

# Effect of Moisture Content on Physical Properties of Mung Bean (*Vignaradiata* (L.))

Inekwe G., Kiniyi B. U., Umunna M., Udensi N.K.

Agricultural and Bio-resources Engineering  
Michael Okpara University of Agriculture, Umudike  
Umuahia, Abia State, Nigeria

**Abstract**—This study investigated the effect of Moisture Content on some physical properties of Mung bean. The length, width, thickness, and geometric diameter of mung beans were determined at moisture contents of 7.29, 10.41, 14.8, 16.6 and 20.4% (dry basis). Also all dimensions of grain increased with the increase of moisture content. For the increase of moisture contents from 7.29 to 20.40% (dry basis), the increase of length, width, thickness, volume and geometric mean diameter were 1.9, 6.2, 6.4, 11.0 and 14.0% respectively. The geometric mean diameter was lower than the length and higher than the width and thickness. The porosity, terminal velocity and angle of repose increased linearly from 30.43 to 46.57%, 4.86 to 5.29m/s, and 25.87 to 29.38°, respectively. The static coefficient of friction on various surfaces increased linearly with increase in moisture content. The parameters used to indicate mung bean grain mechanical behavior were dependent on the shell moisture content for along the axes. As moisture content increased from 7.29 to 20.40%.

**Keywords:**- Physical properties; moisture content; grain mechanical behaviour; dry basis.

## I. INTRODUCTION

Mung bean, *Vignaradiata* (L.) Wilezek has been grown in India since ancient times. It is still widely grown in Southeast Asia, Africa, South and North America, and Australia, principally for its protein rich edible grains. The mung bean is commonly known in Asia as the green gram. Other common names include moong, mungo, golden gram, and chopsyuey bean (Oplinger *et al.*, 1990). Its Turkish name is known as “ma4”. Mung beans are grown widely for use as a human food (as dry beans or fresh sprouts), but they can be used as a green manure crop and as forage for livestock.

The world's mung bean cultivation area is nearly 4 million ha, and 2 million tonnes of yield is obtained from this area (Canci *et al.*, 2005). About 70% of the world production of mung bean is in India (Anonymous 2006). The yields of mung beans depend largely on weather conditions, soil, cultural practices, and variety. Yields can range from 350 to 2,250 kg/ha. Mung bean grains might be between 13 – 15% moisture at harvest time. In developing countries, the mung beans are handpicked as the pods mature. Because the major use of mung bean is for sprouts, excellent germination must be maintained by careful harvesting and storage systems. Furthermore, because the grain is small, careful handling and attention to planting machinery adjustments is necessary to ensure planting with little damage to the grain. Mung beans at about 12% moisture can then be stored in regular grain bins previously fumigated to control bean weevils (Canci *et al.*,

2005). Mung bean contains 26.4g protein, 0.72g non-protein nitrogen, 4.5g ash, 1.75g fat, 6.15 crude fiber, and 61.2g carbohydrates in 100g on dry weight basis (El-Adawy, 2003).

The major moisture-dependent physical properties of biological materials are shape, size, mass, bulk density, true density, porosity and static friction coefficient against various surfaces (Mohsenin, 1970). Size, shape and physical dimensions of mung bean are important in sizing, sorting, sieving, and other separation processes. For instance, *sphericity* is one of the most important properties because it affects how easily mung bean can be processed by the food industry. The *volume and density* of the grain play an important role in numerous technological processes and in the evaluation of product quality. In determining the *true density* of seeds and grains, researchers have used either gas displacement (Suthar *et al.*, 1996, Fraser *et al.*, 1978, Teotia *et al.*, 1989) or liquid displacement (Mohsenin, 1970 Unal *et al.*, 2006, Dutta *et al.*, 1988, Nimkar *et al.*, 2001, Deshpande *et al.*, 1993) methods. The *porosity* affects the resistance to airflow through bulk bean. *Terminal velocity* is very critical in the design of pneumatic conveyor, transporting mung bean using air and separation grain from undesirable materials such as shells, hulls, leaves and small branches. The *terminal velocity* is affected by the *density, shape, size, and moisture content* of samples. The *coefficient of static friction* plays also an important role in transports (load and unload) of goods and storage facilities.

Determination of the physical properties of agricultural materials is often problematic because of their diversity of shapes, sizes, moisture content, and maturity level (Victor, 1997). Recent scientific developments have improved the handling and processing of biomaterials through mechanical and thermal devices, but little is known about the basic physical characteristic of these materials (Waziri and Mittal, 1983).

Such basic information is not only important to engineers but also to food scientists involved in handling and processing (such as transportation, drying, threshing, cleaning, aeration, grading and design of post-harvest machines). The objectives of this study are: (i) to determine the physical properties of mung bean; (ii) to determine the relationship between moisture content and the physical properties.

## II. LITERATURE REVIEW

### A. Mung Bean Description

The mung bean (*Vignaradiata* (L.) R. Wilczek) is a legume cultivated for its edible seeds and sprouts across Asia. There are three (3) subgroups of *Vignardiata*: one is cultivated (*Vignaradiata* subsp. *radiata*), and two are wild (*Vignardiata* subsp. *sublobata* and *Vignardiata* subsp. *glabra*). The mung bean *plant* is annual, erect or semi-erect, reaching a height of 0.015 – 1.25m (FAO, 2012; Lambrides *et al.*, 2006; Mogotsi, 2006). It is slightly hairy with a well-developed *root* system. The *stems* are many-branched, sometimes twining at the tips (Mogotsi, 2006). The *leaves* are alternate, trifoliate with elliptical to ovate leaflets, 5 – 18cm long x 3 – 15cm broad. The *flowers* (4-30) are papilionaceous, pale yellow or greenish in colour. The *Pods* are long, cylindrical, hairy and pending. They contain 7 to 20 small, ellipsoid or cube-shaped seeds. The *seeds* are variable in colour they are usually green, but can also be yellow, olive, brown, purplish brown or black, mottled and/or ridged. Seed colours and presence or absence of a rough layer are used to distinguish different types of mung bean (Lambrides *et al.*, 2006; Mogotsi, 2006). Cultivated types are generally green or golden and can be shiny or dull depending on the presence of a texture layer (Lambrides *et al.*, 2006). Mung beans are cooked fresh or dry. They can be eaten whole or made into flour, soups, prridge, snacks, bread, noodles and ice-cream.

### B. Mung Bean Distribution

The mung bean is thought to have originated from the Indian subcontinent where it was domesticated as early as 1500BC. Cultivated mung beans were introduced to southern and eastern Asia, Africa, Austronesia, the Americas and the West Indies. It is now widespread throughout the Tropics and is found from sea level up to an altitude of 1850m in the Himalayas (Lambrides *et al.*, 2006; Mogotsi, 2006).

The mung bean is a fast-growing legume that reaches maturity very quickly under tropical and subtropical conditions where optimal temperatures are about 28-30°C and always above 15°C. It can be sown during summer and autumn. It does not require large amounts of water (600-1000mm rainfall/year) and is tolerant of drought. It is sensitive to waterlogging. High moisture at maturity tends to spoil the seeds that may sprout before being harvested. It grows on a wide range of soils but prefers well-drained loams or sandy loams, with a pH ranging from 5 to 8 and is somewhat tolerant to saline soils (Mogotsi, 2006).

### C. Nutritional Content

Mung bean seeds are rich in protein (20-30% DM) and starch (over 45% DM) with a low lipid content (less than 2% DM) and variable but generally low amounts of fiber (crude fiber 6.5% DM on average). The amino acid profile of mung beans is similar to that of soybean. The by-product of mung bean vermicelli processing contains 11-23% crude protein, 0.4-1.8% ether extract, 13-36% crude fibre, 0.30-0.68% calcium and 0.17-0.39% phosphorus depending on the mung bean material (Sitthigriponge R. 1998).

Mung beans contain several anti-nutritional factors (trypsin inhibitors, chymotrypsin inhibitor, tannins and lectins) (Wiryawan *et al.*, 1997). The amounts of anti-nutritional factors vary greatly among mung bean types and

can be reduced through processing methods such as soaking, cooking or extruding (Lambrides *et al.*, 2006; Mogotsi, 2006; Wiryawan *et al.*, 1997).

### Tillage Processes

Mung bean crops grown for seeds are generally harvested when pods begin to darken. They are mostly hand-picked at weekly intervals. In newer varieties in which the plants mature uniformly, the whole plants are harvested and sun-dried before being threshed. Once pods have dried, the seeds are removed by beating or trampling (Mogotsi, 2006).

### Environmental Impact

The mung bean can be used as a cover crop before or after cereal crops. It makes good green manure. The mung bean is an N-fixing legume that can provide large amounts of biomass (7.16tonnes of biomass/ha) and N to the soil (ranging from 30 to 251 kg/ha) (Hoorman *et al.*, 2009; George *et al.*, 1995 cited by Devendra *et al.*, 2001; Meelu *et al.*, 1992). Green manure should be ploughed in when the plant is in full flower (FAO, 2012).

## III. MATERIALS AND METHOD

The following materials and equipment were used in carrying out the field experiment: *Mung bean, Polyethylene bags, Refrigerator, Vernier Caliper, Weighing balance, Oven container, Airtight plastic bags*

### D. Moisture Content

The moisture content (MC) of whole seeds was determined using the hot air oven method (AOAC 2000). The weight loss of samples was recorded and the moisture content was determined in percentages. This procedure was replicated three times. The average moisture content was calculated using the relationship:

$$MC (w.b)\% = \frac{W_w - W_d}{W_w} \times 100$$

Where:

$W_w$  = Weigh of wet sample (g)

$W_d$  = Weight of dried sample (g)

### E. Dimensions

The grain dimensions such as length, width and thickness were determined using a vernier caliper. A vernier caliper (fisher scientific company, Pittsburgh, Pa) having a least resolution count of 0.01cm was used. The geometric mean diameter,  $D_g$  of the grain was calculated using the following relationship as described by Mohsenin (1970):

$$D_g = (LBT)^{\frac{1}{3}}$$

Where L, B and T are Length, Width and Thickness of the mung bean. Samples of 200 randomly selected whole mung bean was used to determine the grain dimensions.

#### F. Volume

The volume of the grains was determined by taking the dimensions of the various varieties of the grains in three axes of length, width and thickness, then the volume was estimated using the following relationship as described by Mohsenin (1970).

$$V = \pi Lwh/6$$

Where:

V = Volume of kernel

L = Length of kernel

w = Width of kernel

h = Thickness of kernel

#### Bulk Porosity

Bulk porosity was determined using the density (bulk and solid) parameter as described by Mohsenin (1970):

$$\text{Porosity} = \frac{1 - \text{bulk density}}{\text{solid density}} \times 100$$

#### G. Bulk Density

Bulk density of the grain was determined by weighing the grains packed in a container of known volume. The grains were densely packed by gently tapping the container to allow the settling of grains in the container (Waziri and Mittal, 1983). The volume of the container was estimated by filling the container with water and the water was then poured out into a calibrated measuring cylinder and the volume was then recorded. The following expression was used to determine the bulk density of the two varieties of the crop.

$$\text{Bulk density} = \frac{\text{Weight of material packed}}{\text{Known volume}}$$

#### H. Solid Density

Solid density is another way of describing density and was determined by using a specific gravity bottle. This was carried out by first weighing the empty density bottle, followed by filling the bottle one-third full of grain, and weighing it again. The bottle was then filled with water and the mixture of the grains was also weighed. Next, the bottle was filled with water only and weighed. Finally, the solid density of the material was determined using the following expression as described by Okeke and Anyakoha (1987):

Solid density = Density of water specific gravity of grain (G<sub>sp</sub>)

$$G_m = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$$

Where:

G<sub>sp</sub> = specific gravity of the grains (g/g)

M<sub>1</sub> = weight of empty density bottle (g)

M<sub>2</sub> = weight of empty density bottle about one-third full of grain (g)

M<sub>3</sub> = weight of density bottle filled with grain and water (g)

M<sub>4</sub> = weight of density bottle filled with water only (g)

#### I. Angle of Repose

In determining the angle of repose of the grains, they were piled on plywood, placed on a table in a conical form, and then the plywood was tilted until the grains began to slide (flow) freely, the angle the plywood makes with the table as at the time of free flow was taken as an angle of repose.

### IV. RESULTS AND DISCUSSION

#### A. Results

TABLE I. MEANS AND STANDARD DEVIATIONS OF THE GRAIN DIMENSIONS AT DIFFERENT MOISTURE CONTENTS

Moisture Content (%)	Length (mm)	Width (mm)	Thickness (mm)	Volume (mm <sup>3</sup> )	Geometric Mean Diameter (mm)
7.29	4.02±0.06 <sup>a</sup>	3.03±0.04 <sup>a</sup>	2.99±0.07 <sup>a</sup>	1.98±0.73 <sup>a</sup>	3.31±0.04 <sup>a</sup>
10.41	4.03±0.08 <sup>a</sup>	3.08±0.05 <sup>ab</sup>	3.00±0.05 <sup>a</sup>	1.91±0.07 <sup>a</sup>	3.34±0.04 <sup>a</sup>
14.8	4.08±0.05 <sup>a</sup>	3.15±0.03 <sup>c</sup>	3.06±0.03 <sup>a</sup>	2.03±0.55 <sup>a</sup>	3.43±0.04 <sup>a</sup>
16.6	4.10±0.08 <sup>a</sup>	3.21±0.03 <sup>c</sup>	3.13±0.03 <sup>b</sup>	2.16±0.57 <sup>b</sup>	3.45±0.04 <sup>a</sup>
20.4	4.10±0.07 <sup>a</sup>	3.22±0.03 <sup>c</sup>	3.18±0.03 <sup>c</sup>	2.20±0.70 <sup>c</sup>	3.45±0.04 <sup>a</sup>

a-c mean superscript with different alphabets in the same column differ significantly (p < 0.05).

TABLE II. MEAN VARIATIONS IN THE PHYSICAL PROPERTIES OF MUNG BEAN

Parameter	No. of Samples Measured (n)	Mean Values	Standard Deviation
Mean Moisture Content (%)	100	13.90	5.15
Length, L (mm)	100	4.06	0.30
Width, W (mm)	100	3.14	0.18
Thickness, h (mm)	100	3.07	0.22
Geometric Mean Diameter, D <sub>g</sub> (mm)	100	3.40	0.18
Volume, v (mm <sup>3</sup> )	100	20.57	3.07
Angle of repose (°)	100		
(grain on wood)	100	54.00	7.38
(grain on metal)	100	59.80	6.30
(grain on glass)	100	52.40	7.30
Bulk density (g/mm <sup>3</sup> )	100	0.99	0.03
Porosity (%)	100	38.73	4.71

## DISCUSSION

The data obtained during the experiment are summarized in Tables 1 and 2. The results are also indicated graphically in Figures 1-5. Table 1 shows that there were deviations in all of the measured parameters but the most significant deviation was found with the angle of repose on wood with standard deviation 7.38.

The length, width, thickness and geometric diameter of mung beans at moisture contents of 7.29, 10.41, 14.8, 16.6 and 20.4% (dry basis) are presented in Table 1. It is observed from Table 1 that all dimensions of grain increased with the increase of moisture content. For the increase of moisture contents from 7.29 to 20.40% (dry basis), the increase of length, width, thickness, volume and geometric mean diameter were 1.9, 6.2, 6.4, 11.0 and 14.0% respectively. The geometric mean diameter was lower than the length and higher than the width and thickness.

Unal *et al.*, (2006), Chowdhury *et al.*, (2001), Nimkar and Chattopadhyay, (2001), Baumler *et al.*, (2006) and Gupta and Das (1997) found similar results for black-eyed pea, gram, green gram, safflower, and sunflower seeds, respectively. The following regression equations were obtained for length, width, thickness, volume and geometric diameter with moisture content (MC, % dry basis).

$$\text{Length (mm), } L = 3.579 + 0.009 \text{ MC\%}. \quad (R^2 = 0.886)$$

$$\text{Width (mm), } W = 2.835 + 0.005 \text{ MC\%}. \quad (R^2 = 0.893)$$

$$\text{Thickness (mm), } T = 2.740 + 0.006 \text{ MC\%}. \quad (R^2 = 0.755)$$

$$\text{Volume (mm}^3\text{), } V = 15.58 + 0.098 \text{ MC\%}. \quad (R^2 = 0.872)$$

$$\text{Geometric Diameter (mm), } GMD = 3.116 + 0.005 \text{ MC\%}. \quad (R^2 = 0.835)$$

The values obtained for grain volume of mung bean are graphically shown in Figure 4. The grain volume increased from 1.98mm<sup>3</sup> at 7.29% grain moisture content to 47.30mm<sup>3</sup> at 20.40% grain moisture content. This is explained by the increase in the grain dimensions as the grain moisture content increased. The change was significant at 5% level of significance. Linear increases in volume with increase in grain moisture content have been observed by Unal *et al.*, (2006) for black-eyed pea, Dutta *et al.*, (1988) for gram, Aviara *et al.*, (1999) for guna seed, and Nimkar *et al.*, (2001) for moth gram. Otherwise, Baryeh and Mangope (2006) found the volume of pigeon pea to decrease nonlinearly with increase in seed moisture content. These differences could be due to the shape and dimensional change characteristics of the different grains.

The variation of moisture content and grain volume can be expressed mathematically as follows:

$$V = 15.58 + 0.098 \text{ MC\%}. \quad (R^2 = 0.872)$$

with values for the coefficient of determination  $R^2 = 0.872$ .

The grain bulk density at different moisture levels varied from 0.96 to 1.02 g/mm<sup>3</sup> and indicated a decrease in bulk density with an increase in moisture content with significant ( $p < 0.05$ ) variation. This was due to the fact that an increase in mass owing to moisture gain in the grain sample was lower than accompanying volumetric expansion of the bulk. The percent decrease in bulk density for mung bean was 6.3% corresponding to the increase in moisture content from 7.29 to 20.40% d.b. The negative linear relationship of bulk density with moisture content was also observed by various other research workers (Dursun 2005; Chowdhury *et al.*, 2001; Nimkar and Chatoopadhyay, 2001).

Bulk density of mung bean (1.02 g/mm<sup>3</sup>), at moisture content of 7.29% d.b. was found to be greater than caper seed (0.40 kg/m<sup>3</sup>), (Dursun, 2005) gram (0.769 g/mm<sup>3</sup>), (Chowdhury *et al.*, 2001) guna seed (0.50 g/mm<sup>3</sup>), (Aviara *et al.*, 1999) and soybean (0.72g/mm<sup>3</sup>), (Deshpande *et al.*, 1993).

Whereas it was smaller than moth gram (0.81g/mm<sup>3</sup>), (Nimkar *et al.*, 2001) vetch seed (0.85 g/mm<sup>3</sup>), (Yalcin *et al.*, 2004) and white lupin (0.80 g/mm<sup>3</sup>) (Ogut, 1998). The bulk density of grain was found to bear the following relationship with moisture content:

$$BD = 0.867 - 6.2192 \text{ MC}$$

with a value for the coefficient of determination  $R^2$  of 0.96.

The true density of the grain was measured at different moisture levels and it was found linearly increased and varied from 0.12 to 0.145 g/mm<sup>3</sup>. The variation in true density with moisture content was significant ( $p < 0.05$ ). This increase indicates that there is a higher grain mass increase in comparison to its volume increase as its moisture increases. This agrees with the finding of Tekin *et al.*, (Tekin *et al.*, 2006) for Turkish Goynuk Bombay bean, Aviara *et al.*, (2002) for sunflower seeds, and Yalcin and Ozarslan (2004) for vetch seed. It is, however, contrary to results of Konak *et al.*, (2002), Altunta *et al.*, (2002), Chowdhury *et al.*, (2001), Suthar and Das, (1996) and Nimkar *et al.*, (2001) who found the true density to decrease with moisture content for chickpea, fenugreek, gram, karingda, and moth gram seeds, respectively. These seeds therefore, have lower weight increase in comparison to volume increase as their moisture content increases. The true density and the moisture content of grain can be correlated as follows:

$$rt = 1.0673 + 22.043 \text{ MC},$$

with a value for  $R^2$  of 0.997.

Bulk porosity was evaluated using mean values of bulk density and true density. The bulk porosity was found to increase linearly from 30.43 to 46.57% (with mean value of



38.73) in the specified moisture levels and this change was significant at a 5% level of significance. The results indicate that the increase in bulk porosity value of mung bean is 53% with the corresponding increase in moisture contents from 7.29 to 20.40% d.b. Similar observations of increase in bulk porosity with increase in grain moisture content have been reported. Bulk porosity of mung bean (38.7%), at moisture content of 12.6% d.b., was found to be smaller than chickpea (43.6%), (Konak *et al.*, 2002) green gram (41.6%).

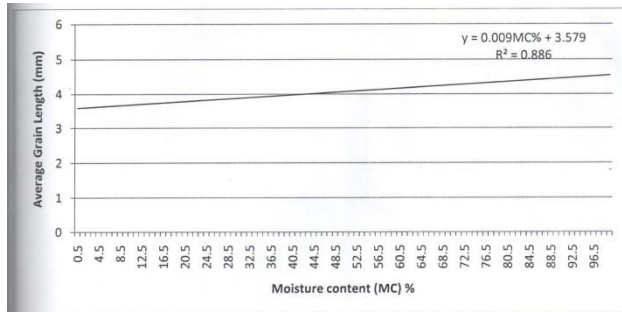


Fig. 1 Variation of Average Length of Mung Bean with Moisture Content

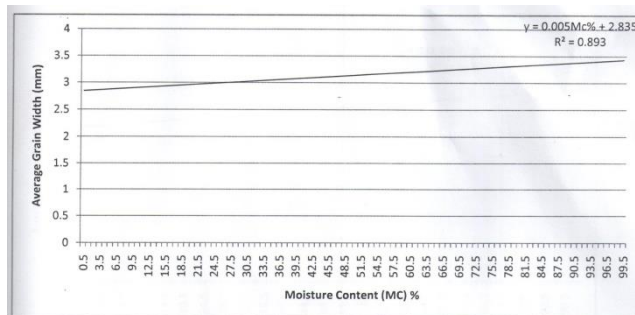


Fig. 2 Variation of Average Grain Width of Mung Bean with Moisture Content

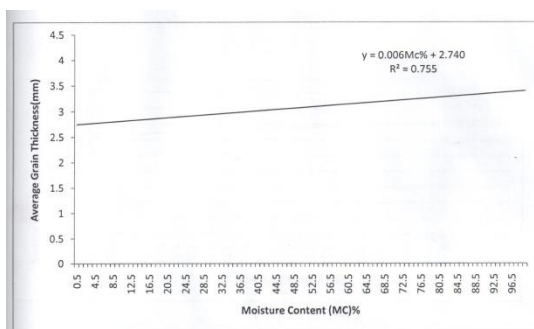


Fig. 3 Variation of Average Grain Thickness of Mung Bean with Moisture Content

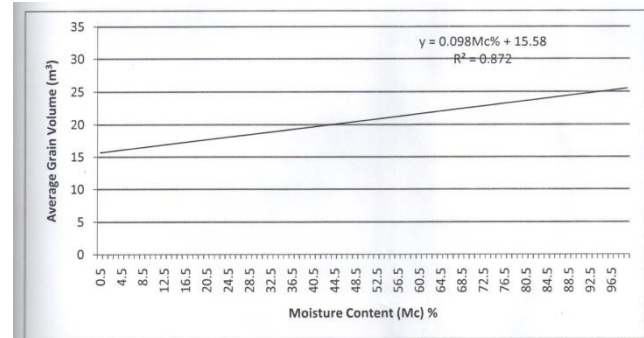


Fig. 1. Variation of Average Grain Volume with Moisture Content

The following conclusions are drawn from the investigation on geometric and mechanical properties of mung bean grain for five moisture content ranges from 7.29 – 20.40% d.b. Physical properties of mung bean grains studied in this work linearly with an increase in grain moisture content with high correlation. All dimensions of gram increased with the increase of moisture content. For the increase of moisture contents from 7.29 to 20.40% (dry basis), the increase of length, width, thickness, volume and geometric mean diameter were 1.9, 6.2, 6.4, 11.9, and 14.0% respectively. The geometric mean diameter was lower than the length and higher than the width and thickness. The bulk density decreased from 1.02 to 0.99 g/mm<sup>3</sup>, whereas true density increased from 1.23 to 1.45 g/mm<sup>3</sup> in the specified moisture levels. The porosity, terminal velocity and angle of repose increased linearly from 30.43 to 46.57%, 4.86 to 5.29 m/s, and 25.87 to 29.38°, respectively. The static coefficient of friction on various surfaces increased linearly with increase in moisture content. The parameters used to indicate mung bean grain mechanical behavior were dependent on the shell moisture content for along the axes.

Physical properties of mung bean vary with changes in moisture content. Also all dimensions of gram increased with the increase of moisture content. Length, width, thickness, volume and geometric mean diameter increased with increase in moisture content. Volume of mung bean increases linearly with increase in moisture content and bulk density of mung bean decreases with an increase in moisture content.

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