

# PHYSICAL PROPERTIES OF MUSTARD SEEDS (*SINAPIS ALBA L.*)

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## Abstract

*Knowledge of the physical properties of the mustard seeds (*Sinapis Alba L.*), is necessary for the design of equipment for harvesting, transporting, cleaning, packing, storing, processing, etc., of the seeds. The physical properties of *Sinapis Alba L.* have been evaluated as a function of moisture range of the seeds. The size and mass increased from 2.8 mm to 3.04 mm and 6.9 g to 7.41 g, respectively, when the moisture content increased from 7% to 15.99%. The bulk density, porosity and angle of repose increased with the increase in the moisture content. The plywood surface offered more frictional resistance than the galvanized iron surface.*

**Key words:** coefficient of friction, *Sinapis Alba L.*, density, moisture content

## INTRODUCTION

The different types of mustard plants (white, brown) have been widely cultivated [1].

Mustard seeds have high energy content, having 28-32% oil with relatively high protein content (28-36%). The amino acid composition of mustard protein is well ballanced, it is rich in essential amino acids. Until now mustard seeds have been used mainly for condiment production. This advantageous chemical composition and its relatively low price offer wide possibilities for usage of this valuable seed, for example in human foods as additive [2, 3] and to feed animals.

Mustard oil is cold extracted from white mustard seeds, which contain between 30 and 38% oil. Cakes from the seed kernels are used in preparing mustard flour, mustard meal manufacture. Well refined mustard oil has a yellow to brown colour and its smell and taste are enjoyable [4]. Mustard oil has a special fatty acid composition: 20-28% oleic acid, 10-12% linolic, 9.0-9.5% linolenic acid and 30-40% erucic acid, which is indigestible for human and animal organisms. The high erucic acid content of mustard seed could be reduced by breeding.

Mustard oil is rich in tocopherols and act as a preservative against rancidity. This high tocopherol content is advantageous in that case when fat containing mustard flour is used as additive, because it contributes to longer shelf life of finished food products.

Mustard seed like other oil seeds are rich source of phenolic compounds [5]. The antioxidant properties of mustard are connected with the rich phenolic content and composition besides the tocopherols compounds. Mustard seed flour has also an anti-microbial property.

There is an unmet consumer demand for the use of natural antimicrobials for use in foods to enhance the safety of the food supply [6].

In some countries the flour is applied as additive mainly in meat industry to increase the taste and flavour of the products. The addition of mustard flour in 1-2% to the meat improves the cooking and slicing characteristics of the products, because of its good colloid-chemical properties, such as water and fat binding capacity, as well as emulsifying characteristics [7].

Mustard seeds have a typical flavour detected as pungency and is also associated with bitterness [8].

Mustard intended for long-term storage should be kept at less than 9% moisture. If the mustard needs to be dried for safe storage, the drying air temperature and seeds'

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temperature should not exceed 65 and 45<sup>0</sup>C, respectively [9].

Mustard can be grown for biodiesel production. Besides economics, the biodiesel has several other advantages such as low sulphur content, no net CO<sub>2</sub> emission compared to conventional diesel fuel, and it is nontoxic and biodegradable [10].

Edible films were developed from a defatted mustard seed meal (*Sinapis alba*), a byproduct from the bio-fuel industry [11].

Various physical properties of seeds are dependent on moisture content, and appear to be important in the design of planting, harvesting, handling operation, transportation, storing and processing equipments [12]. Since currently used systems have been designed without taking these criteria into consideration, the resulting designs lead to inadequate applications. These cases result in a reduction in work efficiency and an increase in product losses. Therefore, determination and consideration of these properties play an important role in designing these equipments. These physical properties affect the conveying characteristics of solid materials by air or water and cooling and heating loads of food materials. Despite an extensive literature search, information on the influence of thermal treatment on physical properties of mustard seeds are not available in the literature. Most of the seeds are very hygroscopic food materials, which easily interact with the moisture in the air.

Many studies have been reported on the physical properties of fruit, grains, and seeds, such as apricot varieties [13], cactus pear [14], carob bean [15], cowpea seed [16], barley [17], faba bean [18], green wheat [19], hawthorn fruit [20], etc., but no detailed studies concerning the influence of thermal treatment on physical properties of mustard seeds have been performed.

In this study, some physical properties were investigated of mustard seeds, namely linear dimension, geometric mean diameter, 1000 seed weight, true density, bulk density, porosity, angle of repose and static coefficient of friction against six structural surfaces at different levels of moisture

content. The knowledge gained will be used in design and development of equipments for cleaning, grading, dehydration, storage and handling.

#### Nomenclature

<i>L</i>	– length (mm)
<i>B</i>	– breadth (mm)
<i>R</i>	– regression coefficient
<i>S</i>	– size (mm)
<i>W</i> <sub>1000</sub>	– 1000 seed mass (g)
<i>a</i>	– initial moisture content of the sample (% w.b.)
<i>A</i>	– initial mass of the sample (kg)
<i>b</i>	– desired moisture content of the sample (% w.b.)
<i>Q</i>	– mass of water to be added (kg)
<i>d.b.</i>	– dry basis
<i>ε</i>	– porosity (%)
<i>μ</i>	– static coefficient of friction
<i>μ</i> <sub>GI</sub>	– static coefficient of friction for galvanized iron
<i>μ</i> <sub>p</sub>	– static coefficient of friction for plywood surface
<i>ρ</i> <sub>b</sub>	– bulk density (kg/m <sup>3</sup> )
<i>ρ</i>	– true density (kg/m <sup>3</sup> )
<i>Φ</i>	– angle of repose (°, degree)
<i>ω</i>	– moisture content (% , d.b.)

## MATERIAL AND METHODS

### 2.1 Sample preparation

Sun dried mustard seeds were obtained from a local market. The seeds were cleaned manually to remove all foreign material and broken seeds.

The mustard seeds were conditioned by adding a calculated quantity of water, mixing thoroughly and then sealing in separate polyethylene bags. The samples were kept at 5<sup>0</sup>C in a refrigerator for one week for the moisture to distribute uniformly throughout the samples. Before each test, the required quantity of samples was taken out of refrigerator and allowed to warm up to room temperature. All the physical properties were determined at the moisture contents of 7.0%, 9.78%, 12.87% and 15.99% (d.b.).

The samples of higher moisture content were prepared by adding distilled water as calculated using the following equation [21]:

$$Q = \frac{A(b-a)}{(100-b)} \quad (1)$$

The experiments were replicated 5 times to avoid error.

## 2.2 Size and 1000 seed mass

The size of the randomly selected 20 seeds was determined from the principal dimensions. The length and breadth of each seed was measured using a micrometer to an accuracy of 0.01 mm, to calculate the geometric mean diameter. The geometric mean diameter, expressed as size, was computed using the following equation [22]:

$$S = (L \times B^2)^{1/3} \quad (2)$$

The mass was determined by randomly selecting 100 samples and weighing in an electronic balance of 0.001 g sensitivity. The weight was then converted into 1000 seed mass ( $W_{1000}$ ).

## 2.3 Determination of true and bulk density

The true density ( $\rho_t$ ) was determined by toluene displacement method [22].

Bulk density ( $\rho_b$ ) of mustard seeds was determined by filling the grains in a cylinder of known volume ( $5.67 \times 10^{-4} m^3$ ) and weighed in an electronic balance. The bulk density was then calculated from the mass and volume.

## 2.4 Determination of porosity

Porosity was calculated using the following equation [23]:

$$\varepsilon = \frac{(\rho_t - \rho_b) \times 100}{\rho_t} \quad (3)$$

## 2.5 Determination of angle of repose

The angle of repose was determined from the height and diameter of the naturally formed heap of seeds on a circular plate [24]. The seeds were allowed to fall from a height of 20 cm on a circular plate of 200 mm diameter for the heap formation.

$$\phi = \tan^{-1} \left( \frac{2H}{D} \right) \quad (4)$$

## 2.6 Determination of static coefficient of friction

The static coefficient of friction  $\mu$  was determined for two different structural materials, namely plywood and galvanized

iron (GI). These are common materials used for transportation, storage and handling operations of grains, pulses and seeds construction of storage and drying bins.

For this measurement one end of the friction surface was attached to an endless screw. The seed was placed on the surface and it was gradually raised by the screw. Vertical and horizontal height values were read from the ruler when the seed started sliding over the surface, then using the tangent value of that angle the coefficient of static friction was found [25].

## RESULTS AND DISCUSSIONS

### 3.1 Size and 1000 seed mass

The size of the mustard seeds increased with increase in moisture content due to swelling. The size increase from the 2.88 mm to 3.04 mm to an increase in moisture content from 7% to 15.99% (Fig. 1).

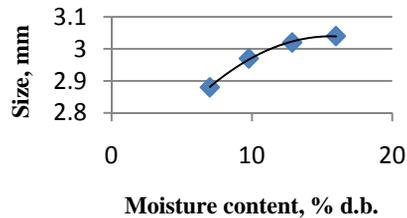


Fig. 1 Effect of moisture content on size

The relationship between size and seed moisture content ( $\omega$ ) can be expressed using the regression equation:

$$S = 2.52 + 0.0066\omega - 0.002\omega^2 (R^2 = 0.998) \quad (5)$$

The 1000 seed mass also increased with increase in moisture content (Fig. 2). It increased linearly with moisture content as given below:

$$W_{1000} = 3.708 + 0.088\omega (R^2 = 0.994) \quad (6)$$

The same trend was observed for dehydrated pomegranate seed [26].

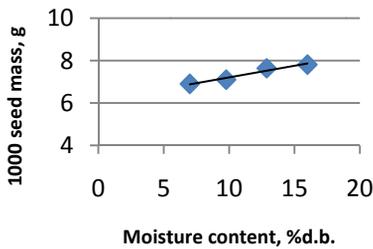


Fig. 2 Effect of moisture content on 1000 seed mass

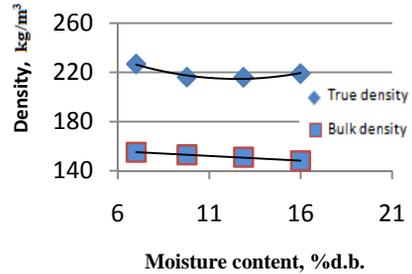


Fig. 3 Effect of moisture content on density

### 3.2 True density and bulk density

The true density of mustard seeds decreased when the moisture content increased until 11.98%. From this point, true density increased with increasing moisture content. The particular increase of true density indicates that the increase in weight gain in the sample is greater than the volume increase of seed between 11.98% and 15.99% moisture content. These discrepancies could be due to the cell structure, and the volume and mass increase characteristics of grains and seeds as moisture content increases [27].

The true density of mustard seeds can be represented by following polynomial equation:

$$\rho_t = 294 - 10.87\omega + 0.372\omega^2 (R^2 = 0.96) \quad (7)$$

While previous researcher reported linear decreasing or increasing trends in true density for some seeds, grains and nuts, Bäumlner et al. (2006) reported polynomial relationship between true density and increasing moisture content for safflower seed [28].

The bulk density of the mustard seeds and its relation with moisture content is given in Fig. 3. The bulk density is found to decrease linearly with moisture content and the relationship is shown below:

$$\rho_b = 162 - 0.759\omega (R^2 = 0.99) \quad (8)$$

The decrease in bulk density of mustard seeds with increase in moisture content indicates that the increase in volumetric expansion in the sample is greater than weight.

### 3.3 Porosity

The variation of the porosity of the mustard seeds with seeds moisture content is plotted in Fig. 4. Porosity starts at 46.32% and reduces nonlinearly to 41.23% at 9.78 seed moisture content.

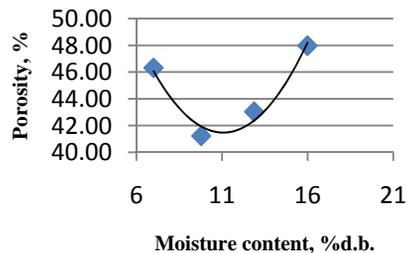


Fig. 4 Effect of moisture content on the porosity of mustard seeds

The polynomial relationship between the porosity and moisture content for mustard seeds can be represented by the following equation:

$$\varepsilon = 75.42 - 6.134\omega + 0.277\omega^2 (R^2 = 0.962) \quad (9)$$

Baryeh (2002) reported similar results for millet seeds [27]. Since the porosity depends on the bulk and true densities the magnitude of variation in porosity depends on these factors only. Therefore the dependency of porosity on these densities is definitely different for each seed or grain with increasing moisture content.

### 3.4 Angle of repose

The experimental data for angle of repose of mustard seeds is presented in Fig. 5. It is

found that the angle of repose increased polynomially with the increase in moisture content, and can be expressed by the following equation:

$$\theta = 31.44 - 0.862\omega + 0.052\omega^2 (R^2 = 0.996) \quad (10)$$

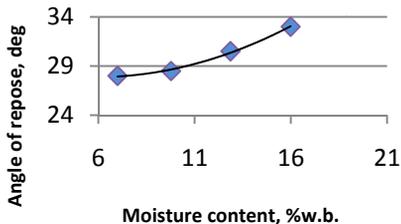


Fig. 5 Effect of moisture content on angle of repose

### 3.5 Coefficient of static friction

The results of the experiments carried out on two test surfaces are presented in Fig. 6. The relation between moisture content and coefficient of friction at different surface can be expressed by the following equations:

$$\mu_p = 0.826 - 0.026\omega - 0.001\omega^2 (R^2 = 0.988) \quad (11)$$

$$\mu_{gl} = 0.82 - 0.039\omega + 0.002 (R^2 = 0.982) \quad (12)$$

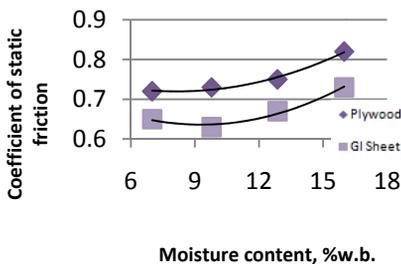


Fig. 6 Effect of moisture content on coefficient of friction

### CONCLUSIONS

The size and 1000 seed mass of the mustard seeds increased from 2.88 to 3.04 mm and 4.3 to 5.1 g, respectively, as the moisture content increased from 7.0 to 15.99% (d.b.). The true density was higher than the bulk density at all seed kernel moisture content studied. Also, porosity values of mustard seeds varied polynomially

from 46.32 to 47.97. Angle of repose increased from 28° to 33.1°, from seed moisture content of 7.0 to 15.99%. The static coefficient of friction of plywood was higher than galvanized iron sheet

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