Determination of some engineering properties of parsley (Petroselinum crispum L.) seeds and modeling

Mojtaba Taheri, Amir Hossein Mirzabe*, Ali Mansouri,Ali Reza Aliakbari

(Department of Mechanical Engineering of Biosystems, Aboureihan College, University of Tehran, Tehran, Iran)

Abstract: To design the planting, separating, threshing, sizing and packing machines for agricultural products, physical and mechanical properties of the products should be known. In this work some physical properties of parsley seeds were studied. Dimensional parameters including three principle dimensions, geometric mean diameter, equivalent diameter, arithmetic mean diameter, sphericity, volume, surface area, projected area, flakiness ratio and elongation ratio were measured using image processing technique. Also length, width and thickness distributions of parsley seeds were modeled using Gamma, Generalized Extreme Value and Weibull distributions. Gravimetrical properties including mass of single seed, thousand seed mass, bulk density, true density and porosity were measured. Effect of the container volume and fall height on bulk density and porosity were studied. Frictional properties of parsley seeds (static coefficient of friction on various surfaces and repose angle of based on bypouring, Hele-Shaw, empting and filling methods) were measured. Results showed that length, width and thickness of the seeds ranged (0.660 - 0.883mm), (0.524 - 0.752mm) and (0.490 - 0.744 mm), respectively. With increasing the container volume from 150 to 550 mL, bulk density of the seeds increased; but from 550 to 750 mL, it was decreased. True density and thousand seed mass of the seeds were 884.658 kg/m3 and 1.390 g. The values of friction coefficient on plywood, rubber, iron and galvanized surfaces were 27.35°, 24.17°, 19.31° and 14.77°, respectively. The values of filling and empting repose angles were 32.64° and 40.16°.

Keywords: image processing technique; dimensional properties; modeling of dimensions; gravimetrical properties; frictional properties

Citation: Mojtaba T., A. H. Mirzabe, A. Mansouri, and A. R. Aliakbari. 2015. Determination of some engineering properties of parsley (Petroselinum crispum L.) seeds and modeling. AgricEngInt: CIGR Journal, 17(4): 192-210.

1 Introduction

Parsley (*Petroselinum crispum*L.) Nym. ex A.W. Hill (Syn. P. sativum Hoffm.); family Umbelliferae, locally known as Baqdunis, has been used medicinally for many centuries in European, Mediterranean and Asian countries (Al-Howiriny et al., 2003). Parsley is a spice native to the countries of the Mediterranean region. It is widely used, both fresh and dry, to enhance the flavor of many different foods in many countries. The essential oil of parsley seeds is widely used in the food industry and even as a fragrance in perfume manufacturing, though the oil for such purposes is obtained from the seeds because of the low yields obtained from the leaves (Díaz-Maroto et al., 2002).

Received date: 2014-03-19 **Accepted date: 2015-10-29**
***Corresponding author: Amir Hossein Mirzabe,** Email: a_h_mirzabe@alumni.ut.ac.ir

Culpeper described Parsley as "comfortable to the stomach" (Grieve, 1979). The herb Parsley is used for flushing the efferent urinary tract, as a diuretic (Kreydiyyehand Usta, 2002) also for the prevention and treatment of kidney gravel. In traditional medicine of many countries, it is used for gastrointestinal disorders (Kreydiyyeh et al., 2001). The seeds and leaves of this plant are used for the treatment of diarrhea, stomachache, indigestion, dropsy, menstrual difficulties and to treat gallstones (Al-Howiriny et al., 2003). The fresh or dried leaves are said to stimulate appetite and treat flatulence (Stuart, 1979).

There are many published literature on parsley in various science such as parsley drying, parsley oil extraction, parsley medicine effects, parsley genetic and etc. The composition of the essential oil from parsley leaves has been studied, the principal constituents being p-mentha-1, 3, 8-triene, myristicin, apiole, β-phellandrene, myrcene, and isopropenyl-4-methylbenzene (Díaz-Maroto et al., 2002). Pinoet al. (1997) have cited that the essential oil of parsleycontains 34 compounds, in which myristicin and apiole are the major constituents. Two compounds, crispane and crispanone, were isolated from Parsley (Spraul et al., 1992). Another chemical investigation (Chaudhary et al., 1986) reported the presence of oxypeucedanin, a major furocoumarin in Parsley. Effect of different drying methods on the volatile components of parsley was investigated by Díaz-Maroto et al. (2002). They cite that air drying at ambient temperature resulted in few losses in volatile compounds compared with the fresh herb, whereas oven drying at 45 ℃ and freeze-drying caused a decrease in the concentrations of the majority of the volatile components, especially those with the greatest impact on parsley aroma: p-mentha-1,3,8-triene and apiol (oily liquid extracted from parsley).

The proper design of process equipment depends essentially on the physical and mechanical properties of agricultural crops and products. Different researchers report the use of characteristic dimensions to determine the size of seeds (Aviara et al., 2013, Garnayak et al., 2008,Sologubik et al., 2013) Size and shape are important for separator and sorter and can be used to determine the lower size limits of conveyors. Furthermore, the characteristic dimensions allow a calculation of the surface area with volume of grains, important aspects for the modeling of drying and ventilation. Porosity affects the bulk density which is also necessary factor in the design of dryer, storage and conveyer capacity while the true density is useful to design separation equipment (Sologubik et al., 2013). The angle of repose and coefficient of friction are considered by engineers as important properties for the design of seed containers and other storage structures and accessories. The static coefficient of friction limits the maximum inclination angle of conveyor and storage bin. The amount of power requirement for conveyor depends on the magnitude of frictional force. Angle of repose is a useful parameter for calculation of belt conveyor width and for designing the shape of storage (Mohhamadi et al., 2014; Sirisomboon et al., 2007).

A lot of researches have been conducted on physical and mechanical properties of agricultural seeds, grains, fruits, nuts and kernels. Fracture resistance of sunflower seed and kernel to compressive loading was calculated by Gupta and Das (2000). Altuntas et al. (2005) measured some physical properties including as length, width, thickness, geometric mean diameter, sphericity, mass, porosity, and bulk density of fenugreek seeds. Some physical properties of rough rice grain were measured (Varnamkhasti et al., 2008). Tabarsa et al. (2011) studied physical and mechanical properties of wheat straw boards bonded with tannin modified phenol-formaldehyde adhesive.

For a single seed, dimensions, mass and other physical properties can be determined; however, values of these properties differ for each individual seed to other. Normally, we are not interested to know the properties of each individual seed, but description of the frequency distributions of the dimensions of the whole sets of the seeds is needed for designing agricultural equipment (Khazaei et al, 2008). There are many reports on modeling the properties of agricultural products based on continues statistical distributions such as normal, lognormal, Weibull, gamma and Generalized Extreme Value and etc. (Nanang, 1998; Gorgoso et al., 2007; Khazaei et al., 2008; Mirzabe et al., 2012).

The aim of this study was to investigate some physical properties (dimensional, gravimetrical and frictional properties) of parsley seeds. The dimensional parameters investigated include three principle dimensions, geometric mean diameter, equivalent diameter, arithmetic mean diameter, sphericity, volume, surface area, projected area, flakiness ratio, elongation ratio and modeling of dimensions and dimensional parameters are measured. The gravimetrical properties including single seed mass, thousand seed mass, bulk density, true density and porosity are measured. Also, frictional properties of seeds including static coefficient of friction on various surfaces and repose angle based on Hele-Shaw, empting and filling methods are measured.

2. Materials and methods

2.1 Sample preparation

Three kilograms of the parsley seeds were obtained from a local market in Varmin, a city of Tehran province in the country of Iran in 2013. The seeds were cleaned manually to remove all foreign materials. The moisture content of each sample was determined using the standard hot air oven method at 105±1°C for 24 h (Gupta and Das, 1997; Özarslan, 2002; Altuntaş et al., 2005.) and using Equation (1) to calculate moisture content of the seeds based on dry bases (d.b.):

$$M = \frac{M_w - M_d}{M_d} \times 100 \qquad (1)$$

Where: M is moisture content of the sample, % (d.b.); M_w is the initial mass of the sample or wet mass, g; and M_d is the final mass of the sample or dry mass, % (d.b.).The average values of three replications were reported as moisture content for the seeds. Value of moisture content of the parsley seeds was 6.12 % (d.b.) in all tests (dimensional, gravimetrical and frictional properties).

2.2 Dimensional properties

2.2.1 Image processing set up

The three major perpendicular dimensions of the each seeds were measured by image processing technique. The image processing system consisted of a camera (Canon, IXY 600F, 12.1 megapixels, USB connection, Japan), and four white-colored fluorescent lamps (32 W) as a source of light and a laptop computer (Dell, 1558, China) equipped with Matlab R2012a software package (Figure 1). A white paper was placed on the floor of the box to provide a white background. Tow RGB color images were captured from up and front views of seed .The contrast between the seeds and the background was improved by several functions of MATLAB. Pixels above a certain threshold value 95 were converted into white, pixels below this threshold to black, resulting in binary image (Koc, 2007). A group of black pixels adjacent to each other represented a seed. The pixels must be converted to millimeter, hence some circulars and squares with identified dimensions were depicted on the paper and then a relation between pixel and length in millimeter was obtained.

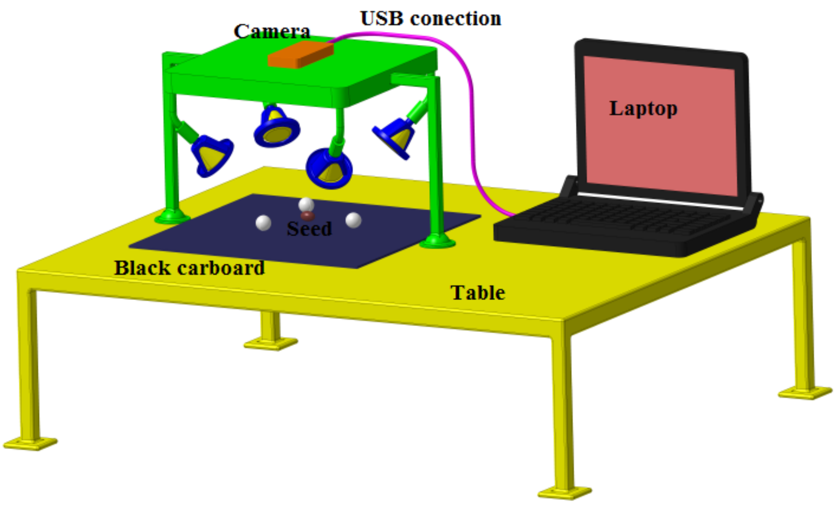

Figure 1 Experimental set up was used to image processing

2.2.2 Calculate dimensional properties

The average diameter of seed was calculated by using the geometric and arithmetic means of the three axial dimensions. The geometric mean diameter, D_G, arithmetic mean diameter, D_A and equivalent diameter, D_E of the seed were calculated using the following Equation (2), Equation (3) and Equation (4) (Milani et al., 2007; Garnayak et al., 2008 and Heidarbeigi et al., 2009):

$$D_G = \sqrt[3]{LWT} \quad (2)$$

$$D_A = \frac{L+W+T}{3} \quad (3)$$

$$D_E = \left[\frac{(T+W)^2}{4} L\right]^{\frac{1}{3}} \quad (4)$$

Where: L is the length, W the width and T is the thickness, all in mm.

The sphericity (φ) of the grains, seeds, nuts, kernels or fruits is an index of its roundness. The sphericity (φ_1 and φ_2) of parsley seeds was calculated using the following Equation (5) and Equation (6) (Sirisomboon et al., 2007; Milani et al., 2007 andMirzabe et al., 2013a):

$$\varphi_1 = \left(\frac{\sqrt[3]{LWT}}{L}\right) \times 100 = \frac{D_G}{L} \times 100 \quad (5)$$

$$\varphi_2 = \left\{\frac{(WT)^{\frac{1}{2}}\left[(2L-(WT)^{\frac{1}{2}}\right]}{L^2}\right\}^{\frac{1}{3}} \times 100 \quad (6)$$

The surface area (S_1, $S_2$and S_3) of seed was found by analogy with a sphere of the same geometric mean diameter, using the following Equation (7), Equation (8) and Equation (9) (McGahon et al., 2007;Milani et al., 2007; Xu et al., 2009; Ersoy, 2010and Mirzabe et al., 2013a):

$$S_1 = \pi {D_G}^2 \quad (7)$$

$$S_2 = \left\{\frac{\left[\pi(WT)^{\frac{1}{2}}\right]L^2}{2L-(WT)^{\frac{1}{2}}}\right\} \quad (8)$$

$$S_3 = 4\pi\left[\frac{(LW)^P + (LT)^P + (WT)^P}{3}\right]^{\frac{1}{P}} \quad (9)$$

Where:P is a constant. P approximation has the least relative error (±1.061% in the worst case) when P≈1.6075.

The volume ($V_1$and V_2) of seed was found by analogy with a sphere of the same geometric mean diameter, using the following Equation (10) and Equation (11) (Perez et al., 2007and Mirzabe et al., 2013a):

$$V_1 = \frac{\pi\,(D_G)^3}{6} \quad (10)$$

$$V_2 = \frac{\pi WTL^2}{6\left[2L-(WT)^{\frac{1}{2}}\right]} \quad (11)$$

Where: D_G is geometric mean diameter.

The projected area, A_P (projected area is one of the most important parameters for determining aerodynamic properties) of the seeds were determined using Equation (12), Equation (13) and Equation (14) (Kabas et al., 2007; Koocheki et al., 2007andMirzabe et al., 2013a):

$$\mathrm{A_{p1}} = \left(\frac{\pi WL}{4}\right) \quad (12)$$

$$\mathrm{A_{p2}} = 1.21\,V_1^{\frac{2}{3}} = 1.21\left[\frac{\pi\,(D_G)^3}{6}\right]^{\frac{2}{3}} \quad (13)$$

$$\mathrm{A_{p3}} = 1.21\,V_2^{\frac{2}{3}} = 1.21\left\{\frac{\pi WTL^2}{6\left[2L-(WT)^{\frac{1}{2}}\right]}\right\}^{\frac{2}{3}} \quad (14)$$

The flakiness ratio, F_r, and elongation ratio, E_r of a single seed were calculated using the Equation (15) and Equation (16). (Mora and Kwan, 2000 and Khazaei et al., 2008):

$$F_r = \frac{T}{w} \quad (15)$$

$$E_r = \frac{L}{W} \quad (16)$$

2.2.3 Modeling of dimensions

Indeed, if $P(x)$ is a density function (DF) for a characteristic of a seeds sample, then as Equation (17):

$$\int_a^b P(x)dx = \left(\begin{array}{c}Fraction\ of\ the\\ seeds\ sample\ for\\ which\ a \le x \le b\end{array}\right) \quad (17)$$

In Equation (17), if $P(x)$ is interpreted as a probability density function (PDF), then the right hand of the equation will be equal to the probability that $a \le x \le b$. We also know that for any density function using the Equation (18) (Mirzabe et al., 2013a):

$$\int_{-\infty}^{+\infty} P(x)dx = 1 \quad (18)$$

Moreover, the cumulative distribution function (CDF) for the seeds characteristic is defined as using the Equation (19):

$P(t) = \int_{-\infty}^{t} P(x)dx$ (19)

This gives either the proportion of the seeds with characteristic value less than *t*, or the probability of having a value less than *t*.

Length, width and thickness of parsley seeds distribution were modeled with three probability density functions. These functions were: 3-parameter Gamma, 3-parameter Weibull and Generalized Extreme Value (G.E.V) distributions. Also geometric mean diameter, equivalent diameter, arithmetic mean diameter, sphericity, volume, surface area, projected area, flakiness ratio and elongation ratio of parsley seeds were modeled with Generalized Extreme Value (G.E.V) distribution. The probability density functions including Equation (20) for three distributions are showed in Table 1(Nanag, 1998; Khazaei et al., 2008; Gorgoso et al., 2008; Mirzabe et al., 2012; Mirzabe et al., 2013a and Mirzabe et al., 2013b).

Table 1 The Gamma, Generalized Extreme Value and Weibull distributions of probability density function

Distribution	Probability density function
Gamma	$f(x) = \frac{(x-\alpha)^{\gamma-1}}{\beta^{\gamma}\Gamma(\gamma)}\exp(-\frac{x-\alpha}{\beta})$ (20)
Generalized Extreme Value	$f(x) = \frac{1}{\beta}\left[1+\gamma\left(\frac{x-\alpha}{\beta}\right)\right]^{(-1/\gamma)-1} exp\left\{-\left[1+\gamma\left(\frac{x-\alpha}{\beta}\right)\right]^{-1/\gamma}\right\}$
Weibull	$f(x) = \frac{\gamma}{\beta}\left(\frac{x-\alpha}{\beta}\right)^{\alpha-1} exp\left(-\left(\frac{x-\alpha}{\beta}\right)^{\gamma}\right)$

Note: α, β, and γ are shift, scale, and shape parameters, respectively.

In the Table 1, $\Gamma\varepsilon$is the Gamma function and Γ_z is the incomplete Gamma function Equation (21) and Equation (22):

$$\Gamma(\varepsilon) = \int_0^{\infty} x^{\varepsilon-1} e^{x} dx \quad , \quad \varepsilon > 0 \qquad (21)$$

$$\Gamma_z(\varepsilon) = \int_0^{z} x^{\varepsilon-1} e^{x} dx \quad , \quad \varepsilon > 0 \qquad (22)$$

The adjustable parameters for each probability density function were calculated using the commercial spreadsheet package of Easy Fit 5.5. Kolomogrov-Smirnov methods were used for comparison of all probability density. Kolmogorov-Smirnov goodness of fit test was used to test how well different prediction techniques work for prediction of diameter, thickness and height distributions (Gorgoso et al., 2007). The test is based on the vertical deviation between the observed cumulative density function and estimated cumulative density function based on the Equation (23). In this equation, small values of the test statistics K_s index indicate a better fit.

$$K_s = max[s(x) - f(x)] \qquad (23)$$

Where: *S(x)* and *F(x)* are the probability observed and theoretical of the cumulative frequency distributions. Also the Kolmogorov-Smirnov index for each probability density function was calculated using the commercial spreadsheet package of Easy Fit 5.5.

2.3 Gravimetric properties

To evaluate the single seed and thousand seed mass, 100 seeds selected from the bulk sample, randomly; the hundred seed mass was measured by a digital balance (Kern, Japan, accuracy of ±0.001 g). Single seed mass was calculated by dividing the hundred seed mass to 100, while thousand seed mass was calculated by multiplying the hundred seed mass by 10.

The bulk material of seeds was obtained by volume containers of 150, 350, 550 and 750 cm^3. The seeds were poured into the containers at a height of 50, 100, 150, 200 and 250 mm (Mirzabe et al., 2013aand Gupta and Das, 1997). The mass (M_s) and volume (V_s) of samples were measured, while bulk density (ρ_b) and true density (ρ_t) were calculated. The volume of sample was determined using the water displacement method. Toluene (C_7H_8) was used in place of water because it is absorbed by seeds to a lesser extent, density of toluene is less than the water and its surface tension is low, so that it fills even shallow dips in a seed and its dissolution power is low (Milani et al., 2007and Garnayak et al., 2008). The volume of the individual sample was determined by weighing displacement volume of toluene using the Equation (24) and Equation (25):

$$V_s = \frac{M_{TD}}{\rho_t} = \frac{(M_T - M_P) - (M_{PTS} - M_{PS})}{\rho_t} \qquad (24)$$

$$\rho_s = \frac{M_s}{V_s} \qquad (25)$$

Where: M_{TD} is the mass of displacement volume of toluene in kg, ρ_t is the density of toluene (870 kg/m^3), M_T is the mass of filled pycnometer with toluene in kg, M_P is the mass of pycnometer kg, M_{PTS} is the mass of pycnometer with toluene and a nut in kg, and M_{PS} is the mass of pycnometer and seeds in kg.

Porosity or void fraction is a measure of the void spaces or empty spaces in a material, which is between 0 to1, or as a percentage between 0 to100 percent. The porosity (ε) of bulk seed was calculated from bulk and true densities using the Equation (26) (Sharma et al., 2011):

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \qquad (26)$$

2.4 Frictional properties

2.4.1 Coefficients of static friction

The coefficients of external static friction of the parsley seeds were determined using sloped plane method on surfaces of galvanized, iron, plywood and rubber. A topless and bottomless cylinder of 100 mm diameter and 50 mm height were filled with the samples. The cylinder was raised slightly so as not to touch the surfaces (Figure 2). The structural surface with the cylinder resting on it was inclined gradually with a screw device until the cylinder just started to slide down over the surface and the angle of tilt at this juncture, the angle of tilt, C_f, in degree was read by Auto Cad 2007 software. The coefficient of static friction, μ_s, was calculated from the following Equation (27) (Mirzabe et al., 2013b).

$$\mu_s = \tan(C_f) \qquad (27)$$

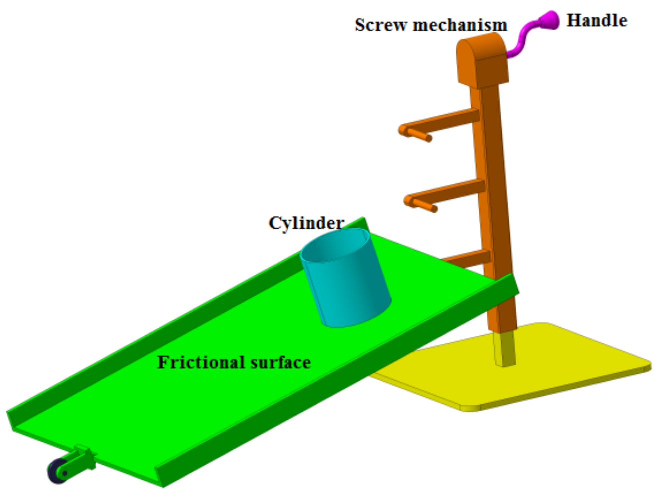

Figure 2 Experimental set up was used to measure coefficient angle of external static friction

2.4.2 Angle of repose

When bulk granular materials are poured onto a horizontal surface, a conical pile will form. Material with a low repose angle forms flatter piles than material with a high repose angle. Repose angle is related to the density, surface area and shapes of the particles, the friction coefficient of the material and gravity-dependent (Kleinhans et al., 2011). In present study, to measure repose angle of the parsley seeds pouring, filling, empting and Hele-Shaw methods were used.

2.4.2.1 Pouring angle of repose

Static repose angle was measured using pouring method. The repose angle of seeds sample was determined using a top and bottomless metallic cylinder, where cylinder diameter was equal to 150 mm, cylinder height was 250 mm, rotational velocity of electromotor was 1400 r/min and linear velocity of chord was 5 mm/s (Mirzabe et al., 2013b). The cylinder was placed on horizontal surface and was filled with seeds and kernels; then, the cylinder was raised very slowly (Figure 3). The camera was place at opposite of the front view of the bulk seeds then photographed from bulk seeds; then pouring angle of repose calculated using image processing technique and Auto Cad 2007 software package. In order to study the effect of the material of the contact surface, galvanized, iron, plywood and rubber plates placed on the frame of the set up (beneath of the cylinder) and pouring angle of repose was measured on these surfaces.

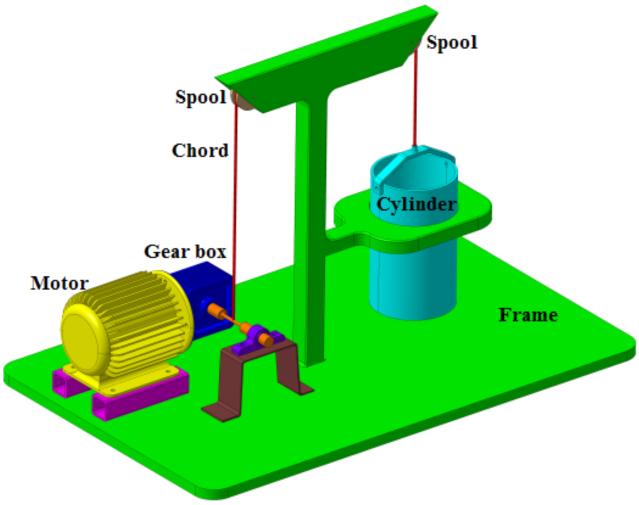

Figure 3 Experimental set up was used to measure pouring repose angle of parsley seeds

2.4.2.2 Filling and emptying angles of repose

The filling and emptying repose angles of the seeds were measured. The device used in this study consists of two boxes, upper and down box, of dimensions 120 mm length, 120 mm height, and 60 mm width (Figure 4). The upper box was filled with the sample seeds. The material of upper box can flow to down through a removable port, the filling or static repose angle is the angle of surface with the horizontal at which the seeds will stand when piled on the ground. While, the emptying or dynamic repose angle is the angle of surface of residual with horizontal in the upper box. The height of the seeds was measured while, the filling (A_{RF}) and emptying (A_{RE}) repose angle were calculated by the following Equation (28) and Equation (29). (Sirisomboon et al., 2007):

$$A_{RE} = tan^{-1}\left(\frac{H}{XL}\right) \quad (28)$$

$$A_{RF} = tan^{-1}\left(\frac{h}{xl}\right) \quad (29)$$

Where: *H* and h are the height (mm), and *XL* and *xl* (mm) are horizontal distance.

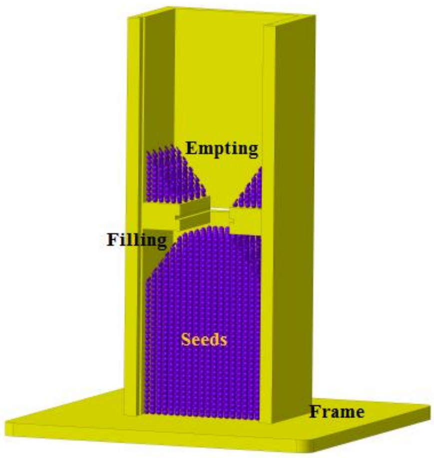

Figure4 Experimental set up was used to measure filling and empting repose angle of parsley seeds

2.4.2.3 Hele-Shaw angle of repose

The Hele-Shaw repose angle of the parsley seeds was measured. The device used in this study consists of a box with dimensions of 300, 200, and 200 mm for length, height and width, respectively. At delivery slop 30°. The small box was filled with the sample seeds. The material of upper main box can flow to down through a removable port, the Hele-Shaw is the angle of surface with the horizontal at which the seeds will stand when piled on the bottom of the main box. The camera was place at opposite of the front view of the box then photographed from bulk seeds (front of the main box was made of the glass); then Hele-Shaw repose angle calculated using image processing technique and Auto Cad 2007 software package. In order to study the effect of the contact surface material, galvanized, iron, plywood and rubber plates placed into the main box (beneath of the main box) and Hele-Shaw angle repose were measured on these surfaces (Figure 5).

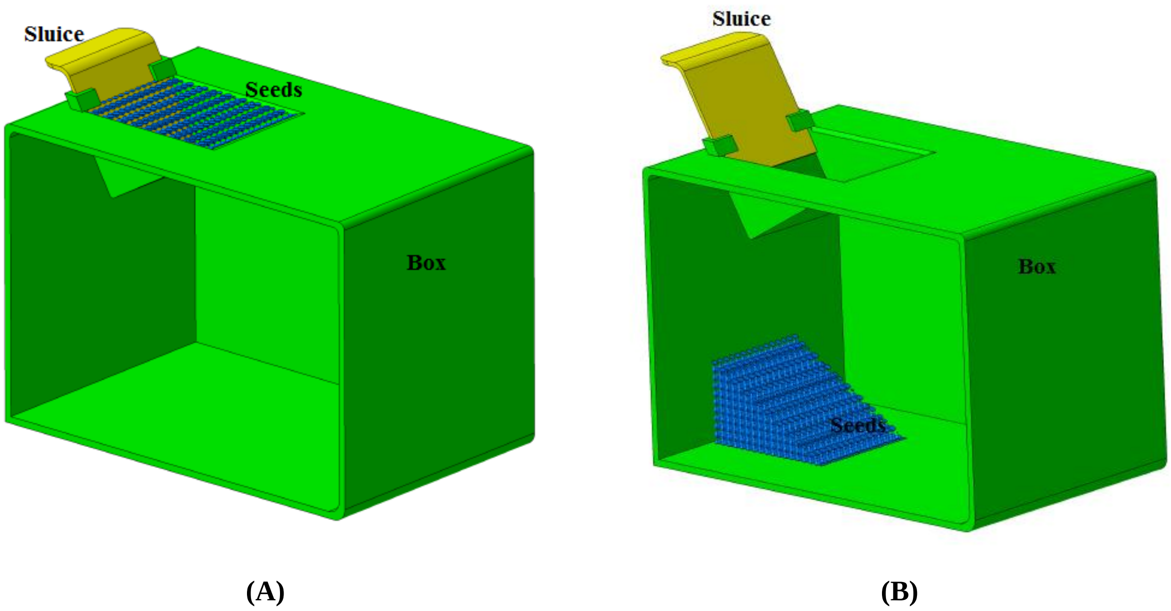

Figure 5 Experimental set up was used to measure Hele-Shaw repose angle of parsley seeds. (A) is experimental set up before seeds falling and (B) is experimental set up after seeds falling

2.5 Data analysis

Based on the measurements and calculations made above, for calculating statistical indices including maximum, minimum, average, standard deviation, skewness, and kurtosis for measured and calculated dimensions and dimensional properties, Microsoft Office Excel 2010 was used. The skewness and kurtosis were calculated using Equation (30) and Equation (31) (Khazaei et al., 2008; Mirzabe et al., 2013a; Mirzabe et al., 2013b).

$$Skewness = \frac{n}{(n-1)(n-2)} \sum_{i=1}^{n} \left(\frac{x_i - x_{avg}}{STD} \right)^3 \qquad (30)$$

$$Kurtosis = \left\{ \frac{n(n-1)}{(n-1)(n-2)(n-3)} \sum_{i=1}^{n} \left(\frac{x_i - x_{avg}}{STD} \right)^4 \right\} - \frac{3(n-1)^2}{(n-2)(n-3)} \qquad (31)$$

Where: n is number of occurrence, STD is standard deviation, x_{avg} is mean seed size, x_i is midpoint of each class interval in metric.

Also in order to calculating the average of the repetitions of all gravimetrical properties and frictional properties, Microsoft Office Excel 2010 was used. Numbers of repetitions of the tests are shown in Table 2.

Table 2 Number of repetitions of the all tests including dimensions, dimensional properties, gravimetrical properties and frictional properties

Property	Measured or calculated parameter	Number of repetitions
Dimensions	Length	100
	Width	100
	Thickness	100
Dimensional properties	Diameters, Sphericity, Surface area, Volume, Projected area, Flakiness ratio, Elongation ratio	100
Gravimetrical properties	Mass of single seed	5
	thousand seed mass	5
	Bulk density	5
	True density	5
	porosity	5
Frictional properties	Coefficient of friction	5
	Pouring angle of repose	5
	Hele-Shaw angle of repose	5
	Filling and empting angle of repose	5

3. Results and discussion

3.1 Dimensional properties

Length, width, thickness and dimensional properties of the parsley seeds are shown in Table 3. The length, width, and thickness of the seeds ranged between (0.660 - 0.883), (0.524 - 0.752) and (0.490 - 0.744 mm), respectively. Average of the geometric mean diameter, arithmetic mean diameter and equivalent diameter of the seeds were 0.648, 0.652 and 0.608 mm, respectively (Table 3).

Table 3 Calculated statistical indices of three principle dimensions and dimensional parameters of parsley seeds

Parameter	Units	Max	Min	Mean	Standard Deviation	Skewness	Kurtosis
L	mm	0.883	0.660	0.740	0.048	0.904	0.822
W	mm	0.752	0.524	0.631	0.055	0.249	-0.865
T	mm	0.744	0.490	0.584	0.056	0.604	0.150
D_g	mm	0.755	0.572	0.648	0.043	0.448	-0.257
D_A	mm	0.760	0.575	0.652	0.043	0.457	-0.223
D_E	mm	0.676	0.560	0.608	0.026	0.489	-0.068
φ_1	%	92.436	83.448	87.547	2.457	0.324	-0.793
φ_2	%	99.585	98.080	98.859	0.414	0.012	-0.904
S_1	mm^2	1.790	1.029	1.324	0.176	0.597	-0.057
S_2	mm^2	1.600	0.927	1.200	0.165	0.492	-0.419
S_3	mm^2	1.808	1.038	1.337	0.177	0.601	-0.034
V_1	mm^3	0.225	0.098	0.144	0.029	0.747	0.196
V_2	mm^3	0.186	0.082	0.122	0.026	0.600	-0.349
A_{p1}	mm^2	0.500	0.271	0.368	0.053	0.707	-0.056
A_{p2}	mm^2	0.448	0.258	0.331	0.044	0.597	-0.057
A_{p3}	mm^2	0.395	0.229	0.297	0.041	0.471	-0.492
F_r	-	1.199	0.748	0.931	0.108	0.647	0.105
E_r	-	1.377	1.041	1.177	0.071	0.363	0.340

Average of the sphericity by Equation (5) and Equation (6); surface area by Equation (7), Equation (8) and Equation (9); volume by Equation (10) and Equation (11); projected area by Equation (12), Equation (13) and

Equation (14); flakiness ratio and elongation ratio were (87.547% and 98.859 %); (1.324, 1.200 and 1.337 mm^2); (0.144 and 0.122 mm^3); (0.368, 0.331 and 0.297 mm^2); 0.931 and 1.177, respectively.

Skewness and kurtosis are two statistical indices calculated so that the reader would better understand the probability density distribution data. The first usually noticed about a distribution's shape is whether it has one mode (peak) or more than one. If it's unimodal (has just one peak), like most data sets, the next thing noticed is whether it is symmetric or skewed to one side. If the bulk of the data is at the left and the right tail is longer, the distribution is skewed right or positively skewed; if the peak is toward the right and the left tail is longer, the distribution is skewed left or negatively skewed.

Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution, that is data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. A uniform distribution would be the extreme case. Results of statistical analysis of dimensional properties of the parsley seeds indicated that values of the skewness in all cases were positive and values of the kurtosis in most cases were negative.

3.2 Modeling of dimensional parameters

Length, width and thickness of the parsley seeds distributions were modeled using the tree-parameter Gamma, Generalized Extreme Value (G.E.V) and three-parameter Weibull probability density functions distribution; the results of modeling are shown in Table 4.Results showed that to model length and thickness of the seeds, G.E.V distribution had the best performance, while Weibull distribution had the worst performance. Also to model the width of the seeds, G.E.V distribution had the best performance, while Gamma distribution had the worst performance (Table 4).

Table 4 Calculated parameter values of the Gamma, Generalized Extreme Value (G.E.V) and Weibulldistribution of probability density function for length, width and thickness of parsley seeds

Parameter	Distribution name	Shape parameter	Scale parameter	Location parameter	Kolmogorov-Smirnov index	Rank
Length	Gamma	3.928	0.024	0.645	0.0378	2
	G. E. V	-0.013	0.038	0.718	0.0354	1
	Weibull	1.817	0.094	0.656	0.0459	3
Width	Gamma	17.381	0.013	0.403	0.1184	3
	G. E. V	-0.165	0.051	0.608	0.1135	1
	Weibull	2.501	0.141	0.506	0.1170	2
Thickness	Gamma	4.987	0.025	0.457	0.0980	2
	G. E. V	-0.092	0.049	0.560	0.0913	1
	Weibull	1.888	0.114	0.483	0.0985	3

Results of modeling showed that whenever skewness and kurtosis had positive values, Generalized Extreme Value distribution had good performance, while Weibull distribution had poor performance to model the data. Also whenever skewness had positive value and kurtosis a negative value, G.E.V distribution showed good performance, while Gamma distribution had poor performance to model data.

For an easy comparison between dimensions of parsley seeds together, probability density functions (PDFs) are shown in Figure 6. For all modeling in Figure 6, Generalized Extreme Value was used, because it had best prediction of probability density functions (PDFs) of length, width and thickness of seeds. For length and thickness of seeds, skewness and kurtosis have positive value and for width, skewness have positive value and kurtosis have negative value; which is shown in Figure 6. This figure shows that there is little overlap between the PDF of length and width, and even lesser overlap between the PDF of length and thickness. It means that the highest measured thickness of seeds is more than the lowest measured length. Also there is great overlap between the PDF of width and thickness; it means that the difference between measured thickness and width of seeds is very low; also in several cases thickness value of seeds is more than the width value of the seeds.

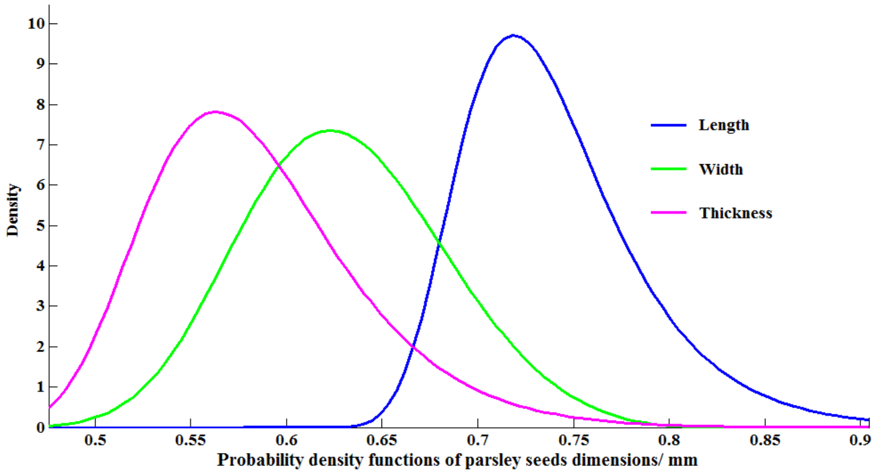

Figure 6 Probability density functions of length, width and thickness distribution of parsley seeds

Khazaei et al. (2008) modeled mass and size distributions of two varieties of sunflower seeds and kernels using the Log-normal, normal and Weibull distributions. They cited that when skewness had a positive value, Log-normal distribution was the best and normal distribution as the worst model for data prediction. Mirzabe et al. (2012) modeled distance between adjacent sunflower seeds on sunflower head of three varieties using the Log-normal, normal and Weibull distributions. They cited that whenever skewness and kurtosis had negative value, Weibull distribution was the best fit.

Because Generalized Extreme Value (G.E.V) distribution had good performance to model the length, width and thickness, this distribution was used to model thegeometric mean diameter, equivalent diameter, arithmetic mean diameter, sphericity, volume, surface area, projected area, flakiness ratio and elongation ratio of parsley seeds. The results of modeling of dimensional parameters using Generalized Extreme Value (G.E.V) distribution are shown in Table 5.

Table 5 Calculated parameter values of the Generalized Extreme Value (G. E. V) distribution of probability density function for dimensional parameters of parsley seeds

Parameter	Shape parameter	Scale parameter	Location parameter	Kolmogorov-Smirnov index
D_g	-0.128	0.039	0.630	0.0505
D_A	-0.126	0.039	0.633	0.0425
D_E	-0.124	0.023	0.597	0.0434
φ_1	-0.139	2.271	86.515	0.0810
φ_2	-0.271	0.418	98.708	0.0813
S_1	-0.078	0.153	1.247	0.0497
S_2	-0.094	0.146	1.128	0.0544
S_3	-0.078	0.154	1.259	0.0443
V_1	-0.003	0.024	0.131	0.0486
V_2	-0.049	0.022	0.111	0.0566
A_{p1}	0.014	0.042	0.344	0.0825
A_{p2}	-0.078	0.038	0.312	0.0497
A_{p3}	-0.097	0.038	0.279	0.0560
F_r	0.061	0.091	0.884	0.0614
E_r	-0.215	0.068	1.150	0.1053

To an easy comparison between diameters of parsley seeds together, probability density functions (PDFs) of geometric mean diameter, arithmetic mean diameter and equivalent diameter are shown in Figure 7. For all modeling, Generalized Extreme Value was used, because it had best prediction of probability density functions (PDFs) of length, width and thickness of seeds. This figure shows that there is great overlap between the PDF of geometric and arithmetic mean diameter. It means that the values of geometric and arithmetic mean diameter are near together; because the value of sphericity is very great.

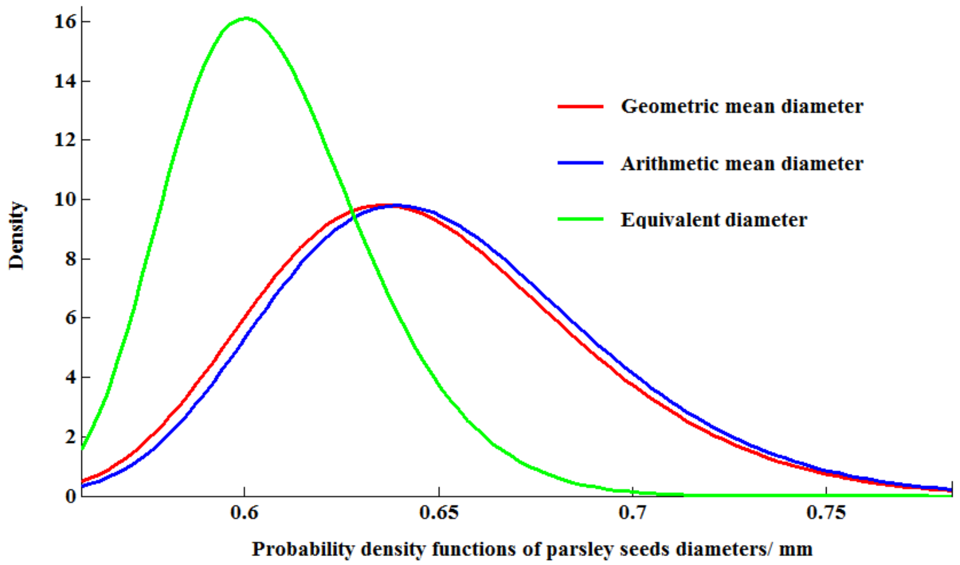

Figure 7 Probability density functions of diameters of parsley seeds

To an easy comparison between sphericity of parsley seeds by Equation (5) and Equation (6) together, and probability density functions (PDFs) of sphericitys are shown in Figure 8. This figure shows that there is no overlap between the PDF of sphericitys and in all cases sphericity value of seeds by Equation (6) was more than the value of Equation (5).

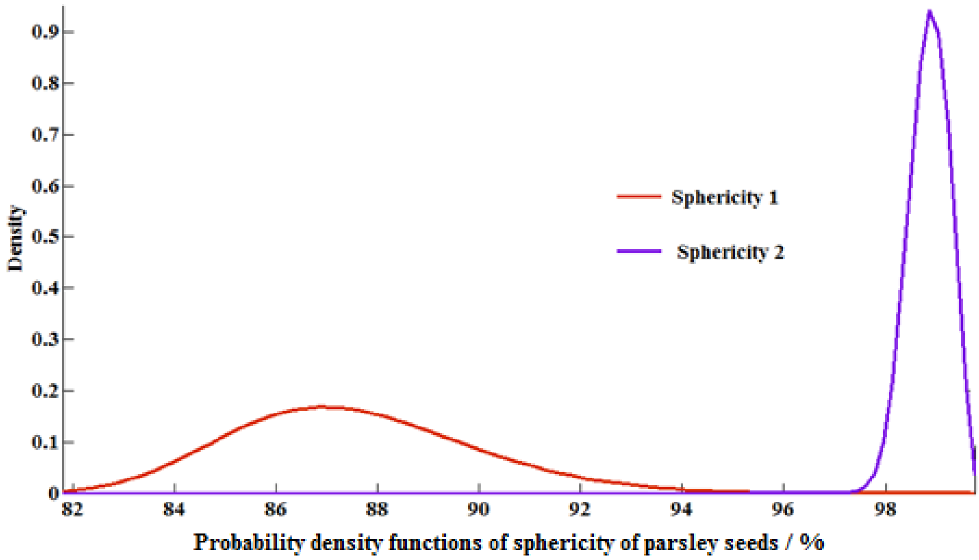

Figure 8 Probability density functions of sphericity of parsley seeds

To an easy comparison between surface areas of parsley seeds together, probability density functions (PDFs) of surface area of seeds by Equation (7), Equation (8) and Equation (9) are shown in Figure 9. This figure shows that there is great overlap between the PDF of surface area of the seeds by Equation (7) and Equation (9). Also in all cases value of surface area by Equation 8 was lower than the value of Equation (7) and Equation (9).

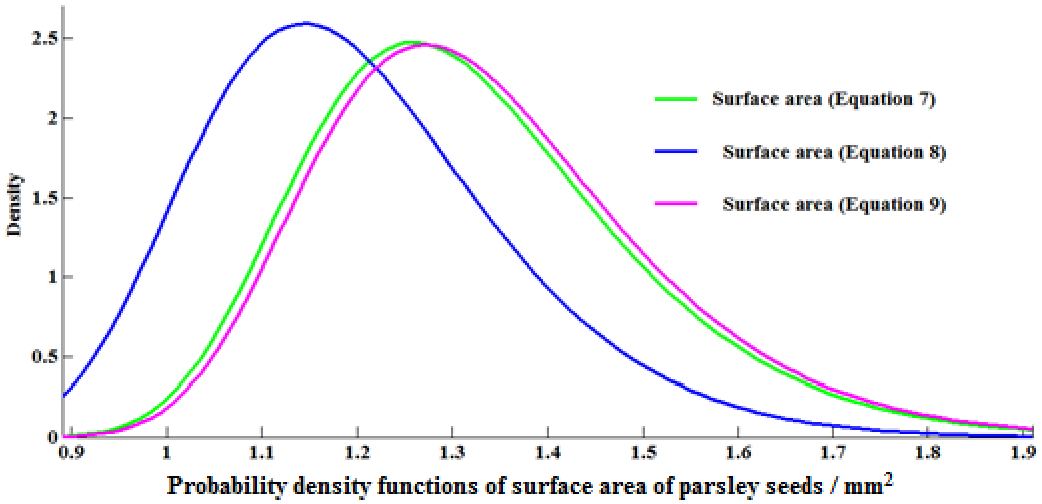

Figure 9 Probability density functions of surface area of parsley seeds based on Equation 7, Equation (8) and Equation (9)

Probability density functions of the seeds volume by Equation (10) and Equation (11) are shown in Figure 10. This figure shows that there is great overlap between the PDF of the seeds volume by Equation (10) and Equation (11) and in all cases value of seeds volume by Equation (11) was lower than the value of Equation (10).

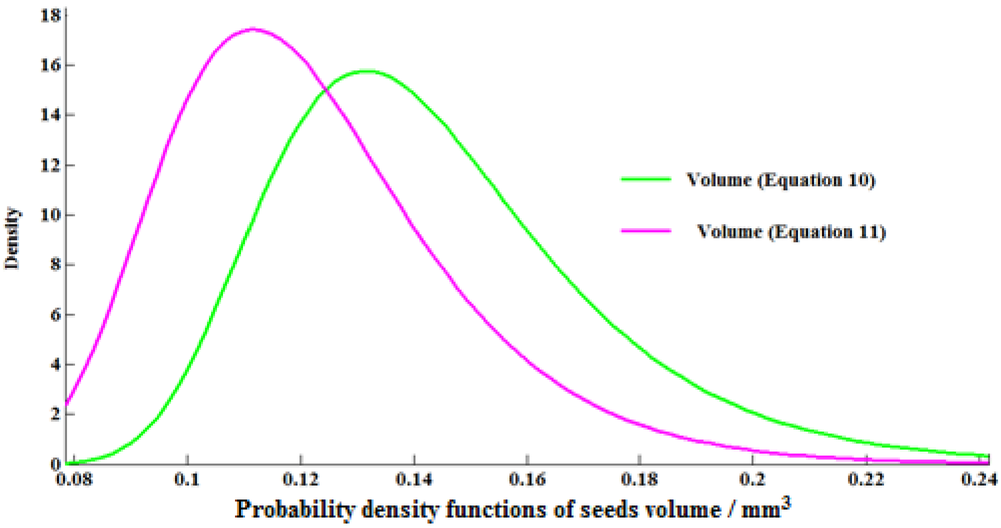

Figure 10 Probability density functions of seeds volume byEquation (10) and Equation (11)

Probability density functions of projected area of the parsley seeds by Equation (12), Equation (13) and Equation (14) are shown in Figure 11. This figure shows that there is great overlap between the PDF of projected area of the seeds by Equation (12) and Equation (14) and there is greater overlap between the PDF of projected area of the seeds by Equation (13) and Equation (14). In all cases value of projected area by Equation (12) was more than the value of surface area by Equation (13). Also in all cases value of projected area by Equation (13) was more than the value of Equation (14).

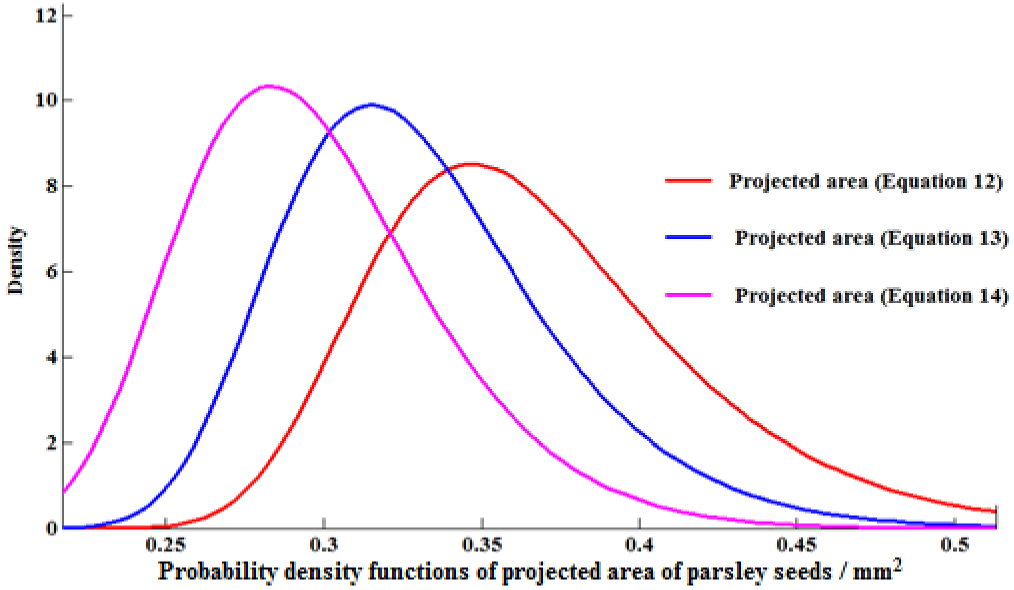

Figure 11 Probability density functions of projected area of parsley seeds by Equation (12), Equation (13) and Equation (14)

3.3 Gravimetrical properties

Average masses of the single seeds and thousand seed were 0.0014 and 1.3900 g. Also true density of the parsley seeds was found to be 884.658 kg/m^3. Results of bulk density of the seeds are illustrated in Figure 12. Results showed that by increasing container volume (from 150 to 550) and (from 550 to 750 mL), the value of bulk density of the seeds increased and decreased. In all cases by increasing fall height of the seeds to the container from 50 to 250 mm, value of bulk density of the seeds increased.

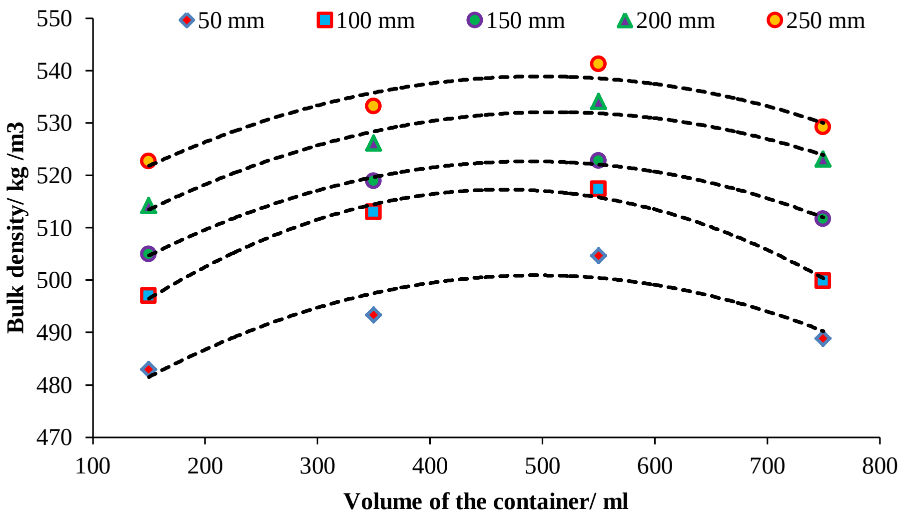

Figure 12 Effect of the container volume and fall height on bulk density of parsley seeds

Using the values of true and bulk densities in different fall height and container volume by Equation (26), the values of the parsley seeds porosity were calculated. Results of porosity of the seeds are illustrated in Figures 13. Results showed that by increasing container volume (from 150 to 550mL) and (from 550 to 750 mL), the value of bulk density of the seeds decreased and increased. In all cases by increasing fall height of the seeds to the container from 50 to 250 mm, the value of the seeds porosity decreased.

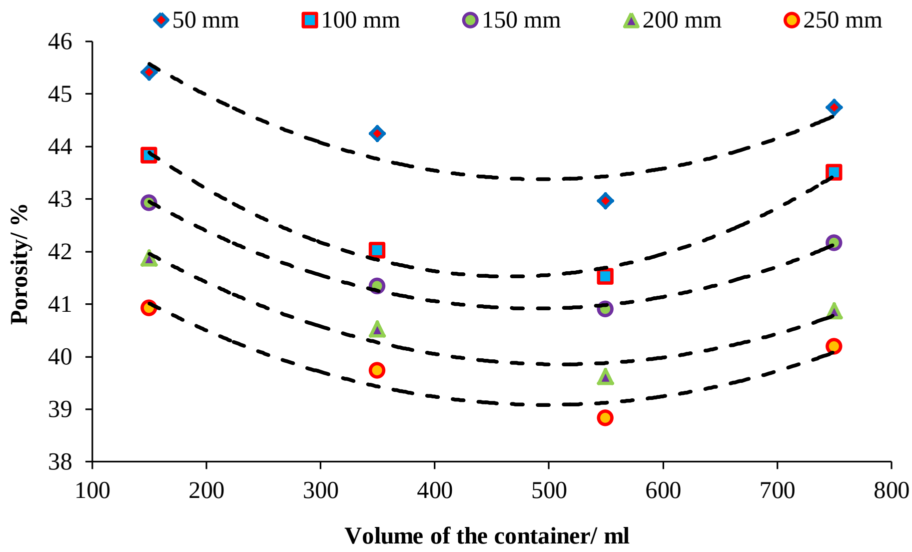

Figure 13Effect of the container volume and fall height on porosity of parsley seeds

The results of bulk density in different level of container volume and fall height of seeds to the container, indicated that bulk density value of parsley seeds ranged from 482.927 kg/m^3 (when container volume, 150 mL and fall height, 50 mm) to 541.167kg/m^3 (when container volume, 550 mL and fall height, 250 mm). The corresponding values for porosity were ranged from 38.83% (when container volume, 550 mL and fall height, 250 mm) to 45.41% (when volume container volume, 150 mL and fall height, 50 mm.

Results of quadratic regression analysis density and porosity of parsley seeds related to container volume, in different levels of fall height of seeds to the containers are shown in Table 6. Results showed that in most cases r-square value was more than 0.90; its means that the quadratic regression have good performance to model the relationship between container volume and both of the bulk density and porosity of seeds.

Table 6 Constant coefficient of quadratic regression of bulk density and porosity of parsley seeds related to container volume

Parameter	Height of fall	$y = \alpha (x)^2 + \beta (x) + \gamma$			
		α	β	γ	R^2*(r-square)*
Bulk density (Kg/m^3)	50 mm	-0.0002	0.1616	460.9600	0.8442
	100 mm	-0.0002	0.1949	471.9100	0.9820
	150 mm	-0.0002	0.1534	485.2100	0.9938
	200 mm	-0.0001	0.1463	494.7300	0.9439
	250 mm	-0.0001	0.1401	503.9500	0.9138
Porosity (%)	50 mm	0.00002	-0.0183	47.8940	0.8442
	100 mm	0.00002	-0.0220	46.6560	0.9820
	150 mm	0.00002	-0.0173	45.1520	0.9938
	200 mm	0.00002	-0.0165	44.0770	0.9439
	250 mm	0.00002	-0.0158	43.0340	0.9138

Note: y is bulk density or porosity and x is volume of the container

3.4 Frictional properties

The static coefficient of friction of parsley seeds on four surfaces (galvanized iron, plywood and rubber plate) in 6.12% (d.b.) moisture content was measured. The friction angles on galvanized iron, plywood and rubber surface were 14.77^o, 19.31^o, 24.17^o and 27.35^o, respectively (Table 7). The maximum and minimum friction is offered by rubber and galvanized surface. The least static coefficient of friction may be owing to the smoother and more polished surface of the galvanized sheet than the other materials used. Wood also offered the maximum friction for tef seed (Zewdu and Solomon, 2007), jatrofa fruit (Pradhan et al., 2009) and for almond(Mirzabe et al., 2013b), but the galvanized iron had higher coefficient of friction than plywood for Roselle seeds (Sánchez-Mendoza et al., 2008) and lentil seeds(Amin et al., 2004).

Table 7 Repose and friction angles using different of methods and surface materials.

Material surface	Angle of repose/ Degree				Friction	
	Filling method	**Empting method**	**Hele-Shaw method**	**Pouring method**	**Angle of friction**	**Coefficient of friction**
Galvanized	32.64	40.16	30.51	31.04	14.77	0.249
Iron steel			31.05	32.68	19.31	0.344
Plywood			32.53	35.26	24.17	0.445
Rubber			33.61	37.42	27.35	0.509

The repose angle is an indicator of the product's flow ability. The results for the repose angle are shown in Table 7. The values of filling and empting repose angles of parsley seeds were32.64and 40.16 °. Different behavior for emptying and filling repose angle have been reported for agricultural materials, the repose angle was obtained from emptying method was greater than filling method for wild pistachio (Fadavi et al., 2013), but the reverse results were shown for jatropha (Sirisomboon et al., 2007).

The repose angles of parsley seeds using pouring and The Hele-Shaw methods were (31.04^o, 32.68^o, 35.26^o and 37.42^o), and (30.51^o, 31.05^o, 32.53^o and 33.61^o) for galvanized iron, plywood and rubber surface, respectively (Table 7). The maximum and minimum values of repose angles using pouring and The Hele-Shaw methods are offered by plywood and galvanized surfaces.

The least repose angle may be owing to the smoother and more polished surface of the galvanized sheet than the other materials used.

A comparison between different methods were used to measure angle of repose of parsley seeds, results showed that the maximum and minimum values of repose angles of seeds were obtained by the empting and Hele-Shaw methods.

4. Conclusions

Three principle dimensions, geometric mean diameter, equivalent diameter, arithmetic mean diameter, sphericity, volume, surface area, projected area, flakiness ratio and elongation ratio of parsley seeds were measured using image processing technique. Also mass of single seed, thousand seed mass, bulk density, true density and porosity were measured and effect of volume of the container (150, 350, 550 and 750 mL) and height of fall on bulk density and porosity were studied. Static coefficient of external friction on galvanized iron, plywood and rubber surface was measured. Also pouring angle of repose Hele-Shaw angle of repose on galvanized iron, plywood and rubber surface were measured. Empting and filling angle of repose were measured. Finally, length, width, thickness and mass distributions of parsley seeds were modeled using Gamma, Generalized Extreme Value and Weibull distributions.

Results showed that: 1) By increasing container volume (from 150 to 550 mL) and (from 550 to 750 mL), the bulk density of the seeds were increased and decreased., 2) In all cases with increasing fall height of the seeds to the container from 50 to 250 mm, the value of the porosity of the seeds decreased., 3) The results of bulk density in different level container volume and fall height of seeds to the container was ranged from 482.927 kg/m^3 (when container volume, 150 mL and fall height, 50 mm) to 541.167 kg/m^3 (when container volume, 550 mL and fall height, 250 mm)., 4) The corresponding values for porosity were ranged from38.83% (when container volume, 550 mL and fall height 250 mm) to 45.41% (when container volume, 150 mL and fall height, 50 mm., 5) A comparison between different methods to measure repose angle of parsley seeds, the maximum and minimum values of repose angle were using empting and Hele-Shaw method and., and 6) Modeling results showed that in all cases, Generalized Extreme Value had the best performance.

Acknowledgement

The authors would like to thank the University of Tehran for providing technical support for this work. We would also like to sincerely thank Mr. Javad Yousefi and Mr. Abdolzahra Neisi for their technical help and supervision while writing the paper. The authors would also like to thank Mr. Mohammad Hassan Torabi for their support in editing the language of the paper.

References

Al-Howiriny, T., M. Al-Sohaibani, K. El-Tahir, and S. Rafatullah. 2003. Prevention of experimentally-induced gastric ulcers in rats by an ethanolic extract of" Parsley" Petroselinum crispum. *The American journal of Chinese medicine*. 31(5): 699-711.

Altuntaş, E., E. Özgöz, and Ö. F. Taşer. 2005. Some physical properties of fenugreek (Trigonellafoenum-graceum L.) seeds. *Journal of Food Engineering*. 71(1): 37-43.

Amin, M. N., M. A. Hossain, and K. C. Roy. 2004. Effects of moisture content on some physical properties of lentil seeds. *Journal of Food Engineering*. 65(1), 83-87.

Aviara, N. A., P. P. Power, and T. Abbas. 2013. Moisture-dependent physical properties of Moringaoleifera seed relevant in bulk handling and mechanical processing. *Industrial Crops and Products*. 42(1):96-104.

Chaudhary, S. K. Ceska, C. Tetu, D. J. Warrington, MJ Ashwood-Smith, and G. A. Poulton. 1986. Oxypeucedanin, a major furocoumarin in parsley, Petroselinum crispum. *Planta Med*.462-464.

Díaz-Maroto, M., M. Pérez-Coello, and M. Cabezudo. 2002. Effect of different drying methods on the volatile components of parsley (Petroselinum crispum L.). *European Food Research and Technology*. 215(3): 227-230.

Ersoy, O. 2010.Surface area and volume measurements of volcanic ash particles by SEM stereoscopic imaging. *Journal of Volcanology and Geothermal Research*. 190(3): 290-296.

Fadavi, A., S. R. Hassan-Beygi, and F. Karimi. 2013.Moisture dependent physical and mechanical properties of Syrjan region wild pistachio nut. *Agricultural Engineering International: CIGR Journal*. 15(2): 221-230.

Garnayak, D. K., R. C. Pradhan, S. N. Naik, and N. Bhatnagar. 2008. Moisture-dependent physical properties of jatropha seed (Jatropha curcas L.). *Industrial crops and products*, 27(1): 123-129.

Gorgoso, J. J., J. G. Álvarez González, A. Rojo, and J. A. Grandas-Arias. 2008. Modelling diameter distributions of Betulaalba L. stands in northwest Spain with the two-parameter Weibull function. *Forest Systems*. 16(2): 113-123.

Grieve, M., and A. M. Herbal. 1979. Dover Publications Inc. *New York*.

Gupta, R. K., and S. K. Das. 1997. Physical properties of sunflower seeds.*Journal of Agricultural Engineering Research*. 66(1): 1-8.

Gupta, R. K., and S. K. Das. 2000. Fracture resistance of sunflower seed and kernel to compressive loading. *Journal of Food Engineering*. 46(1): 1-8.

Heidarbeigi, K., H. Ahmadi, K. Kheiralipour, and A. Tabatabaeefar. 2009. Some physical and mechanical properties of khinjuk. *Pakistan Journal of Nutrition*.8(1): 74-77.

Kabas, O., E. Yilmaz, A. Ozmerzi, and İ. Akinci. 2007. Some physical and nutritional properties of cowpea seed (Vignasinensis L.). *Journal of food engineering*.79(4): 1405-1409.

Khazaei, J., S. Jafari, and S. Noorolah. 2008. Lognormal vs. Normal and Weibull distributions for modeling the mass and size distributions of sunflower seeds and kernels.In *World conference on agricultural information and IT*.

Koc, A. B. 2007. Determination of watermelon volume using ellipsoid approximation and image processing. *Postharvest Biology and Technology*.45(3): 366-371

Koocheki, A., S. M. A. Razavi, E. Milani, T. M. Moghadam, M. Abedini, S. Alamatiyan, and S. Izadkhah. 2007. Physical properties of watermelon seed as a function of moisture content and variety. *International Agrophysics*. 21(4): 349.

Kreydiyyeh, S. I., and J. Usta. 2002. Diuretic effect and mechanism of action of parsley. *Journal of ethnopharmacology*. 79(3): 353-357.

Kreydiyyeh, S. I., J. Usta, I. Kaouk, and R. Al-Sadi. 2001. The mechanism underlying the laxative properties of parsley extract. *Phytomedicine*. 8(5): 382-388.

McGahon, K. Mary, M. Jennine, Dawicki, Aruna Arora, David A. Simpson, Tom A. Gardiner, A. W. Stitt, C. Norman Scholfield, J. Graham McGeown, and Tim M. Curtis. 2007. "Kv1. 5 is a major component underlying the A-type potassium current in retinal arteriolar smooth muscle." *American Journal of Physiology-Heart and Circulatory Physiology*.292(2):1001-1008.

Milani, E., M. Seyed, A. Razavi, A. Koocheki, V. Nikzadeh, N. Vahedi, M. MoeinFard, and A. GholamhosseinPour. 2007. Moisture dependent physical properties of cucurbit seeds. *International Agrophysics*. 21(2): 157.

Mirzabe, A. H., J. Khazaei, and G. R. Chegini. 2012. Physical properties and modeling for sunflower seeds. *Agricultural Engineering International: CIGR Journal*. 14(3): 190-202.

Mirzabe, A. H., J. Khazaei, G. R. Chegini, and O. Gholami. 2013. Some physical properties of almond nut and kernel and modeling dimensional properties. *Agricultural Engineering International: CIGR Journal*. 15(2):256-265.

Mohhamadi, V., B. Abbaspour, S. D. Sharifi, and A. H. Mirzabe, 2014. Gravimetrical and frictional properties of broilers diets.*Agricultural Engineering International: CIGR Journal*, 16(2):167-175

Mora, C. F., and A. K. H. Kwan. 2000.Sphericity, shape factor, and convexity measurement of coarse aggregate for concrete using digital image processing.*Cement and concrete research*. 30(3): 351-358.

Nanang, D. M. 1998. Suitability of the Normal, Log-normal and Weibull distributions for fitting diameter distributions of neem plantations in Northern Ghana. *Forest Ecology and Management*. 103(1): 1-7.

Özarslan, C. 2002. PH—postharvest technology: physical properties of cotton seed. *Biosystems Engineering*. 83(2): 169-174.

Perez, E. E., G. H. Crapiste, and A. A. Carelli. 2007.Some physical and morphological properties of wild sunflower seeds.*Biosystems engineering*.96(1): 41-45.

Pino, J. A., A. Rosado, and V. Fuentes. 1997. Herb oil of parsley (Petroselinum crispum Mill.) from Cuba. *Journal of Essential Oil Research*. 9(2): 241-242.

Pradhan, R. C., S. N. Naik, N. Bhatnagar, and Vijay, V. K. 2009. Moisture-dependent physical properties of jatropha fruit. *Industrial Crops and Products*.29(2): 341-347.

Sánchez-Mendoza, J., A. Domínguez-López, S. Navarro-Galindo, and J. A. López-Sandoval. 2008. Some physical properties of Roselle (Hibiscus sabdariffa L.) seeds as a function of moisture content. *Journal of food engineering*. 87(3): 391-397.

Sharma, V., L. Das, R. C. Pradhan, S. N. Naik, N. Bhatnagar, and R. S. Kureel. 2011. Physical properties of tung seed: An industrial oil yielding crop. *Industrial Crops and Products*. 33(2): 440-444.

Sirisomboon, P., P. Kitchaiya, T. Pholpho, and W. Mahuttanyavanitch. 2007. Physical and mechanical properties of Jatropha curcas L. fruits, nuts and kernels. *Biosystems Engineering*. 97(2): 201-207.

Sologubik, C. A., L. A. Campañone, A. M. Pagano, and M. C. Gely. 2013. Effect of moisture content on some physical properties of barley. *Industrial Crops and Products*. 43, 762-767.

Spraul, M. H., S. Nitz, F. Drawert, H. Duddeck, and M. Hiegemannt. 1992. Crispane and crispanone, two compounds from Petroselinum crispum with a new carbon skeleton. *Phytochemistry*. 31(9): 3109-3111.

Stuart, M. 1979.*The Encyclopedia of Herbs and Herbalism.*Orbis Publishing Ltd., London, p. 283.

Tabarsa, T., S. Jahanshahi, and A. Ashori. 2011. Mechanical and physical properties of wheat straw boards bonded with a tannin modified phenol–formaldehyde adhesive. *Composites Part B: Engineering*. 42(2): 176-180.

Varnamkhasti, M. G., H. Mobli, A. Jafari, A. R. Keyhani, M. H. Soltanabadi, S. Rafiee, and Kheiralipour, K. 2008. Some physical properties of rough rice (Oryza Sativa L.) grain. *Journal of Cereal Science*. 47(3): 496-501.

Xu, D., J. Cui, R. Bansal, X. Hao, J. Liu, W. Chen, and B. S. Peterson. 2009. The ellipsoidal area ratio: an alternative anisotropy index for diffusion tensor imaging. Magnetic resonance imaging. 27(3): 311-323.

Zewdu, A. D., and W. K. Solomon. 2007. Moisture-dependent physical properties of tef seed. *Biosystems engineering*. 96(1): 57-63.