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**E Gowthami**
Assistant Professor, Dr. NTR college of Food Science & Technology, Acharya N. G. Ranga Agricultural University, Bapatla, Guntur, Andhra Pradesh, India

**DD Smith**
Associate Dean, College of Food Science & Technology, Acharya N. G. Ranga Agricultural University, Pulivendula, Kadapa, Andhra Pradesh, India

**L Edukondalu**
Associate Professor, College of Food Science & Technology, Acharya N. G. Ranga Agriculture University, Pulivendula, Kadapa, Andhra Pradesh, India

**Vimala Beera**
Assistant Professor, Dr. NTR college of Food Science & Technology, Acharya N. G. Ranga Agricultural University, Bapatla, Guntur, Andhra Pradesh, India

**V Srinivasa Rao**
Professor, Agricultural College, Acharya N. G. Ranga Agricultural University, Bapatla, Guntur, Andhra Pradesh, India

**Corresponding Author:**
**E Gowthami**
Assistant Professor, Dr. NTR college of Food Science & Technology, Acharya N. G. Ranga Agricultural University, Bapatla, Guntur, Andhra Pradesh, India

# Frictional properties of rice bran

**E Gowthami, DD Smith, L Edukondalu, Vimala Beera and V Srinivasa Rao**

## Abstract
In this study, frictional properties like angle of repose and coefficient of static friction of rice bran were evaluated at seven different moisture contents (9.4, 12, 15, 20, 25, 30 & 35% w.b.) on different surface materials namely; glass, fiber, plywood and mid steel. The results showed that linear relationship noticed between angle of repose and moisture content with high correlation coefficient (0.98). The angle of repose of rice bran was greatest (56.98±0.01) at high moisture content (35%w.b.) and least (23.5±0.27) for low moisture content (9.4% w.b.). The static coefficient of friction value for rice bran on all four structural surfaces (fiber, glass, mild steel and wood) was investigated. The peak value was observed for mild steel (0.687–1.184) at high moisture content (35% w.b.) and lowest for (0.328–0.812) on wood surface. High correlation coefficient (0.99) for mild steel established the relationship between coefficient of static friction and moisture content. The coefficient of static friction of rice bran on all four test surfaces decreased linearly with decreasing the moisture content.

**Keywords:** Rice bran, angle of repose, coefficient of static friction, frictional properties

## 1. Introduction
Rice bran is the key by product of whole rice of about 10% of whole grain weight which is separated from the starchy endosperm during rice milling. It has high oil content (15-25%) has low moisture content (6-7%) and possesses a powdery consistency. In India, about 50 million hectares are under rice production and average yield is about 3,400 kg/hectare. The country's rice production stood at 180 million tonnes in the 2020-21 crop year. Current production of rice bran oil is over 9, 80, 000 tonnes per annum and increasing by about 40,000/50,000 tonnes per annum (SEA, 2020) [15]. Production of rice bran is high but limited research studies done so far on frictional properties of rice bran.

The frictional properties (angle of repose and coefficient of static friction) are important in designing equipments and machines for conveying and handling. Frictional properties are used to attain consistent flow of material without slipping, through the hoppers or conveying parts and also useful in hopper design, since the hopper walls inclination angle should be greater than the angle of repose to ensure the continuous flow of rice bran.

Angle of repose (θ) is a significant mechanical property used for classification of free flowability of material in bulk form. When bran is piled on a flat surface, the sides of the pile are at a definite reproducible angle with the horizontal levelled surface. This angle is called the angle of repose of the bran. This property is important for the design of processing, storage, and conveying systems of materials. For very fine and sticky materials, θ is high. When θ is less than 25 degrees, it can be treated as excellent flow while θ is more than 40 degrees, flow is treated as poor.

Razavi *et al.* (2007) [14] studied the coefficient of static friction and angle of repose of whole pistachio nut on five surfaces (fiberglass, glass, galvanized iron sheet, plywood, and rubber) at five moisture contents. Results showed that angles of repose of pistachio nuts and kernels decreased linearly as the moisture content decreased. The highest friction coefficient for all pistachio varieties (both nut and kernel) obtained on rubber surface and the lowest on fiberglass surface at all moisture content levels. The static coefficient of friction of both nuts and kernels on all five test surfaces decreased linearly with decreasing the moisture content.

Ozguven and Kubilay (2004) [13] determined physical, mechanical and aerodynamic properties of pine nuts at 5.48% (db) moisture content. Results found that the true density, bulk density and porosity were 983.59, 619.85 kg/m$^3$ and 36.96%, respectively. The coefficient of static friction was 0.46 on plywood, 0.43 on galvanized steel sheet and 0.35 on fibreglass. Angle of repose of pine nuts was found to be 23.52°.

Ogunjimi *et al*. (2002) [9] studied the some frictional properties like coefficient of friction on wood, angle of repose at 10.25% (d.b.) moisture content. Results found that coefficient of static friction on wood averaged 0.43 and repose angle (θ) was 20.32°. These results indicate that a mechanical dehulling process to obtain whole kernel from locust bean seed should be possible.

Several researchers (Aviara, & Haque, 2000; Ojha, 1993; Omobuwajo, Akande, & Sanni, 1999; Osunade, & Lasisi, 1994; Lawton, 1980) [1, 10, 11, 12, 7] have worked on the frictional properties of few nuts and grains. Some studies on static friction (μ) at different structural surfaces usually employed are galvanized steel sheet; wood and fibre were conducted by different scientists (Dutta *et al*., 1988; Fraser *et al*., 1978) [3, 4]. There is limited information on the frictional properties of rice bran in the scientific literatures.

The objective of this research was to investigate some frictional properties like angle of repose and coefficient of static friction of rice bran at seven different moisture contents (9.4, 12, 15, 20, 25, 30 & 35% w.b.) on different surface materials.

## 2. Material and methods / experimental details / methodology

Rice bran was purchased from local rice mill located at Bapatla, Andhra Pradesh state, India. The rice bran was sieved through 20μm sieve to remove rice brokens and foreign materials. Bran moisture content was determined using the AOAC (2008) recommended method by oven drying of bran samples at 103 ºC for 72 h. The test samples were allowed to cool in a dessicator after which the weights were recorded and the average moisture content was found to be 9.4% (wb). The bran was adjusted to different moisture contents (12, 15, 20, 25, 30 & 35% (wb)) as per relationship given by Dhingra *et al*., 2012 [2].

### 2.1 Angle of Repose

To investigate the angle of repose (θ) by an apparatus (plate. 1) having hopper followed by circular disc arrangement as recommended by Ozguven and Kubilay, 2004 [13]. The sample was transferred through a hopper having a top and bottom diameters were 28 cm and 3.5 cm respectively and 2.5 cm height and then fell on the raised circular disc having a diameter of 14.5 cm was placed at the hopper centre. Sliding gate was provided below the hopper to regulate the rice bran flow through opening. The gate was moved slowly until it forms a cone on a circular plate, allowing the bran sample to accumulate and form a conical heap on the surface. Cone height was measured in triplicate and the angle of repose was calculated by below following relationship given by Kaleemullah & Gunasekar, 2002 [5].

$$\theta = \tan^{-1}\frac{2H}{D}$$

**Where**

θ = Angle of repose, º

H= Height of the rice bran pile, cm

D= Diameter of the circular plate or disc, cm

**Plate 1:** Apparatus for measuring angle of repose

### 2.2 Coefficient of Static Friction

Static friction coefficient of rice bran was measured by frictional device as shown in plate 2 at different moisture content levels against four frictional surfaces, namely glass, fiber, plywood and mid steel as recommended by Dutta *et al*., 1988 [3] and Fraser *et al*., 1978 [4]. A cylinder with open sides at the top and bottom is made up of poly vinyl chloride with 5 cm diameter and 5 cm height was rested on an adjustable inclined plane, faced with the test surface which was filled by rice bran sample and gradually lifted up to 2 mm, so as not to contact the surface. The test surface with the cylinder was inclined slowly by regulating screw device, until the test cylinder just started to slide on test surface and angle of tilt was measured from a graduated scale. Static friction coefficient was measured in triplicate then calculated by given below relationship (Mohsenin, 1978) [8].

$\mu_s$= tan α

**Where**

$\mu_s$= Coefficient of static friction

α = Angle of tilt, º

**Plate 2:** Apparatus for measuring coefficient of static friction

## 3. Results and Discussion

Experimental results of angle of repose with respect to moisture content are shown in Fig 1. The angle of repose values found to increase from 23.75º to 56.97º in the moisture range of 9.4-35 (% w.b.). The increasing trend of angle of repose with moisture content occurs because the surface moisture surrounding the particle holds the aggregates together by the surface tension and also higher stickiness of the particles on each other. Similar trends were observed in Ozguven and Kubilay, 2004 [13]; Zewdu and Solomon, 2006 [16] and Razavi *et al*, 2007 [14].

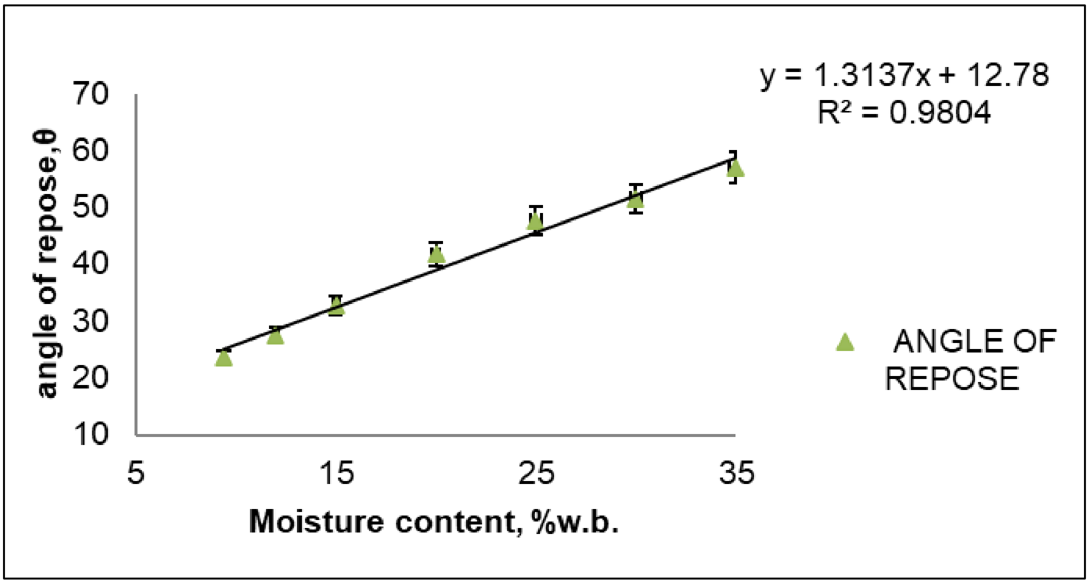


**Fig 1:** Effect of moisture content on the angle of repose of rice bran

Equations presenting relationship between angle of repose and moisture content and their coefficient of determination ($R^2$) is shown in Fig 4.1. It can be establish that, linear relationship between angle of repose and moisture content with high correlation coefficient. Correlation coefficient of 0.98 for the developed model indicates that, the model has good quality fit and is presented below (equation 1).

$\Theta = 1.310(M_c) + 12.87$ ... (1)

**Where**

$\Theta$ = Angle of repose, º

$M_c$ = Moisture content, % w.b.

Coefficient of static friction ($\mu_s$) of rice bran on different surface materials namely wood, glass, mild steel and fibre at various moisture contents are plotted against moisture content as presented in Fig. 2. The highest coefficient of static friction was obtained on the mild steel i.e., (0.687–1.184), followed by glass (0.603–1.091), fiber (0.536–0.975) and the lowest for wood surface (0.328–0.812). This trend is due to smooth and polished surface of the mild steel test surface has offered high friction value, which in case of the wood, the roughness of it, has revealed the minimum friction value. It was observed that the material surface had greater impact on coefficient of static friction than the moisture content. These linear Behaviors are in agreement with similar results reported by Dutta *et al.*, 1988 [3]; Fraser *et al.*, 1978 [4]; Razavi *et al.*, 2007 [14].

**Table 1:** Equations representing relationship between coefficient of static friction ($\mu_s$) and moisture content ($M_c$) of rice bran

| Surface material | Regression equation | Correlation coefficient ($R^2$) |
|---|---|---|
| Fiber | $\mu_s=0.017M_c+0.404$ | 0.966 |
| Wood | $\mu_s=0.016M_c+0.263$ | 0.961 |
| Metal sheet | $\mu_s=0.018M_c+0.538$ | 0.990 |
| Glass | $\mu_s=0.019M_c+0.461$ | 0.982 |

It was furthermore observed that the coefficient of static friction for rice bran on all four structural surfaces increased as moisture content increased from 9.4 to 35%w.b. (Fig. 2). The lowest values of static friction obtained at lower moisture content and high static friction values obtained at 35% wb moisture content. This is due to increasing the stickiness and adhesion between rice bran and material surfaces and also decreased sliding characteristics at higher moisture contents; it results in increased static coefficient of friction. The obtained trends in this research were same with the Kashaninejad *et al.*, 2005 [6] and Razavi *et al.*, 2007 [14].

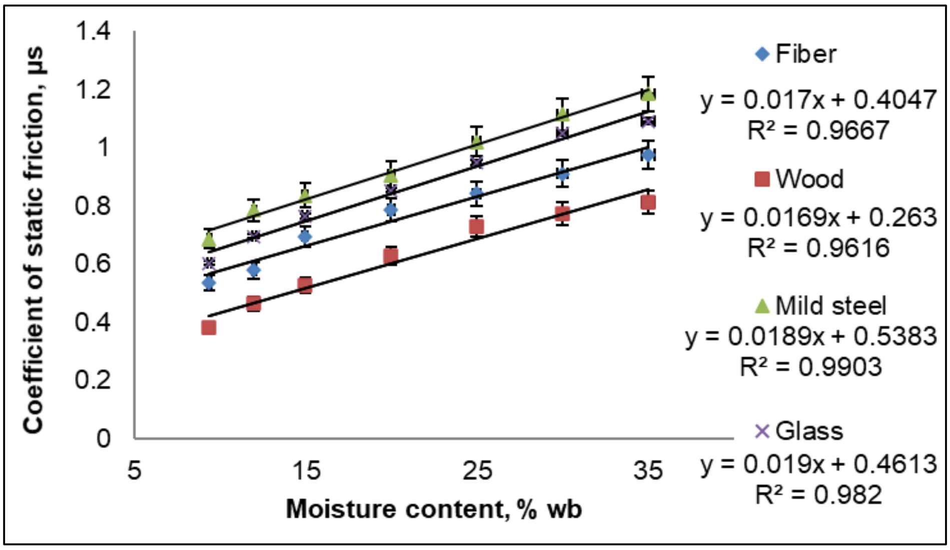


**Fig 2:** Effect of moisture content on the Coefficient of static friction, $\mu_s$ of rice bran at different surfaces

Equation obtained for predicting the coefficient of static friction of rice bran as a function of moisture content are given in Table 1. It can be found out; there were positive correlation linear relationships obtained between static friction and moisture content. High correlation coefficient ($R^2$=0.99) was obtained for metal sheet followed by glass (0.982), fiber (0.966) and wood (0.961). High $R^2$ shows that the model has good fit.

## 4. Conclusion

- Frictional properties of rice bran were dependent to their moisture content.
- For moisture content increased, the angle of reposes and static coefficient of friction increased linearly.
- Coefficient of static friction of rice bran on all four test surfaces decreased linearly with decreasing the moisture content.
- It was observed that the material surface had greater impact on coefficient of static friction than the moisture content.

## 5. Acknowledgements

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