

# Development of an Apparatus for Measuring Coefficient of Friction of Crops.

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## ABSTRACT

This work presents the development of an apparatus based on tilting plate method for measuring the coefficient of friction of crops. The apparatus was fabricated at the Department of Agricultural and Bio-Resources Engineering, Faculty of Engineering, Taraba State University, Jalingo. The apparatus consists the frame, screw jack, surface plate, base plate, protractor, lever arm and glass cover. To appraise performance of the apparatus, the static friction coefficient of two common and neglected crops, African Yam Bean (*Sphenostylis stenocarpa*) and African Mesquite (*Prosopis africana*) seeds, were measured on five different structural surfaces (mild steel, stainless steel, glass, plastics and Plywood) commonly used in agricultural processing equipment fabrication, construction of storage structures, packaging and handling equipment. Results obtained with the developed device were close to the standard coefficient of static friction from literatures. From practical point of view, the apparatus would be a beneficial tool for experimental, educational, demonstrational, and research works.

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## 1.0 Introduction

The knowledge of coefficient of friction of agricultural materials on various surfaces has long been recognized by engineers concerned with rational design of grain bins, silos and other storage structures. In design of agricultural machinery, however, the need for this information has been recognized rather recently. Friction is a set of phenomena observed between materials in contact, which leads to the loss of energy between moving objects and the wear of surfaces that come into contact, which increases surface temperature and can even produce acoustic effects. The processes that occur between a particle and the friction surface are termed as external friction, whereas internal friction takes place between particles. External friction conditions can be expressed by the angle and the coefficient of static and kinetic friction. Various methods and devices are applied to measure to above parameters. In the simplest approach, an adjustable inclined plane and a friction plate are used. The angle of static friction is measured by placing the analyzed material on a horizontally adjusted friction plate and by slowly increasing the angle of inclination until the seed begins to move [1, 2].

Friction is a complex phenomenon, and the angles and coefficients of friction given by researchers vary considerably, including for the same species and variety of seeds. Those variations

can be attributed to the non-homogenous nature of granular material as well as different testing conditions [3]. The coefficient of friction ( $\mu$ ) is the ratio of the force of friction ( $F$ ) to the force normal to the surface of contact ( $W$ ) as shown in Equation 1.

$$\mu = \frac{F}{W} \quad (1)$$

Frictional forces acting between surfaces at rest with respect to each other and those existing between the surfaces in relative motion are, respectively, called forces of static and kinetic friction. Static and kinetic coefficients of friction can be denoted by  $\mu_s$  and  $\mu_k$ , respectively [4]. In experiments where the sample is placed on an adjustable inclined plane, the coefficient of static friction ( $\mu_s$ ) is determined using Equation 2.

$$\mu_s = \tan\alpha \quad (2)$$

Distance ( $S$ ) traveled by the particle in expected time ( $t$ ) or time ( $t$ ) required by the particle to travel distance ( $S$ ) are measured to determine the coefficient of kinetic friction ( $\mu_k$ ). If the particle travels in uniformly accelerated motion and air drag is negligibly small, the force causing sliding motion (Figure 1) is as described by Equation 3. If the particle's initial velocity equals zero, its acceleration can be calculated from Equation 4. Equation 4 was substituted into Equation (3), and particle weight was reduced and transformed to produce.

$$ma_c = mg(\sin\alpha - \mu_k \cos\alpha) \quad (3)$$

$$a_c = \frac{2S}{r^2} \quad (4)$$

$$\mu_k = \tan\alpha - \frac{2S}{gt^2 \cos\alpha} \quad (5)$$

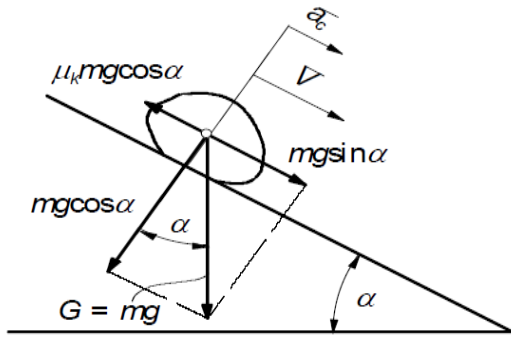


Figure 1: Forces Acting Upon a Particle Moving Along an Inclined Plane [5].

In the design of machines for handling and processing of food and agricultural products, certain frictional properties of the material constitute important and essential engineering data. The knowledge of frictional properties of plant material is essential for designing mechanical units in machines and for selecting harvesting, cleaning, sorting, storage and processing parameters [2, 6]. Obviously, before granular materials or unconsolidated materials can flow from a bin or an auger can be started by a power source, the force of static friction must be overcome. Likewise, once the force flow has begun, the dynamic coefficient of friction is needed before the power requirement for continued flow can be estimated. Therefore, the aim of this work is to develop an apparatus for measuring the coefficient of friction of crops based on tilting plate method.

## 2.0 Materials and Methods

### 2.1 Materials

The materials used for the development of an apparatus for measuring coefficient of friction of crops are glass, mild steel sheet, angle iron, iron rod, flat bar, cutting disc, filing disc, try square and measuring tape.

### 2.2 Methods

An angle iron of 3 mm thickness with dimension 50×50 mm was cut into sizes and welded to form a rectangular frame of length 400 mm, width 400mm and height 400 mm. A mild steel sheet of 3 mm thickness was cut to 400×400 mm dimension and welded to the frame to form the base plate that supports the screw jack. A mild

steel sheet of 3 mm thickness was cut to 400×400 mm dimension and welded to the frame to form the surface plate that supports or holds the test surface. Two pieces of 3 mm glass with dimension 300×400 mm were installed at two opposite sides of the frame to serve as windows. An adjustable screw jack was mounted on the base plate for raising and lowering of the surface plate. A protractor was attached to one side of the frame for reading the angle of inclination of the tilting surface. The developed apparatus is presented in Figure 2.

### 2.2.1 Description and operational procedure of the apparatus

The friction measuring apparatus is illustrated in Plate 1. It consists of a screw Jack, protractor, test surface, surface plate, cover plate, lever arm, base plate, glass cover and structural frame. The lever arm is rotated in a clockwise direction; and one revolution of a screw Jack raises the platform base, giving a pitch of 1.00 mm and test surface inclination of 0.5°. At the contact point between the screw Jack and the testing surface plate holder, a damper material is fitted into the arrangement to minimize vibration. The protractor registers any little change in the inclination of the test surface up to an angle of 45° which is within the range of angle of friction for most biological materials. The device provides stable and reliable readings and errors may only result from wrong reading of the calibrated values of the protractor. Proper alignments, settings and joining of the various components were done to ensure stability of the device.

### 2.2.2 Test procedure

Two common and neglected crops; African Yam Bean (*Sphenostylis stenocarpa*) and African Mesquite (*Prosopis africana*) were used in this study. The crops were obtained from a local market in Jalingo, Taraba State, Nigeria. The five different structural material surface (mild steel, stainless steel, glass, plastics and Plywood) were used for testing the friction apparatus. These were selected based on their use in agricultural processing equipment fabrication, construction of storage structures, packaging and handling equipment in the locality. The test sample was carefully loaded and the screw Jack spindle rotated while the test sample was observed for sliding. The rotation of the screw Jack handle was done gradually and steadily for an accurate result; and the angle at which the material started to slide down the test surface was read from the protractor. The tangent of this angle gave the static coefficient of friction of the grains on the test surfaces.

## 3.0 Results and Discussion

The data obtained using the developed apparatus was the angle of friction. The coefficient of friction of each selected agricultural material was calculated as the tangent of the angle of friction and the summary of the results is presented in Table 1. Different materials possess different angle of friction with plywood having the

highest values while glass have the lowest values of angle of friction. The coefficient of friction is therefore proportional to the angle of friction. The smooth nature of glass does not allow it to adhere together, hence, the seeds slide down quickly at a small tilt of the surface and thus has a smaller angle of friction. Conversely, the rough nature of plywood surface made it adhere together, hence, the seeds do not slide down quickly at a small tilt of the surface and thus has a higher value of angle of friction. The results of coefficient

of static friction for African Yam Bean Seeds obtained with the developed device were close to the results of coefficient of static friction reported by Ohaegbulam *et al.* [7] and the results of coefficient of static friction for African Mesquite Seeds obtained with the developed device is in line with the results of coefficient of static friction stated by Olajide *et al.* [8].



1. Surface Plate 2. Absorber 3. Protractor 4. Lever Arm 5. Glass Cover 6. Jack Base 7. Base Plate

Figure 2: The Developed Coefficient of Friction Apparatus

Table 1: Coefficient of Static Friction ( $\mu$ ) on Various Structural Surfaces

Test Surface	Crop Type			
	African Yam Bean Seeds		African Mesquite Seeds	
	Experimental	Literature [7]	Experimental	Literature [8]
Mild Steel	0.311	-	0.64	0.56-0.66
Stainless Steel	0.268	0.225	0.60	0.51-0.67
Glass	0.243	0.297	0.58	0.55-0.73
Plastics	0.246	-	0.63	0.60-0.68
Plywood	0.325	0.258	0.66	0.58-0.70



Generally, plywood and mild steel were observed to offer some resistance to sliding of seeds in either of the crop types. Though the size and weight of seeds, as well as the packing differences of seeds in the box, and surface characteristics of each of the structural surfaces used (even at the microscopic level) may have resulted in the degrees of disparities observed in the values of the coefficient of static friction. This observation may make a case for using less expensive, natural sources of contact surfaces when selecting and determining the slopes of the feed hopper seed processing equipment, or in the design of seed hopper in mechanized planters.

### Conclusion

Having tested the developed apparatus with two different agricultural materials and comparing the results with the standard from literature, a very little difference was noticed. In conclusion, the developed apparatus can be used to determine the static coefficient of friction of selected grains, which have application in the design of bins, hoppers and other storage structures.

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