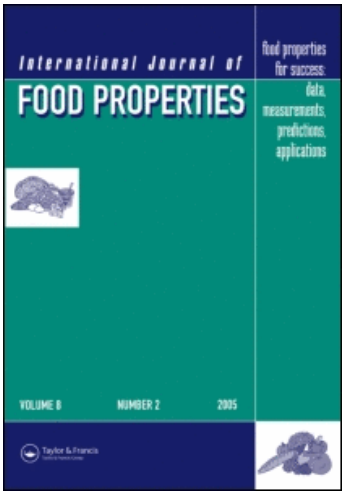
This article was downloaded by: *[Razavi, Seyed M.A.]*
On: *4 March 2010*
Access details: *Access Details: [subscription number 919650765]*
Publisher *Taylor & Francis*
Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



International Journal of Food Properties
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597259

Computer Image Analysis and Physico-Mechanical Properties of Wild Sage Seed (*Salvia macrosiphon*)

Seyed M. A. Razavi [a]; A. Bostan [a]; R. Rahbari [a]
[a] Department of Food Science and Technology, Ferdowsi University of Mashhad (FUM), Khorasan, Iran

Online publication date: 03 March 2010

To cite this Article Razavi, Seyed M. A., Bostan, A. and Rahbari, R.(2010) 'Computer Image Analysis and Physico-Mechanical Properties of Wild Sage Seed (*Salvia macrosiphon*)', International Journal of Food Properties, 13: 2, 308 — 316
To link to this Article: DOI: 10.1080/10942910802398453
URL: http://dx.doi.org/10.1080/10942910802398453

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.informaworld.com/terms-and-conditions-of-access.pdf

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

International Journal of Food Properties, 13: 308–316, 2010
Copyright © Taylor & Francis Group, LLC
ISSN: 1094-2912 print / 1532-2386 online
DOI: 10.1080/10942910802398453

Downloaded By: [Razavi, Seyed M.A.] At: 10:39 4 March 2010

COMPUTER IMAGE ANALYSIS AND PHYSICO-MECHANICAL PROPERTIES OF WILD SAGE SEED (*Salvia macrosiphon*)

Seyed M.A. Razavi, A. Bostan, and R. Rahbari

Department of Food Science and Technology, Ferdowsi University of Mashhad (FUM), Khorasan, Iran

A computer vision system was developed to evaluate the geometrical properties of small seeds and the results compared to the measurements obtained by a micrometer. The correlation found between the results of two methods for principal dimensions of wild sage seed with R^2 values ranged between 0.64-0.99. Some physical properties were investigated including projected area, sphericity, roundness, surface area, unit mass, 1000 grain mass, volume, true density, bulk density and porosity. While the mechanical properties evaluated were static coefficient of friction, filling and funning angles of repose, terminal velocity and textural properties including rupture force, hardness and energy absorbed.

Keywords: ***Image processing, Physical properties, Textural properties,*** Salvia macrosiphon***.***

INTRODUCTION

Wild sage seed is a small, rounded, and mucilaginous seed, which comes from *Salvia macrosiphon*. The genus Salvia (*Labiatae*) contains more than 700 species, which about 200 out of them exist in Iran. Plants belonging to this genus are pharmacologically active and have been used in folk medicine all around the world, but very few formal studies have looked at this little seed, only the composition of essential oil of this species has been reported by Matloubi-Moghaddam et al.[1] Sage seeds become gelatinous when soaked in water due to its high mucilage content. As a part of our continuing research about the Iranian high mucilaginous seeds, which can be used as novel source of food hydrocolloid, investigating the physico-mechanical properties of wild sage seed is quite necessary.[2]

Measuring the dimensions of small seeds, which is necessary in quality control and design of postharvest processing equipments, is difficult and time consuming and so many seeds become lost or damaged because of small size of the seeds during size inspection. These reasons confirm the requirement for an automated, rapid, and non destructive measurement technique. In recent years, computer vision system (CVS) has been increasingly used in agricultural and food industry. CVS generally consists of five major components:

Received 18 March 2008; accepted 9 August 2008.
Address correspondence to Seyed M.A. Razavi, Department of Food Science and Technology, Ferdowsi University of Mashhad (FUM), Khorasan, P.O. Box 91775-1163, Iran. E-mail: s.razavi@um.ac.ir

light source, an image-capturing device, an image capture board (frame grabber or digitizer) and computer hardware and software. By using this system, it is possible to receive standard pictures from samples and bring out some important and necessary data. Some examples of CVS application in food industry are: classification of cereal grains, evaluation of pork color, measurement and classification of corn whiteness, automated sorting of pistachio nuts, quality inspection of bakery products, inspection of Golden Delicious apples, detection of pinhole damage in almonds, detection of bones in fish and chicken and seed size determination.[3–6]

Basic physical properties of seeds are required in order to design the machines for handling, harvesting, transporting, cleaning, separating, packing, and processing. The designs would be inadequate without taking into consideration proper physical properties of seeds. Some studies have been published about the physical and mechanical properties of grains and seeds such as cumin,[7], millet,[8] hemp,[9] amaranth seed,[10] vetch seed,[11] sesame,[12] rapeseed,[13] fenugreek,[14] caper,[15] dried pomegranate seeds,[16] sorghum,[17] flaxseed,[18] and basil seed.[6] Survey of the literature shows there is no information on the physic-mechanical properties of sage seeds. Therefore, the objectives of this study were: (i) to develop a CVS system for evaluation the geometrical properties of sage seeds; (ii) to determine experimentally the physical and mechanical properties of sage seeds; and (iii) to compare two methods used for measuring the geometrical properties of this seed.

Downloaded By: [Razavi, Seyed M.A.] At: 10:39 4 March 2010

MATERIAL AND METHODS

Sample Preparation

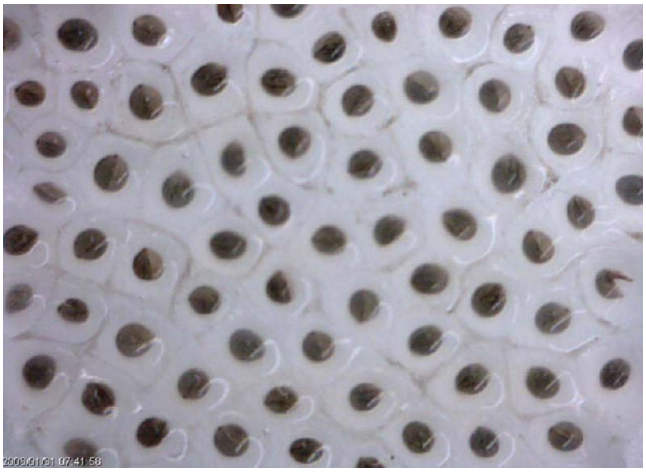
The sage seeds used in this study were obtained from a local market in Mashhad, Iran (Fig. 1). The seeds were cleaned manually to remove all foreign matter such as dust, dirt, stones and chaff. The moisture content of the seed was determined by the vacuum oven method (temperature 70°C and pressure 250 mbar) until a constant mass was obtained.[7] The measurement was replicated three times. The natural moisture content of the seed was 5.13% (w.b). According to the mucilaginous nature of the seed, adding water and adjusting different moisture content levels was impossible and the low moisture content of the seed make the additional drying difficult, therefore all physico-mechanical properties of the seed investigated at its natural moisture content in which the seeds were stored and processed.

Image Processing

A Computer Vision System (CVS) was developed for determining some geometrical properties of wild sage seeds. The system consists of a digital camera (Canon A550, Kuala Lampur, Malaysia), an image-capturing box and image analysis software (Clemex Vision Professional, PE4, Longueuil Canada). A sample holder was placed at the bottom of the box and it was covered with white translucent material. Two fluorescent lamps (Farhad lightening 10W, 0.09A, Mashhad, Iran) were placed behind the sample holder to eliminate the shadows and the camera was located 15 cm above it to capture standard image from samples with as good resolution as possible.[19]

Before image processing, one of the most important steps is calibration. A correct calibration is required to obtain an accurate measurement. To perform a calibration, an

(a)



(b)

Figure 1 The pictorial view of (a) the Wild sage seeds (Magnification=55×); and (b) the seeds soaked in water.

image was taken of a caliper in the exact same orientation as sample images were taken. The loaded image of the caliper was adjusted in the software program to the minimum distance seen on the caliper and then introduced the width of the selected distance. The software determined the width of each pixel at various magnifications. After calibration and the sample's image loaded, picture modification was required and consisted of the following three steps:

1. Delineation; the delineation filter used to remove intermediate gray levels to increase contrast and it was selected from gray operation section of the software toolbox.

Downloaded By: [Razavi, Seyed M.A.] At: 10:39 4 March 2010

2. Thresholding; the gray threshold function used to define the seed on the background and it was selected from the gray transformation section of the software toolbox.
3. Chord size; chord size is used for eliminating small and unwanted objects from picture and it was selected from binary operation section of the software toolbox.

The software offered the possibility of extracting the values of some geometrical properties such as principal dimensions, projected area which is the sum of the pixel in an object within a selected bitplane, sphericity and roundness which are calculated according to Eqs. (1) and (2), respectively.[20]

$$\text{Sphericity} = \frac{4\pi A}{\text{p}^2} \tag{1}$$

$$\text{Roundness} = \frac{4 \times Area}{\pi \times L^2} \tag{2}$$

In this research, the physical properties of wild sage seeds, such as length, width, thickness, projected area, sphericity and roundness were extracted by the image processing software,[6] and the results of the image analysis were compared to the data was obtained by experimental method, then the regression relationship and correlation between them (in terms of coefficient of determination, R^2) determined using SlideWrite statistical software (version 2.0). For both CVS and experimental measurements, 50 seeds randomly were selected.

Downloaded By: [Razavi, Seyed M.A.] At: 10:39 4 March 2010

Physico-Mechanical Properties Measurement

The principle dimensions of wild sage seed namely, length (L), width (W) and thickness (T) were measured using a digital micrometer (model QLR digit-IP54, Qinghai, China) with an accuracy of 0.001 mm. According to Mohsenin,[21] the geometric mean diameter (D_g), arithmetic mean diameter (D_a), and sphericity (Φ) values determined using both experimental and CVS's data, as follows:

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

$$D_a = \frac{L + W + T}{3}, \tag{4}$$

and

$$\phi = \frac{(LWT)^{1/3}}{L}. \tag{5}$$

The surface area was calculated using the following relationship[21]:

$$S = \pi D_g^2. \tag{6}$$

To obtain the unit mass, each sample was weighed by an analytical balance (AS120, OHAUS Corporation, NJ07058, USA) reading to an accuracy of 0.0001 g. Thousand seed mass was determined by counting 1000 seeds by seed counter (Numigral, Iticator, Stockholm, Sweden) and weighing them in an electronic balance of 0.01g sensitivity. The pycnometric method described by Mohsenin[21] was used to determine the volume and true density of seeds. Toluene was used instead of water because wild sage seeds absorb water rapidly and toluene has the advantages of little tendency to soak into seed, a low surface tension thus enabling it to flow smoothly over the seed surface, little solvent action on constituents of the seed especially fats and oils, a fairly high boiling point, not changing its specific gravity and viscosity materially on exposure to the atmosphere, and a low specific gravity. The true volume and true density of seed were determined using the following equations[20]:

$$V = \frac{M_{td}}{\rho_{tol.}} = \frac{(M_{pt} - M_p) - (M_{pts} - M_{ps})}{\rho_{tol.}}, \tag{7}$$

and

$$\rho_t = \frac{M_{ps} - M_p}{V}, \tag{8}$$

where, V is the seeds volume (m^3), M_{td} is the mass of displaced toluene (kg), ρ_{tol} is the toluene density (kgm^{-3}), M_{pt} is the mass of pycnometer and toluene (kg), M_p is the mass of empty pycnometer (kg), M_{pts} is the mass of pycnometer filled with toluene and sample (kg), M_{ps} is the mass of pycnometer and seeds (kg), and ρ_t is the true seed density in (kgm^{-3}).

The bulk density (ρ_b, kg/m^3) was determined by filling a container with a known volume from a height of 150 mm at a constant rate and then weighing the contents. No separate compaction of seed was done. The bulk density was calculated by dividing the mass of the seeds obtained by the volume of the container.[10,16] The porosity of seed was calculated from bulk and true densities using the relationship given by Mohsenin[20] as follows:

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100. \tag{9}$$

The static coefficient of friction of seeds was measured for five frictional surfaces, namely glass, fiberglass, rubber, plywood, and galvanized iron sheets. A fiberglass topless and bottomless box of 0.15-m length, 0.10-m width, and 0.04-m height was placed on an adjustable inclined plane, faced with the test surface and filled with the sample. The box was raised slightly (2 mm), so as not to touch the surface. The structural surface with the box resting on it was inclined gradually using a screw device until the box just started to slide down over the surface and the angle of tilt (α) was read from a graduated scale. The static coefficient of friction (μ_s) was then calculated by the following equation[20]:

$$\mu_s = \tan\alpha. \tag{10}$$

Downloaded By: [Razavi, Seyed M.A.] At: 10:39 4 March 2010

The filling or static angle of repose is the angle with the horizontal at which the seeds will stand when piled. This was determined using a topless and bottomless cylinder of 0.15 m diameter and 0.25 m height. The cylinder was placed at the centre of a raised circular plate having a diameter of 0.35 m and was filled with wild sage seeds. The cylinder was raised slowly until it formed a cone on a circular plane. The height of the cone was measured and the filling angle of repose (θ_f) was calculated by the following relationship[12]:

$$\theta_f = \tan^{-1}\left(\frac{2H}{D}\right), \tag{11}$$

where, H and D are the height and diameter of the cone, respectively. In order to determine the emptying or dynamic angle of repose, a plywood box of 0.2 m × 0.2 m× 0.2 m, having a removable front panel was used. The box was filled with the seed from 150 mm height, and then the front panel quickly slid upwards allowing the samples to flow to their natural slope. The emptying angle of repose (θ_e) was obtained from measurements of height of samples at two points (h1 and h2) in the sloping wild sage heap and the horizontal distance between these points (x1 and x2) using the following equation (9):

$$\theta_e = \tan^{-1}\left(\frac{h_2 - h_1}{x_2 - x_1}\right). \tag{12}$$

The terminal velocity of seeds was measured using an air column device. Samples were dropped into an air stream from the top of the air column, and then airflow rate was gradually increased until the seed became suspended in the air stream. The air velocity which kept the seeds in suspension was measured using a digital anemometer having a least count of 0.1 m/s.[7]

The mechanical properties of wild sage seed was measured using a texture analyzer (QTS Texture analyzer, CNS Farnell, Essex, UK) with a TA41 (6 mm, platen) probe. The operational conditions of texture analyzer were compression test, 0.5 mm target value, one cycle and 6 mm/min test speed. According to the operational manual of Texture Analyzer used, peak force of the compression cycle was taken as hardness (g), work done (energy) required to obtain a given deformation to a target value was taken as energy absorbed (g.mm), and the first significant break in the compression cycle was reported as rupture force (g).

RESULT AND DISCUSSION

The mean value and standard deviation of all physico-mechanical properties of wild sage seed measured experimentally and by using CVS is summarized in Table 1. According to the CVS datas It can be found that the length of wild sage seed ranged from 2.203 to 3.023 mm with the mean value as 2.650 mm, the width ranged from 1.641 to 2.437 mm with the mean value as 2.052 mm and the thickness ranged from 1.235 to 1.771 mm with the mean value as 1.521 mm, while the range of length, width and thickness measured by micrometer were between 2.185 to 3.020 mm the mean value as 2.649 mm, 1.045 to 2.437 mm the mean value as 2.032 mm, and 1.240 to 1.774 mm the mean value as 1.519 mm, respectively. The correlation between CVS and experimental results for length, width and thickness were 0.99, 0.64, and 0.99, respectively (Table 2). These results showed that there is

Downloaded By: [Razavi, Seyed M.A.] At: 10:39 4 March 2010

Table 1 Some physico-mechanical properties of wild sage seed at a moisture content of 5.13 ± 0.002 (w.b.%).

Physical properties	No. of observations	Experimental method		CVS method	
		mean	Standard deviation	mean	Standard deviation
Length, mm	50	2.649	0.164	2.650	0.163
Width, mm	50	2.032	0.234	2.052	0.186
Thickness, mm	50	1.519	0.139	1.521	0.138
Surface area, mm^2	50	12.723	2.08	12.827	1.952
Projected area, mm^2	50	–	–	4.039	0.517
Geometric mean diameter, mm	50	2.006	0.169	2.015	0.157
Arithmetic mean diameter, mm	50	2.060	0.164	2.067	0.155
Sphericity	50	0.76	0.03	1.0	0.0
Roundness	50	–	–	0.731	0.061
Unit mass, g	10	0.00274	0.0005	–	–
Mass of 1000 seed, g	5	2.766	0.015	–	–
Volume, mm^3	5	2.84	0.04	–	–
True density, kg m^{-3}	5	970	3	–	
Bulk density, kg m^{-3}	7	907	20.5	–	–
Porosity, %	5	7.01	2.08	–	–
Filling angle of repose (°)	5	17.3	1.7	–	–
Emptying angle of repose (°)	5	19.3	1.1	–	–
Static coefficient of friction on					
Glass	5	0.262	0.01	–	–
Fiber glass	5	0.324	0.01	–	–
Galvanized iron	5	0.276	0.005		-
Rubber	5	0.382	0.05	–	–
Plywood	5	0.382	0.05	–	–
Terminal velocity, ms^{-1}	20	4.2	0.39	–	–
Hardness, g	15	1650	196	–	–
Rupture force, g	15	1611	196	–	–
Energy absorbed, g.s	15	7147	849	–	–

Table 2 The relationship between CVS (x, mm) and experimental (y, mm) data determined for principal dimensions of wild sage seed.

Dimension	Regression equation	R^2
Length	Y = 0.006736 + 0.997118x	0.99
Width	Y = 0.034736 + 1.007025x	0.65
Thickness	Y = –0.002268 + 1.000715x	0.99

an excellent potential to use computer vision system for measuring small seed dimensions, although the correlation between CVS and micrometer results were lower than those reported for basil seed.[6] It may be because of the round and more sphere shape of wild sage seed that make the right identification of dimension by micrometer difficult.

The projected area, sphericity, and roundness of wild sage seed ranged from 2.742–4.957 mm^2, 1 and 0.564–0.879, respectively. The projected area of wild sage seed was lower than basil seed, while the sphericity and roundness of wild sage seed were higher than basil seed (6). Range of geometric mean diameter, arithmetic mean diameter, surface area and sphericity calculated by Eqs. 1–4 were 1.647–2.263 mm, 1.693–2.313 mm, 8.518–16.083 mm^2, and 0.749–0.779, respectively. Geometric and arithmetic mean diameters of wild sage seed were lower than values reported for basil seed.[6] Surface area of

Downloaded By: [Razavi, Seyed M.A.] At: 10:39 4 March 2010

wild sage seed obtained higher than amaranth,[10] caper seed,[15] and flaxseed,[18] and lower than basil seed,[6] fenugreek,[14] and vetch seed.[11]

The unit mass of wild sage seed ranged from 0.0017–0.0025 g. However, the thousand grain mass of wild sage seeds were between 2.–2.79 g, which were lower than values reported for basil seed,[6] flaxseed,[18] pomegranate seed,[16] rapeseed,[13] and higher than sesame seed.[12] The volume of wild sage seeds ranged from 7.46–7.63 mm^{-3} (Table 1), which was lower than fenugreek volume,[14] and higher then amaranth volume [10] and basil seed.[6] The bulk density of wild sage seeds varied between 901 kgm^{-3} and 911 kgm^{-3}, which was higher than amaranth,[10] basil seed,[6] cumin seed,[7] fenugreek seed,[14] flaxseed,[18] millet,[8] rapeseed,[13] sesame,[12] and similar to vetch seed.[11] The wild sage seeds had averagely a true density of 970 kgm^{-3}, which were higher than basil seed[6] and lower than amaranth,[10] millet,[8] sesame,[12] and similar to flaxseed[18] and pomegranate seed.[16] The porosity of seed, because of the little difference between true and bulk densities, was low and ranged from 5–10%. This was lower than the value reported for amaranth,[10] basil seed,[6] caper seed,[15] fenugreek,[14] flaxseed,[18] hemp seed,[9] pomegranate seed,[16] rapeseed,[13] and vetch seed.[11]

The static coefficient of friction of wild sage seeds obtained experimentally on five surfaces namely plywood, galvanized iron, rubber, fiberglass and glass. Plywood and rubber surface had the highest coefficient of friction and it is found that the static coefficient of friction is lowest against glass (Table 1). This is owing to the smoother and polished surface of glass sheet compared other sheets used. The coefficient of friction of wild sage seed was higher than basil seed,[6] and lower than millet,[8] pomegranate seed,[16] and sesame seed.[12] The round shape of this seed may cause sliding more easily than other seeds. The filling angle of repose of wild sage seeds ranged from 14.95–19.03 with the mean value as 17.3 ± 1.7 (Table 1), which was higher than those reported for basil seed,[6] and lower than pomegranate seed,[16] and sesame seed.[12]Furthermore, the angle was lower than values obtained for hemp seed,[9] millet,[8] and similar to flaxseed.[18]

The terminal velocity of wild sage seeds ranged from 3.5–5.3 ms^{-1} with the mean value as 4.2–0.39 (Table 1), which was almost similar to the values obtained for basil seed.[6] This characteristic can be used to design separating, cleaning, and handling processes for seed, since the high tendency for water absorption by the seed makes washing and using water impossible. The rupture force, hardness, and energy absorbed of the sage seeds were between 1186–1922 g, 1484–2114 g, and 6044.32–9528.22 g mm. These values were lower than those reported for basil seed, [6] and pomegranate seed.[16] For mucilaginous seed, mechanical properties are useful information in designing gum extractor, therefore low hardness and rupture force may lead to producing more dust in extracted gum.[2]

CONCLUSION

In present study, the computer vision system seems to be an accurate method for measurement of small seed dimension. The image analysis and manual method showed high correlation for seed length, width, and thickness. The unit mass and thousand grain mass of the seed were 0.00274 and 2.766 g, respectively. The true & bulk densities of the seed were 970 and 907 kg m^{-3}, the filling, and emptying angle of repose were 17.3 and 19.3, respectively. The average coefficient of friction against plywood and rubber 0.382 was the highest while 0.262 for glass was the lowest. The average terminal velocity of basil seed was 4.2 and according to the mucilaginous nature of the seed higher or lower air

Downloaded By: [Razavi, Seyed M.A.] At: 10:39 4 March 2010

velocities can be used for separation or cleaning process. The hardness, energy absorbed and fracture force were 1650 g, 7147g.s, and 1611 g, respectively.

REFERENCES

1. Matloubi-Moghaddam, F.; Amin, Gh.; Safavipoorsohi, E. Composition of stembark essential oil from Salvia macrosiphon Boiss. Iranian Journal of Daru. **2000**, *8*, 28–29.
2. Razavi, S.M.A.; Farhoosh, R.; Bostan, A. Functional properties of hydrocolloid extract of some Iranian seeds. Research project No.1475. Unpublished report. **2007**, Ferdowsi University of Mashhad, Iran.
3. Brosnan, T.; Sun, D.W. Improving quality inspection of food products by computer vision. Journal of Food Engineering. **2004**, *61*, 3–16.
4. Du, C.J.; Sun, D.W. Recent developments in the applications of image processing techniques for food quality evaluation. Trends in Food Science and Technology **2004**, *15*, 230–249.
5. Utku, H.; Koksel, H. Use of statistical filters in the classification of wheat by image analysis. Journal of Food Engineering **1998**, *36*, 385–394.
6. Razavi, Seyed. M.A.; Bostan, A.; Rezaie, M. Image processing and physic-mechanical properties of basil seed (Ocimum basilicum). Journal of Food Process Engineering **2008**, Article in press.
7. Singh, K.K.; Goswami, T.K. Physical properties of cumin seed. Journal of Agricultural Engineering Research **1996**, *64*, 93–98.
8. Baryeh, E.A. Physical properties of millet. Journal of Food Engineering **2002**, *51*, 39–46.
9. Sacilik, K.; Ozturk, R.; Keskin, R. Some physical properties of hemp seed. Biosystems Engineering **2003**, *86* (2), 191–198.
10. Abalone, R.; Cassinera, A.; Gaston, A.; Lara, M.A. Some physical properties of amaranth seeds. Biosystems Engineering **2004**, *89* (1), 109–117.
11. Yalcın, I.; Ozarslan, C. Physical Properties of Vetch Seed. Biosystems Engineering **2004**, *88* (4), 507–512.
12. Tunde-Akintunde, T. Y.; Akintunde, B. O. Some physical properties of sesame seed. Biosystems Engineering. **2004**, *88* (1), 59–65.
13. Calısır, S.; Marakoglu, T.; Ogut, H.; Ozturk, O. Physical properties of rapeseed. Journal of Food Engineering **2005**, *69*, 61–66.
14. Altuntas, E.; Ozgoz, E.; Faruk Taser, O. Some physical properties of fenugreek seeds. Journal of Food Engineering **2005**, *71*, 37–43.
15. Dursun, E.; Dursun, I. Some physical properties of caper seed. Biosystems Engineering **2005**, *92* (2), 237–245.
16. Kingsly, A.R.P.; Singh, D.B.; Manikantan, M.R.; Jain, R.K. Moisture dependent physical properties of dried pomegranate seeds. Journal of Food Engineering **2006**, *75*, 492–496.
17. Mwithiga, G.; Masika Sifuna, M. Effect of moisture content on the physical properties of three varieties of sorghum seeds. Journal of Food Engineering **2006**, *75*, 480–486.
18. Coskuner, Y.; Karababa, E. Some physical properties of flaxseed, Journal of Food Engineering **2007**, *78*, 1067–1073.
19. Kilic, K.; Boyaci, I.H.; Koksel, H.; Kusmengoglu, I. A classification system for beans using computer vision system and artificial neural networks. Journal of Food Engineering **2007**, *78*, 897–904.
20. Clemex Vision Professional, PE4. Help files. 2005. Available from <http://www.clemex.com/Products/Imageanalysis/Software/VisionPE.aspx>
21. Mohsenin, N.N. *Physical properties of plant and animal materials*; Gordon and Breach Science Publishers: New York, 1978, pp. 51–87.

Downloaded By: [Razavi, Seyed M.A.] At: 10:39 4 March 2010