Design and Development of Vertical Rotor for Precision Seeding of Okra: Incorporating Physical and Engineering Attributes

Comment [AZ1]: Suggest the title should reflect only the design of the vertical rotor metering plate because the manuscript does not present the report of the fabrication of the metering plate.
Therefore, the title should change to;

Design of Vertical Rotor Metering Plate for Precision Seeding of Okra: Incorporating Physical and Engineering properties

ABSTRACT

An investigation was conducted with the aim of examining the physical and engineering attributes of okra seeds. The physical and frictional characteristics of okra seeds play a crucial role in the design of a seeder, influencing decisions regarding cell size, shape, metering disc thickness, and material, as well as the inclination of the seed hopper. The study aimed to determine these attributes of okra seeds. The primary findings indicated that the typical values for the length, width, and thickness of the seeds were 5.58 mm, 4.61 mm, and 4.18 mm, respectively. The maximum width and length of the seeds served as the basis for the design of the cell diameters and thickness of the seed metering rotor. The VNR-Deepika variety exhibited a geometric mean diameter of 4.79 mm, with sphericity and roundness values of 85.2% and 82.85%, respectively. The roundness and sphericity of the seed affected its ability to move through the seeder's components.Test weight, bulk density, true density, volume, porosity, angle of repose, and coefficient of static friction were measured as 57.06 g, 0.56 g cm^{-3}, 1.12 g cm^{-3}, 111.46 mm^{-3}, 50.22%, 25.97° and 0.42, respectively. The depth of the vertical rotor cells was established at 6.25 mm, slightly exceeding the average seed length to ensure singular seed dispensing. Simultaneously, the width of each cell was calculated to be 6.98 mm, offering adequate space for accommodating one seed per cell.Featuring 14 cells positioned around the vertical rotor's circumference, the seed metering rotor was intended to have an 85 mm diameter.

Comment [AZ2]: Okra variety?

Comment [AZ3]: Intended or designed?

Keywords: Vertical rotor design,Okra seeds, Seed properties of okra

INTRODUCTION

Planting is a pivotal process in agricultural cultivation, encompassing considerations such as selecting the right amount of seeds, ensuring optimal depth of planting, and achieving proper seed spacing to enhance crop productivity to its maximum potential.The exact insertion of a single seed at the appropriate spacing into the soil is the characteristic of precision planting. Typically, farmers and researchers employ the manual dibbling method to achieve this level of accuracy. Planters, equipped with single-seed metering mechanisms, are employed to facilitate this process.These devices prevent seed scattering and excessive seed usage by ensuring a consistent seed distribution in rows. This is achieved by avoiding the metering of multiple seeds and minimizing bouncing in the furrow.

In India, there are various types of planters with different seed metering mechanisms, such as horizontal plate, vertical plate, inclined plate, and cup type. These models cater to both animal and tractor power sources, offering diverse options for precision planting in agricultural practices. Kumar *et al.* (2018) studied on physical attributes of okra seed and reported that the physical attributes of any seed are vital information for the metering mechanism's development.Rathore and Shrivastava (2021) examined and found that developing a seed's metering mechanism requires a thorough understanding of its physical characteristics.

The physical attributes of seeds, such as their size, shape, the angle of repose, test weight, and bulk density, are crucial factors according to design of seed metering units. These characteristics significantly influence the effectiveness of seed metering systems utilized in planters or seed drills. Research by Jayan and Kumar (2004) investigated the physical properties of maize, red gram, and cotton seeds, highlighting the importance of sphericity and roundness in seed flow through various planter components. Variations in parameters like average unit mass, volume, true density, bulk density, and thousand-seed mass, and porosity among different seed varieties also impact the performance of seed metering mechanisms, as noted by Ramesh *et al.* (2015).When designing the seed hopper volume for the seed planter, bulk density plays a crucial role.

Physical and engineering attributesof the okra seeds namely size, shape, mean diameter, test weight, bulk density, coefficient of friction and angle of repose were studied in the Department of Processing and Food Engineering Laboratory, IGKV, Raipur (C.G.).The results of which are discussed here below.

Comment [AZ4]: Please kindly modify this statement.

This suppose to be the aim and objectives of the study.
If so, from the title and body of the manuscript, the selected okra properties were determined to aid the design of the rotor metering plate.

Then, the objective of the study should capture both the properties (as presented) and design of the metering plate.

Comment [AZ5]: Remove

MATERIALS AND METHODS

Determination of Physical and Engineering attributes of Okra Seed

The physicaland engineering attributes of seeds, such as size-shape, bulk density, angle of repose, and thousand-grain weight, are pivotal in ensuring the efficiency of seed metering mechanisms. These properties were extensively analyzed to inform the design of an effective seed metering system. Size specifications guided the dimensions of grooves, including length, depth, and the requisite number of seeds per groove. Shape characteristics facilitated smooth and uniform seed flow within the grooves. True density and bulk density values were instrumental in determining optimal seed hopper volume and thickness. The optimal slope for unimpeded seed flow from the hopper was determined by accounting for the angle of repose and coefficient of friction. Measurement of the coefficient of static friction aided in selecting suitable hopper materials conducive to consistent seed flow. Furthermore, thousand-grain weight played a vital role in calculating the necessary seed quantity per meter area to achieve desired seeding rates.

Physical attributes of okra seed(Variety- Deepika) namelysize, shape, sphericity, thousandseed weight, bulk density, angle ofrepose and moisture content weredetermined using standard procedures.For estimating the size, onehundred seeds were randomly selectedand their dimensions were measuredalong all the three major planes. Themeasurement was replicated fivetimes and their means computed.Sphericity and shape were characterizedusing the seed dimensions.Test weight was determined for fiverandom samples of one thousandseed using electronic balancewith 0.01 g sensitivity. Bulk density was calculated using a thousand cubic centimeter measuring cylinder by determining the weight to volume ratio of the seed.Standard methodology was also employed to ascertain the angle of repose.

Average width (W),length (L), and thickness (T) were calculated as suggested by (Singhal and Samuel, 2003). Twenty seeds were chosen randomly for measuring the dimensions with following relationship:

$$\mathrm{L} = \frac{\sum_{i=1}^{n} \mathrm{L}}{n} - - - (1)$$

$$\mathrm{W} = \frac{\sum_{i=1}^{n} \mathrm{W}}{n} - - - (2)$$

$$T = \frac{\sum_{i=1}^{n} \mathrm{T}}{n} - - - (3)$$

In which,

L = Longest intercept (mm),

W= Width (mm),

T = Thickness (mm.

Comment [AZ6]: (mm)

The subsequent equation was used to compute the geometric mean diameter (D_p) (Mohsenin, 1986).

$$D_p = (\mathrm{LWT})^{1/3} - - - (4)$$

Sphericity (ϕ) was calculated by following given formula (Sahay and Singh, 1994).

$$\text{Sphericity} = \frac{(LWT)^{1/3}}{L} \quad --- (5)$$

The following formula was used to determine the roundness (R) of the okra seeds (Sahay and Singh, 1994).

$$R = \frac{\left(\frac{W}{L}\right) + \left(\frac{T}{L}\right) + \left(\frac{T}{W}\right)}{3} \quad --- (6)$$

Test weight was determined (Singh and Goswami, 1996) for five random samples of selected crop variety of okra seed on an electronic balance having least count of 0.001 g.One thousand seeds of okra were counted manually and then weighed on the electronic balance.

The true density and volume of the seed plays an important role in cell design of vertical rotor seed metering mechanism. The volume and true density of seed are determined by toluene (C_7H_8) displacement method. The true density and volumeis evaluated for a sample of 100 seed. The weight of sample is recorded. The sample is then immersed in a graduated glass jar containing known volume of toluene (Tavakkoli*et al.*, 2009). The displaced volume of toluene is recorded for each sample, thus volume of sample of seed is calculated. True density is the ratio of weight of sample to toluene displaced volume. Observations were taken for ten samples and the mean was calculated separately for true density and volume of seed(Singh andGoswami, 1996).

The following formula (Deshpande *et al.*, 1993; Mohsenin, 1986) was used to determine the bulk density.

$$b_d = \frac{Wt}{L \times \left(\pi d^2/4\right)} \quad --- (7)$$

In which,

b_d = Bulk density (g cm^{-3}),

W_t = Weight of the sample (g),

L = Length of the cylinder (cm),

d = Diameter of the cylinder (cm).

The porosity of seed is estimating using following expression (Chakraverty, 1981):

$$\text{Porosity}\,(\%) = \left(1 - \frac{\text{Bulk density}}{\text{True density}}\right) \times 100 \quad --- (8)$$

Comment [AZ7]: are

Comment [AZ8]: was

Comment [AZ9]: was

Comment [AZ10]: was

Angle of repose was also crucial in correctly calculating stability in box. Tilting box method was used for fine-grained, non-cohesive materials, with individual particle size. To guarantee that seeds flow freely, the slope of the seed hopper is maintained slightly higher than the average angle of repose of seeds. Angle of repose forokra seed weredetermined using the following expression (Jayan and Kumar, 2004).

$$\mathrm{Tan}\phi = \frac{2(H_a - H_b)}{D} \qquad ---(9)$$

Where,

ϕ = Angle of repose

H_a = Height of the cone,

H_b= Height of the platform and

D = Diameter of platform.

Coefficient of staticfriction (μ_s) of okra seed was estimated with respect to each of the following three structural materials such as fiber glass plate surface, galvanized iron sheet and mild steel sheet. The okra seed were placed on the test surface at the top edge. The inclined surface was tilted until the samples begin to move leaving inclined surface. Angle of inclination to the horizontal was measured directly on the instrument scale and it was taken as angle of internal friction. The tangent of the above angle was taken as co-efficient of friction between the test surface and okra seed sample. This procedure was repeated five times for each structural material with okra seed. The coefficient of friction was determined as the tangent of the angle using the equation given below (Mohesenin, 1986).

$$\mu_s = \tan\theta \qquad ---(10)$$

In which,

μ_s = Coefficient of static friction,

θ=Material surface inclination angle (°).

Okra seed metering mechanism design using a vertical rotor

A vertical rotor type seed metering device was designed for sowing okra. The major considerations were taken into account when designing the precision planter's okra seed metering mechanism:

Comment [AZ11]: was

Comment [AZ12]: Present their respective unit

Comment [AZ13]: Kindly include the following.

These considerations are as follows;

1. The metering rotor should meter one seed per cell accurately.
2. Seed to seed spacing of 200 mm should be achieved.
3. The maximum permissible peripheral velocity of the plate should be 16.5 m min^{-1} (Sharma and Jain, 2013).
4. The maximum permissible speed of seed metering feed shaft should be 60 rpm (Sharma and Jain, 2013).
5. Precision seed metering device was designed for 'VNR-Deepika' variety of okra. The measurement of physical attributes showed the mean length of the seed as 5.58±0.20 mm, however, the variation in the maximum dimension of length was noted in the range of 5.51 mm to 5.87 mm. The size and shape of the cells of the metering plate were designed considering the design parameters used (Ryu and Kim, 1998). Fig. 1 shows the shape of the cell on the seed metering plate which was designed considering the following four variables.

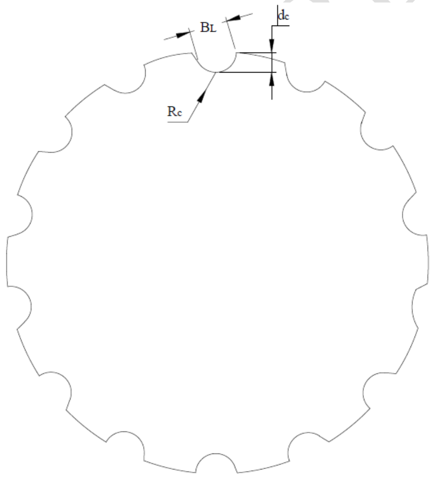

Fig. 1: Vertical rotor cell design parameters

d_c is the depth of the cell. It was slightly higher than the average length of the seed to feed only one seed at a time. Considering the average length of the okra (5.58mm), cell depths of 1.12, times the average length of the seeds were designed for the seed metering device. The depth of the cells was therefore obtained as 6.25 mm.

Comment [AZ14]: Why the choice of 1.12 times average seed length?

β_L is the left (seed delivery) side angle of the cell. Since this angle affects time delay between consecutive dropping, consequently, a compromise needs to be made. It was noted that a cell depth of 6.25 mm with 50^{o}will allow two seeds to be filled in the cell and therefore angle was maintained at zero throughout the cellswere used in the design of the seed metering plates (Sharma and Dewangan, 2023).

$\beta_R$is the right side angle of the cell. The right side cell angle should be less as compared with the left side cell angle. This angle was maintained at zero throughout the cells.

R_C is the radius of curvature of the cell bottom. The value of this radius of curvature was taken as half the depth of the cells.

Considering the above design parameters, seed metering rotor were designed. Profile of seed metering plates appear in Fig. 1.Width of a cell should be such that a single seed could be accommodated. Considering the largest length (5.58 mm) of okra, width of the cell in the seed metering device was designed to be1.25 times of the length. Width of the cell was therefore obtained as 6.98 mm.

To ensure that,~~accommodate~~ a positive knockout mechanism,5.31 mm thick and 24.16 mmin diameter brush was provided in between seed metering vertical rotor with cells.

If number of cells is more than necessary in a rotor, it is difficult to keep the time interval between two consecutive seeds. Therefore a proper numbers of cell were determined considering the agronomic requirement. The diameter of seed metering verticalrotor was estimated using the following equation (Sharma and Jain, 2013):

$$d_p = \frac{V_r}{\pi N_r} \qquad --- (11)$$

Where,

d_P = The seed metering rotor's diameter (mm),

V_r =Maximum permissible,the rotor's periphery velocity for seed metering (m min^{-1}),

N_r = Expected rpm of the rotor.

The numbers of cell on the seed metering rotor is the function of the speed of operation and the spacing between seeds and therefore it was calculated by applying the formula (Sharma and Jain, 2013).

$$N_c = \frac{\pi P_w}{G_r S_s} \qquad --- (12)$$

Where,

N_c = Number of cells on the periphery of seed metering vertical rotor;

P_w = Diameter of okra precision planter wheel, mm;

Comment [AZ15]: .. and

Comment [AZ16]: Why 1.25?

Comment [AZ17]: ..is accommodated, …..

Comment [AZ18]: Comma (,)

Comment [AZ19]: Unit please?

Comment [AZ20]: ..are

Gr = Gear ratio;

S_S = Expected seed to seed spacing, mm;

RESULTS AND DISCUSSION

The design of the vertical rotor seed metering mechanism involved an assessment of the physical and engineering characteristics of selected variety of okra seed,these characteristics encompassed size, shape, geometric mean diameter, sphericity, roundness, test weight,bulk density, true density, volume, porosity, coefficient of static frictionand angle of repose.These properties constitute pivotal factors guiding design of efficient seed meteringmechanisms essential for agricultural seeders. Dimensions of okra seeds, encompassing their length, width, and thickness, were measured,length of seed varied from 5.15-5.87 mm, width4.24-4.87 mm, and the thickness 4.02-4.41 mm having mean values average length, average width and average thickness of the seed was 5.58 mm, 4.61 mm and 4.18 mm, respectively. The standard deviation and coefficient of variation of okra seed sample were also calculated to check the variation and uniformity of seed parameters such as length, width and thickness within the seed sample. Standard deviation was determined to be 0.20 with coefficient of variation of 3.59% for the length dimension similarly for width and thickness dimension found 0.19, 4.06% and 0.10, 2.40% respectively.

Comment [AZ21]: Space this 5.15 – 5.87 mm

Same with others

The VNR-Deepika variety of okra was found to have a geometric mean diameter of 4.79 mm. The coefficient of variation was determined to be 2.44%, while the standard deviation was found to be 0.20.

The sphericity ranged from 82.16 to 91.25% and it mean value came out to be 85.26% having Standard deviation was found to be 2.26 with coefficient of variation of 2.65%. The higher value of sphericity showed that seeds were nearly spherical in shape.

The roundness was the measure ofsharpness of the corner of okra seed and it was varied from79.69-90.29% and mean value found to be 82.85% having Standard deviation was found to be 2.58 with coefficient of variation of 3.11%.

The weight of 1000 seeds of okra varied from 54.38 g to 58.02 g with average value of 57.06 g.Bulk density of okra seed varied between 0.52 g cm^{-3} and 0.58 gcm^{-3}. The average value of bulk density of seed was 0.56 gcm^{-3}. Coefficient of variation of bulk density was 3.22%.

True density of okra seed varied between 1.05 g cm^{-3} and 1.21 gcm^{-3}. The average value of true density of okra seed was 1.12 gcm^{-3}. Coefficient of variation of true density was 2.97%.The mean volume of okra was 111.46 mm^3 and it varied in range from 106.05 mm^3 to 114.86 mm^3.

Porosity indicates the percentage of inter-seed space to volume of the seed bulk. The mean value of porosity of okra seed was 50.22%. It ranged between 45.71% and 54.39% with coefficient of variation as 4.61%.

One of the most important design parameters for the hopper is the angle of repose, which is used to drop seeds into the planter's metering mechanism.The average value of angle of repose under study as observed in the laboratory were 25.97°. Observation to find out angle of repose varies from 25.34° to 26.32°.

The coefficient of static friction for okra seed was tested on the fiber glass plate surface. The coefficient of static friction was found to be 0.42. Observation to find out coefficient of the static friction varies from 0.34 to 0.49. These findings are of paramount importance for designing tailor-made seed metering vertical rotor and related components, ensuring efficient seed handling, dispensing, and sowing, while minimizing damage and losses in agricultural practices. The study also found that the frictional coefficient between okra seeds and galvanized iron sheet as well as mild steel sheet is higher than that between okra seeds and fiber glass plate surface. This suggests that fiber glass plate surface is a more suitable material for vertical rotor in okra seed seeders, as it reduces the risk of seed jamming. The physical attributes of seeds, such as their size, shape, weight, and surface properties, can affect their behavior in vertical rotor planter. For example, larger and heavier seeds may be more likely to jam or damage other seeds during the metering process. Seeds with a higher sphericity may also be more likely to roll and jam. Engineering properties of okra seeds, such as their coefficient of friction with different materials, can also affect their behavior in vertical rotor planter.

The study findings highlight the importance of considering the engineeringand physical properties of seeds when designing vertical rotor okra seed metering mechanism for precision planter. This information utilized to optimize the design of vertical rotor okra seed metering mechanism for minimizing seed damage, losses, and jamming while ensuring optimal sowing performance.

Vertical rotor okra seed metering mechanism design

Peripheral velocity of rotor for minimum seed breakage and expected rpm of the rotor assumed 14.67 m min^{-1} (14679 mm min^{-1}) and 55 rpm respectively, which is less than

Comment [AZ22]: Define this as it appearing for the first time maximum permissible peripheral velocity 16.5 m min^{-1} and The seed metering feed shaft's maximum allowable speed should be 60 revolutions per minute. (Sharma and Jain, 2013).

$$d_p = \frac{14679}{3.14 \times 55} = 84.99 \text{ mm}$$

Accordingly, the vertical rotor for metering okra seeds, as shown in Fig. 2, was designed with a diameter of 85 mm.

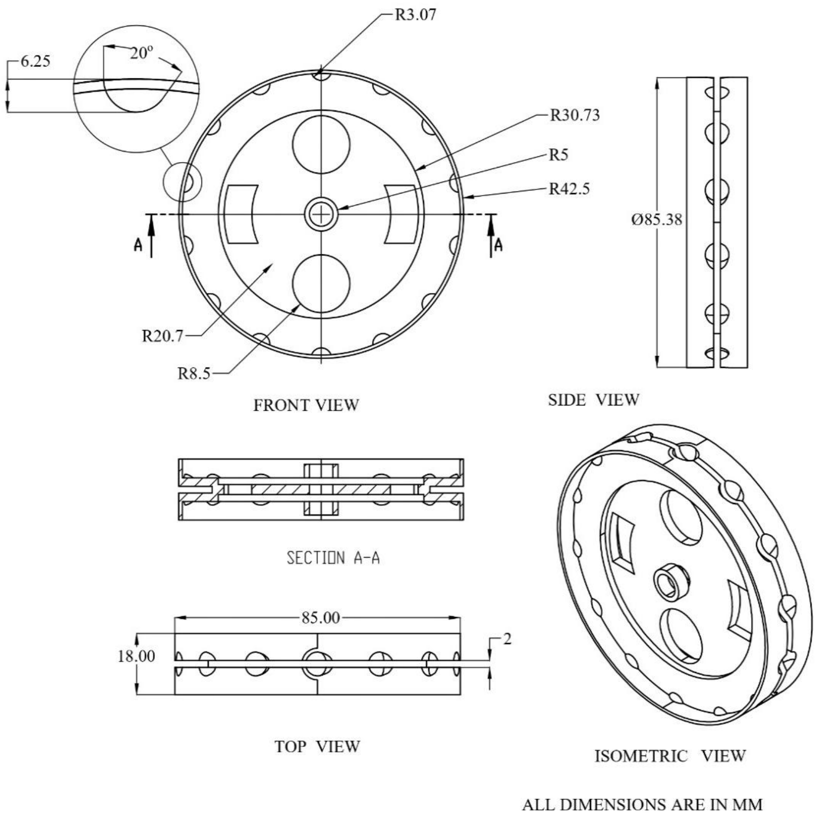

Fig. 2: Design detail of okra seed metering vertical rotor

Number of cells on okra seed metering vertical rotor was found to be:

$$N_c = \frac{3.14 \times 238}{0.267 \times 200} = 13.99$$

Thus, the seed metering rotor was designed with 14 cells around the periphery of the vertical rotor for okra seed metering. The quantity of cells on the okra seed metering vertical rotor depends on the operational speed and the spacing between seeds, as illustrated in Fig. 2.

CONCLUSION

The okra seeds exhibited a range of dimensions, with lengths ranging from 5.15 to 5.87 mm, widths from 4.24 to 4.87 mm, and thicknesses from 4.02 to 4.41 mm. The mean values for length, width, and thickness were recorded as 5.58 mm, 4.61 mm, and 4.18 mm, respectively. Additionally, the geometric mean diameter was computed as 4.79 mm, while the sphericity and roundness were revealed to be 85.2% and 82.85%, respectively. The test weight was measured at 57.06 g, with bulk density and true density recorded as 0.56 $gcm^{-3}$and 1.12 gcm^{-3}, respectively. Volume of the seeds was determined to be 111.46 gcm^{-3}, resulted to a porosity of 50.22%. The angle of repose was measured at 25.97°, and the coefficient of static friction was found to be 0.42.The seed metering rotor was specifically engineered to have a diameter of 85 mm, additionally, it was designed to accommodate 14 individual cells positioned around its periphery.The depth of the vertical rotor cells was determined to be 6.25 mm, it was slightly higher than the average length of the seed to feed only one seed at a time. Meanwhile, the cell width for a single seed was computed at 6.98 mm to provide sufficient space for accommodating one seed per cell.

REFERENCES

Chakraverty, A. 1981. Handbook of Postharvest Technology: Cereals, Fruits, Vegetables, Tea, and Spices. CRC Press, Boca Raton, United States of America.

Deshpande, S.D., Bal, S. and Ojha, T.P., 1993. Physical properties of soybean. J Agric.Engg. Res., 56: 89-98.

Jayan, P.R. and Kumar, V.J.F. 2004. Planter design in relation to the physical properties of seed. J. Trop. Agri., 42(2):69-71.

Kumar V., Rani V., Jain M., Kumar A., Kumar S. and Naresh. 2018. A study on physical properties of okra seed:*Abelmoschus Esculentus (L.)*, Advances in Research, 14(3): 1-7.

Mohsenin, N.N. 1986. Physical properties of plant and animal materials. Gordon and Breach Science Publishers. New York.

Ramesh, B., Reddy, B.S., Veerangoud, M., Anantachar, M., Sharanagouda, H., Shanwad, U.K. 2015. Properties of cotton seed in relation to design of a pneumatic seed metering device. Indian Journal of Dryland Agricultural Research and Development, 30(1):69-76.

Rathore, F. and Shrivastava, A.K. 2021. Determination of Various Physical Properties of Okra Seeds. International Journal of Current Microbiology and Applied Sciences, 10(02): 3575-3582

Ryu, H.I. and Kim, K.U. 1998. Design of roller type metering device for precision planting. Transactions of the ASAE. American Society of Agricultural Engineers, 41(1):923-30.

Sahay, K.M. and Singh, K.K. 1994. Unit Operations of Agricultural Processing.Vikas Publishing house Pvt. Ltd, New Delhi, 7-8.

Sharma, D.N. and Jain, M. 2013. Farm Machinery Design Principles and Problems. Jain Brothers, New Delhi.

Sharma, P.T. and Dewangan, K.N.2023. Design and development of a vertical plate precision seed metering device with positive seed knockout mechanism. Agric. Eng. Int.: 25(1) 27-42

Singh, K.K. and Goswami, T.K. 1996. Physical properties of cumin seed. Journal of Agricultural Engineering Research, 64: 93-98.

Singhal,O.P. and Samuel, D.V.K. 2003. Engineering Properties of Biological Material, Saroj Prakashan.

Tavakkoli, H., Rajabipour, A., Mohtasebi, S.S. 2009. Moisture dependent some engineering properties of soybean grains.Agricultural Engineering International, 11:1110.