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# PHYSICAL PROPERTIES 0F CUMIN (CUMINUM CYMINUM) AND CARAWAY (CARUM CARVI) SEEDS

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**ABSTRACT** Cumin and caraway seeds are two important agricultural commodities growing in western Asia and Iran, which are usually consumed as spices. Also, these products are widely used as herbaceous medicine. Physical properties of cumin and caraway seeds are vital parameters regarding the design of the planting and post harvest processing equipments such as metering devices, sieves, sorters and conveyers. In this study, physical properties of cumin and caraway seeds were measured at constant moisture content (7.5% d.b.) and compared statistically. The average of thousand weight of grains, mean length, mean width, mean thickness, equivalent diameter, geometric mean diameter, surface area, volume, sphericity, aspect ratio, true density, bulk density and porosity were 2.905 g, 4.553 mm, 1.185 mm, 0.817 mm, 1.654 mm, 1.634 mm, 7.964 $mm^2$, 2.487 $mm^3$, 36.24%, 0.266, 1155.6 $kg/m^3$, 622.0 $kg/m^3$ and 46.18 %, respectively, for cumin-seed. In the case of caraway-seed, the corresponding values were 1.583 g, 3.941 mm, 1.016 mm, 0.618 mm, 1.377 mm, 1.348 mm, 5.469 $mm^2$, 1.400 $mm^3$, 34.61%, 0.262, 1294.1 $kg/m^3$, 736.5 $kg/m^3$ and 43.08%. For green cumin, the average static coefficient of friction varied from 0.312 on aluminium to 0.569 on plywood, while for caraway seeds the corresponding value varied from 0.277 to 0.535 on the same surfaces. The angle of repose values for cumin and caraway seeds were 47.7º and 49.8º, respectively. Furthermore, there were significant differences in most physical properties of cumin and caraway seeds excepted for grain porosity.

**Keywords:** Physical properties, cumin-seed, caraway-seed, friction coefficient, angle of repose

**NOMENCLATURE**

| | | | |
|---|---|---|---|
| $L$ | length of grain, mm | $S$ | surface area of grain, $mm^2$ |
| $W$ | width of grain, mm | $\rho_t$ | true density, $kg/m^3$ |
| $T$ | thickness of grain, mm | $\rho_b$ | bulk density, $kg/m^3$ |
| $D_P$ | equivalent diameter, mm | $\varepsilon$ | porosity, decimal |
| $D_g$ | Geometric mean diameter, mm | $\phi$ | sphericity, decimal |
| $V$ | volume of grain, $mm^3$ | $R_a$ | aspect ratio, decimal |
| $\mu_s$ | coefficient of static friction, decimal | $R^2$ | determination correlation |

**INTRODUCTION** Cumin is one of the most important medicine and spicy plants in the world grown in Iran and other countries since many years ago. There are two types of Cumin seeds. Cumin (cuminum cyminum) called green cumin in Iran, is a small gramineous plant with 15 to 50 cm height, long and thin roots having very thin leaves and white or pink flowers. This plant is native of Egypt and Nile shores. Caraway (carum carrvi) called black cumin in Iran, is a two-year plant with 30 to 60cm height having empty stems and thin light green leaves which is native of a limited area of west Asia including east regions of Iran. Due to their numerous applications in producing of medicine and food additives planting of these plants have increased in recent years. Iran is one of exporters of these products nowadays. Physical properties are very important factors in designing agricultural equipments such as dryers, aerators, cleaners, and conveyers. Measuring principal axial dimensions of grain is important in selecting grain separating sieves and removing foreign materials from product as well as calculating surface area, volume and sphericity of grain which are useful in designing postharvest equipments.

The equivalent spherical diameter (ESD) of an irregularly-shaped object is the diameter of a sphere of equivalent volume (Jennings and Parslow, 1988). The geometric average is useful in estimation of projected area for a particle moving in the turbulent or near-turbulent region of an air stream (Omobuwajo et al., 2000). Static friction is friction between two solid objects that are not moving relative to each other. The coefficient of static friction, typically denoted as $\mu_s$, is usually higher than the coefficient of kinetic friction. The static coefficient friction for a grain shows that in which angle of chute the seed has the most ability to have a consistent flow which is so important in designing of transport machines and tank discharge hoppers. The angle of repose (sometimes incorrectly confused with 'angle of internal friction') is an engineering property of granular materials. It is the maximum angle of a stable slope determined by friction, cohesion and shapes of grain. The angle of repose is sometimes used in designing of equipment for processing of particulate solids. For example, it may be used in designing an appropriate hopper or silo to store the material. The angle of hopper wall must be greater than the angle of repose to ensure continuous flow of materials by gravity. Knowing frictional properties is important for optimum designing of mechanical transmission systems of conveyors, helixes etc. Thousand grain weight of cumin is used for calculating the bulk density and also porosity of gain. Bulk density is the ratio of sample mass to its total volume. It is a moisture dependent property and is found by filling a standard container with grain by pouring it from a certain height, striking off the top level and then weighing the contents (Dutta et al., 1988). The bulk density of grains is useful in designing silos and storage bins (Nalladulai et al., 2002). The true density of a matter is the mass of sample per occupied solid volume. Bulk density, true density, and porosity (the ratio of inter granular space to the total space occupied by the grain) are useful in sizing grain hoppers and storage facilities (Thompson and Isaacs, 1967). They can affect the rate of heat and mass transfer during aeration and drying processes. Cereal grain kernel densities have been of interest in breakage susceptibility and hardness studies (Morita et al., 1987). No detailed study on physical properties of cumin has been reported until now. Therefore, our aim in this study is to measure the physical properties of the cumin seeds which are very important in designing of grain handling and processing machinery.

**MATERIALS AND METHODS** Green and black cumin seeds were obtained from local shops. Before measuring properties of grains, foreign matters such as dust, stones, straw and chaff were removed manually. The initial moisture content of seeds was determined by using a standard method (USDA, 1970; Brusewitz, 1975). The average moisture content was 7.5% (d.b.). Using digital micrometer with accuracy of 0.001mm, the principle dimensions (Length, width and thickness) of the cumin and caraway grains which were randomly selected were measured. Weight of 1000 grains of two types of caraway and cumin seeds were measured by an electronic balance having the accuracy of 0.001g.

Calculating grain volume (v) and surface area was performed using the following equations (Jain and Bal, 1997).

$$V = 0.25\left[(\frac{\pi}{6})L(W+T)^2\right] \tag{1}$$

$$S = \frac{\pi B L^2}{(2L-B)} \tag{2}$$

where B is calculated as:

$$B = \sqrt{WT} \tag{3}$$

The bulk density ($\rho_b$) of grains was determined using the relationship of mass/volume by filling an empty plastic container with predetermined volume from grains and measuring the tare weight of the grains.

The true density of grains ($\rho_t$) was determined using a pycnometer and the method of toluene displacement (Mohsenin, 1986). Then the porosity ($\varepsilon$) of grains was computed by (Jain and Bal, 1997):

$$\varepsilon = \frac{(\rho_t - \rho_b)}{\rho_t} \times 100 \tag{4}$$

The aspect ratio of a shape is the ratio of its longer dimension to its shorter dimension. The aspect ratio of grains was calculated as (Maduako and Faborode, 1990):

$$R_a = \frac{W}{L} \tag{5}$$

The equivalent diameter ($D_p$) for a grain, was calculated by (Mohsenin, 1986):

$$D_P = \left( L \frac{(W+T)^2}{4} \right)^{\frac{1}{3}} \quad (6)$$

The geometric mean diameter for each sample was calculated using following relationship:

$$D_g = (LWT)^{\frac{1}{3}} \quad (7)$$

Sphericity of a grain is the ratio of the surface area of a sphere (with the same volume as the given particle) to the surface area of the grain. This parameter can be determined as (Mohsenin, 1986):

$$\phi = \frac{(LWT)^{\frac{1}{3}}}{L} = \frac{D_g}{L} \quad (8)$$

The angle of repose for grains was measured using the instrument shown in Fig.1 consisting of a plywood box of 140×160×35mm and two fixed and adjustable plates. For measuring the angle of repose, the box was filled with sample, and then the adjustable plate was inclined gradually allowing the seeds to flow (Tabatabaeefar, 2003).

Static coefficient of friction was measured on different surface of wood, aluminium and painted metal. For this purpose a cylinder with the diameter and depth of 75mm and 50mm was filled with grains, the cylinder was mounted on a surface and the slope of the surface was increased gradually. When the cylinder started to slide down, the angle value was measured. The value of static friction coefficient was calculated from below equation:

$$\mu_s = tg\alpha \quad (9)$$

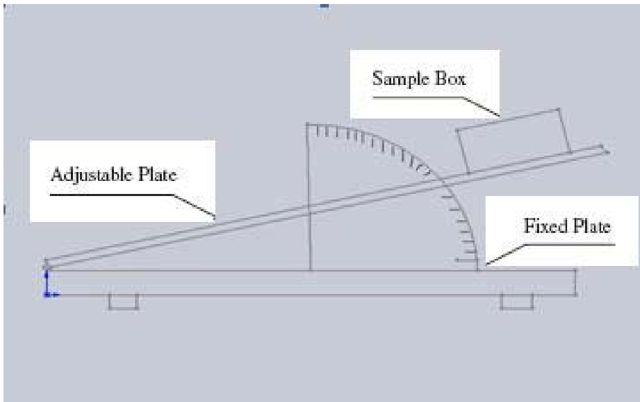


Figure 1. Schematic of instrument for measuring angle of repose and static coefficient of friction

The internal friction angle for both cumin and caraway seeds was measured using a shear cell tester, different normal loads were applied and the sample were sheared until failure occurs, using curve fitting method on shear-normal stress data, the slope of curve was introduced as internal friction coefficient.

The normal stresses caused by applied forces ($F_n$) calculated as:

$$\delta = F_n / A \qquad (10)$$

The shear stress at the moment of failure calculated using below equation:

$$\tau = F_t / A \qquad (11)$$

A is cross sectional area of ring filled with sample and $F_t$ is the shear force at the time of failure.

In this study 1, 2 and 3 kg of weights were applied for normal force. The statistical data analysis was done using "SPSS15" software.

**RESULTS AND DISCUSSIONS** A summary of some physical properties of green and black cumin is shown in the table 1. Statistical analysis showed that there were significant differences ($p<0.01$) in the length, width and thickness of grains between green and black cumin seeds. The averages of length, width and thickness for green cumin were found to be 4.553, 1.185, and 0.817 mm, respectively, while 3.941, 1.016, and 0.618mm were measured for black cumin. The averages sphericity of green and black cumin were observed 0.362 and 0.346, respectively which are in the range of 0.32-1 reported by Mohsenin (1986). Based on statistical analysis there were no significant difference in the sphericity of green and black cumin grains. The averages equivalent diameters for green and black cumin seeds were significantly different ($p<0.01$) with value of 1.654 and 1.377 mm, respectively. Geometric mean diameters for grains were calculated 1.634 mm for green cumin and 1.348 mm for black cumin grains and also in this case there were a significant difference in geometric mean diameters ($p<0.01$). The aspect ratio values are shown in the table1. There were no significant differences in aspect ratio of two types of cumin.

There were significant differences in grain volume and surface area of green and black cumin shown in table 1. Ratio of volume per unit surface area calculated 0.312 for cumin seeds and 0.256 for caraway seeds. Any particle that has smaller ratio of volume per unit surface has better condition for rapid heat transfer (Stroshine and Hamann, 1994) this means that caraway seeds consume less time and energy in drying process. Average bulk density of green and black cumin seeds were calculated 622 $kg/m^3$ and 736.6 $kg/m^3$, respectively. With the same weight, black cumin grains require less space for storage. The value of bulk and true density for green and black cumin grains are shown in table 1 and a significant difference was observed for two types of cumin density.

Table 1: Some physical properties of green and black cumin seeds

| property | No. of observation | Green cumin | | | | Black cumin | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Max | Min | SD | Mean | Max | Min | SD |
| Length( $mm$ ) | 30 | 4.553 | 6.19 | 3.02 | 0.697 | 3.941 | 5.16 | 2.81 | 0.568 |
| Width( $mm$ ) | 30 | 1.185 | 1.53 | 0.89 | 0.133 | 1.016 | 1.21 | 0.80 | 0.120 |
| Thickness( $mm$ ) | 30 | 0.817 | 1.60 | 0.63 | 0.068 | 0.618 | 0.74 | 0.51 | 0.055 |
| Equivalent diameter( $mm$ ) | 30 | 1.654 | 2.475 | 1.317 | 0.207 | 1.377 | 1.629 | 1.192 | 0.124 |
| Geometric mean diameter( $mm$ ) | 30 | 1.634 | 2.474 | 1.294 | 0.21 | 1.348 | 1.578 | 1.17 | 0.118 |
| Sphericity (%) | 30 | 36.24 | 44.41 | 27.44 | 3.802 | 34.61 | 45.44 | 30.03 | 3.703 |
| Aspect ratio | 30 | 0.266 | 0.369 | 0.171 | 0.046 | 0.262 | 0.405 | 0.202 | 0.048 |
| Volume( $mm^3$ ) | 30 | 2.487 | 7.938 | 1.197 | 1.167 | 1.4 | 2.262 | 0.886 | 0.388 |
| Surface area( $mm^2$ ) | 30 | 7.964 | 17.414 | 4.671 | 2.214 | 5.469 | 7.727 | 3.849 | 1.023 |
| Bulk density(kg/m³) | 5 | 622.0 | 628.5 | 617.3 | 4.554 | 736.5 | 739.3 | 731.7 | 2.865 |
| True density(kg/m³) | 5 | 1155.6 | 1186.3 | 1121.2 | 27.358 | 1294.1 | 1313.5 | 1278.2 | 14.424 |
| Thousand weight of grains | 5 | 2.905 | 2.912 | 2.897 | 0.006 | 1.583 | 1.591 | 1.575 | 0.013 |
| Angle of repose(deg) | 5 | 47.7 | 48 | 47 | 1.17 | 49.8 | 51 | 48 | 1.13 |

The static coefficient of friction for green and black cumin seeds on different surfaces is shown in the table 2. Statistical analysis showed a significant difference in the static coefficient of friction of green and black cumin grains at level of 5%. There was no significant difference between the green and black cumin angle of repose.

Charts related to the internal friction angle of green and black cumin seeds are shown in Fig. 2 and Fig. 3. The average of thousand grain weight values of green and black cumin seeds were 2.90 and 1.59 g, respectively.

Table 2: Static coefficient of friction for green and black cumin seeds on different surfaces

| Surface | No. of Observations | Green cumin | | | | Black cumin | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Max | Min | SD | Mean | Max | Min | SD |
| Plywood | 3 | 0.569 | 0.589 | 0.554 | 0.018 | 0.535 | 0.543 | 0.531 | 0.006 |
| Galvanized iron | 3 | 0.459 | 0.466 | 0.445 | 0.012 | 0.387 | 0.404 | 0.374 | 0.015 |
| Aluminium | 3 | 0.312 | 0.315 | 0.306 | 0.006 | 0.277 | 0.286 | 0.268 | 0.009 |

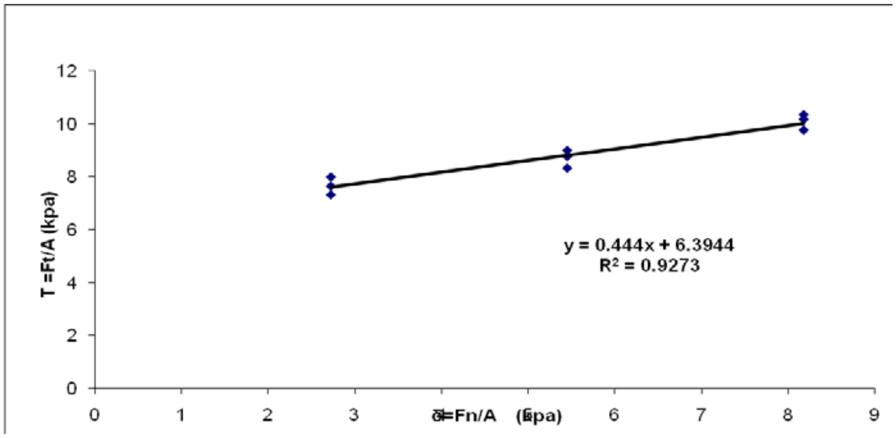


Figure 2. Internal friction curve for green cumin

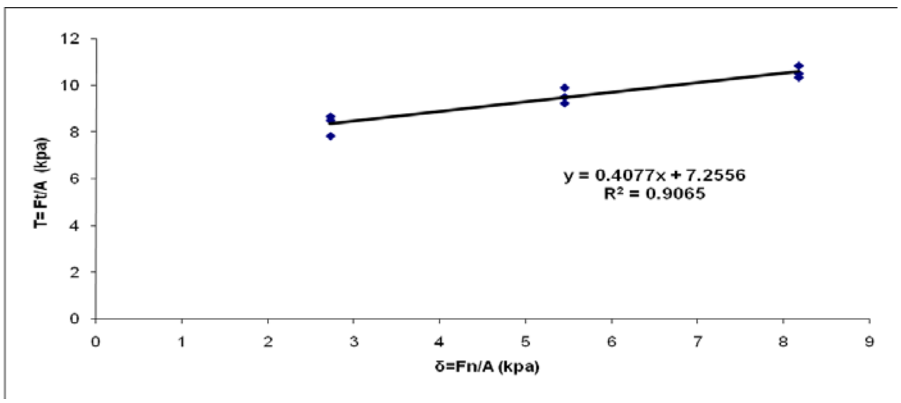


Figure 3. Internal friction curve for black cumin

**CONCLUSION** The physical properties of green and black cumin grains were reported in this study. This information is very useful especially in postharvest machineries. Result shows that there are significant differences ($p<0.01$) in most physical properties of green and black cumin, except porosity. In addition, there is differences ($p<0.05$) in the static friction coefficient of green and black cumin. It is recommended that more studies to be done on the other useful engineering properties of grains such as mechanical, thermal, and rheological properties and the effect of grain moisture content on all of these properties to provide comprehensive information on parameters involved in designing of green and black cumin grain processing unit.

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