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GEOMETRIC, VOLUMETRIC, COLOUR AND FRICTIONAL PROPERTIES OF SELECTED *SALVIA* SPECIES OF TURKEY

Mustafa Bayram[1] , Ebubekir Altuntas[1*] Melih Yilar[2]

[1]Department of Biosystem Engineering, Faculty of Agriculture, University of Gaziosmanpasa, Tokat-Turkey.
[2]Department of Plant Protection, Faculty of Agriculture, University of Ahi Evran, Kırsehir-Turkey.

***Corresponding author E-mail**: ebubekir.altuntas@gop.edu.tr

Abstract

Background: *Salvia* seeds are promite to dietary and healthy oils because they contain essential fatty acids. *Salvia* seeds frequently produce mucilage on soaking, and this mucilage is used for the treatment of eye diseases in eastern countries. *Salvia* species studied for medicine, food and cosmetics, have the potential to be used in the various fields. In the present study, selected engineering (geometrical, volumetrical, colour and frictional) properties of 6 *Salvia* species seeds were determined and compared.
Materials and Methods: This study was performed on selected engineering properties of seeds of 6 *Salvia* species (*Salvia viridis* L., *Salvia aethiopis* L., *Salvia cryptantha* Montbert & Aucher ex Benthan., *Salvia tomentosa Mill*., *Salvia sclarea* L., *Salvia virgata* Jacq.,) cultivated in Turkey. Plants were collected during the vegetation in 2012-2013 (May-Agust). The seeds were cleaned from foreign matter, dirt and broken seeds manually.
Results: The average length, width and thickness were found in the range of 2.61 to 3.53 mm, 1.59 to 2.92 mm and 1.14 to 2.52 mm, respectively. *Salvia viridis* L. specie had the lowest geometric mean diameter and surface area, whereas *Salvia cryptantha* L. had the least values among these 6 *Salvia* species for these properties. The bulk density, true density and the porosity were between 296.83 and 702.80 kg m^{-3}, 285.69 and 718.08 kg m^{-3}, 10.27 and 44.05%, respectively. The volume of unit seed and sphericity ranged between 2.56 and 13.64 mm^3, 62.90 and 90.40%, respectively. The coefficient of friction of salvia species were largely influenced by the friction surfaces studied, and highest values were found for polywood in the *Salvia crytantha* L.. In the study, the static friction coefficient and the angle of repose of salvia species changed from 0.477 to 0.955, and from 14.09 to 23.57°, respectively.
Conclusion: Determination of geometric, volumetric, colour and frictional properties of *Salvia* spp. seeds may increase their economic value.

Keywords: *Salvia* seed, geometric mean diameter, chroma, static friction coefficient

Introduction

Salvia genus, which belongs to Lamiaceae family, is one of the most well–known aromatic (sage) herbs (Yalcin *et al.* 2011). *Salvia* species are one of the most important ones in this group (Celep *et al*. 2009). Turkey has one of the important gene centers of the Lamiaceae family, and 45 genus and 558 species of this family are available in Turkey (Belen, 2012). Moreover, recent studies have reported 95 species of *Salvia* in Turkey (Celep *et al*. 2009).
Lamiaceae family seeds contain large amount of oils, and are, therefore, economically important because of the oils. In recent years, many species of Lamiaceae family have provided alternatives to conventional, synthetic and natural antioxidants. This is because many species of Lamiaceae family have been shown to possess strong antioxidant properties (Zupkó *et al.* 2001). *Salvia* species (Lamiaceae) have been reported to be used against memory loss in European folk medicine (Orhan *et al.* 2007).

Salvia viridis quickly grows to 1 to 2 feet tall and 1 foot wide, with a flowering period of over a month. Colorful bracts almost hide the tiny two-lipped flowers, which are cream-colored, with the upper lip tinged with purple or rose, reflecting the bract color. Its seeds and leaves have been added to fermenting vats to greatly increase the inebriating quality of the liquor. Its flowers last well as cut flowers or dried flowers. An infusion of the leaves was used for sore gums, and powdered leaves for snuff. It was also reported to be a good honey-producing plant. Its seed can be sown in late March in a greenhouse or directly into the border after the last frost (Wikipedia, 2016 a).

Salvia aethiopis is a species of perennial plant known by the common Mediterranean name of sage or African sage. It is best known as a noxious weed, particularly in the western United States. It is native to Eurasia and was probably introduced to North America as a contaminant of alfalfa seed. It is a weed of rangelands and pastures. It is unpalatable to livestock, it disrupts native floral communities, and it becomes a physical nuisance due to its habit of becoming an abundant tumbleweed (Wikipedia, 2016 b).

Salvia cryptantha Montbert & Aucher ex Benthan is a perennial bush branching in a disorderly fashion on the ground and its older branches are brittle and rough. The younger branches are soft and covered by fine fuzz. *Salvia cryptantha* flowers in May up to late August and its plants are generally propagated through cuttings (İpek et al. 2012).

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Salvia tomentosa Mill. is a low-growing shrub, resembling *Salvia fruticosa*, from which it is distinguished mainly by its larger flowers. Its native distribution extends from southeastern Europe to the Transcaucasus. *Salvia tomentosa* is used in the Turkish folk medicine, and its oils have antibacterial and antioxidant activities (Hanlidou et al. 2014).

Salvia sclarea (clary, or clary sage), is a biennial or short-lived herbaceous perennial in the genus *Salvia.* It is native to the northern Mediterranean, along with some areas in north Africa and Central Asia. It is one of the most common *Salvia* species and is used as an ingrediant for tea in Turkey known as 'misk sage tea'. The plant has a lengthy history as a medicinal herb, and is currently grown for its essential oil. *Salvia sclarea* reaches 3 to 4 ft in height, with thick square stems that are covered in hairs. The leaves are approximately 1 ft long at the base, 5 ft long higher on the plant. The flowers are in verticils, with 2-6 flowers in each verticil, and are held in large colorful bracts that range in color from pale mauve to lilac or white to pink with a pink mark on the edge. The lilac or pale blue corolla is approximately 1 in (2.5 cm), with the lips held wide open (Yalcin *et al*. 2011; Wikipedia, 2016 c).

Salvia virgata (wand sage, southern meadow sage) is a perennial plant that is native to Asia and southeastern Europe, and it is considered a noxious weed in many parts of the world. *Salvia virgata* is sometimes included within *Salvia pratensis*. Flowers grow in whorls of 4-6 with a blue-violet corolla that is 0.39 to 0.79 in long. The ovate to oblong leaves are dull green on the top surface, with the underside covered with glands and think hairs (Wikipedia, 2016 d).

Salvia seeds are promite to dietary and healthy oil rich because they contain in essential fatty acids. *Salvia* seeds frequently produce mucilage on soating, and this the mucilage is used for the treatment of eye diseases in eastern countries (Ben Taarit *et al.* 2014). Salvia species have a great use in the production of the pharmaceutical, food and cosmetics (Asadi *et al.* 2010; Yalcin *et al*. 2011). Therefore, it is important to determine the geometrical, volumetrical, colour and frictional properties of particular *Salvia* seeds which may increase its economic value.

The knowledge of the size distribution of *Salvia* seeds is essential for the adequate design of the equipment for cleaning, grading and separation. The information on engineering properties such as the geometrical, volumetrical, colour and frictional of seeds areimportant to facilitate and improve the design of equipment which for handling, harvesting, processing, transportation, storage, separation and packing of *Salvia* seeds (Guiotto *et al.* 2011). The frictional properties, such as the angle of repose and the static friction coefficient, are important for the design of grain bins, conveying systems, transport and other storage structures whose operation is influenced by the compressibility and flow behaviour of materials. The designs lead to inadequate applications if the systems are designed without taking these engineering properties into consideration (Guiotto *et al*. 2013).

Several researchers have studied the some selected engineering properties of the different types seeds such as flaxseed (Krishna *et al*. 2013); fenugreek (Altuntas *et al.* 2005); chia (*Salvia hispanica* L.); cumin (Singh and Goswami, 1996); knotweed (*Polygonum cognatum* Meissn.) (Önen *et al*. 2014); buckwheat, vetch, pea, lupine and faba bean (Kaliniewicz *et al.* 2014), respectively.

No detailed study concernthe selected engineering (geometrical, volumetrical, colour and frictional) properties of 6 *Salvia* species (*Salvia viridis* L., *Salvia aethiopis* L., *Salvia cryptantha* Montbert & Aucher ex Benthan., *Salvia tomentosa Mill.*, *Salvia sclarea* L., *Salvia virgata* Jacq.,) were not studied and comparatively. Therefore, the geometric, volumetric, colour and frictional properties of *Salvia* species have been investigated in this study.

Materıals and Methods

This study was performed on selected engineering properties of seeds of 6 salvia species (*Salvia viridis* L., *Salvia aethiopis* L., *Salvia cryptantha* Montbert & Aucher ex Benthan., *Salvia tomentosa Mill.*, *Salvia sclarea* L., *Salvia virgata* Jacq.,) cultivated in Turkey. Plant materials of Salvia species were obtained from Artova, Resadiye and Almus province in Tokat city of Turkey. Harvested *Salvia* seeds were transferred to the laboratory in polyhthene bags to reduce water loss during transport (Table 1). Plants were collected during the vegetation in 2012-2013 (May-Agust). The seeds were cleaned from foreign matter, dirt and broken seeds manually.

To determine size dimension of the *Salvia* seeds, one hundred *Salvia* seeds from each species were randomly taken and the seeds were cleaned to remove all foreign matter sand immature and damaged seeds. The length, width and thickness of *Salvia* seeds were measured by using a dial-micrometer (Model No; 3109-25A, Insize Co., China, 0.01 accuracy), and the *Salvia* seed masses were measured by using a digital electronic balance (ModelNo; 612-1S, Sartorius Secura, Göttingen, Germany, 0.01g. resolution). The geometric mean diameter (D_g), sphericity (Φ), seed volume, true and bulk densities of seeds of *Salvia* species were determined methods presented by Mohsenin (1970). The initial moisture content of *Salvia* seeds was determined by using a standard method (Brusewitz, 1975). Moisture content of six *Salvia* species seeds ranged from 4.87% ±0.31 to *(Salvia viridis) 6.76*% ±0.54 (*Salvia tomentosa*), 6.59% ±0.18 (*Salvia aethiopis*), 5.85.59% ±0.18 (*Salvia cryptantha*), 5.49% ±0.10 (*Salvia sclarea*) 6.73 % ±0.53 *(Salvia virgata*) (dry basis), respectively.

The geometric mean diameter (D_g) and sphericity (Φ) of *Salvia* species seeds were determined according to Mohsenin (1970). The volume (V) of *Salvia* species seeds in mm^3 was calculated according Özarslan (2002). The porosity (ε) was determined according to Mohsenin (1970). The surface area (S) of *Salvia* seeds in mm^2 was found by analogy with a sphere of same geometric mean diameter, using expression cited by Tunde-Akintunde and Akintunde (2004).

The colour of *Salvia* seeds was determined by using a Minolta colourimeter (Model CR-3000,(Konica Minolta, Osaka, Japan) in terms of L, a, b values. *L** denotes the lightness or darkness of *Salvia* seed; *a** is green or red colour of *Salvia* seed; and *b** is blue or yellow colour of the *Salvia* seed samples. Chroma and hue angle are effective parameters for describing the visual colour appearance. Hue angle (*h*°) and chroma (*C**) were calculated according to Bernalte *et al.* (2003). The colours were measured by colourimeter for each *Salvia* species as the means of three replication values. Colour measurements were conducted on bulk seed samples of *Salvia* species (Jha *et al.* 2005). The Hunter Lab colour coordinate system *L**, *a** and *b** values were recorded and the brown index was calculated using expression cited by Akissoe *et al.* (2003). The coefficient of friction of *Salvia* seed is defined as tangent value of the angle of slope between sliding surface and vertical and horizontal planes (Celik *et al.* 2007). The experiment was conducted by using laminate, plywood, galvanized metaland silicone friction surfaces by a friction device.

Experimental results were analyzed as per one-factor analysis of variance using Duncan of SPSS 13.0 software statistical package programme (SPSS, 2000).

Results and Dıscussıon

Some engineering properties of selected engineering (geometrical, volumetrical, colour and frictional) properties of 6 *Salvia* species (*Salvia viridis, Salvia aethiopis, Salvia cryptantha, Salvia tomentosa, Salvia sclarea, Salvia virgata)* were evaluated.

Table 1: Sampling locations of Salvia species

Sampling Location	Species	Location	Altitude (m)
Tokat-Artova	*Salvia viridis* L.	Field-field edge	900
Tokat, Tokat-Artova	*Salvia cryptantha L*	Mountainous area, pasture area	1133, 1279
Tokat-Artova	*Salvia aethiopis* L.	Wasteland	1166
Tokat-Almus	*Salvia tomentosa* L.	Grassland, mountainous area	812
Tokat-Almus	*Salvia sclarea* L.	Grassland, mountainous area	812
Tokat-Reşadiye	*Salvia virgata* L.	'Yolustu' village area	1132
Tokat-Reşadiye	*Salvia sclarea* L.	Roadside, grassland	963

Table 2: The geometrical properties of *Salvia* species.

Salvia species	Length *L* (mm)	Width *W* (mm)	Thickness *T* (mm)	Geometric mean diameter D_g (mm)	Sphericity Φ (%)	Surface area *S* (mm^2)
Salvia viridis	2.701bc	1.585e	1.137f	1.690f	62.902c	9.019e
	(0.036)	(0.023)	(0.019)	(0.018)	(0.806)	(0.186)
Salvia aethiopis	2.816b	1.924d	1.900c	2.171c	77.268b	14.903c
	(0.031)	(0.031)	(0.037)	(0.028)	(0.938)	(0.376)
Salvia cryptantha	3.532a	2.915a	2.523a	2.956a	84.060ab	27.530a
	(0.032)	(0.0239	(0.020)	(0.016)	(0.532)	(0.298)
Salvia tomentosa	3.420a	2.750b	2.320b	2.780b	90.401a	24.638b
	(0.048)	(0.029)	(0.031)	(0.034)	(9.182)	(0.573)
Salvia sclarea	2.539d	2.068c	1.456d	1.968d	77.558b	12.194d
	(0.024)	(0.032)	(0.0149	(0.0179)	(0.505)	(0.213)
Salvia virgata	2.612c	1.827d	1.343e	1.852e	71.171bc	10.828d
	(0.032)	(0.034)	(0.018)	(0.019)	(0.751)	(0.224)
F value	90.03**	208.30**	264.57**	323.43**	5.27**	266.59**

Values in the parenthesis are standard error of the mean (SEM) **P<0.01

Geometrical properties

The geometrical properties of the different 6 *Salvia* species *Salvia viridis* L., *Salvia aethiopis* L., *Salvia cryptantha* Montbert & Aucher ex Benthan., *Salvia tomentosa Mill.*, *Salvia sclarea* L., *Salvia virgata* Jacq.,) are given in Table 2, respectively. The length of the *Salvia* seed species varied from 2.61 mm (*Salvia virgata*) to 3.53 mm (*Salvia cryptantha*), and width ranged from 1.59 (*Salvia viridis*) to 2.92 mm (*Salvia cryptantha*), whereas thickness ranged

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from 1.13 mm (*Salvia viridis*) to 2.52 mm (*Salvia cryptantha).* The length, width and thickness varied statisticaly significantly for all the six species (P≤ 0.01).The geometric mean diameter (D_g), sphericity and surface area *Salvia* species ranged from 1.69 to 2.96 mm, 62.90% to 90.40% and 9.01 to 27.53 mm^2, respectively. The highest sphericity was found of *Salvia tomentosa* of *Salvia* seed. Significant differences were found for sphericity between seed of *Salvia* species (Table 2). Sphericity indicated that the shape of the seeds is spherical and thus makes it easy to roll on surface. The sphericity ofthe *Salvia viridis* seed is the low tendency of the shape towards a sphere between species. The highest geometric mean diameter and surface area at the moisture content 5.84% w.b.was found of *Salvia cryptantha* of *Salvia* seed.

Ixtaina *et al.* (2008), reported the length, width and thickness value of *Salvia hispanica* seed 2.15, 1.40 and 0.83 mm (for white seeds); 2.11, 1.32 and 0.81 mm (for dark seeds), respectively. Coskuner and Karababa (2007) reported that the length, width, thickness and the geometric mean diameter of flaxseed changed from 4.74 to 4.61 mm, 3.67 to 3.93 mm, 3.39 to 3.54 mm, and 3.88 to 3.99 mm for the moisture ranged from 7.10 to 18.94% (dry basis), respectively. Abalone *et al*. (2004) found the average length, width and thickness of Amaranth seeds as 1.42, 1.29 and 0.87 mm, respectively, and they were lower than the *Salvia* species. The sphericity seed of *Salvia viridis*, *Salvia aethiopis, Salvia cryptantha, Salvia sclarea, Salvia virgata* resulted to be lower than that of rapeseed Unal *et al*. (2009) and coriander seeds (Coşkuner and Karababa, 2007). The sphericity of *Salvia tomentosa* seed was found higher than that of millet quinoa seed (Vilche *et al.* 2003), sesame (Tunde-Akintunde and Akintunde, 2004), knotweed (Önen *et al.* 2014) and *Salvia hispanica* L. seeds (Ixtaina *et al.* 2008).

Abalone *et al.* (2004) have reported the geometric mean diameter of seed ranged from 1.10 to 1.24 mm and mean sphericity found as 82%. Selvi *et al*. (2006) have reported the geometric mean diameter in the range of 2.24 to 2.43 mm for the moisture range from 8.25 to 22.25 % (d.b.) which were higher than *Salvia viridis*, *Salvia aethiopis*, *Salvia sclera and Salvia virgata*. Ixtaina *et al*. (2008) reported that geometric mean diameter of dark and white chia (*Salvia hispanica L.*) seeds ranged between 1.31 and 1.36 mm for the mean moisture content was 7.0% (d.b) respectively, and they were lower than the six *Salvia* species.

Volumetrical Properties

The volumetrical properties of six species of *Salvia* seeds were presented in Table 3. The effects of species on volumetrical properties were statistically found significant. The seed mass, 1000-seed mass and seed volume were in the range of 0.0028 to 0.0123 g, 1.58 to 4.26 g, 2.56 to 13.64 mm^3, respectively. The least seed mass and seed volume values were shown by *Salvia viridis*, whereas, the highest seed mass and seed volume values were recorded for *Salvia cryptantha* specie among the *Salvia* species. In this study, the 1000-seed mass was found lower than reported by Selvi *et al.* (2006), which was 6.0 g at 8.25% (d.b.) moisture content for linseed. Although the seed mass, 1000-seed mass and seed volume of tef seed (Zewdu and Solomon, 2007) were lower than six salvia species but millet seed (Baryeh, 2002) and caper seed (Dursun and Dursun, 2005) higher than six *Salvia* species.

Table 3: The volumetrical properties of *Salvia* species.

Salvia species	Seed mass, *M* (g)	Thousand seed mass M_{1000} (g)	Volume V (mm^3)	Bulk density, ρ_f (kg m^{-3})	True density, ρ_f (kg m^{-3})	Porosity *P* (%)
Salvia viridis	0.0028c	2.190d	2.564e	527.15b	587.25b	10.27b
	(0.00005)	*(0.055)*	*(0.078)*	*(0.23)*	*(5.25)*	*(0.769)*
Salvia aethiopis	0.0034c	2.215d	5.462c	477.47b	483.50c	27.04c
	(0.00014)	*(0.062)*	*(0.203)*	*(4.95)*	*(92.268)*	*(0.003)*
Salvia cryptantha	0.0123a	9.136a	13.642a	473.63a	718.08d	36.03d
	(0.00103)	*(0.3749*	*(0.220)*	*(3.09)*	*(30.69)*	*(2.41)*
Salvia tomentosa	0.0070b	4.263b	11.728b	296.83b	569.13e	44.05e
	(0.00021)	*(0.166)*	*(0.418)*	*(3.19)*	*(40.17)*	*(3.66)*
Salvia sclarea	0.0040c	3.410c	4.017d	702.80a	568.13a	19.16a
	(0.00009)	*(0.090)*	*(0.106)*	*(0.06)*	*(0.006)*	*(0.006)*
Salvia virgata	0.0029c	1.580e	3.375de	453.22c	285.69f	32.56f
	(0.00011)	*(0.052)*	*(0.106)*	*(84.34)*	*(1.73)*	*(12.09)*
F value	62.31**	190.12**	194.15**	12.74**	9213.03**	16.28**

Values in the parenthesis are standard error of the mean (SEM), **P<0.01

The porosity of the *Salvia* specie seeds ranged from 10.27 (*Salvia viridis)* to 44.05% (*Salvia tomentosa).* Porosity values were found higher in *Salvia tomentosa* than the other *Salvia* species. This may be due to differences of properties of geometrical and volumetrical of *Salvia tomentosa*. The effect of species on porosity of *Salvia* seeds was

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found significantly (P<0.01). Similar results for porosity have also been reported by Vilche *et al.* (2003), whereas, porosities of *Salvia* species were found lower than tef seed (Zewdu and Solomon, 2007) and cumin seed (Singh and Goswami, 1996), respectively. The true density of saliva species changed from 285.69 to 718.08 kg m^{-3} for the moisture range of 4.87% to 6.76% d.b. The highest true density was observed for *Salvia cryptantha* (718.08 kg m^{-3}) at the moisture content of 5.84% d.b. The true density values for *Salvia viridis*, *Salvia aethiopis*, *Salvia cryptantha*, *Salvia tomentosa*, *Salvia sclarea*, *Salvia virgata* species were statistically found significant (p<0.01) (Table 3). The true density of *Salvia* seeds can be used to design separation or cleaning process in post-harvest application (Unal *et al.* 2009). The highest bulk density of *Salvia* seeds was found for *Salvia sclarea* (702.8 kg m^{-3}) and the lowest (296.83 kg m^{-3}) was observed for *Salvia tomentosa.* Although the moisture content of *Salvia viridis, Salvia aethiopis, Salvia tomentosa* were different among the *Salvia* species seeds (moisture range of4.87 to 6.76 %), the bulk density of these species are statistically similar.Singh *et al.* (2015) reported that bulk and true densities of nigella seed varied from 482.29 to 552.50 kg m^{-3}; 1054.28 to 1113.43 kg m^{-3} for the moisture ranged from 5.2 to 25.1% (d.b.), respectively. Zewdu and Solomon (2007) reported that the bulk and true densities of tef seeds changed from 840 to 696 kg cm^{-3} and 1361 to 1207 kg m^{-3} with the increase in moisture content from 5.6–29.6% w.b., respectively. Singh and Goswami (1996) reported that the bulk and true densities for cumin seed varied from 410 to 502 kg m^{-3}, 1047 to 1134 kg m^{-3}, whereas, the porosity of cumin seed changed from 54 to 64%, respectively. Dursun and Dursun (2005) reported that the bulk density, true density and porosity of caper seed were as 438 to 399 kg m^{-3}, 806 to 678 kg $m^{-3}$and 45.7 to 41.1%, respectively. Range of true density in the studied *Salvia* specie seeds was lower than the reported values of Selvi *et al.* (2006). This may be due to specie differences among these *Salvia* seeds. Ixtaina et al., (2008) reported the bulk density of chia seed observed between 667 and 722 kg m^{-3}, whereas, Coskuner and Karababa (2007) found the bulk density was between 555.6 and 726.6 kg m^{-3} for coriander seed. Önen *et al.* (2014) reported that the bulk density of knotweed (Polygonum cognatum Meissn.) seeds changed from 696.11 to 707.73 kg m^{-3}, but Singh and Goswami (1996) reported that the bulk density of cumin seed varied from 410 to 502 kg m^{-3} and Selvi *et al. (*2006) found betwen 545.0 and 690.5 kg m^{-3} for linseed, respectively.

Colour Characteristics

*L**, *a**, *b** values represent brightness, green-red color and blue-yellow colors, for parameters of colour respectively (Jha *et al.* 2005). Colour characteristic (lightness, redness, and yellowness) values of the different *Salvia* species seed were presented in Table 4. The maximum lightness (L) was found to be 26.39 for *Salvia sclarea*, whereas minimum *L** value was recorded as 21.34 for *Salvia tomentosa*, respectively. Significant differences (p<0.01) were found between *Salvia* species for colour characterictics such as lightness, redness and yellowness. Lightness was found statistically similar in between *Salvia viridis* with *Salvia aethiopis* and *Salvia cryptantha* with *Salvia sclarea* among *Salvia* species. The hue angle ranged from 42.32 to 53.09° with the highest value for *Salvia sclarea* and the lowest for *Salvia viridis* of *Salvia* seeds. The hue angle values of *Salvia aethiopis*, *Salvia cryptantha*, *Salvia sclarea* and *Salvia virgata* of *Salvia* seeds were statistically similar. Chroma values were in the range of 6.76 to 12.59 with the lowest for *Salvia viridis* and the highest for *Salvia sclarea* of salvia seeds. Brown index values were in the range of 36.08 to 68.26 with lowest for *Salvia viridis* and the highest for *Salvia sclarea* of *Salvia* seeds. Brown index values of six species of *Salvia* seeds were statistically different (p<0.01).

Table 4: The colour characteristics properties of *Salvia* species.

Salvia species	*L**	*a**	*b**	*Chroma*	*Hue angle*	*Brown index*
Salvia viridis	23.71b	5.00d	4.53e	6.76e	42.32c	36.08e
	(0.527)	(0.187)	(0.115)	(0.1969	(0.774)	(0.473)
Salvia aethiopis	22.75b	5.80c	7.50c	9.49d	52.24a	58.18c
	(0.418)	(0.081)	(0.111)	(0.108)	(0.507)	(0.846)
Salvia cryptantha	25.31a	7.03b	8.73b	11.22b	51.04a	62.08b
	(0.514)	(0.144)	(0.265)	(0.2679	(0.731)	(1.602)
Salvia tomentosa	21.34bc	5.29d	5.65d	7.80e	46.40b	48.33d
	(0.596)	(0.161)	(0.296)	(0.224)	(1.889)	(1.206)
Salvia sclarea	26.39a	7.56a	10.07a	12.59a	53.09a	68.26a
	(0.263)	(0.107)	(0.110)	(0.131)	(0.369)	1.057)
Salvia virgata	25.73c	6.37e	8.45f	10.58f	52.94a	57.29f
	(0.296)	(0.0659	(0.150)	(0.1389	(0.485)	(0.6609
F value	20.57**	164.14**	145.58**	211.57**	16.87**	199.41**

Values in the parenthesis are standard error of the mean (SEM), **P<0.01

Frictional Properties

The frictional properties of *Salvia* species seed are given in Table 5. The coefficient of static friction for the *Salvia* species seeds was determined on the laminate, plywood, silicone, rubber and galvanized metal friction surfaces. The static coefficient of friction was the lowest and the highest for all *Salvia* species on laminate and plywood among the studied friction surfaces. The static coefficient of friction ranged from 0.47 to 0.64, 0.76 to 0.96, 0.63 to 0.76, 0.64 to 0.79, and 0.60 to 0.71 for laminate, plywood, silicone, rubber, and galvanized metal, among the six *Salvia* species seeds, respectively. There were significant differences of the static friction coefficients among the *Salvia* species on the five different surfaces statistically (p<0.01) (Table 5). *Salvia cryptantha* showed the lowest static coefficient of friction for laminate surface among five surfaces, respectively. This may be due to more polished surface of than the other test surfaces. Static friction coefficient of *Salvia* species largely influenced by friction surfaces.

Table 5*:* The frictional properties of *Salvia* species.

Salvia species	*Static friction coefficient*					
	Laminate	*Plywood*	*Silicone*	Rubber	Galvanized metal	*F value*
Salvia viridis	0.601c	0.894a	0.763b	0.736b	0.712b	
	(0.014)	*(0.032)*	*(0.009)*	*(0.025)*	*(0.025)*	34.19**
Salvia aethiopis	0.638c	0.920a	0.633c	0.794b	0.655c	
	(0.067)	*(0.052)*	*(0.022)*	*(0.031)*	*(0.018)*	10.52**
Salvia cryptantha	0.477d	0.959a	0.675b	0.643b	0.601c	
	(0.006)	*(0.029)*	*(0.010)*	*(0.006)*	*(0.010)*	222.25**
Salvia tomentosa	0.607b	0.906a	0.743ab	0.771ab	0.656b	
	(0.025)	*(0.135)*	*(0.200)*	*(0.021)*	*(0.084)*	*0.05***
Salvia sclarea	0.517c	0.763a	0.668b	0.695b	0.653b	
	(0.007)	(0.009)	(0.046)	(0.015)	(0.051)	16.46**
Salvia virgata	0.640a	0.901b	0.658a	0.727a	0.646a	
	(0.054)	(0.032)	(0.096)	(0.012)	(0.048)	11.75*

Values in the parenthesis are standard error of the mean (SEM)
*p<0.05, **p<0.01 , all values are mean of five replicates

Singh and Goswami (1996) reported that the static coefficient of friction of cumin seed changed on four metal surfaces, namely, mild steel from 0.54 to 0.70, galvanized iron from to 0.48 to 0.65, stainless steel from 0.37 to 0.62 and aluminium from 0.43 to 0.63 in moisture content from 7 to 22% (d.b.), respectively. Dursun and Dursun (2005) reported that the static coefficient of friction for caper seed increased from 0.55 to 0.70 for rubber, 0.52 to 0.66 for plywood, 0.40 to 0.47 for galvanized metal sheet and 0.36 to 0.46 for aluminium sheet friction surfaces.The highest static coefficient of friction was found on the plywood surface in this study as Coskuner and Karababa (2007). Static coefficient of friction for *Salvia* species of seed on polywood surface washigher than that of cumin (Singh and Goswami, 1996) and flaxseed (Coskuner and Karababa, 2007).

Angle of repose

The angle of repose of the *Salvia* species studied ranged from 13.13° (*Salvia sclarea)* to 23.57° (*Salvia virgata*). The effect of salvia species on angle of repose was found statically significant (p<0.01) (Fig 1). The angle of repose of *Salvia viridis, Salvia cryptantha* and *Salvia sclearea* speciesshowed statistically similar. Also *Salvia aethiopis* and *Salvia tomentosa* species were found to be statistically similar as angle of repose. Among six *Salvia* species, the the longest length was found in *Salvia sclarea* seed at the same time, and also, it has been seen that *Salvia sclarea* has the smallest angle of repose. The angle of repose values for the *Salvia* species are lower than that of millet (Baryeh, 2002), quinoa (Vilche *et al.,* 2003) and Knotweed (*Polygonum cognatum* Meissn.) seeds (Önen et al., 2014), whereas, the angle of repose values for the *Salvia* species are generally higher than that of fenugreek seeds (Altuntas *et al.*, 2005). The similar results for angle of repose of *Salvia* species in this study were reported for chia seed (*Salvia hispanica*) (Ixtaina *et al.*, 2008; Guiotto *et al.*, 2011).

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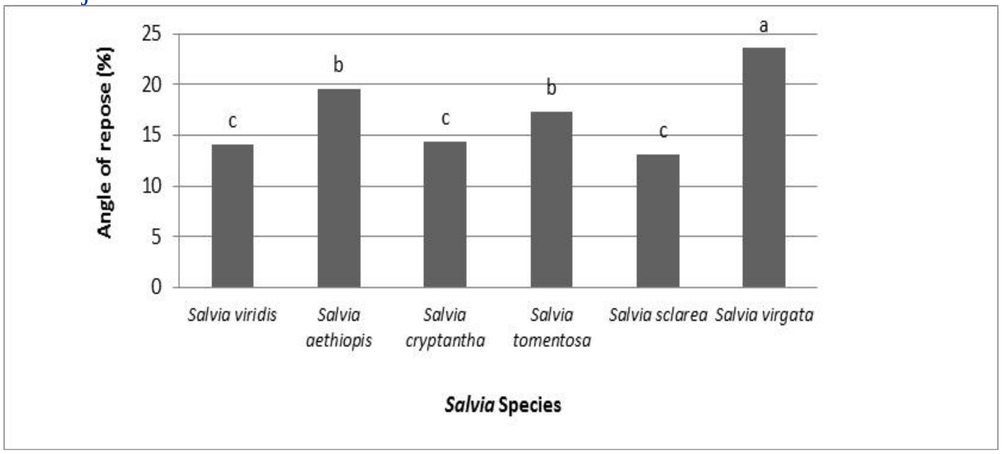

Figure1: Effect of *Salvia* species on angle of repose.

Conclusion

The measured selected engineering (geometrical, volumetrical, colour and frictional) properties of six *Salvia* species seeds will serve to design the equipment used in postharvest treatment and processing of *Salvia* species seeds. The following conclusions are drawn from the investigation on some selected engineering (geometrical, volumetrical, colour and frictional) properties of six *Salvia* species seeds.

1. Among these six *Salvia* species, *Salvia viridis* specie had the the lowest geometric mean diameter and surface area, whereas, *Salvia cryptantha* had the least values for geometric mean diameter and surface area. Bulk density of *Salvia* seeds was found the highest for *Salvia sclarea* and the lowest values for *Salvia tomentosa,* whereas, the highest true density was observed for *Salvia cryptantha* among the six *Salvia* species.
2. The hue angle ranged from 42.32 to 53.09° with the highest value for *Salvia sclarea* and the lowest for *Salvia viridis* among the six *Salvia* species *Salvia cryptantha* showed the lowest static coefficient of friction for laminate among five surfaces, respectively. Static friction coefficient of salvia species largely influenced by friction surfaces. The lowest and the highest angle of repose of the studied species were found in *Salvia sclarea* and *Salvia virgata*, respectively. The laminate surface offered the minimum static coefficient of friction among test surfaces for all *Salvia* species.

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