 ± 2.73	7.21 ± 0.2	0.05 ± 0.034
Sponge Gourd										
7.53	6.19 ± 0.26	0.48 ± 0.02	89.23 ± 9.80	554.31 ± 10.45	984.20 ± 27.69	43.68 ± 2.6	0.393 ± 0.024	20.46 ± 1.25	4.60 ± 0.13	0.63 ± 0.016
11.11	6.40 ± 0.25	0.51 ± 0.017	96.84 ± 9.01	538.97 ± 15.79	968.49 ± 2.25	44.35 ± 1.6	0.390 ± 0.020	23.40 ± 1.21	6.24 ± 0.11	0.43 ± 0.014
14.94	6.54 ± 0.25	0.50 ± 0.01	102.35 ± 7.52	486.88 ± 4.35	907.07 ± 21.45	46.32 ± 1.8	0.442 ± 0.034	24.47 ± 1.00	6.74 ± 0.28	0.42 ± 0.027
19.04	6.77 ± 0.21	0.51 ± 0.02	112.47 ± 6.64	473.45 ± 6.36	870.85 ± 34.20	45.63 ± 2.7	0.457 ± 0.019	25.86 ± 2.77	6.95 ± 0.2	0.40 ± 0.026
Garden Pea										
7.53	5.81 ± 0.43	0.83 ± 0.03	36.12 ± 7.67	774.88 ± 7.36	1588.90 ± 5.91	54.12 ± 0.4	0.054 ± 0.008	14.97 ± 1.26	7.96 ± 0.31	0.92 ± 0.062
11.11	6.34 ± 0.36	0.83 ± 0.04	46.58 ± 7.49	732.10 ± 1.33	1463.83 ± 39.88	49.99 ± 1.9	0.200 ± 0.010	23.31 ± 1.00	9.59 ± 0.3	0.62 ± 0.058
14.94	6.78 ± 0.41	0.83 ± 0.03	55.74 ± 9.35	729.68 ± 6.78	1172.58 ± 2.95	37.77 ± 0.7	0.382 ± 0.023	25.92 ± 2.37	9.91 ± 0.42	0.53 ± 0.058
19.04	6.88 ± 0.42	0.83 ± 0.05	57.13 ± 8.33	710.61 ± 2.92	1109.79 ± 66.70	35.97 ± 3.2	0.414 ± 0.020	26.41 ± 1.23	10.13 ± 0.21	0.54 ± 0.034
Radish										
7.53	2.68 ± 0.24	0.76 ± 0.05	9.25 ± 1.41	706.84 ± 8.63	1073.58 ± 33.76	34.03 ± 2.4	0.320 ± 0.029	24.32 ± 1.02	5.44 ± 0.38	0.79 ± 0.23
11.11	2.70 ± 0.37	0.76 ± 0.05	8.96 ± 2.20	675.73 ± 16.77	1045.61 ± 64.52	34.85 ± 0.5	0.311 ± 0.025	24.80 ± 0.83	5.65 ± 0.26	0.71 ± 0.06
14.94	2.79 ± 0.28	0.76 ± 0.04	10.13 ± 2.12	669.82 ± 6.5	1023.94 ± 30.82	34.44 ± 1.4	0.414 ± 0.027	24.98 ± 3.44	5.59 ± 0.14	0.63 ± 0.03
19.04	2.88 ± 0.23	0.77 ± 0.05	10.22 ± 1.40	661.8 ± 3.24	972.21 ± 27.53	32.25 ± 1.5	0.429 ± 0.035	25.59 ± 1.36	6.54 ± 0.14	0.53 ± 0.02

okra, and faba bean grains, respectively. It implies that geometric properties of seed meticulously linked with its moisture content.

Effect of moisture content on gravimetric properties: Gravimetric properties of all selected seeds were found to be inversely proportional to its moisture content. It is evident from data shown in Table 1, that garden pea and radish can be classified as high-density seed whereas bottle gourd and sponge gourd as low-density seed. The reducing quadratic trends of bulk density and true density were observed with increasing moisture content irrespective of the type of seed (Fig 1). It might be due to increase in kernel size with moisture content thereby, resulting in lowering the amount of seed that occupied the same volume. Similar results were found by other researchers (Amin *et al.* 2004, Calisir *et al.* 2005, Altuntas and Yildiz 2007, Altuntas and Demirtola 2007, Aydin 2007 and Garnayak *et al.* 2008).

Unlike other gravimetric properties, the porosity of selected seeds did not exhibit any particular relationship with moisture content except garden pea. Porosity of bottle gourd and sponge gourd seeds increased while it decreased for garden pea and radish (Table 1). It did not follow any specific pattern with changing moisture level due to its bulk behaviour.

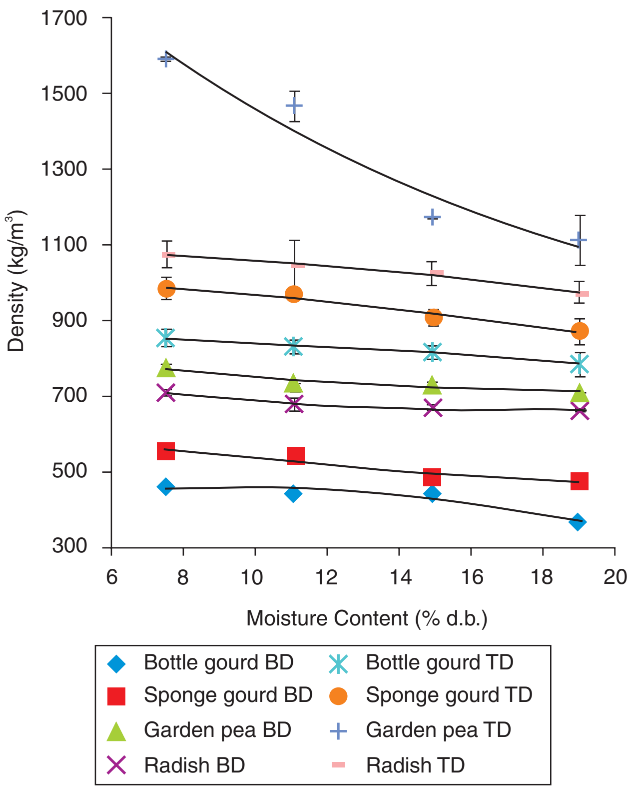

Fig 1 Effect of moisture content on the bulk density (BD) and true density (TD) of seeds

Effect of moisture content on frictional properties: All frictional properties were found to increase with an increase in moisture content. The coefficient of friction was found to be lowest (0.054±0.008 to 0.414±0.020) for garden pea seeds in the given moisture range. It was observed to be highest for sponge gourd seeds (0.393±0.024) at lower moisture level (7.53% d.b.) and for bottle gourd seeds (0.727±0.047) at higher moisture level (19.04 % d.b.). This might be due the surface structure of bottle gourd seeds and sponge gourd

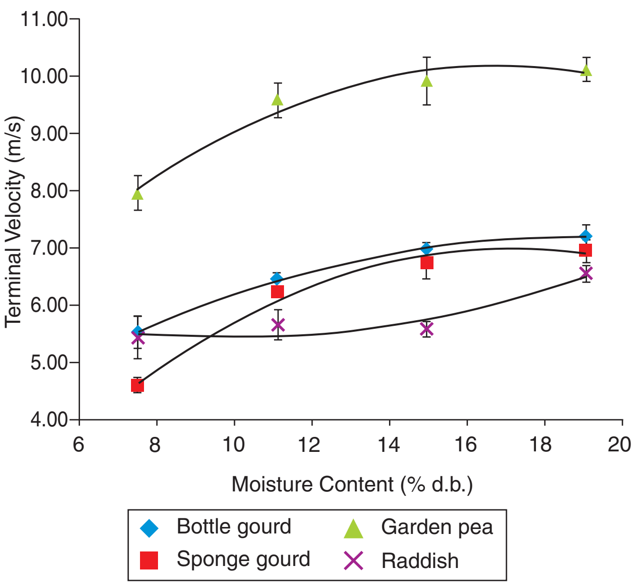

Fig 2 Effect of moisture content on terminal velocity of seeds

Table 2 Regression coefficient and coefficient of determination of different seeds

Property	Bottle Gourd				Sponge Gourd				Garden Pea				Radish			
	Intercept	M	M^2	R^2	Intercept	M	M^2	R^2	Intercept	M	M^2	R^2	Intercept	M	M^2	R^2
GMD (mm)	6.5177	0.0296	0.0002	0.9236	5.8516	0.0454	0.0001	0.9933	3.9003	0.3143	-0.0083	0.9975	2.7493	-0.0209	0.0015	0.9546
Ap (mm^2)	97.344	0.6825	0.0134	0.933	78.772	1.2307	0.0275	0.9927	-3.0177	6.4587	-0.1726	0.9947	8.9838	-0.0188	0.0047	0.7225
ρb (kg/m^3)	367.04	19.024	-0.9933	0.9347	634.27	-11.023	0.1262	0.9393	870.9	-16.406	0.4269	0.9199	777.3	-11.386	0.2734	0.9826
ρt (kg/m^3)	878.45	-2.5979	-0.1214	0.9893	1034	-4.3441	-0.2305	0.9686	2176.3	-87.158	1.5884	0.9527	1086.9	0.535	-0.3401	0.9894
ε (%)	59.662	-2.6072	0.1185	0.8977	38.182	0.8996	-0.0262	0.831	65.393	-1.8095	0.0112	0.8805	28.015	1.1721	-0.0498	0.9993
μ	0.5376	-0.0447	0.0028	0.8147	0.3686	0.001	0.0002	0.8689	-0.5302	0.0935	-0.0023	0.9827	0.2596	0.0047	0.0002	0.8186
θ (°)	19.822	0.1944	-	0.9703	12.989	1.2318	-0.0295	0.9822	-12.068	4.6804	-0.1402	0.9884	23.786	0.0653	0.0015	0.9684
Vt (m/s)	2.6426	0.48	-0.0126	0.9993	-0.487	0.8758	-0.0256	0.9856	3.1162	0.8419	-0.025	0.9683	6.6382	-0.2424	0.0123	0.9015
Cd	1.1181	-0.0633	0.0018	0.9943	0.8703	- 0.0402	0.0006	0.9989	1.7066	-0.1261	0.0027	0.9952	1.0058	-0.0253	-	0.9542

seeds (Altuntas and Demirtola 2007).

The angle of repose of bottle gourd seeds varied linearly, while sponge gourd, garden pea, and radish seeds were varied quadratically in selected moisture range (Table 2). The data of frictional properties (Table 1) illustrated the positive relationship with moisture content, irrespective of the seed type. It might be attributed that at higher moisture content, the adhesive force between the seed and surface increases which in turn decreases the sliding characteristics of the seeds resulting in a lower value of the coefficient of friction. It was in tune with the observations of Pradhan *et al.* (2013), Altuntas and Demirtola (2007) and Garnayak *et al.* (2008).

Effect of moisture content on aerodynamic properties: The terminal velocity was found to be positively related to its moisture content (Fig 2). Maximum terminal velocity (10.13 m/s) was observed for garden pea seed at moisture content 19.04 % d.b. However, minimum terminal velocity (4.60 m/s) was exhibited by sponge guard seed at 7.5% d.b. moisture content. Interestingly, it was observed that radish seed exhibited a different pattern of terminal velocity than other seed with same moisture content (Fig 2). It might be due to the seed coat characteristics of radish seed; which resulted in different water-absorbing trend and thereby affected weight and volume variation differently.

The drag coefficient of 0.92±0.062 was highest for garden pea followed by radish, bottle gourd and sponge gourd. The computed drag coefficient was observed to be closely linked with moisture content of seed and type of seed. In general, the drag coefficient was found to be decreasing with the increase in moisture level except for the radish seed in the said moisture range. It was due to the physical structure and water-absorbing characteristics of radish seed. Similar trend was observed by Gupta *et al.* (2007) for sunflower seeds.

From the above results, it could be concluded that all engineering properties of seeds varied with its moisture content (7.5–19% d.b.) except sphericity. Geometric properties (size, projected area) and frictional properties (coefficient of friction and angle of repose) were observed to have an increasing trend with moisture content. Gravimetric properties (bulk density and true density) have a decreasing trend with moisture content. Among aerodynamic properties, terminal velocity increases with increasing moisture content, but the drag coefficient decreased with moisture content. Most of the properties like sphericity (0.83), bulk density (710.61 kg/m^3), true density (1109.79 kg/m^3), angle of repose (26.41°), terminal velocity (10.13 m/s) and drag coefficient (0.92) were observed to be highest for garden pea seeds, while size (7.17 mm), projected area (115.68 mm^2), porosity (53.40%) and coefficient of friction (0.727) were highest for bottle gourd seeds.

ACKNOWLEDGEMENT

The authors would like to thank the Division of Agricultural Engineering, ICAR-IARI for providing Lab facilities. Authors are grateful to Dr Indra Mani, Dr Cini Varghese, Dr Tapan K. Khura and Er. J K Singh for their kind support and valuable suggestions during the research work.

REFERENCES

Altuntas E and Demirtola H. 2007.Effect of moisture content on physical properties of some grain legume seeds. *New Zealand Journal of Crop and Horticultural Science* **35**(4): 423–33.

Altuntas E and Yildiz M. 2007. Effect of moisture content on some physical and mechanical properties of faba bean (*Vicia faba L.*) grains. *Journal of Food Engineering* **78**(1): 174–83.

Amin M N, Hossain M A and Roy K C. 2004. Effects of moisture content on some physical properties of lentil seeds. *Journal of Food Engineering* **65**(1): 83–7.

Aydin C. 2007. Some engineering properties of peanut and kernel. *Journal of Food Engineering* **79**(3): 810–6.

Calısır S, Ozcan M, Haciseferogullari H and Yıldız M U. 2005. A study on some physico-chemical properties of Turkey okra (*Hibiscus esculenta L.*) seeds. *Journal of Food Engineering* **68**(1): 73–8.

Cetin M, Simsek E, Akbas T and Ozarslan C. 2010. Physical properties of radish (*Raphanus sativus L.*) seed as a function of moisture content. *The Philippine Agricultural Scientist* **93**(3): 291–8.

Coskuner Y and Karababa E. 2007. Physical properties of coriander seeds (*Coriandrum sativum L.*). *Journal of Food Engineering* **80**(2): 408–16.

Garnayak D K, Pradhan R C, Naik S N and Bhatnagar N. 2008. Moisture-dependent physical properties of jatropha seed (*Jatropha curcas L.*). *Industrial crops and products* **27**(1): 123–9.

Gupta R K, Arora G and Sharma R. 2007. Aerodynamic properties of sunflower seed (*Helianthus annuus L.*). *Journal of Food Engineering* **79**(3): 899–904.

McCormack, J. H. 2004. Principles of seed harvesting and processing. *Seed processing and storage: principles and practices of seed harvesting, processing, and storage: an organic seed production manual for seed growers in the Mid-Atlantic and Southern US*. McCormack.

Mohsenin N N. 1986. *Physical Properties of Plant and Animal Material*. Gordon and Breach science publishers. New York.

National Horticultural Board. 2017. Horticultural Statistics at a glance 2017, New Delhi, India.

Ogunsina B S, Adegbenjo A O and Opeyemi O O. 2010. Compositional, mass-volume-area related and mechanical properties of sponge gourd (*Luffa aegyptiaca*) seeds. *International Journal of Food Properties* **13**(4): 864–76.

Pradhan R C, Said P P and Singh S. 2013. Physical properties of bottle gourd seeds. *Agricultural Engineering International: CIGR Journal* **15**(1): 106–13.

Sahay K M and Singh K K. 2001. *Unit Operations of Agricultural Processing*. Vikas Publishing House Pvt. Ltd, New Delhi.

Vanitha S M, Chaurasia S N S, Singh P M and Naik P S. 2013. Vegetable statistics. *Technical Bulletin IIVR* 51.