DE GRUYTER OPEN

INTERNATIONAL **Agrophysics**
www.international-agrophysics.org

Int. Agrophys., 2015, 29, 121-126
doi: 10.1515/intag-2015-0001

Note

Evaluation and modeling of aerodynamic properties of mung bean seeds

Feizollah Shahbazi

Department of Agricultural Machinery, Lorestan University, Khorramabad, 6813717133, Iran

Received January 28, 2014; accepted May 14, 2014

A b s t r a c t. Aerodynamic properties of solid materials have long been used to convey and separate seeds and grains during post harvest operations. The objective of this study was the evaluation of the aerodynamic properties of mung bean seeds as a function of moisture content and two grades referred to above and below a cut point of 4.8 mm in length. The results showed that as the moisture content increased from 7.8 to 25% (w.b.), the terminal velocity of seeds increased following a polynomial relationship, from 7.28 to 8.79 and 6.02 to 7.12 m s^{-1}, for grades A and B, respectively. Seeds at grade A had terminal velocities with a mean value of 8.05 m s^{-1}, while at grade B had a mean value of 6.46 m s^{-1}. The Reynolds number of both grades increased linearly with the increase of seeds moisture content, while the drag coefficient decreased with the increase of moisture content. Mathematical relationships were developed to relate the change in seeds moisture content with the obtained values of aerodynamic properties. The analysis of variance showed that moisture content had a significant effect, at 1% probability level, on all the aerodynamics properties of mung beans.

K e y w o r d s: aerodynamic properties, separation, post harvest operation, mung bean seed

INTRODUCTION

Mung bean (*Vigna radiata* L.) is also known as green bean, green gram, golden gram and mash (in Persian). It is primarily grown in Asia, Africa, South and North America, and Australia, principally for its protein-rich edible seeds (Liu and Shen, 2007). Mung bean is similar in composition to other members of the legume family, with 24% protein, 1% fat, 63% carbohydrate and 16% dietary fibre (USDA, 2008). In addition to being an important source of human food and animal feed, mung bean also plays an important role in sustaining soil fertility by improving soil physical properties and fixing atmospheric nitrogen.

The behaviour of particles in an air stream during pneumatic conveying and separation greatly depends on their aerodynamic properties. The aerodynamic forces which exist during relative motion between the air and the materials act differently on different particles. Separation of a mixture of particles in a vertical air stream is only possible when the aerodynamic characteristics of the particles are so different that the light particles are entrained in the air stream and the heavy particles fall through it. Knowledge of aerodynamic properties is therefore essential in the proper design of separating and cleaning equipments. When an air stream is used for separating a product such as mung bean seed from its associated foreign materials, such as straw and chaff, knowledge of aerodynamic characteristics of all the particles involved is necessary. This helps to define the range of air velocities for effective separation of the grain from foreign materials. For this reason, the terminal velocity has been used as an important aerodynamic characteristic of materials in such applications as pneumatic conveying and their separation from foreign materials (Mohsenin, 1978).

Several investigators determined the aerodynamic properties of various seeds, such as millet grain, cheat seed, chickpea and hemp seed (Baryeh, 2002; Hauhouot *et al*., 2000; Konak *et al*., 2002; Sacilik *et al*., 2003), different varieties of: makhana, wheat kernel, rice, corn, wheat and barley, pine nuts, pistachio nut (Jha and Kachru, 2007, Khoshtaghaza and Mehdizadeh, 2006; Matouk *et al*., 2005;

*Corresponding author e-mail: shahbazi.f@lu.ac.ir

Ozguven and Vursavus, 2005; Razavi *et al*., 2007) and Turgenia latifolia seeds, wheat kernels and wild mustard (Nalbandi *et al*., 2010; Shahbazi, 2013).

Information about the aerodynamic properties of mung bean seeds is limited. Hence, the objective of this study was to investigate the aerodynamic properties of mung bean seeds as a function of moisture content. Tests were conducted over a range of moisture contents from 7.8 to 25% w.b., which spans the moisture range of harvest to the post harvest operations.

MATERIALS AND METHODS

Samples of mung bean seeds at optimum maturity were harvested by hand in Lorestan province, Iran, and cleaned in an air screen cleaner. The seeds were then classified into two grades based on their length, the cut point being 4.8 mm. Grades A and B referred to above and below the cut point, respectively. The initial moisture content was 7.8% (wet basis), determined with ASAE S352.2 (ASAE Standards, 1988). Higher moisture content samples were prepared by adding calculated amounts of distilled water, then sealing in polyethylene bags, and storing at 5ºC for 15 days. Samples were warmed to room temperature before each test and moisture content was verified. Sample mass was recorded with a digital electronic balance having an accuracy of 0.001 g. The major dimensions of the seeds (L, W and T) were measured using a digital caliper with an accuracy of ± 0.01 mm (Gupta *et al*., 2007; Unal *et al*., 2013; Zare *et al*., 2013). The true density of the seeds was measured using the toluene displacement method (Chakraverty and Poul, 2001; Mohsenin, 1978). To determine the terminal velocity value of mung bean seeds, a vertical wind tunnel was designed, constructed and used. A centrifugal fan powered by 0.75 kW motor was used in the inlet of the wind tunnel to supply airflow. The airflow rate of the fan was controlled at inlet and adjusted by changing the velocity of the electric motor through an inverter set and a diaphragm. The final section of the wind tunnel consisted of a Plexiglas region where the terminal velocity of seed was measured. To determine the terminal velocity, each seed was placed in the centre of the cross section of the wind tunnel on the screen. The airflow was then increased until the seed flotation point. At this moment, when the rotational movement of the seed was the lowest, the air velocity was measured using a hot-wire anemometer with an accuracy of 0.1 m s^{-1}. The terminal velocity of each seed was measured two times. For each condition the terminal velocity was calculated as the average of the velocity values obtained at the centre of the test section and at four equidistantly distributed points on two orthogonal axes located at the test section. To determine the terminal velocity at each moisture content level, ten seeds were selected and used as ten replications in the statistical analysis. The values of air density and viscosity were taken as 1.21 kg m^{-3} and 1.816×10^{-5} N s m^{-2}, respectively, at room temperature of 20ºC. In free fall, the object will attain constant terminal velocity (V_t) at which the net gravitational accelerating force (F_g) equals the resisting upward drag force (F_r) under the condition where terminal velocity has been achieved at air velocity which is equal to the terminal velocity (V_t). Substituting for F_g and F_r, the expression for terminal velocity will be as follows (Mohsenin, 1984):

$$V_t = \sqrt{\frac{2mg(\rho_p - \rho_f)}{\rho_p \ \rho_f \ A_p \ C_d}} \ . \tag{1}$$

In addition, the drag coefficient can be derived as follows:

$$C_d = \frac{2mg(\rho_p - \rho_f)}{\rho_p \ \rho_f \ A_p V_t^2}, \tag{2}$$

$$A_P = \frac{\pi}{4} LW, \tag{3}$$

where: A_p is projection area of the particle (m^2), C_d is drag coefficient (decimal), g is acceleration due to gravity (9.81 m s^{-2}), L is seed length (m), m is mass of seed (kg), V_t is terminal velocity (m s^{-1}), W is seed width (m), ρ_f is density of air (1.21 kg m^{-3}), ρ_p is density of seed (kg m^{-3}).

In this study, Reynolds number (Re) was calculated using the terminal velocity of each seed sample. Reynolds number (dimensionless) equations include a velocity term using the following relationship (Mohsenin, 1984):

$$Re = \frac{\rho_f \ V_t \ D_g}{\mu}, \tag{4}$$

$$D_g = (LWT)^{1/3}, \tag{5}$$

where: D_g is geometric mean diameter of seed (m), T is seed thickness (m), μ is air viscosity at room temp (1.816×10^{-5} N s m^2). In this study, the effects of Mung bean seeds size (grades A and B) and moisture content (7.8, 12.5, 15, 17.5, 20 and 25%, wet basis) on the terminal velocity, drag coefficient and Reynolds number of seeds were studied. Tests were conducted over a range of moisture contents from 7.8 to 25% which spans the moisture range of harvest to the processing operations. The factorial experiment was conducted as a randomised design with three replicates. For each test, 10 seeds were selected randomly from each sample and tested by using the airflow device. Mean comparison of factors was carried out at 5% probability level. The terminal velocity, drag coefficient, Reynolds number and the moisture content data of different seed grades were fitted to linear, power, exponential and polynomial models. The models were evaluated according to the statistical criterion R^2 and root mean square error (RMS) for verifying the adequacy of fit. The best model with the highest R^2 and RMS below 0.05 was selected to predict the terminal velocity, drag coefficient and Reynolds number of seeds as a function of the moisture content. Data were analyzed by SPSS 17 software.

RESULTS AND DISCUSSION

The analysis of variance showed that there was a significant difference between the terminal velocity of mung bean seeds at grades A and B. Also the effect of seed moisture content on this property was significant (Table 1). Terminal velocities for grade A were observed to be higher than those obtained for grade B. Mung bean seeds at grade A had terminal velocities with a mean value of 8.05 m s^{-1}, at different moisture contents, while the seeds at grade B had a mean value of 6.46 m s^{-1}. This result can be explained by the fact that the seeds of grade A were bigger than those of grade B. Since the square of terminal velocity is directly related to particle size and shape, it follows that larger particles of similar shape need higher terminal velocities than smaller ones. Similar results were obtained by Kahrs (1994) on three fractions of wheat seeds. Wheat seeds > 2.8 mm had mean terminal velocity of 8.8 m s^{-1} while the fraction < 2 mm had mean terminal velocity of 6.4 m s^{-1}. The terminal velocity of mung bean seeds increased with increasing moisture content (Table 2). The terminal velocity of mung bean seeds at grades A and B increased from 7.28 to 8.79 and from 6.02 to 7.12 m s^{-1}, respectively, as the moisture content of seeds increased from 7.8 to 25% (Fig. 1). The maximum terminal velocity value (8.79 m s^{-1}) was obtained in grade A at a moisture content of 25%, and the minimum value (6.02 m s^{-1}) was obtained in grade B at a moisture content of 7.8%. These results are in agreement with published literatures for some seeds. Gupta *et al*. (2007) showed that in the moisture range of 6 to 14% d.b. the terminal velocity of NSFH-36, PSF-118 and Hybrid SH-3322 variety of sunflower seed increased from 2.93 to 3.28, 2.54

T a b l e 1. Analysis of variance of the data of the aerodynamic properties of mung bean seeds

Source of variation	df	Mean squares		
		Terminal velocity	Drag coefficient	Reynolds number
Seed size (S)	1	104.533*	3.714*	5.592×10^{8}*
Moisture content (*M*)	5	17.972*	2.302*	3.211×10^{8}*
S×*M*	5	0.793*	0.357*	3.121×10^{8}*
Error	108	0.001	0.045	3922077.188

*Significant difference at 1% probability level, df – degree of freedom.

T a b l e 2. Average values of dimensions, projected area, geometric mean diameter, true density and terminal velocity of mung bean seeds at different moisture contents

Moisture content	Length	Width	Thickness	Projected area	Geometric mean diameter	True density	Terminal velocity
(%)		(mm)		(mm^2)	(mm)	(kg m^{-3})	(m s^{-1})
				Grade A			
7.8	4.34 (0.24)	3.70 (0.19)	3.25 (0.14)	12.61 (1.03)	3.74 (0.11)	1252.97 (13.63)	6.02 (0.21)
12.5	4.42 (0.32)	3.71 (0.21)	3.26 (0.23)	12.89 (1.06)	3.77 (0.08)	1303.13 (12.24)	6.09 (0.35)
15	4.51 (0.31)	3.78 (0.20)	3.33 (0.35)	13.38 (0.98)	3.84 (0.14)	1346.24 (17.98)	6.21 (0.12)
17.5	4.52 (0.21)	3.79 (0.33)	3.35 (0.29)	13.49 (1.12)	3.86 (0.19)	1376.16 (11.85)	6.53 (0.46)
20	4.63 (0.42)	3.87 (0.24)	3.42 (0.58)	14.07 (1.23)	3.94 (0.15)	1404.23 (10.12)	6.85 (0.22)
25	4.79 (0.37)	4.01 (0.34)	3.56 (0.52)	15.09 (1.31)	4.09 (0.23)	1425.13 (11.02)	7.12 (0.52)
				Grade B			
7.8	5.54 (0.65)	4.61 (0.44)	4.11 (0.63)	20.07 (2.12)	4.72 (0.36)	1186.33 (13.65)	7.28 (0.41)
12.5	5.82 (0.56)	4.62 (0.54)	4.22 (0.52)	21.10 (1.05)	4.84 (0.27)	1193.52 (10.87)	7.54 (0.52)
15	5.91 (0.43)	4.67 (0.34)	4.24 (0.63)	22.65 (2.04)	4.89 (0.35)	1202.42 (11.25)	7.95 (0.31)
17.5	6.10 (0.75)	4.81 (0.39)	4.30 (0.32)	23.03 (1.25)	5.02 (0.52)	1296.36 (18.98)	8.15 (1.02)
20	6.15 (0.81)	5.02 (0.46)	4.42 (0.25)	24.25 (0.98)	5.15 (0.41)	1325.63 (14.52)	8.59 (0.58)
25	6.72 (0.88)	5.10 (0.54)	4.50 (0.22)	26.83 (1.54)	5.36 (0.47)	1369.87 (14.25)	8.79 (0.62)

Standard deviation is given in brackets.

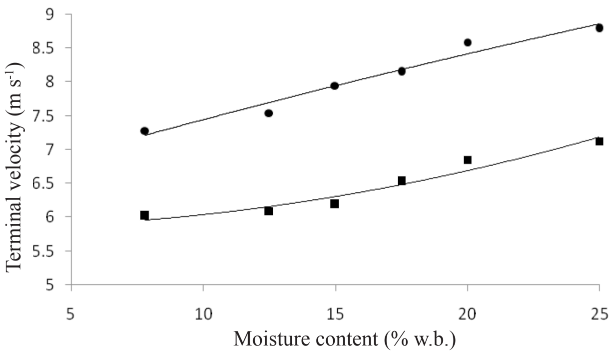

Fig. 1. Terminal velocity variation versus seed moisture content: ● grade A, ■ grade B.

to 3.04, and 2.98 to 3.53 m s^{-1}, respectively. Zewdu (2007) measured the terminal velocity of teff grains (*Eragrostis tef*). He reported that it increased linearly from 3.08 to 3.96 m s^{-1} with increasing moisture content from 6.5 to 30.1% w.b. Hauhouot *et al*. (2000) showed that the mean value of terminal velocity of wheat seeds was 7.84 m s^{-1}. The terminal velocity of millet grain varied from 2.75 to 4.63 m s^{-1} for an increase in moisture content from 5 to 22.5% d.b. (Baryeh, 2002). Matouk *et al*. (2008) reported that the terminal velocity of sunflower, soybean and canola seeds increased from 5.34 to 5.91, from 10.16 to 10.38 and from 5.10 to 5.32 m s^{-1} with the increase of seeds moisture contents from 7.35 to 23.7, 9.52 to 24.64 and 7.11 to 25.72% w.b., respectively. Similar results were reported for coffee cherries and beans (Afonso *et al*., 2007) and African yam bean (Irtwange and Ugbeka, 2003). The increase in terminal velocity with an increase in moisture content may be attributed to the increase in mass of an individual seed per unit frontal area presented to the air stream. The other reason is probably that the drag force is affected by the moisture content of particle.

Figure 1 shows the variation of the terminal velocity with moisture content for grades A and B of mung bean seeds. The terminal velocity data for mung bean seeds in Fig. 1 were fitted to mathematical models. These models were evaluated for verifying the adequacy of fit using the R^2 and RMS values. By comparing the average values of R^2 and RMS, it was obvious that the polynomial model had the highest R^2 value and RMS below 0.05. Then it was stated that fitting of polynomial model to experimental data was very good. Accordingly, the polynomial model was selected as a suitable model to predict the terminal velocity of mung bean seeds as a function of moisture content. Razavi *et al*. (2007) developed a linear equation between the terminal velocity of pistachio nut and kernel as a function of moisture content. Zewda (2007) reported that the terminal velocity of teff grain was linearly related to moisture content. However, Afonso *et al*. (2007) reported a nonlinear equation for the terminal velocity of coffee cherry and bean as a function of combination of moisture content and true density. Nalbandi *et al*. (2010) reported a polynomial relationship for the terminal velocity of wheat kernels a function of moisture content. The following equations were found for the relationship between the terminal velocity (V_t, m s^{-1}) and moisture content (M, %) for each mung bean seeds grade:

Grade A

$$V_t = -0.001M^2 + 0.114M + 6.351 \quad R^2 = 0.961, \qquad (6)$$

Grade B

$$V_t = -0.002M^2 - 0.004M + 5.856 \quad R^2 = 0.945. \qquad (7)$$

All the indexes are significant at the level of 99.99%.

The values of the drag coefficient and the projected area of mung bean seeds were calculated using Eqs (2) and (3) by measuring the terminal velocity, true density and the two principal dimensions (length and width) of seeds (Table 2). The analysis of variance showed that there was a significant difference between the drag coefficients of mung bean seeds at different moisture content. However, the drag coefficients were not affected significantly by mung bean seeds grade. The results showed that the drag coefficient of mung bean seeds decreased as moisture content increased. Afonso *et al*. (2007), Gupta *et al*. (2007) and Irtwange and Ugbeka (2003) reported similar results for coffee cherries, sunflower seed and African yam bean (*cv*. TSS 138), respectively. However, some odd results have been reported for some products. Irtwange and Ugbeka (2003) reported that the drag coefficient of African yam bean (cv. TSS 137) increased as moisture content increased from 4 to 16% w.b. Afonso *et al*. (2007) showed that the drag coefficient of coffee beans (*cv*. Catual), coffee cherries and beans (*cv*. Conilon) increased as moisture content increased.

The drag coefficient values of mung bean seeds in grade A were found to be 0.845, 0.827, 0.773, 0.700, 0.619 and 0.565 (with a mean value of 0.722 and standard deviation of 0.113) for the moisture contents of 7.8, 12.5, 15, 17.5, 20 and 25%, respectively. In grade B, the drag coefficients of seeds were found to be 0.846, 0.826, 0.776, 0.703, 0.644 and 0.575 (with a mean value of 0.729 and standard deviation of 0.106) over the same moisture contents (Fig. 2). Hauhouot *et al*. (2000) reported that the drag coefficient of wheat seeds is 0.74. Matouk *et al*. (2008) reported that the drag coefficient of sunflower, soybean, and canola seeds, decreased from 0.75061 to 0.6178, from 0.6841 to 0.6829 and from 0.6301 to 0.5687, with the increase of seeds moisture contents from 7.35 to 23.7, 9.52 to 24.64 and 7.11 to 25.722%, respectively.

Figure 2 shows the variation of the drag coefficient with moisture content for two grades of mung bean seeds. The values of this interaction varied from 0.565 to 0.846 that occurred in the grade A at the highest moisture content and in the grade B at the lowest moisture content, respectively. The models fitted to the data using the regression techniques,

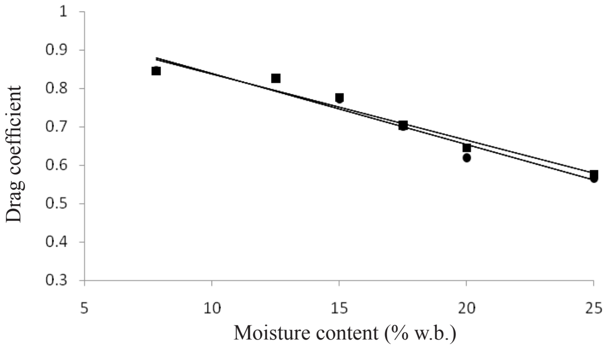

Fig. 2. Drag coefficient variation versus seed moisture content. Explanation as in Fig. 1.

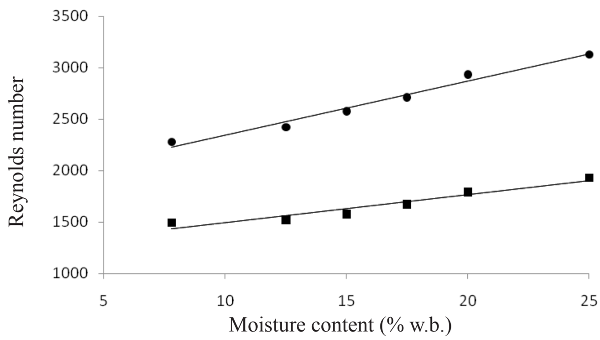

Fig. 3. Reynolds number variation versus seed moisture content. Explanation as in Fig. 1.

based on R^2 and RMS values, showed that the drag coefficient decreased linearly with increases in the moisture content for two grades of mung bean seeds. Similar results were also reported by Matouk *et al*. (2005) for rice, corn, wheat and barley. They stated that the relationship between terminal velocity and moisture content may be described by an exponential model, while drag coefficient and Reynolds number have linear relationships. So the following equations were found for the relationship between drag coefficient (C_d) and moisture content (M, %), for each grade of mung bean seeds:

Grade A

$$C_d = - 0.018\, M + 1.021 \quad R^2 = 0.969, \tag{8}$$

Grade B

$$C_d = - 0.017\, M + 1.011 \quad R^2 = 0.945. \tag{9}$$

All the indexes are significant at the level of 99.99%.

The values of the Reynolds number and the geometric mean diameter of mung bean seeds were calculated using Eqs (4) and (5) by measuring the terminal velocity and the three principal dimensions (length, width and thickness) of seeds (Table 2). The analysis of variance showed that there was a significant difference between the Reynolds number of mung bean seeds at grades A and B. In addition, the effect of seed moisture content on this property was significant. The results showed that the Reynolds number of mung bean seeds increased with moisture content. Similar results were reported by Matouk *et al*. (2005) for rice, corn, wheat and barley. The Reynolds number values of mung bean seeds in grade A were found to be 2281, 2424, 2579, 2714, 2937 and 3129 (with a mean value of 2677 and standard deviation of 317) for the moisture contents of 7.8, 12.5, 15, 17.5, 20 and 25%, respectively. In grade B, the Reynolds number of seeds were found to be 1494, 1524, 1579, 1673, 1793 and 1934 (with a mean value of 1666 and standard deviation of 170) over the same moisture contents (Fig. 3). Matouk *et al*. (2008) reported that the Reynolds number of sunflower and soybean seeds were in the ranges of 2 226-2 571 and 4 379-4 652, with the increase of seeds moisture contents from 7.35 to 23.7 and from 9.52 to 24.64%, respectively.

Figure 3 shows the variation of the Reynolds number with moisture content for two grades of mung bean seeds. The models fitted to the data using the regression technique, based on R^2 and RMS values, showed that the Reynolds number increased linearly with increases in the moisture content. Similar results were also reported by Matouk *et al*. (2005) for rice, corn, wheat and barley. So the following equations were found for the relationship between the Reynolds number (R_n) and moisture content (M, %) for each grade of mung bean seeds:

Grade A

$$R_n = 52.42\, M + 1823 \quad R^2 = 0.988, \tag{10}$$

Grade B

$$R_n = 27.50\, M + 1218 \quad R^2 = 0.973. \tag{11}$$

All the indexes are significant at the level of 99.99%.

CONCLUSIONS

1. The analysis of variance showed that there is a significant difference between the terminal velocity and Reynolds number of mung bean seeds at both grades referred to above and below a cut point of 4.8 mm in length, and at different moisture contents.

2. The terminal velocity of mung beans seeds increased following a polynomial relationship from 7.28 to 8.79 and 6.02 to 7.12 m s^{-1}, for grades A and B, respectively, as the moisture content increased from 7.8 to 25%. Mung bean seeds at grade A had terminal velocities with a mean value of 8.05 m s^{-1}, at different moisture contents, while the seeds at grade B had a mean value of 6.46 m s^{-1}.

3. There was a significant difference between the drag coefficients of mung bean seeds at different moisture content. The drag coefficients were not affected significantly by the mung bean seeds grade.

4. The Reynolds number of mung bean seeds increased linearly with the increase of seeds moisture content, while the drag coefficient decreased with the increase of moisture content.

5. Mathematical relationships were developed to predict the terminal velocity, drag coefficient and Reynolds number of seeds as a function of the moisture content.

REFERENCES

Afonso Jr. P.C., Correa P.C., Pinto F.A.C., and Queiroz D.M., 2007. Aerodynamic properties of coffee cherries and beans. Biosystems Eng., 98, 39-46.

ASAE, **1998.** ASAE Standards. St. Joseph, MI, USA.

Baryeh E.A., 2002. Physical properties of millet. J. Food Eng., 51, 39-46.

Chakraverty A. and Paul S.R., 2001. Post Harvest Technology: Cereals, Pulses and Vegetables. Sci. Publ., India.

Gupta R.K., Arora G., and Sharma R., 2007. Aerodynamic properties of sunflower seed (*Helianthus annuus* L.). J. Food Eng., 79, 899-904.

Hauhouot O.M., Criner B.R., Brusewitz G.H., and Solie J.B., 2000. Selected physical characteristics and aerodynamic properties of cheat seed for the separation from wheat. Agric. Eng. Int., 2, 1-14.

Irtwange S.V. and Ugbeka J.C., 2003. Effect of accession and moisture content on aerodynamic properties of African yam bean (*Sphenostylis stenocarpa*). Appl. Eng. Agric., 19(3), 321-328.

Jha S.N. and Kachru R.P., 2007. Physical and aerodynamic properties of makhana. J. Food Proces. Eng., 21, 301-316.

Kahrs J., 1994. Aerodynamics properties of weeds seeds. Int. Agrophysics, 8, 259-262.

Khoshtaghaza M.H. and Mehdizadeh R., 2006. Aerodynamic properties of wheat kernel and straw materials. Agric. Eng. Int., CIGR Ejournal, 8, 1-10.

Konak M., Carman K., and Aydin C., 2002. Physical Properties of Chick Pea Seeds. Biosystems Eng., 82(1), 73-78.

Liu W.J. and Shen Q., 2007. Studies on the physicochemical properties of mung bean starch from sour liquid processing and centrifugation. J. Food Eng., 79, 358-363.

Matouk A.M., Abd El-latif S.M., and Tharwat A., 2008. Aerodynamic and mechanical properties of some oil crops. J. Agric. Sci. Mansoura Univ., 33(6), 4195-4211.

Matouk A.M., El-Kholy M.M., Hamam A.S., and Ewis T.R., 2005. Aerodynamic characteristics for different varieties of some cereal crops. J. Agric. Eng., 22(3), 1086-1102.

Mohsenin N.N., 1978. Physical properties of plant and animal materials. Gordon Breach Sci. Press, New York, USA.

Mohsenin N.N., 1984. Physical properties of plant and animal materials. Gordon Breach Sci. Press, New York, USA.

Nalbandi H., Seiiedlou S., and Ghassemzadeh H.R., 2010. Aerodynamic properties of *Turgenia latifolia* seeds and wheat kernels. Int. Agrophys., 24, 57-61.

Ozguven F. and Vursavus K., 2005. Some physical, mechanical and aerodynamic properties of pine (*Pinus pinea*) nuts. J. Food Eng., 68, 191-196.

Razavi S.M.A., Rafe A., and Akbari R., 2007. Terminal velocity of pistachio nut and its kernel as affected by moisture content and variety. African J. Agric. Res., 2(12), 663-666.

Sacilik K., Ozturk R., and Keskin R., 2003. Some physical properties of hemp seed. Biosystems Eng., 86(2), 191-198.

Shahbazi F., 2013. Aerodynamic properties of wild mustard (*Sinapis arvensis* L.) seed for separation from canola. J. Sci. Food Agric., 93, 1466-1470.

Unal H., Alpsoy H.C., and Ayhan A., 2013. Effect of the moisture content on the physical properties of bitter gourd seed. Int. Agrophys., 27, 455-461.

USDA, **2008.** National Nutrient Database for Standard Reference, Release 18.

Zare D., Bakhshipour A., and Chen G., 2013. Physical properties of cumin and caraway seeds. Int. Agrophys., 27, 491-494.

Zewdu A.D., 2007. Aerodynamic properties of teff grain and straw material. Biosystems Eng., 98, 304-309.