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EFFECT OF GRAIN MOISTURE CONTENT ON REPOSE ANGLE OF SOME VARIETIES OF CEREAL CROPS

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ABSTRACT

The present study was carried out to determine the repose angle for different varieties of rice, corn, wheat and barely at different levels of grain moisture content. The results show that, the angle of repose was increased with the increase of grain moisture content for all varieties of the studied crops, while it was varied with the nature of texture surface of different grain. The recorded repose angle was ranged from 29.75 to 40.25° for rice, from 26.58 to 41.53° for corn, from 25.08 to 37.16° for wheat and from 28.08 to 38.67° for barely. The regression analysis of the obtained data showed a direct simple relationship between the angle of repose and the grain moisture content for different varieties of rice. While, the relationship was found to be a second degree polynomial for different varieties of corn, wheat and barely.

INTRODUCTION

The angle of repose and the frictional properties of grain play an important role in the selection of design features of hoppers, chutes, dryers, storage bins, and other equipment for grain flow. The angle of repose is defined as the angle between the base and the slop of the cone formed on a free vertical fall of the grain mass to a horizontal plan. (Chakraverty 1987)

Mohsenin (1984) reported that, the dynamic angle of repose is one of the physical properties needed for the design of material, handling systems and storage facilities for corncobs.

Srivastava *et al.* (1990) studied the effect of physical properties of wheat and barely on the separation and cleaning efficiency of combine harvester. They found that, the cleaning efficiency was greatly affected by the angle of repose and the density of straw and grain.

Soliman (1994), studied the effect of moisture content on angle of repose of paddy rice. He mentioned that, the dynamic angle of repose is one of the physical properties needed for the design of material handling systems and storage facilities for rice and rice products. Also, the angle of repose varies with the grain variety, degree of impurities and moisture content. In general, the angle of repose of paddy changed in the range between 40 to 47 degrees depending on variety and moisture content.

Owis, (1995) determined the angle of repose for different varieties of wheat, rice and corn. He found that, the angle of repose was varied from 27 ° to 29° for wheat varieties, from 32° to 46° for rice varieties, and from 31° to 34° for corn varieties. He also mentioned that, the variance of repose angle was due to the texture surface of grain varieties.

El-Raie *et al.*., (1996) reported that, the angle of repose is varied for different crops and varieties of each crop. Also they mentioned that, the angle of repose was observed to increase with the increase of grain moisture content.

The present study aims to determine the angle of repose for some varieties of rice, wheat, corn and barley. Meanwhile, to develop mathematical relationships relating the change in angle of repose with the change in grain moisture content for all studied crops.

MATERIAL AND TEST PROCEDURE

Material:

Different varieties of rice, corn wheat, and barley were collected from the experimental farm of Agricultural Research Center at Sakha experimental station, Kafr El-Sheikh governorate.

The varieties of each crop were selected based on their recent coverage area and total production. The obtained samples were cleaned from foreign matters and broken and immature grains.

Equipment:

1- grain conditioning unit

The grain conditioning unit developed by Matouk et. al., (2004) was used to adjust different levels of grain moisture content. Five desired moisture levels of each studied variety were obtained by adding a pre-calculated amount of tap water and mixed with the grain into the conditioning unit for 72 hours. The conditioned samples of each variety were sealed in poly-ethylene bags and stored in a freezer adjusted to a temperature of 5±1 °C. Before each test, the required quantity of grain was taken out of the freezer and allowed to reach the normal room temperature.

The moisture content of the samples was determined before each test using the oven drying method at 130°C for 16 hours as recommended by Matouk, (1976).

2- angle of repose apparatus:

Angle of repose apparatus was designed and fabricated at the workshop of Agric. Eng. Dept. Fac. of Agric. Mansoura Univ. The apparatus consists of a wooden box with an inner dimensions of 18 x 18 x 20 cm, a transparent plastic sides of which one side is sliding up and down, and a wooden parallelogram with a base fixed in the protractor. The instrument was used to measure the angle between the base and the inclined of the formed cone due to a free side fall of the grain as shown in Fig. (1).

Test procedure and measurements:

Grain from each variety was used to determine repose angle at different levels of grain moisture content. The grain was then poured into the wooden box of the apparatus until completely filling the box. The surface of the box is carefully leveled and the transparent sliding side is quickly taken up to give a chance for the grain to flow down under natural slope forming an inclined angle between the box side and the horizontal surface of the table. This angle was measured using the wooden parallelogram with the protractor shown in Fig. (1).

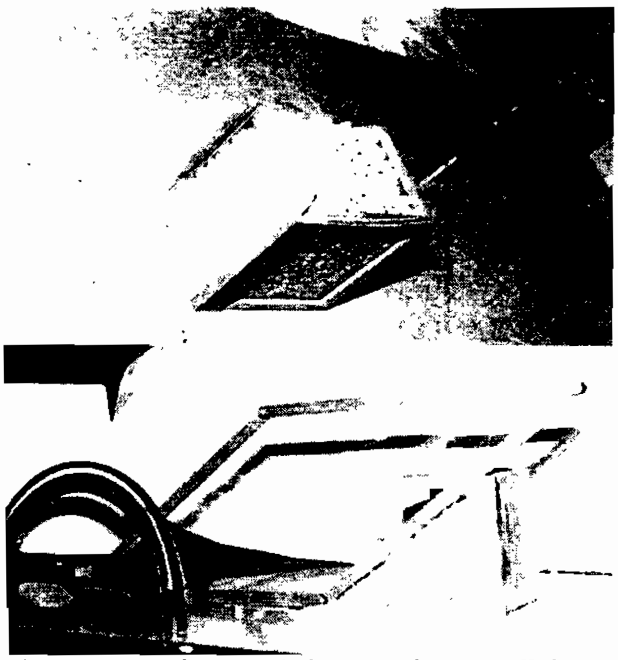

Fig. (1): The transparent box and the wooden parallelogram used for measuring the repose angle.

RESULTS AND DISCUSSION

In general, the angle of repose for different varieties of rice, corn, wheat, and barely was varied with change in moisture content and the nature of texture surface of the grain of each crop.

Fig. (2) shows, the angle of repose for different varieties of rice crop as related to grain moisture content. It can be seen that the angle of repose was ranged from 29.75° to 34.08 °. It can also be seen that the angle of repose was higher for long grain varieties (Giza 181 and Yasmin) in comparison with short grain varieties (Giza 177, Giza 178, Sakha 101 and 102). It was also clear that long grain variety Yasmin recorded the highest angle of repose which increased from 37.58° to 43.08° with the increase of grain moisture content from 12.08 to 25.11% w.b., followed by long grain variety Giza 181 which increased from 37.85° to 42.16° with the increase of grain moisture contents from 12.39 to 25.82% respectively.

Meanwhile, short grain variety Sakha 102 recorded the lowest angle of repose which increased from 29.75° to 40.25° with the increase of grain moisture content from 12.17 to 25.09% followed by varieties Giza 178, Giza 177, and Sakha 101 respectively.

For corn crop Fig. (3) shows that, for all studied varieties, the angle of repose increased with the increase of grain moisture content and it was ranged from 26.58° to 41.53°. Also variety balady recorded the highest angle of repose which increased from 30.41° to 41.53° with the increase of grain moisture content from 10.40 to 26.65% followed by varieties triple hybrid 310 and single hybrid 10. While variety triple hybrid 321 recorded the lowest repose angle which increased from 26.58° to 37.08° with the increase of grain moisture content from 11.50 to 26.08% respectively.

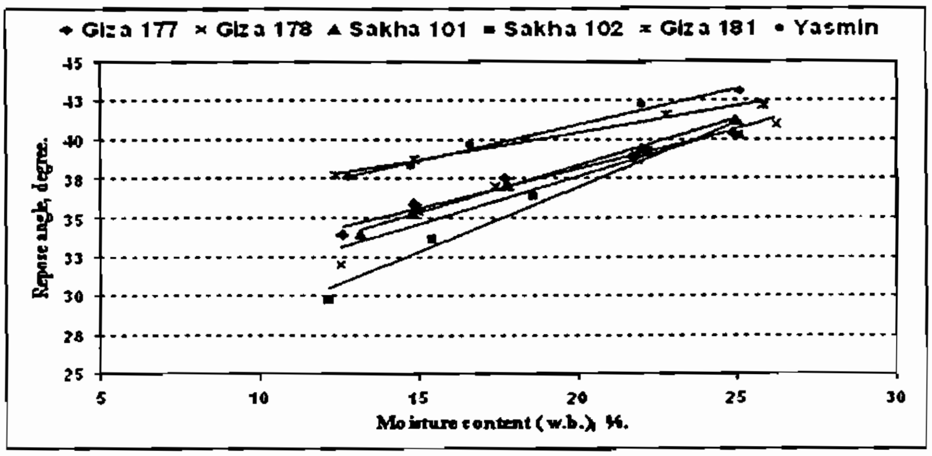

Fig. (2): Effect of moisture content on grain repose angle for the investigated rice varieties.

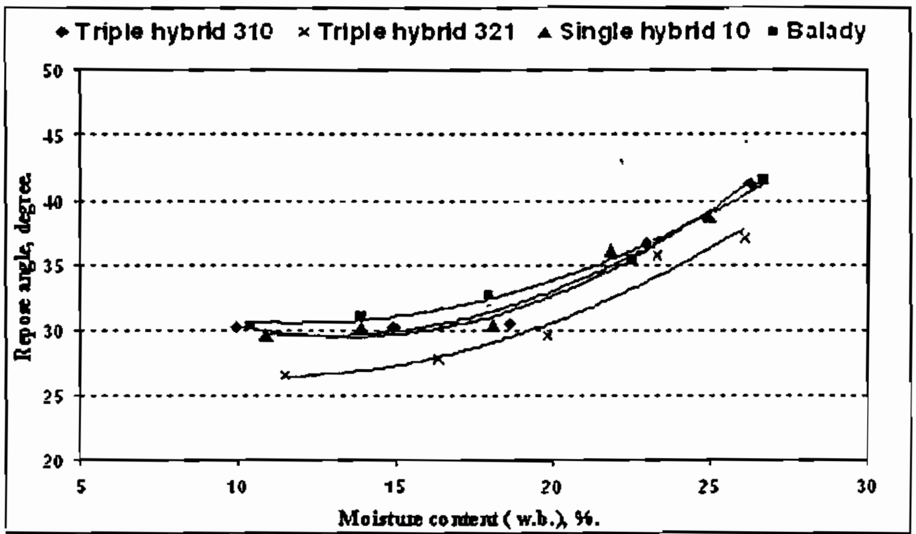

Fig. (3): Effect of moisture content on grain repose angle for the investigated corn varieties.

For wheat crop, Fig. (4) shows that, for all studied varieties, the angle of repose increased with the increase of grain moisture content and it was ranged from 25.08° to 37.16°. Meanwhile, variety Giza 168 recorded the highest repose angle which increased from 26.54° to 37.16° with the increase of grain moisture content from 10.58 to 25.56% followed by varieties Sids 1 and Sakha 93. While variety Sakha 93 recorded the lowest values which increased from 25.08° to 36.25° with the increase of grain moisture content from 10.87 to 25.77% respectively.

For barely crop, Fig. (5) shows that the angle of repose increased with the increase of grain moisture content and the repose angle for different varieties of wheat was ranged from 28.08° to 38.67°.

On the other hand, variety Giza 125 recorded the highest repose angle which increased from 29.24° to 38.67° with the increase of grain moisture content from 11.95 to 24.71% followed by varieties Giza 124 and Giza 123. While variety Giza 126 recorded the lowest repose angle which increased from 28.08° to 38.58° with the increase of grain moisture content from 11.22 to 24.72% respectively.

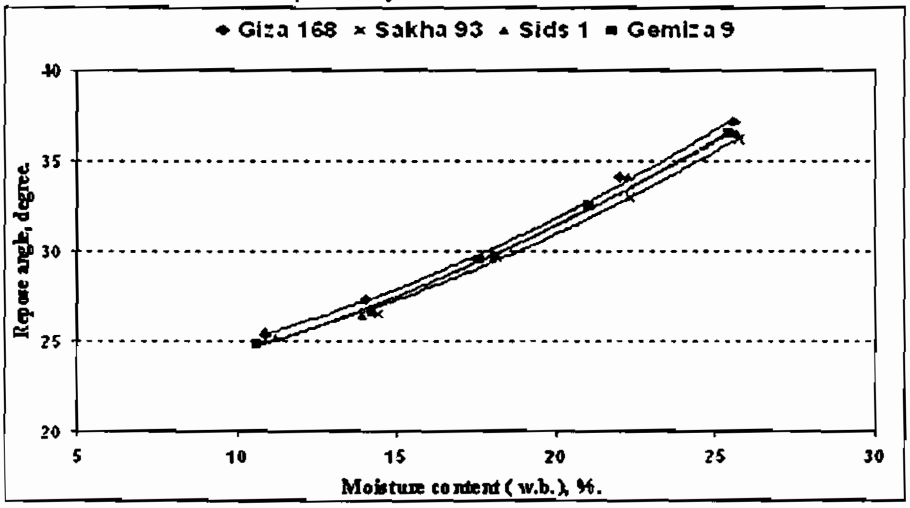

Fig. (4): Effect of moisture content on grain repose angle for the investigated wheat varieties.

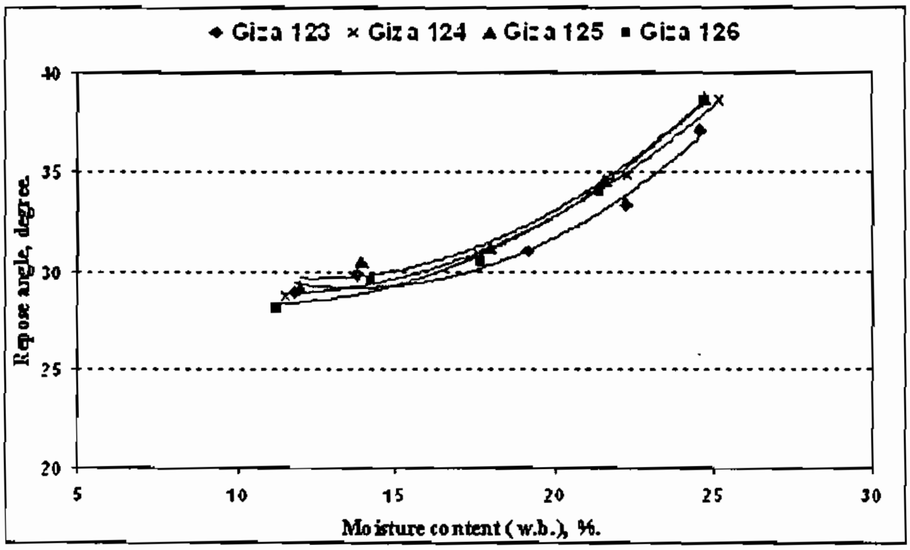

Fig. (5): Effect of moisture content on grain repose angle for the investigated barley varieties.

In general, the obtained results for different studied crops reflected that, the forces of solid friction at grain interface were generally lower in corn, wheat, and barely in comparison with rice and it was also lower for short grain varieties of rice as compared to long grain varieties. These results are in agreement with those obtained by (Owis, 1995 and Omobuwajo *et al.*, 2003). They mentioned that, as the force of solid friction increased the angle of repose also increased. However, the increment rate with the increase of grain moisture content is higher for the grain having lower forces of solid friction at their interface in comparison with those having higher forces. This was clear from the results of
regression analysis relating the change in grain moisture content with the change in angle of repose. The results of analysis show a direct simple linear relationship between the grain moisture content and the repose angle of rice varieties on the form of:

$$Ra = A + B\,M.C \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

While, for corn, wheat and barely the relationship was a second degree polynomial on the form of:

$$Ra = A + B\,M.C^2 + C\,M.C \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where:

Ra = angle of repose °
M.C = grain moisture content % w.b
A, B, C = equation constants

The regression parameters for the obtained regression equations were tabulated for all varieties of the studied crops as presented in tables (1) to (4) for rice, corn, wheat and barely respectively.

Table (1): Regression parameters of equation (1) relating the change in grain M.C with repose angle of different varieties of rice.

Variety	Range of grain M.C. % w.b.	Regression parameters		
		A	B	R^2
Giza 177	12.58 – 24.90	28.1910	0.4986	0.96
Giza 178	12.56 – 26.22	25.6370	0.6016	0.93
Sakha 101	13.18 – 24.95	26.2690	0.6021	0.99
Sakha 102	12.17 – 25.09	20.5330	0.8186	0.97
Giza 181	12.39 – 25.82	33.7680	0.3338	0.98
Jasmin	12.80 – 25.11	31.7600	0.4611	0.98

Table (2): Regression parameters of equation (2) relating the change in grain M.C with repose angle of different varieties of corn.

Variety	Range of grain M.C. % w.b.	Regression parameters			
		A	B	C	R^2
Triple hybrid 310	9.920 – 26.240	42.471	0.0721	-0.19329	0.98
Triple hybrid 321	11.500 – 26.080	31.617	0.0474	-0.9977	0.95
Single hybrid 10	10.870 – 24.940	39.331	0.0623	-1.5589	0.95
Balady	10.400 – 26.650	37.129	0.0476	-1.1163	0.98

Table (3): Regression parameters of equation (2) relating the change in grain M.C with repose angle of different varieties of wheat.

Variety	Range of grain M.C. % w.b.	Regression parameters			
		A	B	C	R^2
Giza 168	10.85 – 25.56	21.876	0.0193	0.1102	0.99
Sakha 93	10.87 – 25.77	21.701	0.0182	0.0983	0.99
Sids 1	11.17 – 25.70	19.843	0.0138	0.3022	0.99
Gemiza 9	10.60 – 25.40	20.515	0.0162	0.2203	0.99

Table (4): Regression parameters of equation (2) relating the change in grain M.C with repose angle of different varieties of barely.

Variety	Range of grain M.C. % w.b.	Regression parameters			
		A	B	C	R^2
Giza 123	11.81 – 24.58	41.221	0.0642	1.7608	0.97
Giza 124	11.51 – 25.17	34.570	0.0476	1.0423	0.99
Giza 125	11.95 – 24.71	38.660	0.0588	1.4557	0.98
Giza 126	11.22 – 24.72	34.343	0.0518	1.1147	0.99

Conclusions

The following conclusions may be drawn from the obtained results and the mathematical analysis:

1-The angle of repose tended to increase with the increase of grain moisture content for all varieties of the studied crops.

2-The relationship between the angle of repose and the grain moisture content was found to be a direct simple linear relationship for all varieties of rice, while it was a second degree polynomial relationship for corn, wheat and barely.

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REFERENCES

Chakraverty A. (1987). Post harvest technology of cereal, pulses and oil seeds (Revised Edition). Oxford and IBH publishing Co. PVT LTD. New Delhi, Bombay, Calcutta.

Dursun E. and I. Dursun (2005). Some physical properties of crops seed. Biosystems Engineering 92 (2), 237 – 245.

El-Raie A.E.; N.A. Hendawy and Z. Taieb (1996). Study of physical and engineering properties for some agricultural products. Misr. J. of Agric. Eng. 13 (1) : 211 – 226.

Gupt R.K. and S.K. Das (1997). Physical properties of sunflower seeds. J. Agric. Eng. Res. 66, 1 – 8

Matouk A.M. (1976). Heat and moisture movement during low temperature drying and storage of maize grain. Ph.D Thesis. Univ. New Castle Upon Tyne.

Matouk A.M. ; S.M. Radwan; M.M. El-Kholy and T.R. Owies (2004). Determination of grain density and porosity for some cereal crops. Misr. J. Agric. Eng. 21 (3):623 – 641

Mohsenin, N.N. (1984). Physical properties of plant and animal materials. Structure physical characteristics and rheological properties. Part 1. vol. 1. 3rd. Edition Gordon and Breach Sc. Put., N.Y. pp 734.

Nimkar P.M. ; D.S. Mandew and R.M. Dudhe (2005). Physical properties of moth grain. Biosystems Engineering 91 (2), 163 – 189.

Omobuwajo T.O. ; O.R. Omobuwajo and L.A. Sanni (2003). Physical properties of calabash nutmeg (Monodora Myristica) seeds. Journal of Food Eng. 57: 375-381.

Owis T.R. (1995). Physical and engineering properties of cereal grain and their relation to the selection and design of cleaning devices. M. Sc. Thesis, Agric. Eng. Dept. Fac. of Agric. Cairo Univ.

Soliman, N.S. (1994). Effect of moisture content on angle of repose of paddy rice and its products. Misr J. of Agric. Eng. 11 (1) : 163 – 173.

Srivastava A.K.; W.T. Mahony and N.L. West (1990). The effect of crop properties on combine performance. Trans. of The ASAE, 3 : (1) 63 – 72; presented as ASAE paper no. 1583.

تأثير المحتوى الرطوبي على زاوية المكوث لبعض أصناف محاصيل الحبوب

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أجريت هذه الدراسة لتعيين زاوية المكوث لبعض أصناف محاصيل الأرز، الذرة، القمح، الشعير كداله للتغير في المحتوى الرطوبي لحبوب تلك الأصناف. أظهرت النتائج المتحصل عليها زيادة قيم زاوية المكوث للأصناف المختلفة بزيادة المحتوى الرطوبي، كما إختلفت تلك القيم بإختلاف طبيعة السطح لتلك الحبوب. وتراوحت قيم زاوية المكوث بين ٢٩,٧٥ – ٤٠,٢٥° للأرز، ٢٦,٥٨ – ٤١,٥٣° للذرة، ٢٥,٠٨ – ٣٧,١٦° للقمح، ٢٨,٠٨ – ٣٨,٦٧° للشعير. تم أيضا إيجاد علاقات رياضية تربط بين التغير في المحتوى الرطوبي للحبوب وقيم زاوية المكوث للأصناف المختلفة التي تم دراستها حيث أظهرت النتائج وجود علاقة خطية طردية للتغير في قيم زاوية المكوث والمحتوى الرطوبي لأصناف الأرز بينما أخذت تلك العلاقة صورة معادلة كثيرة الحدود من الدرجة الثانية لأصناف الذرة، القمح، الشعير.