Physico-chemical Properties of Seeds in Valuable Medicinal Species of the Genus *Salvia* L.

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Abstract

Background: **The seeds of some medicinal plants and their compounds have long been valued for their numerous health benefits.**
Objective: **To investigate some physical and chemical properties of *Salvia* spp.**
Methods: **Some physico-chemical properties in five species of *Salvia* seeds (consisted of *S. officinalis* L., *S. macrosiphon* L., *S. hypoleuca* L., *S. sclarea* L. and *S. nemorosa* L.) were measured at 8.73 ± 0.09% moisture content (d.b.) in four categories of large, medium, small size and ungraded lots with replication.**
Results: **The largest major diameter (L_1) value was recorded in *S. hypoleuca* L. The highest intermediate (L_2) and minor diameters (L_3), seed weight, volume, surface area, sphericity, arithmetic, geometric and square mean diameters, equivalent diameter and mucilage content were obtained in *S. officinalis* L. seeds. Also, the most percentage of oils content was observed in *S. sclarea* seeds. Maximum kurtosis index was obtained in *S. officinalis* L. for major and minor diameter, surface area, sphericity, arithmetic, geometric and square mean diameters and equinalant diameter, in *S. hypoleuca* L. for intermediate diameter and seed volume, and in *S. nemorosa* L. for seed weight. The highest skewness index was observed in *S. hypoleuca* L. for minor diameter, seed volume, surface area, arithmetic and square mean diameter and equivalent diameter, in *S. nemorosa* L. for major diameter and seed weight, in *S. officinalis* L. for intermediate diameter and sphericity, and in *S. sclarea* L. for geometric mean diameter.**
Conclusion: **The maximum content of mucilage and oils were found in *S. officinalis* and *S. sclarea*, respectively. The mucilage content was significantly correlated to minor diameter and sphericity, while there was not significant correlation between content of seed oils and measured parameters.**

Keywords: ***Salvia officinalis, S. macrosiphon, S. hypoleuca, S. sclarea, S. nemorosa,*** **Physico-chemicalproperties, Seed**

Introduction

The genus *Salvia* L. belongs to the family Lamiaceae and comprises about 900 species all over the world [1]. Information on physical and aerodynamical properties of agricultural products is needed to design and adjustment of machines used during harvesting, separating, cleaning and handling and storing of agricultural materials and to convert them into food, feed and fodder. The properties which are useful during design must be known and these properties must be determined at laboratory conditions. The geometric properties such as size and shape are of the most important physical properties considered during the separation and cleaning of medicinal and field crops seeds. In theoretical calculations, seeds of medicinal plants are assumed to be spheres or ellipse because of their irregular shapes [2, 3]. In recent years, salvia seeds have become important for human health and nutrition because of their high content of α-linolenic fatty acid and beneficial health effects arising from consuming the ω-3 fatty acids it contains [4]. Seeds of family Lamiaceae are economically important due to presence of oil materials and so they must be regarded as a new source of edible oil. Knowledge about oils in the Lamiaceae plant seeds relates mainly to the discovery of new, economically important oil resources in which a number of species from different genera were analyzed [5]. Chia (*Salvia hispanica*), *Perilla*, *Lallementia*, *Elsholtzia*, *Dracocephalum* and some other genera were also investigated and evaluated for use as alternative oilseed crops or renewable resources [6, 7].

No detailed study concerning the physico-chemical properties of different common species of *salvia* seeds have been reported. Hence, the present study was undertaken to (i) determine chemical properties including mucilage and oils content (ii) determine the important physical properties for five common species of *Salvia* seeds.

Materials and Methods

The *Salvia* seeds used in this study were obtained from the seed bank of Iranian Academic Centre for Education, Culture & Research (ACECR) Institute of Medicinal Plants. The species consisted of *Salvia officinalis* (422-MPISB), *S. macrosiphon* (209-MPISB), *S. hypoleuca* (21-MPISB), *S. sclarea* (103-MPISB), and *S. nemorosa* (27-MPISB) (Figure 1).

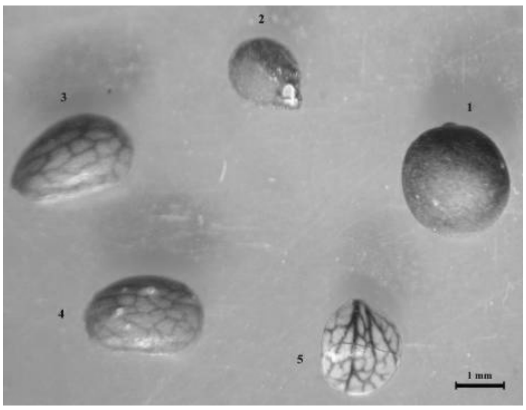

Figure 1- *Salvia* seeds consisted of *S. officinalis* (1), *S. nemorosa* (2), *S. hypoleuca* (3), *S. sclarea* (4), and *S. macrosiphon* (5)

The samples were cleaned manually to remove all foreign material, dust, and dirt, broken and immature seeds. They were put in a thick polyethylene bag and kept in cold storage at 5 ˚C for 72 h. They were then removed and spread on a table at room temperature of 25-27˚C for 3h before making any measurements. Twenty of the seeds were used to determine the initial moisture content of the seeds using the ASAE Standards [8]. The initial moisture content was found to be 8.73 ± 0.09% (d.b.). The remaining 100 seeds were mixed thoroughly and randomly selected and labeled for easy identification, using a sampling method similar to that used by Dutta et al., (1988) and Joshi et al., (1993) [9, 10].

For each individual seed the principal dimensions of major (L_1), intermediate (L_2) and minor (L_3) diameters were measured using a vernier caliper (to 0.01 mm). Since seed size plays an important role in handling, processing and storage, under approximately the same operating conditions [11], the bulk seed sample was classified into small, medium and large categories based on the major diameter and their frequency distribution by number determined and recorded as for their skewness index and kurtosis index. Using the measured dimensions, the following size descriptors (1) were calculated.

Equivalent diameter $D_e = (F_1 + F_2 + F_3)/3$ (1)[12]

Where F_1= Arithmetic mean diameter = $(L_1+L_2+L_3)/3$

F_2= Geometric mean diameter = $(L_1L_2L_3)^{1/3}$

F_3= Square mean diameter = $[(L_1L_2 + L_2L_3 + L_3L_1)/3]^{1/2}$

Its sphericity was calculated using the following equation (2) [13, 14]

$S=F_2/L_1$ (2)

Even though the determination of the surface area of irregular seeds is difficult, the surface area (A_s) of *Salvia* seed was first obtained by tracing method [15] and calculated using the planimeter. The result was subjected to statistical analysis compared to results from the following equations (3) and (4).

$A_s = \pi D_e^2$ (3)

And A_{sp}= (k) $6/D_e$ (4) [16]

Where k = constant depending on seed shape, since the equation was developed for grains.

While the weight of each seed was determined using a precision electronic balance reading up to 0.0001 g with an accuracy of ± 0.2 mg, the volume of the individual seeds was obtained by the liquid displacement method using a top loading balance [9, 17, 18]. The experiment was done at room temperature of 25-27°C and 53-58% RH. The seeds were rubbed with oil before immersion in the water in the beaker which lasted 3-5 sec. For the few seeds that floated in the water, a rod sinker was used to submerge them without the sinker displacing water. The mass of the displaced water is the balance reading with the seed submerged minus the mass of the beaker and water. The seed volume is expressed as V (cm^3) = [mass of displaced water (g) / density of water ($g.cm^{-3}$)] (5).

Isolation and extraction of mucilage

Salvia seeds (200 g) were soaked in distilled water (1.5 L) at room temperature for 1 h and then boiled under stirring condition in a water bath until the slurry was prepared. The solution was cooled and kept in a refrigerator overnight to settle out undissolved materials. The upper clear solution was decanted and centrifuged at 500 rpm for 20 min. The supernatant was separated and was concentrated at 60˚C on a water bath to one third of its original volume. The solution was cooled to the room temperature and was poured into thrice the volume of acetone with continuous stirring. The dried material was powdered and kept in a desiccator [19].

Determination of oils (fixed oils), using the soxhlet method

Oils are soluble in organic solvents, but sparingly soluble or insoluble in water. Extraction of oils into hexane or low-boiling petroleum ether is easily achievable, provided that the moisture content of the sample does not exceed 10%. This method may be used for quantitation of oils in both low-fat and high-fat source materials but it removes mainly nonpolar oils from samples as polar oils are generally scarcely soluble in nonpolar solvents The extraction and measurement of oils may require several steps, these include (1) Grind 60 g seeds or nutmeg in a coffee grinder with occasional shaking for 1 to 2 min. (2) Weigh exactly 20 g of sample into cellulose extraction thimbles. Cover the top of each thimble with glass wool to prevent floating. (3) Weigh the pre-dried flat-bottom extraction flask with a few boiling chips or glass beads. (4) Extract oils with 150 to 200 mL of hexane or petroleum ether at the boiling point for 7 to 12 h in a soxhlet extract using a heating mantle. The condensation rate for the solvent should be set at about 2 to 6 drops per second, depending on the extraction period envisaged. For longer extraction periods, a lower condensation rate is selected and vice versa. Usually an extraction period of 8 h at a rate of 150 drops per min is considered adequate. The boiling point of hexane is ~69˚C. (5) Let the sample cool. (6) Remove the solvent from the extract in a rotary evaporator at 40˚C under reduced pressure. (7) Calculate amount of oil recovered and its percentage in the original sample as given as given below [20]:

Mass of oil = (weight of the flask + boiling chips + extracted oil) – (weight of the flask + boiling chips). Oil content (%) = mass of oil extracted (g) / sample weight (g) × 100.

Results

The size distribution and physical properties for the different varieties of *Salvia* seeds is presented in Tables 1 and 2. In ungraded, large and medium lot, the largest major diameters with average dimensions of 2.71 ± 0.024, 2.92 ± 0.023, 2.72 ± 0.011 were related to *S. hypoleuca*, respectively with negative skewness index (-0.207) and positive kurtosis index (0.008). The seed of *S. sclarea* with the largest major diameter and as small size seeds with average dimension of 2.52 ± 0.010 was positively skewed (0.035) and platykurtic (-0.127). Generally, the highest and positive skewness index (0.115) with *S. nemorosa* seeds and the highest peaked (leptokortic) (2.652) with *S. offifcinalis* seeds were shown in Tables 1 and 3. *S. officinalis* seeds showed the highest intermediate diameter in the ungraded (2.16 ± 0.014), large (2.35 ± 0.006) intermediate (2.19 ± 0.010) and small (2.04 ± 0.010) size seeds. This species had the most and positive skewness index (0.095) and its kurtosis index was platykurtic (-0.717). The maximum and positive kurtosis index (4.562) was related to *S. hypoleuca* (Tables 1 and 3). The largest minor diameters in four size categories were related to *S. officinalis* seeds with skewness index of -0.872 and kurtosis index of 8.128 (Tables 1 and 3). The highest average value for seed weight in ungraded, large and mediumm size seeds were 0.004 ± 0.0002, 0.007 ± 0.0002, 0.005 ± 0.0001, respectively for *S. officinalis*. In Small size seeds the highest weight was related to *S. sclarea* seeds. The seed of *S. nemorosa* showed the maximum and positive skewness index (1.806) and also its kurtosis index was maximum and leptokurtic (4.364) (Tables 1 and 3). The most volume for ungraded (5.43 ± 0.09), large (6.39 ± 0.087), medium (5.40 ± 0.04) and small (4.53 ± 0.14) size seeds were obtained by *S. officinalis*. The volume seed skewed to the right (0.707) and its kurtosis index was leptukortic (2.532) (Tables 1 and 3). In *Salvia* seeds the highest surface area was observed in *S. officinalis* species with four size categories of ungraded (14.99 ± 0.18), large (16.73 ± 0.15), medium (14.89 ± 0.09) and small (13.09 ± 0.32). In this parameter the highest and positive skewness index (0.392) was related to *S. hypoleuca* and the highest kurtosis index as leptokurtic (1.337) to *S. officinalis* seeds (Tables 1 and 3). The maximum average for sphericity in ungraded (0.88 ± 0.005 cm^2), large (0.92 ± 0.009 cm^2), medium (0.87 ± 0.001cm^2) and small (0.85 ± 0.003 cm^2) seeds were obtained in *S. officinalis* seeds with the most and positive skewness index (2.751) and kurtosis index (14.00) (Tables 1 and 3). In arithmetic, geometric and square mean diameters *S. officinalis* seeds had the most average in ungraded, large medium and small lots and their kurtosis index are the most and leptokurtic (Tables 1 and 3). *S. officinalis* seeds showed the most equivalent diameter in three size categories with the most kurtosis index (1.887) (Tables 1 and 3). In phytochemical parameters among all of the species, *S. officinalis* seeds had the highest amount of mucilage (0.4 g), however, in terms of oils percentage, *S. sclarea* seeds showed maximum value (24.14%) (Figures 2 and 3).

Regarding the correlation of the measured traits (Table 4), intermediate diameter was significantly correlated to minor diameter, minor diameter to major diameter and intermediate diameter. Arithmetic mean diameter had significant correlation with major, intermediate and minordiameters, geometric mean diameter with major, intermediate, minor diameters and arithmetic mean diameter; and also square mean diameter with major, intermediate and minor diameters, arithmetic and geometric mean diameters. Equivalent diameter in *Salvia* seeds showed significant correlation to major, intermediate and minor diameters, arithmetic, geometric and square mean diameters. Sphericity was significantly correlated to intermediate and minor diameters, arithmetic, geometric and square mean diameters and equivalent diameter. Surface area had significant correlation with major, intermediate and minor diameters, arithmetic, geometric and square mean diameters, equivalent diameter and sphericity. Seed volume was significantly correlated tomajor, intermediate and minor diameters, arithmetic, geometric and square mean diameters, equivalent diameter, sphericity and surface area. Seed weight showed significant correlation with intermediate and minor diameters, arithmetic, geometric and square mean diameters, equinalent diameter, sphericity, surface area and seed volume. The content of mucilage in *Salvia* seeds was significantly correlated to minor diameter and sphericity and oils content showed insignificant correlation with all of measured parameters.

Table 1- Particulars (average dimensions) Mean + satandard error (SE)

Species	Size category	Average dimensions				
		L_1 (mm)	L_2 (mm)	L_3 (mm)	W (g)	V (cm^3)
S. officinalis	ungraded	2.45 ± 0.019	2.16 ± 0.014	1.94 ± 0.018	0.004 ± 0.0002	5.43 ± 0.09
	Large	2.63 ± 0.023	2.35 ± 0.006	2.08 ± 0.02	0.007 ± 0.0002	6.39 ± 0.087
	Medium	2.45 ± 0.010	2.19 ± 0.010	1.94 ± 0.006	0.005 ± 0.0001	5.40 ± 0.04
	Small	2.23 ± 0.041	2.04 ± 0.010	1.81 ± 0.030	0.001 ± 0.0002	4.53 ± 0.14
S. macrosiphon	ungraded	2.23 ± 0.015	1.98 ± 0.012	1.22 ± 0.009	0.0019 ± 0.00012	2.85 ± 0.047
	Large	2.34 ± 0.008	2.07 ± 0.011	1.34 ± 0.009	0.0031 ± 0.000085	3.21 ± 0.028
	Medium	2.25 ± 0.005	1.96 ± 0.005	1.24 ± 0.005	0.002 ± 0	2.82 ± 0.022
	Small	2.08 ± 0.021	1.84 ± 0.012	1.14 ± 0.008	0.0008 ± 0.000046	2.35 ± 0.059
S. hypoleuca	ungraded	2.71 ± 0.024	1.96 ± 0.023	1.38 ± 0.029	0.0014 ± 0.00010	3.88 ± 0.102
	Large	2.92 ± 0.023	2.17 ± 0.026	1.65 ± 0.077	0.0023 ± 0.00014	4.69 ± 0.141
	Medium	2.72 ± 0.011	2.018 ± 0.010	1.36 ± 0.008	0.0010 ± 0.00002	3.83 ± 0.039
	Small	2.46 ± 0.025	1.75 ± 0.042	1.21 ± 0.030	0.0005 ± 0.000013	3.06 ± 0.090
S. sclarea	ungraded	2.61 ± 0.011	2.04 ± 0.016	1.50 ± 0.010	0.003 ± 0.0001	4.20 ± 0.059
	Large	2.71 ± 0.011	2.17 ± 0.009	1.57 ± 0.009	0.005 ± 00	4.69 ± 0.072
	Medium	2.62 ± 0.003	2.05 ± 0.009	1.49 ± 0.004	0.004 ± 0	4.15 ± 0.019
	Small	2.52 ± 0.010	1.90 ± 0.017	1.39 ± 0.017	0.002 ± 0.0001	3.73 ± 0.063
S. nemorosa	ungraded	1.93 ± 0.012	1.34 ± 0.014	0.96 ± 0.010	0.001 ± 0.00006	1.28 ± 0.023
	Large	2.06 ± 0.011	1.47 ± 0.014	1.05 ± 0.008	0.002 ± 0.00018	1.44 ± 0.000
	Medium	1.93 ± 0.0047	1.36 ± 0.0046	0.96 ± 0.004	0.001 ± 0.00001	1.32 ± 0.016
	Small	1.82 ± 0.010	1.21 ± 0.014	0.85 ± 0.016	0.0009 ± 0.00003	1.02 ± 0.032

L_1, L_2, L_3, W and V are abbreviations for major, intermediate and minor diameter, seed weight and seed volume, respectively.

Table 2- Calculated physical properties of *Salvia* seeds

Species	Size category	As (cm^2)	Sp	F_1 (mm)	F_2 (mm)	F_3 (mm)	De (mm)
S. officinalis	ungraded	14.99 ± 0.18	0.88 ± 0.005	2.18 ± 0.013	2.17 ± 0.013	2.18 ± 0.013	2.18 ± 0.013
	Large	16.73 ± 0.15	0.92 ± 0.009	2.34 ± 0.014	2.27 ± 0.010	2.27 ± 0.010	2.29 ± 0.010
	Medium	14.89 ± 0.09	0.87 ± 0.001	2.19 ± 0.008	2.14 ± 0.005	2.17 ± 0.004	2.19 ± 0.005
	Small	13.09 ± 0.32	0.85 ± 0.003	2.003 ± 0.036	2.01 ± 0.031	2.08 ± 0.017	2.08 ± 0.017
S.macrosiphon	ungraded	10.05 ± 0.113	0.78 ± 0.002	1.81 ± 0.010	1.75 ± 0.010	1.78 ± 0.010	1.78 ± 0.010
	Large	10.87 ± 0.060	0.80 ± 0.002	1.88 ± 0.004	1.83 ± 0.005	1.87 ± 0.005	1.85 ± 0.005
	Medium	10.02 ± 0.053	0.77 ± 0.001	1.81 ± 0.003	1.75 ± 0.005	1.80 ± 0.005	1.78 ± 0.003
	Small	8.90 ± 0.148	0.75 ± 0.002	1.72 ± 0.013	1.64 ± 0.015	1.68 ± 0.014	1.69 ± 0.013
S. hypoleuca	ungraded	12.38 ± 0.20	0.71 ± 0.005	2.02 ± 0.016	1.94 ± 0.017	1.98 ± 0.016	1.98 ± 0.016
	Large	14.001 ± 0.24	0.75 ± 0.005	2.17 ± 0.020	2.07 ± 0.019	2.10 ± 0.016	2.08 ± 0.015
	Medium	12.30 ± 0.086	0.71 ± 0.0009	2.050 ± 0.006	1.95 ± 0.006	1.96 ± 0.007	1.95 ± 0.006
	Small	10.59 ± 0.18	0.67 ± 0.012	1.89 ± 0.013	1.80 ± 0.018	1.82 ± 0.016	1.82 ± 0.016
S. sclarea	ungraded	12.92 ± 0.118	0.76 ± 0.003	2.05 ± 0.009	2.00 ± 0.009	2.02 ± 0.009	2.02 ± 0.009
	Large	14.21 ± 0.15	0.79 ± 0.001	2.14 ± 0.010	2.06 ± 0.010	2.10 ± 0.010	2.10 ± 0.010
	Medium	12.97 ± 0.05	0.76 ± 0.001	2.05 ± 0.0041	1.98 ± 0.003	2.02 ± 0.003	2.02 ± 0.003
	Small	12.002 ± 0.119	0.74 ± 0.004	1.97 ± 0.009	1.91 ± 0.011	1.95 ± 0.009	1.95 ± 0.009
S.nemorosa	ungraded	6.05 ± 0.090	0.70 ± 0.003	1.41 ± 0.010	1.35 ± 0.010	1.38 ± 0.010	1.38 ± 0.010
	Large	6.86 ± 0.075	0.72 ± 0.003	1.49 ± 0.007	1.43 ± 0.007	1.47± 0.008	1.46 ± 0.007
	Medium	6.18 ± 0.042	0.69 ± 0.001	1.40 ± 0.004	1.35 ± 0.005	1.40 ± 0.005	1.38 ± 0.005
	Small	5.28 ± 0.094	0.65 ± 0.005	1.31 ± 0.013	1.24 ± 0.014	1.29 ± 0.012	1.28 ± 0.013

As, Sp, F_1, F_2, F_3 and D_e are abbreviations for surface area, sphericity, arithmetic, geometric and square mean diameter and equivalent diameter, respectively.

Table 3- Skewness index and kurtosis index tests for measured parameters in *Salvia* seeds

Species		L_1 (mm)	L_2 (mm)	L_3 (mm)	W (g)	V (cm^3)	As (cm^2)	Sp	F_1 (mm)	F_2 (mm)	F_3 (mm)	De (mm)
S. officinalis	Skewness	-0.636	0.095	-0.872	-0.162	-0.345	-0.493	2.751	-0.642	-0.811	-0.717	-0.722
	Kurtosis	2.652	-0.717	8.128	-0.881	1.0587	1.337	14.00	1.635	2.204	1.862	1.887
S. macrosiphon	Skewness	-1.149	0.002	-0.067	0.258	-0.556	-0.734	0.374	-0.895	-0.802	-0.861	-0.858
	Kurtosis	1.851	0.261	-0.234	-0.969	0.103	0.389	0.106	0.771	0.576	0.680	0.679
S. hypoleuca	Skewness	-0.207	-1.478	1.852	1.269	0.707	0.392	-0.212	0.183	-0.058	0.118	0.125
	Kurtosis	0.008	4.562	7.651	1.436	2.532	1.179	13.22	0.313	2.046	0.882	0.880
S.sclarea	Skewness	0.035	-0.609	-0.490	-0.754	0.311	0.209	-1.250	0.140	0.013	0.066	0.079
	Kurtosis	-0.127	0.508	1.714	-0.080	0.844	0.555	2.961	0.268	0.931	0.565	0.576
S. nemorosa	Skewness	0.115	-0.211	-0.878	1.806	-1.140	-0.404	-0.559	-0.522	-0.709	-0.620	-0.617
	Kurtosis	-0.331	0.086	1.576	4.364	1.071	0.426	0.636	0.735	1.099	0.920	0.920

L1, L2, L3, W, V, As, Sp, F1, F2, F3 and De are abbreviations for major, intermediate and minor diameter, seed weight, seed volume, surface area, sphericity, arithmetic, geometric and square mean diameter and equivalent diameter, respectively.

Table 4- The correlation of the measured Traits in *Salvia* seeds

	L_1	L_2	L_3	F_1	F_2	F_3	De	Sp	As	V	W	Mucilage	Oils
L_1	1												
L_2	0.80^{**}	1											
L_3	0.66^{**}	0.88^{**}	1										
F_1	0.88^{**}	0.96^{**}	0.91^{**}	1									
F_2	0.85^{**}	0.96^{**}	0.93^{**}	0.99^{**}	1								
F_3	0.84^{**}	0.96^{**}	0.93^{**}	0.99^{**}	0.99^{**}	1							
De	0.82^{**}	0.96^{**}	0.94^{**}	0.99^{**}	0.99^{**}	0.99^{**}	1						
S	0.35^{ns}	0.78^{**}	0.88^{**}	0.71^{**}	0.75^{**}	0.76^{**}	0.77^{**}	1					
As	0.84^{**}	0.95^{**}	0.94^{**}	0.99^{**}	0.99^{**}	0.99^{**}	0.99^{**}	0.76^{**}	1				
V	0.79^{**}	0.92^{**}	0.97^{**}	0.97^{**}	0.98^{**}	0.97^{**}	0.98^{**}	0.80^{**}	0.99^{**}	1			
W	0.39^{ns}	0.62^{*}	0.74^{**}	0.61^{*}	0.62^{*}	0.62^{*}	0.63^{*}	0.81^{**}	0.68^{**}	0.72^{**}	1		
Mucilage	0.07^{ns}	0.33^{ns}	0.71^{*}	0.34^{ns}	0.37^{ns}	0.38^{ns}	0.38^{ns}	0.74^{*}	0.40^{ns}	0.47^{ns}	0.47^{ns}	1	
Oils	0.24^{ns}	-0.06^{ns}	-0.24^{ns}	-0.031^{ns}	-0.06^{ns}	-0.05^{ns}	-0.06^{ns}	-0.36^{ns}	-0.05^{ns}	-0.12^{ns}	-0.08^{ns}	-0.48^{ns}	1

Ns, nonsignificant; *, significant at $p<0.05$; **, significant at $p<0.01$. L1, L2, L3, W, V, As, S, F1, F2, F3 and De are abbreviations for major, intermediate and minor diameter, seed weight, seed volume, surface area, sphericity, arithmetic, geometric and square mean diameter and equivalent diameter, respectively.

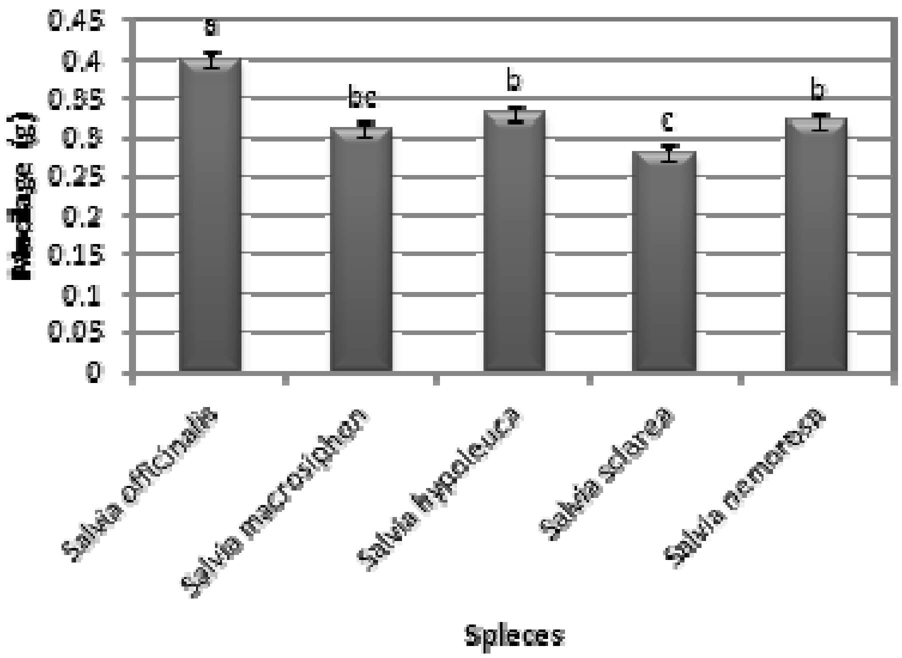

Figure 2- The amount of mucilage (g) in different species of *Salvia* seeds

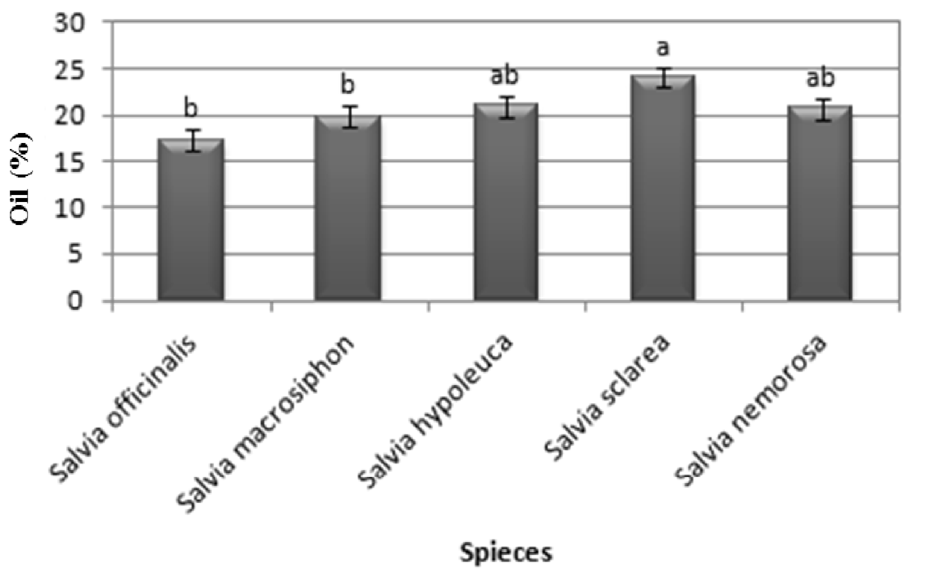

Figure 3- The amount of oil (%) in different species of *Salvia* seeds

Discussion

The axial seed dimensions in medicinal plants have an important role in determining aperture sizes used in the design of seed handling machinery and storing. Furthermore, the geometric mean of axial seed dimensions is useful to define the characteristics of the behavior of irregular shaped seeds [13]. Sphericity is a degree of irregularity for an incompletely spherical shape of a solid seed relative to the same volume of same materials with a complete sphere [21]. The results for sphericity indicate that *Salvia* seeds can roll rather than slide especially in *S. officinalis*and *S. macrosiphon*. It has been reported that the practical significance of volume is in the design of sowing and sizing machinery.*S. officinalis* seeds had the most weight and volume in different size categories. As it is shown in Fig. 1 and 2, the highest content of mucilage was related to*S. officinalis*, while the lowest amount of oils is found in this species. It indicates that among *Salvia* seeds, medicinal species of *S. officinalis*withheavy and massive seeds have more amount of mucilage and these properties are related to each other. On the contrary the lowest percent of oils was observed in this species. *S. sclarea* with highest amount of oils, after *S. officinalis* from the viewpoint of weight and volume, is the best species for oil extraction. Similar results have been reported by Sacilik et al. (2003) for hemp seeds, Sirisomboon et al. (2006) for green soybean, Ozarslan (2002) for cotton seeds, Aviara et al. (1999) for guna seeds, Konak et al. (2002) for mahaleb kernels, Altuntaş et al. (2005) for fenugreek seeds and Çetin (2006) for barbunia bean [21 - 28].

In according to Fig. 1 and 2, *S. hypoleuca* seeds with largest major diameter showed the average amount of mucilage and oils extracts. *S. officinalis* seeds with the most intermediate and minor diameter, surface area, sphericity, arithmetic, geometric and square mean diameter and also equivalent diameter had the highest content of mucilage, while they showed the lowest amount of oil in their extraction (Table 1 and 2; Figure 2 and 3).

Conclusion

In conclusion, through physical properties (except for major diameter) can be foreseen the amount and yield of phytochemicals especially content of seed mucilage and these parameters are related to each other. The most content of mucilage and oils were found in *S. officinalis* and *S. sclarea*, respectively. The mucilage content was significantly correlated to minor diameter and sphericity, while there was not significant correlation between content of seed oils and measured parameters.

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