Mustafa Bayram¹, Ebubekir Altuntas¹* Melih Yilar²

¹Department of Biosystem Engineering, Faculty of Agriculture, University of Gaziosmanpasa, Tokat-Turkey.  
²Department of Plant Protection, Faculty of Agriculture, University of Ahi Evran, Kirsehir-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, volumetric, 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-Augst). 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 mm³, 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 cryptantha 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 Lamiaeaceae 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 Lamiaeaceae 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). Lamiaeaceae family seeds contain large amount of oils, and are, therefore, economically important because of the oils. In recent years, many species of Lamiaeaceae family have provided alternatives to conventional, synthetic and natural antioxidants. This is because many species of Lamiaeaceae family have been shown to possess strong antioxidant properties (Zupkó et al. 2001). Salvia species (Lamiaeaceae) 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 (Ipek et al. 2012).
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 ingredient 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 (Yalcın 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 oblance leaves are dull green on the top surface, with the underside covered with glands and think hairs (Wikipedia, 2016 d).

Salvia seeds are prone to dietary and healthy oil rich because they contain in essential fatty acids. Salvia seeds frequently produce mucilage on soaking, 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; Yalcın 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 are important 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 (Krisha 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 fava bean (Kalniewicz et al. 2014), respectively.

No detailed study concern the selected engineering (geometrical, volumetrical, colour and frictional) properties of 6 Salvia species (Salvia viridis L., Salvia aethiopis L., Salvia cryptantha Montbērt & 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.

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 Montbērt & 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 polythene bags to reduce water loss during transport (Table 1). Plants were collected during the vegetation in 2012-2013 (May-August). 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 using a digital electronic balance (ModelNo; 612-1S, Sartorius Secura, Göttingen, Germany, 0.01g. resolution). The geometric mean diameter (D₃), 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% ±0.18 (Salvia cryptantha), 5.49% ±0.10 (Salvia sclarea) 6.73 % ±0.53 (Salvia virgata) (dry basis), respectively.

The geometric mean diameter (D₃), and sphericity (Φ) of Salvia species seeds were determined according to Mohsenin (1970). The volume (V) of Salvia species seeds in mm³ was calculated according Özarslan (2002). The porosity (ε) was determined according to Mohsenin (1970). The surface area (S) of Salvia seeds in mm² 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 metal and 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 Discussion

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

| Species                  | Location                        | Altitude (m) |
|--------------------------|---------------------------------|--------------|
| *Salvia viridis*         | Field-field edge                | 900          |
| *Salvia cryptantha*      | Mountainous area, pasture area  | 1133, 1279   |
| *Salvia aethiopis*       | Wasteland                       | 1166         |
| *Salvia tomentosa*       | Grassland, mountainous area     | 812          |
| *Salvia sclarea*         | Grassland, mountainous area     | 812          |
| *Salvia virgata*         | ‘Yolustu’ village area           | 1132         |
| *Salvia sclarea*         | Roadside, grassland             | 963          |

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

| *Salvia* species | Length (mm) | Width (mm) | Thickness (mm) | Geometric mean diameter \( D_2 \) (mm) | Sphericity \( \Phi \) (%) | 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      | 2.915b     | 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                  | 24.6388b                    |
|                 | (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...
from 1.13 mm (Salvia viridis) to 2.52 mm (Salvia cryptantha). The length, width and thickness varied statistically significantly for all the six species (P<0.01). The geometric mean diameter (Dg), 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 mm², 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 of the 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 (Coskuner 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 (Onen 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 sclarea 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 mm³, respectively. The least seed mass and seed volume values were shown by Salvia cryptantha 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, M1000 (g) | Volume V (mm³) | Bulk density, $\rho_b$ (kg m⁻³) | True density, $\rho_t$ (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 04.87 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 seed changed from 840 to 696 kg cm⁻³ and 1361 to 1207 kg cm⁻³ with the increase in moisture content between 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 density of cumin seed varied from 410 to 502 kg m⁻³ and Selvi et al. (2006) found between 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 characteristics 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
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     | Laminate | Plywood | Silicone | Rubber | Galvanized metal | F value |
|----------------------|----------|---------|----------|--------|------------------|---------|
| *Salvia viridis*     | 0.601c   | 0.894a  | 0.763b   | 0.736b | 0.712b           | 34.19** |
|                      | (0.014)  | (0.032) | (0.009)  | (0.025) | (0.025)          |         |
| *Salvia aethiopis*   | 0.638c   | 0.920a  | 0.633c   | 0.794b | 0.655c           | 10.52** |
|                      | (0.067)  | (0.052) | (0.022)  | (0.031) | (0.018)          |         |
| *Salvia cryptantha*  | 0.477d   | 0.959a  | 0.675b   | 0.643b | 0.601c           | 222.25**|
|                      | (0.006)  | (0.029) | (0.010)  | (0.006) | (0.010)          |         |
| *Salvia tomentosa*   | 0.607b   | 0.906a  | 0.743ab  | 0.771ab| 0.656b           | 0.05**  |
|                      | (0.025)  | (0.135) | (0.200)  | (0.021) | (0.084)          |         |
| *Salvia sclarea*     | 0.517c   | 0.763a  | 0.668b   | 0.695b | 0.653b           | 16.46** |
|                      | (0.007)  | (0.009) | (0.046)  | (0.015) | (0.051)          |         |
| *Salvia virgata*     | 0.640a   | 0.901b  | 0.658a   | 0.727a | 0.646a           | 11.75*  |
|                      | (0.054)  | (0.032) | (0.096)  | (0.012) | (0.048)          |         |

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 was higher 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 sclarea* 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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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 highest 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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Figure 1: Effect of Salvia species on angle of repose.
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