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Variation in Angle of Repose with Moisture Content and Shape for Cereals and Pulses

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Abstract

A study was conducted on "Variation in Angle of Repose with Moisture Content and Shape for Selected Food Grains (cereals and pulses)." Physical properties, i.e. sphericity, moisture content and angle of repose were measured. The main aim of the study was to study the effect of moisture content and sphericity on the angle of repose for selected cereals and pulses and to develop the prediction model to quantify the effect of moisture content and sphericity on angle of repose. The variable observed were moisture content and sphericity 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, as well as sphericity and angle of repose. The angle of repose increased as moisture content of the grains increased. The angle of repose decreased as sphericity of grain increased. 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.

Key words: Angle of repose, Bio-materials, Moisture content, Sphericity, Straight line model.

Introduction

The angle of repose is the angle with horizontal at which the materials will stand when piled. The physical properties of materials such as the shape, moisture content and the orientation of the materials have a deciding influence on the angle of repose. 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 is likely collapse, the slope derived from angle of repose represent the steepest slope a pile of granular material will take. The effect of moisture content on angle of repose, he found that the angle of repose increased linearly with the increase of moisture content for all varieties under study.

The effect of sphericity on angle of repose and he was found the angle of repose decreased linearly with increase of sphericity for all the varieties.

Aim of the Study

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

Material and Methods

$\text{Angle of repose} = \tan^{-1}\left(\frac{2h}{d}\right)$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:

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.

3. 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.
4. The angle of repose was calculated by using above formula.
5. This procedure was repeated 5 times.

Variable observed

Independent Variable		Dependent Variable
Moisture Content (%)	Sphericity (mm)	Angle of Repose
8, 10, 12, 14, 16.	0.46,0.66,0.73, 0.83, 0.88	

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 posses 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 Sphericity on Angle of Repose

Sphericity is primarily a function of shape of grain, in the present study different whole grains having different shape and hence the different sphericity were used for determination of angle of repose, variability in sphericity due to variation in shape of selected grains provided the range of the study in sphericity from 0.46 mm for paddy to 0.88 mm for peas. In every case the angle of repose was determined separately. The angle of repose for given grain was determined five time each and the average data was utilized in the analysis. Similarly, 25 grains of each type was selected randomly for determination of sphericity and the average of these 25 observations was used to characterize the sphericity of biomaterial. 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 (R^2) was developed as shown in fig.1showsthe relationship between sphericity and angle of repose is a straight line with a strong but negative correlation (R^2 = 0.982). The linear prediction model developed was,

$$y = -3.367x + 32.79$$

Where, y = angle of repose, and; x = sphericity of biomaterial.

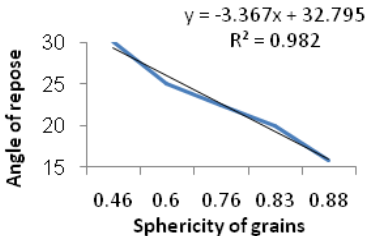

Fig. 1 Effect of sphericity on angle of repose

The coefficient of sphericity as shown in the equation is (-3.367) which shows that for the unit change in the sphericity, the angle of repose is reduced by 3.367 unit, and a coefficient of determination of 0.982 shows that the observed and predicted variables used to predict the value of angle of repose with fairly high degree of accuracy within the sphericity range of 0.46 mm to 0.88 mm.

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 R^2 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 (R^2 = 0.989). The linear prediction model developed was,

$$y = 0.865x + 26.771$$

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

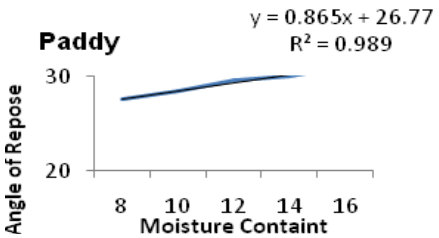

Fig. 2 Effect of moisture content on angle of repose

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 R^2 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 (R^2 = 0.993). The linear prediction model developed was,

$$y = 2.09x + 16.72$$

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

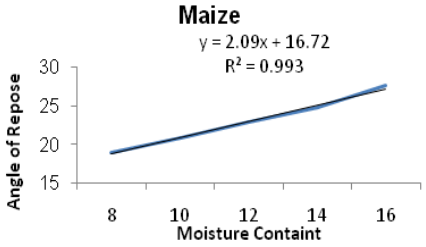

Fig. 3 Effect of moisture content on angle of repose

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 R^2 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 (R^2 = 0.949). The linear prediction model developed was,

$$y = 1.32x + 21.256$$

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

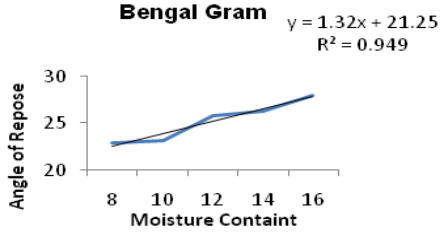

Fig. 4 Effect of moisture content on angle of repose

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 R^2 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 (R^2 = 0.965). The linear prediction model developed was,

$$y = 1.123x + 17.415$$

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

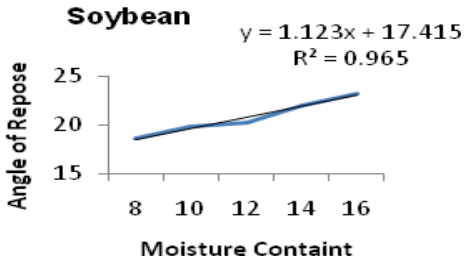

Fig. 5 Effect of moisture content on angle of repose

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 R^2 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 (R^2 = 0.972). The linear prediction model developed was,

$$y = 1.085x + 16.783$$

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

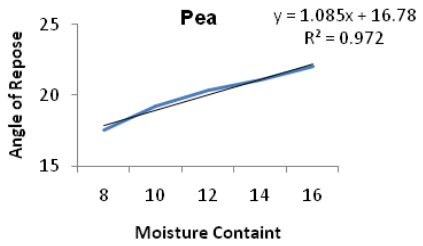

Fig. 6 Effect of moisture content on angle of repose

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 27.55^0, 28.53^0, 29.58^0, 30.06^0 and 31.11^0, for maize 18.98^0, 20.85^0, 22.92^0, 24.69^0 and 27.51^0, for Bengal gram 22.89^0, 23.21^0, 25.75^0, 26.27^0 and 27.96^0, for soybean 18.63^0, 19.88^0, 20.19^0, 22.07^0 and 23.15^0, and for pea 17.52^0, 19.23^0, 20.36^0,21.04^0 and 22.04^0
2. The angle of repose decreased as sphericity of grain increased, the sphericity of grains i.e. paddy, maize, Bengal gram, soybean and pea are 0.46mm, 0.6mm, 0.73mm, 0.83mm and 0.88mm and their angle of repose was, 30.13^0, 25.11^0, 22.36^0, 20.04^0 and 15.83^0.
3. 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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