



## Investigations on the Effects of Moisture Content and Variety Factors on Some Mechanical Properties of Pumpkin Seed (*Cucurbitaceae spp*)

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**Abstract:** The study investigated the effects of moisture content and varietal factors on some mechanical properties of pumpkin seed at three moisture content levels (18.1, 22.2, and 26% d.b) and two levels of variety (*c. maxima* and *c. pepo*). Similarly, oil content was investigated for the effect of variety factor. A 2X3 factorial experiment in a Randomized Complete Block Design (RCBD) was used, and results were analyzed with the analysis of variance (ANOVA) using the General Linear Model procedure of the SPSS 17 at 5% level of probability. The coefficient of static friction increased linearly with moisture content on all surfaces investigated ( $p < 0.05$ ), with the least and highest coefficients of 0.36 and 0.97 recorded by *c. pepo*, and *c. maxima* varieties on the zinc-plated, and concrete surfaces respectively. The static and dynamic angles of repose varied from 13.4 to 22.9°, and from 38.3 to 36.7° respectively in *c. maxima*. while in *c. pepo* from 16.0 to 20.4° and from 30.3 to 43.1° respectively as the moisture content was increased from 18.1 to 26% d.b. The hardness of pumpkin seed decreased from 0.23 to 0.117 N/mm<sup>2</sup> and from 0.172 to 0.0784 N/mm<sup>2</sup> in *c. maxima*, and *c. pepo* respectively for the same increase in moisture content. The oil contents of 55.8 and 52.3% were recorded in *c. maxima* and *c. pepo* varieties respectively.

**Keywords:** variety, moisture content, *c. maxima*, *c. pepo*, oil content.

### I. Introduction

Pumpkin is a fruity vegetable belonging to the family of cucurbitaceae; it has been cultivated for the more than 10,000 years in different locations of the world, [1]; with records of its oil extraction in countries such as Austria, Slovenia and Hungary, [2]. Pumpkins generally perform well in the tropical, subtropical and in temperate climates of the world [3]. The yield of pumpkin fruits and seeds varies with climate, variety/cultivar, production system, weed competition, plant diseases and management practices. Reference [4] reported that the normal expected yield of oil pumpkin in the Styrian region of Austria ranged between 500 and 800 kg dry seed/ha and often up to 1200 kg/ha.

Pumpkins have been cultivated for nutritional and medicinal/pharmacological applications; some of the pharmacological effects include antidiabetic, antihypertensive, antibacterial, antihypercholesterolemic, immunomodulating, intestinal antiparasitic, antalgic and antiinflammation effects have been reported, [26]. Despite the suitability of these agro-climatic regions for the growth of, and the wide range of applications of pumpkin, [1], [5], it has not been cultivated on a commercial scale probably due to difficulties associated with its processing such as seed extraction from pumpkin fruit, bulk handling, decortication etc. Pumpkin seed processing machine are not readily available in this part of the globe based on literatures reviewed; Reference [6] observed that reduction in work efficiency and an increase in product losses usually result from the design of processing machine without consideration of the engineering properties of agricultural materials. Thus, it is clear that the investigation of the mechanical properties of pumpkin seed is a necessary prerequisite to the design of its processing machine.

Engineering properties have been investigated on rapeseed, corn, soybean, cowpea, canola, barley, and pearl millet seeds. [29], [19], [22], [15], [32], [16], [30], [18]. Some of the researches conducted on pumpkin fruits and seeds include investigations on the kinetic and temperature dependent diffusivity of pumpkin seed during drying [28], mechanical properties of pumpkin tissue, [27]; chemical properties of some cucurbitaceae from Cameroun [3], and the oil and tocopherol content and composition of pumpkin seed oil in 12 cultivars [24].

### II. Materials and Methods

Dry pumpkin seeds were obtained from a local market in Mayo-Nguli, Maiha local government area of Adamawa state (located between latitude 10° 02' N and 10° 15' N and longitude 13° 09' E and 13° 16' E). The post harvest moisture content of 14.47% d.b and 12.13% d.b for the *c. maxima* and *c. pepo* varieties respectively were determined by oven drying method in accordance with the procedures of [33] and computed using (1)

$$MC_{db} = \frac{(m_2 - m_1) - (m_3 - m_1)}{m_3 - m_1} \quad \dots (1)$$

Where

$m_1$  = mass of empty moisture can (g),  $m_2$  = mass of air-dried sample + moisture can (g)

$m_3$  = mass of oven dried sample + moisture can (g)

The desired moisture content of 18.1, 22.2 and 26.0% d.b were obtained by conditioning pumpkin seed (i.e. rewetting); this involved adding calculated quantity of distil water. The procedure of seed rewetting adopted was earlier employed by researchers in investigating engineering properties of agricultural materials, [9], [18], [15], [31], and [32].

$$Q = \frac{W_i(m_f - m_i)}{(100 - m_f)} \quad \dots (2)$$

$Q$  = The quantity of distil water needed to obtain the desired moisture content during the rewetting process.

$W_i$  = Weight of pumpkin seed before rewetting (g),  $m_f$  = final moisture content of pumpkin seed (% d.b),  $m_i$  = Initial moisture content of pumpkin seed (% d.b)

The rewetted pumpkin seed were packed in a low density polyethylene bags and stored in a refrigerator at 5°C for 72 hours [15]; this was done to create a favourable environment for absorption of moisture by pumpkin seed and to prevent the action of microbes on wet pumpkin seed.

The filling/static angle of repose of pumpkin seed was determined in accordance with the procedures of [16], [19], and [29]; it involves using a topless-bottomless PVC cylinder with the length of 213mm and internal diameter of 105mm, and a circular plate of 350mm diameter. The cylinder was placed at the center of a circular plate, and then filled with pumpkin seed at noted moisture content level. The cylinder was gradually raised until it formed cone on the circular plate. The height and the diameter of the cone formed were measured. The filling angle of repose was calculated using equation (3) in accordance with [7].

$$\theta_f = \tan^{-1} \left( \frac{2H}{D} \right) \quad \dots (3)$$

Where

H, and D are the height and the diameter of the cone formed by pumpkin seed.

The emptying angle of repose of pumpkin seed was determined in accordance with the procedures of [17] and [18]; it involves using a topless-bottomless wooden box of dimensions 130 x 130 x 135mm having a removable front panel. The box was filled with pumpkin seed at a desired moisture content level, and then the front panel was removed allowing the seeds to follow and assume a natural slope [8]. The emptying angle of repose was calculated using equation (4) in accordance with [9].

$$\theta_e = \tan^{-1} \left[ \frac{h_2 - h_1}{x_2 - x_1} \right] \quad \dots (4)$$

Where

$\theta_e$  = emptying/dynamic angle of repose,  $h_2$  = slope height of pumpkin seed at point 2,  $h_1$  = slope height of pumpkin seed at point 1,  $x_2 - x_1$  = horizontal distance between point 1 and 2.

The coefficient of static friction was determined using a standard procedure [10]; it involves placing pumpkin seed at the required moisture content on the friction surface. The surface was raised gradually until the seeds started to slide down the inclined surface of the friction apparatus. The angle of tilt at which the seeds began to slide was read from a graduated scale of a protractor. The concrete slab used for the experiment was made up of 1:5 (cement: aggregate by mass), and the aggregate constituted of 1:2 (fine: coarse by mass), [11]. The coarse aggregates were obtained by using standard sieve number #4 and number #200 based on standard procedures [13]. The coefficient of static friction was computed in terms of the angle of tilt using equation (5) in accordance [13].

$$\mu_s = \tan^{-1} \theta \quad \dots (5)$$

Where

$\mu_s$  = coefficient of static friction,  $\theta$  = Angle of tilt in degrees

To determine the hardness of pumpkin seed, Meyer's apparatus was used [13]. A cylindrical falling weight of mass of 220g and dimensions of length 8.56cm, diameter of 2cm and a firmly fitted steel ball of 2.09mm diameter at its lower end. The height of fall of 14cm was kept constant throughout the experiment. Upon release, the falling weight created an indentation on the pumpkin seed sample. The actual diameter of indentation on the pumpkin seed sample was read using a plastic rule of resolution of 0.5mm and magnifying glass. The hardness of pumpkin seed was calculated using equation (6) in accordance with [13].

$$H_m = \frac{4F}{\pi d^2} \quad \dots (6)$$

Where

F = load of the falling body (N), d = Actual diameter of indentation (mm).

Vegetable oil was extracted from pumpkin seed using the Soxhlet extraction method in accordance with the procedures of [14]; it involves boiling 3g of decorticated ground pumpkin seed in the presence of petroleum ether. The Soxhlet apparatus was allowed to reflux for six (6) hours. The thimble was carefully removed and the

petroleum ether in the top container of the set up was drained into a separate container for reuse. The same procedure was repeated for 50g and 75g of the sample.

The oil content of pumpkin seed was calculated using the expression in equation (7) in accordance with [23].

$$\text{percentage oil content} = \frac{W_2 - W_1}{W} \times 100 \quad \dots (7)$$

Where

$W$  = weight of sample (g),  $W_1$  = weight of beaker with glass ball (g),  $W_2$  = weight of beaker with glass ball and oil (g),  $W_2 - W_1$  = weight of oil.

### III. Results and Discussions

#### A. Results:

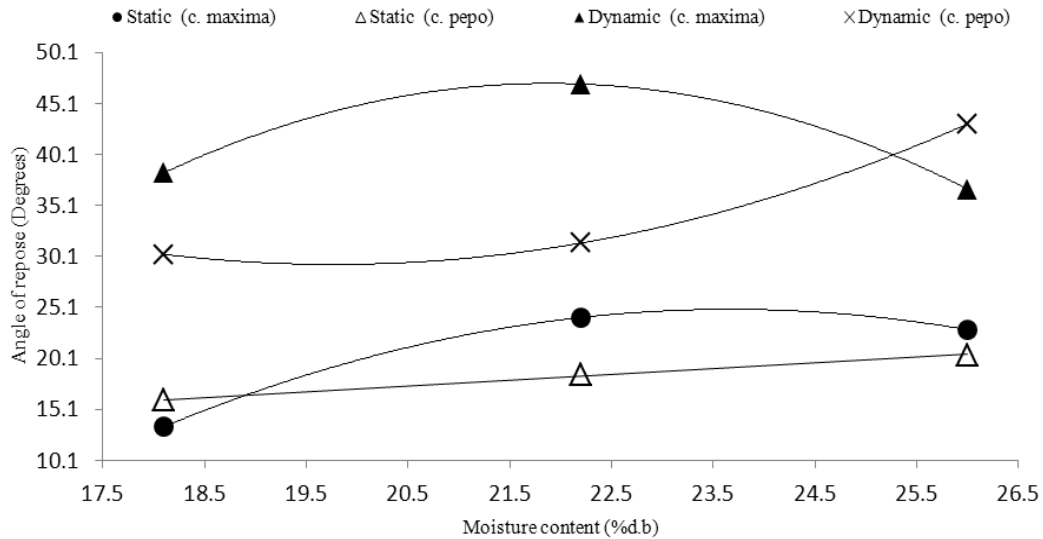


Figure 1. Static and Dynamic angles of repose of pumpkin seed at varying moisture content

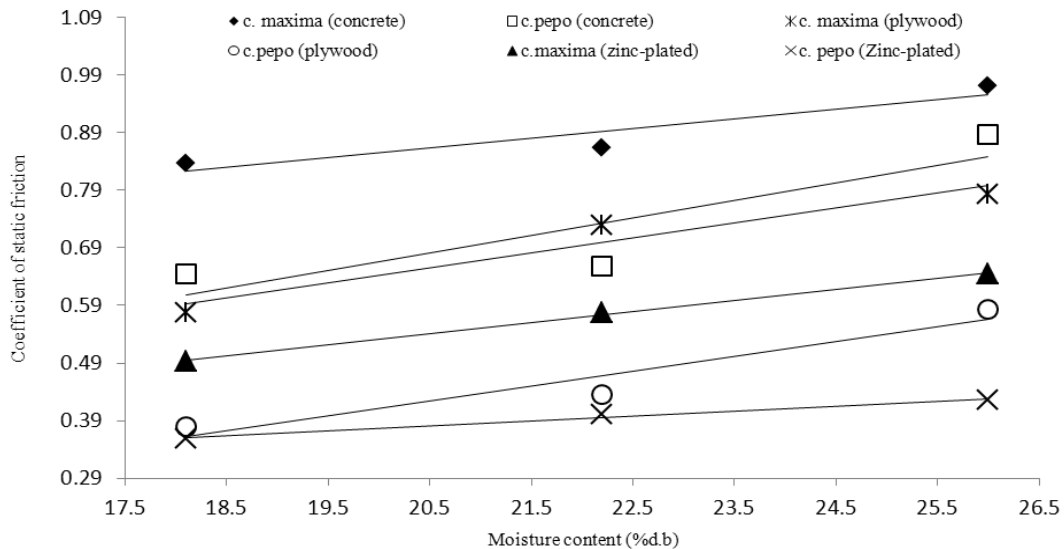


Figure 2. Coefficient of static friction of pumpkin seed on varying surfaces and moisture content

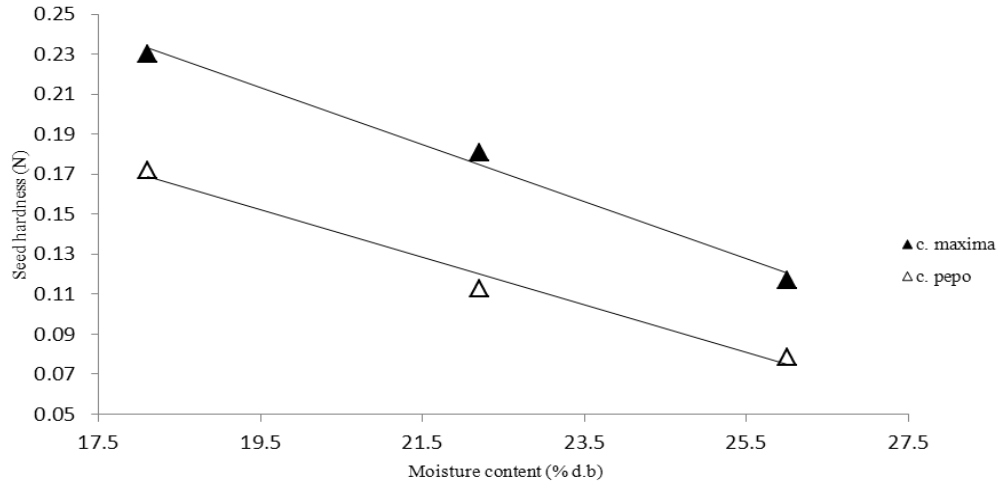


Figure 3 Hardness of pumpkin seed at varying Moisture content

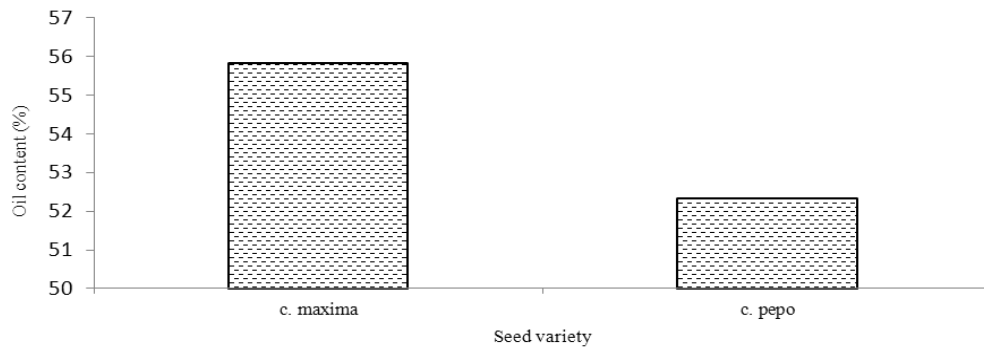


Figure 4 oil content of pumpkin seed

Table 1 Regression Equations for the Coefficient of Static Friction of Pumpkin Seed on Varying Friction Surface

Surface	Variety	Equation	R <sup>2</sup>
Concrete	c. maxima	$\mu_s = 0.0167MC + 0.521$	0.876
	c. pepo	$\mu_s = 0.0303MC + 0.061$	0.769
Plywood	c. maxima	$\mu_s = 0.0261MC + 0.12$	0.944
	c. pepo	$\mu_s = 0.0258MC + 0.104$	0.925
Zinc-plated	c. maxima	$\mu_s = 0.0193MC + 0.146$	0.998
	c. pepo	$\mu_s = 0.008MC + 0.21$	0.986

Table 2 Analysis of Variance for the Coefficient of Static Friction of pumpkin seed

Sources of variation	DF	SS	MS	F	P
Replication	3	0.0263	0.00377	2.47	0.073 <sup>ns</sup>
Variety	1	0.634	0.634	178	<0.001*
Moisture content (MC)	2	0.340	0.170	47.8	<0.001*
Surface	3	1.33	0.665	187	<0.001*
MC * Variety	2	0.0132	0.0066	1.86	0.166 <sup>ns</sup>
Variety * Surface	2	0.0168	0.00841	2.37	0.104 <sup>ns</sup>
MC * Surface	4	0.0431	0.0431	3.03	0.026*
MC*Variety*surface	4	0.0252	0.00629	1.77	0.15 <sup>ns</sup>
Error	51	0.181	0.00356		
Total	71	2.61			

\* Significant, <sup>ns</sup> not significant at 0.05 probability level

Table 3 Analysis of Variance (Mean Squares) for filling angle of repose ( $\theta_f$ ), Dynamic angle of repose ( $\theta_e$ ), and seed hardness

SV	DF	$\theta_f$	$\theta_e$	Seed hardness
Replication	3	1.62 <sup>ns</sup>	68730.5*	0.0006 <sup>ns</sup>
Treatment	5	73.8*	28099.49*	0.0123*
Variety	1	23.8*	197.23*	0.0181*
Moisture cont.	2	107.5*	74.62 <sup>ns</sup>	0.214*
Var. * MC	2	64.8*	250.43*	0.00041 <sup>ns</sup>
Error	15	1.92	27.27	0.00048

\* Significant, <sup>ns</sup> not significant at 0.05 probability level

### B. Discussions:

The variation of the angle of repose (static and dynamic) with the moisture content is presented in figure (1). The figure shows that the dynamic angle of repose at any moisture content level was higher than the static angle of repose. In *c. maxima* the static angle of repose increased from  $13.9^{\circ}$  to  $23.8^{\circ}$  as the moisture content was increased from 18.1 to 26% d.b. Similarly, the static angle of repose of *c. pepo* variety increased linearly from  $17.0^{\circ}$  to  $20.1^{\circ}$  for the same increase in moisture content (18.1 – 26% d.b). Similar trend of increase in the static angle of repose with moisture content was reported for rapeseed [29], corn seed [19], and canola seed, [16]. While non linear increase in the static angle of repose with increase in moisture content was reported for cowpea, [15]. The increase in the angle of repose with moisture content was probably due to increased adhesive force resulting from increased stickiness and surface roughness of pumpkin seed at higher moisture content. Correspondingly, the dynamic angle of repose increased from  $38.3^{\circ}$  to  $47.0^{\circ}$  between 18.1 and 22.2% d.b, but further increase in moisture content to 26% d.b resulted in a decline in the angle of repose to  $36.7^{\circ}$  in *c. maxima*. Similar polynomial trend between the dynamic angle of repose and moisture content was reported for Dragon's head seed, Ex-Borno variety of millet [17] and [18] respectively. Whereas, in *c. pepo* variety, the dynamic angle of repose increased from  $30.3^{\circ}$  to  $43.1^{\circ}$  for the same increase in moisture content between 18.1 and 26% d.b. Variety factor was significant on both the static and dynamic angles of repose of pumpkin seed ( $p < 0.05$ ), but moisture content was only significant on the static angle of repose of pumpkin seed, (Table 1).

The variation of the coefficient of static friction for pumpkin seed is presented in figure (2). The figure shows that moisture content had an increasing linear effect on all the surfaces and varieties investigated. The coefficient of friction of *c. maxima* variety increased linearly from 0.837 to 0.97, 0.49 to 0.645 and from 0.578 to 0.783 on the concrete, zinc-plated and plywood surfaces respectively. Correspondingly, the coefficient increased from 0.645 to 0.887, 0.10 to 0.725, and from 0.379 to 0.584 on the concrete, zinc-plated and plywood surfaces respectively as the moisture content was increased from 18.1 to 26.0% d.b. The highest coefficient of static friction was indicated by *c. maxima* variety on concrete surface (i.e. 0.97) at 26% d.b and the least coefficient was indicated by *c. pepo* variety on zinc-plated surface at 18.1% d.b. The increase in the coefficient of static friction was probably due to the fact that at higher moisture content pumpkin seed became stickier; this increased the force with which it adheres itself to the friction surface. This trend was similar to the trend between moisture content and cotton, canola seeds, soybean, cowpea, Ex-Borno variety of millet, lablab purpureus, [14], [23], [10], [12], [17]; however, polynomial increase in the coefficient of static friction with increase in moisture content was reported for cowpea [15]. The range of the coefficient of static friction in this study for plywood surface was higher than for cowpea, and soybeans on plywood surface within comparable moisture content range [15], and [31], but lower to the coefficient of friction of rapeseed on same friction surface. For comparably the same range of moisture content, the values of static friction coefficient in this study were within the range reported earlier for rapeseed and barley grain, [29] and [30]. The main effects of moisture content, friction surface and variety factors were significant on the coefficient of static friction ( $p < 0.05$ ); similarly, the two-way interaction effects of moisture content and variety, variety and friction surface, and the three-way interaction effect of moisture content x variety x friction surface were not significant on the coefficient of static friction of pumpkin seed ( $p > 0.05$ ), (Table 2).

The variation of the hardness of pumpkin seed with moisture content is presented in figure (3). The figure shows that moisture content had a decreasing linear effect on the hardness of pumpkin seed; it decreased from 0.23 to 0.117 N/mm<sup>2</sup> and from 0.172 to 0.0784 N/mm<sup>2</sup> in *c. maxima* and *c. pepo* varieties respectively as the moisture content was increased from 18.1 to 26% d.b. The decline in the hardness of pumpkin seed upon increase in moisture content was probably due to the fact that pumpkin seed became softer at higher moisture content; thus reducing its resistance to impact deformation, [21]; however Alonge (2003) reported an increasing effect of moisture content on the hardness of soybean seed between the moisture content of 10.9 and 12.5% w.b. The main effects of variety and moisture content were significant on the hardness of pumpkin seed ( $P < 0.05$ ), (Table, 1).

The oil content of pumpkin seed extracted using the Soxhlet method was displayed in figure (4). The figure shows that the oil content of *c. maxima* (55.8%) was higher than the oil content of *c. pepo* (52.3%) varieties of pumpkin seed. The oil content was statistically important between the varieties investigated ( $p < 0.05$ ). In comparison to the oil content of other seeds, the oil content of both varieties were higher than the oil content of soybean (19 – 21%), mustard seed (33 – 41%), cottonseed (15 – 20%), [23]; 24.8%, 30%, 27.5%, 24.8% and 28% for sesoswane, Agusi, wrewre, Tsama and desert varieties of melon respectively, [25]. The oil content of twelve (12) varieties of pumpkin seed in Iowa USA with oil content ranging between 10.9 to 30.9% [24]; these were lower in comparison to the oil content of the two varieties in this study. The variation may be attributed to the climatic and geologic differences existing between the regions of these studies.

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