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Effect of moisture content on angle of repose for different cereals and pulses

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Abstract
The study was conducted on "Effect of Moisture Content Effect of Moisture Content on Angle of Repose for different cereals and pulses" Physical property, i.e. moisture content and angle of repose were measured. The main aim of the study was to study the effect of moisture content on the angle of repose for selected cereals and pulses and to develop the prediction model to quantify the effect of moisture content on angle of repose. The variable observed were moisture content as independent variables while angle of repose is observed variable. The grains used were paddy, maize, Bengal gram, soybean and pea. Five levels of moisture content were considered 8%, 10%, 12%, 14% and 16% (d.b.). In this method, angle of repose is measured by measuring slope with horizontal pile formed on the free vertical fall of the grains. In all the cases the prediction model having nature of straight line function was generated to characterize the relationship between moisture content and angle of repose and angle of repose. The angle of repose increased as moisture content of the grains increased. In this study straight line function shows best relationship in between moisture content and angle of repose for paddy, maize, bengal gram, soybean and pea.

Keywords: Angle of Repose, Bio-Materials, Moisture Content, Straight Line Model

Introduction
The angle of repose is the angle with horizontal at the materials will stand when piled [1] The angle of repose, or angle with a horizontal surface formed when free-flowing grain comes to rest, can be used to estimate the height or width of grain piles. Angle of repose depends on properties like size and shape of kernels, moisture content, fines and foreign material content, presence of mold, and submerging, pouring, pilling or emptying method, and can vary greatly. The angle of repose, or angle with a horizontal surface formed when free-flowing grain comes to rest, can be used to estimate the height or width of grain piles. Angle of repose depends on properties like size and shape of kernels, moisture content, fines and foreign material content, presence of mold, and submerging, pouring, pilling or emptying method, and can vary greatly. The angle of repose sometimes used in the design of equipment for the processing of particulate solids for example, it may be used to design an appropriate hopper or silo to store the material, or to size a conveyor belt for transporting the material. It can also be used in determining whether or not a slope will likely collapse the slope is derived from angle of repose and represent the steepest slope a pile of granular material will take. This angle of repose is also crucial in correctly calculating stability in vessels.

Moisture Content
Moisture content is one of the most fundamental and important characteristic of biological material. The moisture content of food grains and other agricultural products plays an important role in maintaining the desirable quality of product. Changes in moisture content of agricultural material occur during their harvesting, processing and marketing. The change in moisture content during successive post-harvest stages is dependent upon the initial moisture content of product and atmospheric conditions. The information of moisture content is necessary because it tells us whether the product is suitable for safe storage or for any other processing job. For some period, if the moisture content of food grains increases beyond a fixed critical value, under such conditions chances of metabolic reactions inside the grain become higher. Due to such reactions, viability of seed reduces. Drying of agricultural product become necessary at higher moisture contents.

Moisture content representation

The amount of moisture in a product is given on the basis of the weight of water present in the product and is usually expressed in percent. Moisture content is designated by two methods, (1) wet basis (wb) and (2) dry basis (db).

Wet basis

The moisture content in this method is represented by the following expression,

$$\text{Percent moisture content} = \frac{\text{Weight of water in product}}{\text{Weight of product sample}} X100$$

Dry basis

In this method of representing moisture content; it is given on the basis of dry weight of product. The dry basis moisture content is determined by the following expression.

$$\text{Percent moisture content} = \frac{\text{Weight of water in product}}{\text{Weight of dry matter of product sample}} X100$$

The value of dry basis moisture content is more than wet basis moisture content.

Aim of the Study

To characterize the bulk flow behavior indicates at different moisture content for Paddy, Maize, Bengal Gram, Soybean and Pea.

Material and Methods

In this method, angle of repose is measured by measuring the slope with horizontal of the pile formed on the free vertical fall of the grains. For this purpose a hollow cylinder standing vertically on the horizontal plan is filled with desired grain sample at rest position. The hollow cylinder is lifted vertically allowing the grains to pile on horizontal plane. In this condition height and diameter of cone is measured manually by measuring scale, and angle of repose is calculated by following formula:

Angle of repose =tan−1 2hd

Where, h= the height of pile, and d= the base (diameter).

1. 2 feet pipe was taken for experiment
2. 1/3 portion of pipe was filled by the grains. The pipe was lifted vertically and grains were allow to pile on the horizontal plane. In this condition height and diameter of cone is measured manually by measuring scale.
3. The angle of repose was calculated by using above formula.
4. This procedure was repeated 5 times.

Variable Observed

Independent variable	Dependent Variable
Moisture Content (%) 8, 10, 12, 14 and 16	Angle of Repose

Looking to the inherent variability in characteristics of biomaterials, initially at the time of planning the experiment it was decided to test four different type of model namely, straight line or linear function, power function, exponential function and second order polynomial function. However after fitting the observed data by using MS-excel it was noted that, in all the experiments the equation developed to express the effect of moisture content and sphericity on the angle of repose was found to possess in general the very high correlation between two variables on a straight line model. Although, the correlation coefficient was more or less similar for the other models i.e. power function**,** exponential function and second order polynomial function. But it was observed that, the relationship was best illustrated for straight line model. Therefore in all the cases the prediction model having nature of straight line function was generated to characterize the relationship between moisture content and angle of repose, as well as the relationship between sphericity and angle of repose for paddy, maize, Bengal gram, soybean and pea.

Result and Discussion

Effect of Moisture Content on Angle of Repose

Paddy

The moisture content of food grains and other agricultural products play an important role in maintaining the desirable quality of product. In the present study different grains having different moisture content were used for determination of angle of repose. The range of study for moisture content was 8%, 10%, 12%, 14% and 16% (d.b.) for all grains i.e. paddy, maize, Bengal gram, soybean and pea. In every case the angle of repose was determined separately the angle of repose for a given grain was determined five times each and the average data was utilized in the analysis. For the paddy grain after analyzing the data using MS – excel for straight line model a data plot and a linear trend line was developed along with linear prediction model and coefficient of determination R2 was developed as shown in fig. 2 shows the relationship between moisture content and angle of repose is a straight line with a strong positive correlation (R2 = 0.989). The linear prediction model developed was,

y = 0.865x + 26.771

where, y = angle of repose, and; x = moisture content

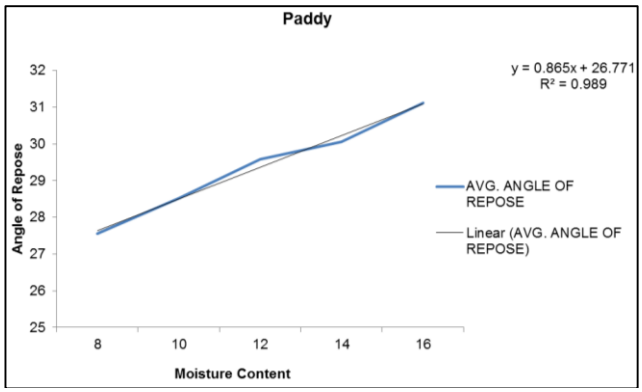

Fig 4.1: Effect of moisture content on angle of repose

The coefficient of moisture content as shown in the equation is (0.865) which shows that for the unit change in the moisture content. The angle of repose is increase by 0.865unit and the coefficient of determination of 0.970 shows that the observed and predicted variables are highly correlated and the developed model can be used to predict the value of angle of repose with fairly high degree of accuracy within the moisture content range of 8% to 16%.

Maize

For the maize grain after analyzing the data using MS – excel for straight line model a data plot and a linear trend line was developed along with linear prediction model and coefficient of determination R2 was developed as shown in fig.3 showsthe relationship between moisture content and angle of repose is a straight line with a strong positive correlation (R2 = 0.993). The linear prediction model developed was,

y = 2.09x + 16.72
Where, y = angle of repose and; x = moisture content of biomaterial.

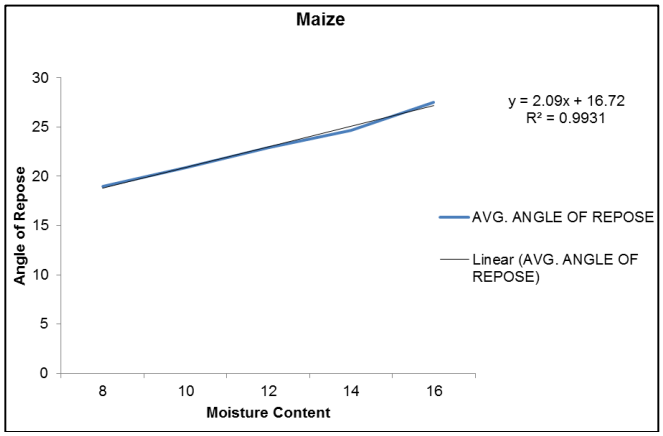

Fig 4.2: Effect of moisture content on angle of repose

The coefficient of moisture content as shown in the equation is (2.09) which shows that for the unit change in the moisture content. The angle of repose is increase by 2.09 unit and the coefficient of determination of 0.993 shows that the observed and predicted variables are highly correlated and the developed model can be used to predict the value of angle of repose with fairly high degree of accuracy within the moisture content range of 8% to 16%.

Bengal Gram

For the Bengal gram grain after analyzing the data using MS – excel for straight line model a data plot and a linear trend line was developed along with linear prediction model and coefficient of determination R2 was developed as shown in fig. 4 shows the relationship between moisture content and angle of repose is a straight line with a strong positive correlation (R2 = 0.949). The linear prediction model developed was,

y = 1.32x + 21.256
Where, y = angle of repose and; x = moisture content of biomaterial.

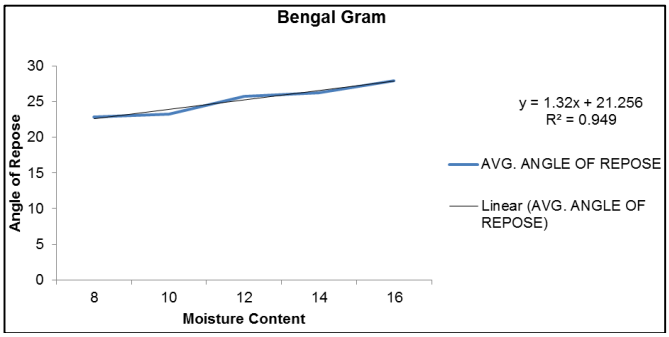

Fig 4.3: Effect of moisture content on angle of repose

The coefficient of moisture content as shown in the equation is (1.32) which shows that for the unit change in the moisture content. The angle of repose is increase by 1.32 unit and the coefficient of determination of 0.949 shows that the observed and predicted variables are highly correlated and the developed model can be used to predict the value of angle of repose with fairly high degree of accuracy within moisture content range 8% to 16%.

Soybean

For the soybean grain after analyzing the data using MS – excel for straight line model a data plot and a linear trend line was developed along with linear prediction model and coefficient of determination R2 was developed as shown in fig. 5 showsthe relationship between moisture content and angle of repose is a straight line with a strong positive correlation (R2 = 0.965). The linear prediction model developed was,

y = 1.123x + 17.415
Where, y = angle of repose and; x = moisture content of biomaterial.

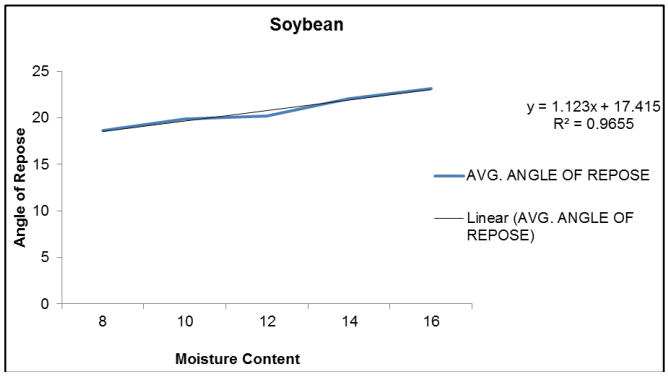

Fig 4.4: Effect of moisture content on angle of repose

The coefficient of moisture content as shown in the equation is (1.123) which shows that for the unit change in the moisture content. The angle of repose is increase by 1.123 unit and the coefficient of determination of 0.965 shows that the observed and predicted variables are highly correlated and the developed model can be used to predict the value of angle of repose with fairly high degree of accuracy within moisture content range 8% to 16%.

Pea

For the pea grain after analyzing the data using MS – excel for straight line model a data plot and a linear trend line was developed along with linear prediction model and coefficient of determination R2 was developed as shown in fig.6 shows the relationship between moisture content and angle of repose is a straight line with a strong positive correlation (R2 = 0.972). The linear prediction model developed was, y = 1.085x + 16.783 Where,y = angle of repose and; x = moisture content of biomaterials.

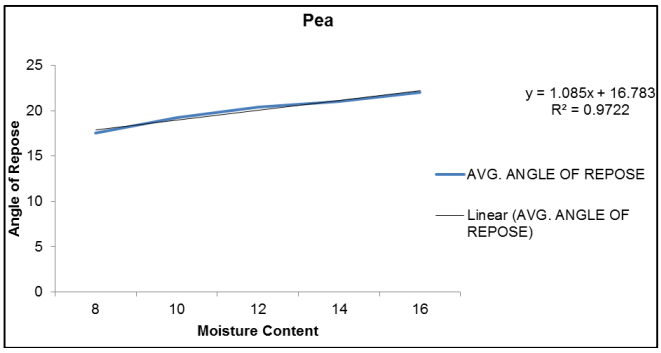

Fig 4.5: Effect of moisture content on angle of repose

The coefficient of moisture content as shown in the equation is (1.085) which shows that for the unit change in the moisture content. The angle of repose is increase by 1.085

unit and the coefficient of determination of 0.972 shows that the observed and predicted variables are highly correlated and the developed model can be used to predict the value of angle of repose with fairly high degree of accuracy within moisture content range 8% to 16%.

Conclusion

1. The angle of repose increased as moisture content of the grains increased, grains having moisture content ranges 8%, 10%, 12%,14% and 16% for all grains i.e. paddy, maize, Bengal gram, soybean and pea. Angle of repose for paddy grain is 27.550, 28.530, 29.580, 30.060 and 31.110, for maize 18.980, 20.850, 22.920, 24.690 and 27.510, for Bengal gram 22.890, 23.210, 25.750, 26.270 and 27.960, for soybean 18.630, 19.880, 20.190, 22.070 and 23.150, and for pea 17.520, 19.230, 20.360,21.040 and 22.040
2. In this study straight line function shows best relationship in between moisture content and angle of repose, as well as sphericity and angle of repose for paddy, maize, bengal gram, soybean and pea.

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