Agricultural engineering and variables of the present epoch: 1586-1597

SOME MECHANICAL PROPERTIES OF HULLED PEANUTS AND KERNELS

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ABSTRACT

This study was carried out to evaluate some mechanical properties for two different varieties of peanuts, namely: Ismailia1 "Is1" and Giza5 "G5"such as shelling force, terminal velocities of shells and kernels, repose and friction angles for two different levels of moisture content averages of 16 and 3.5 % dry basis.

Empirical equations based on a large numberof measurements of peanuts shelling force and void space parameter (space between hull and kernel) were suggested. The force required for peanuts shelling ranged between 0.323-0.581 N and 0.434-0.467 N for Is1 and G5 respectively. During chute conveying , inclination angle should exceed 35.5, 37^o for Is1 and G5 varieties at average moisture content of 16%db and 31, 32^o at average moisture content range of 3.5 %db for both tested varieties respectively. The terminal velocities of half shell to very small shell were 0.5-10.3 m/s and 9.5-17.8 m/s for kernels of both varieties tested. So, a vertical air stream of 9.8 and 9.9 m/s is sufficient to separate 98.5 and 96.5 % of peanuts shells, fine particles and dust from peanuts kernels for both studied varieties.

The main objective of the present study is to evaluate some mechanical properties of two different Egyptian verities that affect design and development of handling, storage, shelling and cleaning machines.

INTRODUCTION

Peanut (*Arachis hypogea* L.) is one of the most important oil bearing seeds. In Egypt, the cultivated area is about 3.024 x 10^6 ha (FAO 2008),that produce, about 15.12 x 10^6 tons. In the last few years, there was a marked deterioration in quality of peanut grown in Egypt, due to high incidence of aflatoxin contamination and increased percentage of immature seeds. The growth of mould on the peanut is the indirect result of too much moisture for unsafe storage.

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To control the fungal attack on the peanut it was recommended by Hummeida and Ismail (1989) that the moisture content of the peanuts should be maintained below 8% w.b. However, in storage, the moisture content is controlled by circulation of air and control of the relative humidity.

Chen et al. (1989) reported that the cutting energy of peanuts is affected by peanut variety. They added that the cutting energy reached its maximum value at moisture contents of 20-30 %db. They also added that the cutting energy decreases as the moisture content decreases.

Helmy, (1995) reported that in the field of bulk storage, grading and handling of agricultural products, there is an urgent need to determine the friction coefficients and the repose angle of some cereal crops on various surfaces. Frictional characteristics are very important in determining the proper design of conveying, grading and forage-chopping machinery.

Kaleem et al. (1993) reported that the angle of repose is very important in determining the inclination angles of the machine hopper tank.

Harmond et al. (1965) reported that the terminal velocity represents the maximum velocity of a seed will attain in free falling through the still air. If conditions are reversed so that seed remains suspended in a rising air stream, the air must be moving at speed equal to the terminal velocity of the seed. They mentioned that air separation could be employed in seed cleaning to separate inert material, weed and other contaminants from crop seeds provided that these components possess different terminal velocities.

Awady and El-Sayed (1994) studied the effects of mass, projected area, drag coefficient on the terminal velocity of shells, unshelled , split and intact peanut seeds. They recommended that separation speed of 5.7 m/s separate 96 % of shells. Meanwhile, more air speed of 0.6 m/s , 100% of shells could be blown of , but with more losses of 15 and 3 % of unshelled and split seeds.

Due to the lack of information about mechanical properties of new created varieties of hulled peanuts, kernels and shells, and also owing to losses during harvesting, handling and the marked deterioration in quality of peanuts as a result of unsafe storage. This work was carried out to study some mechanical properties of two different Egyptian verities that affect design and development of handling, storage, shelling and cleaning machines such as shelling force, friction angle, repose angle, and terminal velocities of both kernels and shells.

MATERIALS AND METHODS

This work was carried out to determine some mechanical properties of two common Egyptian varieties of peanuts, namely: Ismailia1 “Is1” and Giza5 “G5”.

Measuring instrumentations:

1- Digital vernire caliper, with accuracy of 0.01 mm was used for measuring length, diameter, and shell thickness.
2- Electrical balance: made in Japan, Sartorius type , accuracy 0.0001 g.
3- Electrical oven with forced hot air circulation no. 299 of maximum temperature of 300 ^oC made in Germany.
4- The moisture content for peanut pods (shells and kernels) is evaluated according to the ASAE standards (1994) i.e., oven dried at 130 ^oC for 6 hours.
5- Turbo meter was used for measuring air velocity. It is made in U.S.A. by Davis instruments, measuring range of 0-44.8 m/s.
6- Shelling force: A digital force gauge Fig.(1) of accuracy 0.2% was used for measuring the shelling force. It has a maximum reading of 2200 gram. Alever construction was developed as that used by Zaalouk and Ghanem (2003) and modified to be compatible with peanut shelling force.

Experimental procedure:

1. **Shelling force**: The shelling force was evaluated using the digital force gauge and a lever setup for amplifying the measured force Fig.(2) shows the setup and the exerted force can be evaluated as follows :

$$F_2 = C_1\{[(F_1 x L1)/L_2]+R\}\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$F_2 = 0.001[0.375F_1+218.3]\ \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where:

F_1 : Force exerted by the gauge sensor, g;

F_2 : Total force exerted by the lever on the peanut hull using a chisel of 4 cm width to transform the force along the whole length of the hull;

L_1 : Long arm of the lever, 85.5 cm;

L_2 : Short arm of the lever, 22.8 cm.

C_1 : Constant to convert the total load to Newtons.

The shelling force was evaluated at two different levels of moisture content rang between 16and 3.5% db.

In the present study correlation between the void space parameter and shelling force is evaluated at the previously defined levels of moisture contents of the hulled peanuts. The void space parameter"V_{sp} in mm" Fig.(3), is defined as the internal space between the hull and kernel. It can be determined as follows:

$$V_{sp} = D - (2t + d) \quad \text{.....................................(3)}$$

Where

D : Average hull diameter, mm,

t : Average shell thickness, mm;

d : Average kernel diameter ,mm.

2. **Terminal velocity apparatus**: The terminal velocity apparatus Fig.(4) , was fabricated in the Agr.Eng.Dept., Al-Azhar Univ. by Zaalouk and Ghanem(2003) according to Awady and El-Sayed (1994). It was constructed of tapered transparent (plexi-glass) of a rectangular cross sections, connected with electrical blower. Two wire screens were fitted at the bottom and top of the transparent tube. An air –flow straightener was attached with the lower screen to improve flow uniformity. In this work the air inlet area of blower was changed to have a broad range of air velocity required to carry kernels or shells.
3. **Friction angles ϕ^o**: This angle was measured between steel surface and hulls according to Mohsenin (1970). Fifteen samples of each variety were used to evaluate the friction angle on steel, wood and rubber surfaces at two different levels of moisture contents ranging between 16 and 3.5 % db for each variety tested..
4. **Repose angle θ^o** : This is the angle between the horizontal base and the inclined side of the formed cone due to free fall of hulls sample. The horizontal base of the cone (x) and its height (h) were

measured by a ruler and the repose angle can be calculated as follows:

$$\tan\theta = h/0.5x \quad \text{………………………………}(4)$$

1 Universal sensing head,
2 LED disply,
3 Zero indicator,
4 Power button,
5 Tension/ compression function select switch,
6 Average (peak off), peak load, peak on select switch,
7 Select swich,
8 Mounting screws,
9 Battery cover;
10 Chisel adapter.

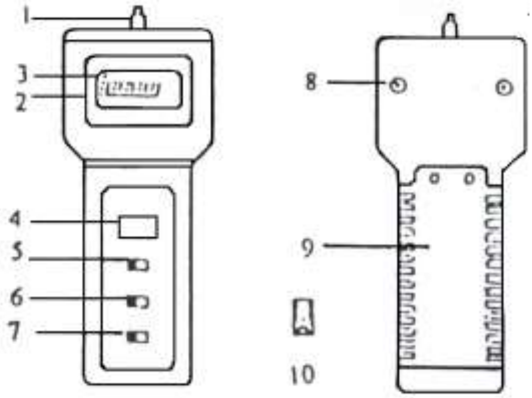
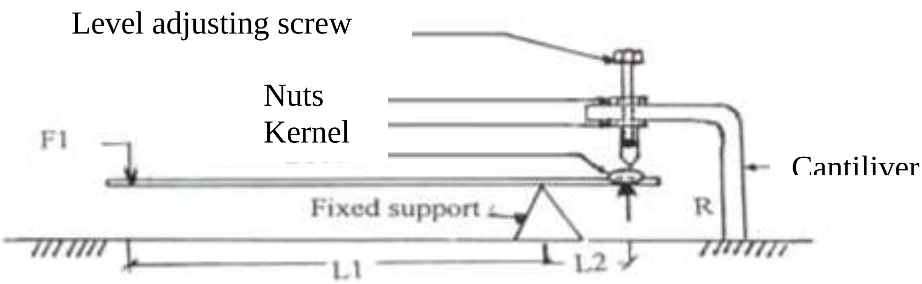


Fig.(1)Digital force gauge.



F_1 : force exerted by the gauge sensing element,g,
R : Reaction force exerted by the lever arm due to its weight at f1 = zero, g and the lever at horizontal position.

Fig.(2) Lever setup used for amplifying the force measured by the digital force gauge.

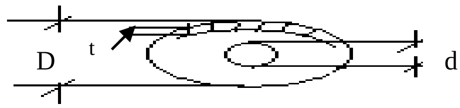


Fig.(3)Directions of measuring hull diameter 'D' ,kernel diameter 'd' and shell thickness 't' used in determining void space parameter.

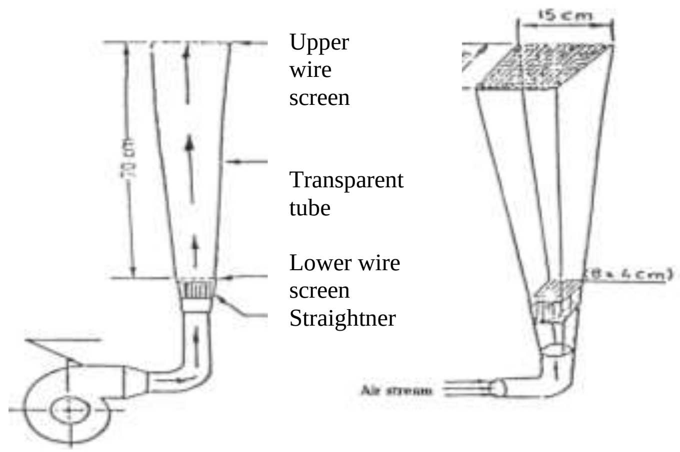


Fig.(4) Terminal velocity setup Awady and El-Sayed 1994.

RESULTS AND DISCUSSIONS

1 **Shelling force "F_s":** Table(1) shows the average minimum, maximum values of the shelling forces and void space parameters. It is clear that the shelling forces for the Is1 variety were slightly higher than those of the G5 variety. The shelling forces of peanuts were correlated to void space parameter v_{sp} in mm -as previously defined in methods- at a moisture content of 16 % db and 3.5 % db for both studied varieties, Figs. (5) and (6). The following linear forms were found to be satisfied:

Hulled peanuts at moisture content of 16 % db:

For SI1 variety: $Fs = 0.1004\ v_{sp} + 0.0177$ $R^2 = 0.69$

For G5 variety: $Fs = 0.129\ v_{sp} + 0.0119$ $R^2 = 0.65$

Hulled peanuts at moisture content of 3.5 % db:

For SI1 variety: $Fs = 0.099\ v_{sp} + 0.2966$ $R^2 = 0.60$

G5 variety $Fs = 0.968\ v_{sp} + 0.4869$ $R^2 = 0.59$

It is clear that the shelling force is affected by peanut variety. The shelling force is increased at peanuts moisture content of 16 % db. As the moisture content decreases to 3.5 %db, the shelling force is also decreased. These results agree with Chen et al. (1989).

2 **Terminal velocity of kernels and shells:** Table (1) shows average terminal velocity, minimum, maximum values and their standard deviations. Terminal velocity of kernels and shells for both varieties were

studied. Fig.(7) shows their frequency distributions curves. It was found that the terminal velocities of a half a hull shell and the very small shells were 0.5-10.15 m/s for both tested varieties. Whereas, the terminal velocities of kernels were 9.4-17.8 m/s for both tested varieties. So, a vertical air stream of 9.8-9.9 m/s is successfully sufficient to separate 98.5 and 96.5 % of shells, fine particles and dust for Is1 and G5 varieties respectively. This trend agree with Awady and El-sayed (1994). Meanwhile, variations of terminal velocity values may be due to higher level of moisture contents and varieties differences.

3 **Friction angle" ϕ^o ":** The friction angle "ϕ^o" for steel, wood and rubber surfaces were evaluated at two different levels of moisture content i.e. 16 and 3.5 % db for all hulled peanut varieties tested Table (1). It is clear that friction angle is increases as the moisture content increases. During chutes conveying the inclination angle should exceeds 37, 32 ^{o} at moisture content of 16 % db, and it should exceeds 31, 32^o at moisture content of 3.5 %db for Is1 and G5 varieties, respectively.

4 **Repose angle" θ^o ":** The repose angles "θ^o" for hulled peanuts were evaluated at two different levels of moisture content i.e. 16 and 3.5 % db for all varieties tested . Table (1) indicates that, the repose angle is increases as the moisture content increases. For flat plate belt conveyor, it is recommended that the inclination angle should be less than the repose angle. When the IS1 variety is conveyed, the inclination angle should be

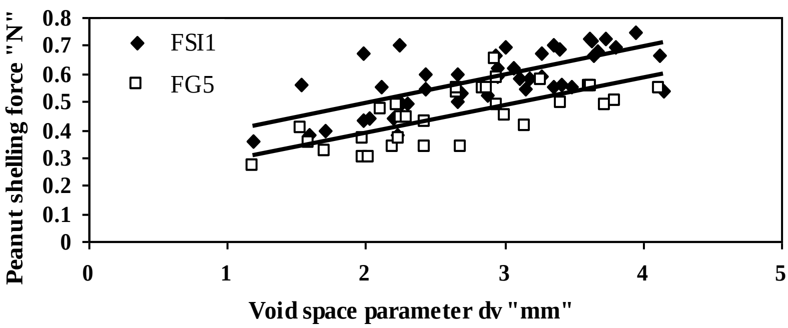


Fig.(5) Correlation between the force required for peanuts shelling and void space parameter Vsp at moisture content of 16 %.

less than 28.2 and 30.8^o for the two levels of moisture contentrespectively. It is also recommended that the inclination angle for conveying G5 variety should be less than 30.8 and 34.6º for the two levels of moisture contents respectively.

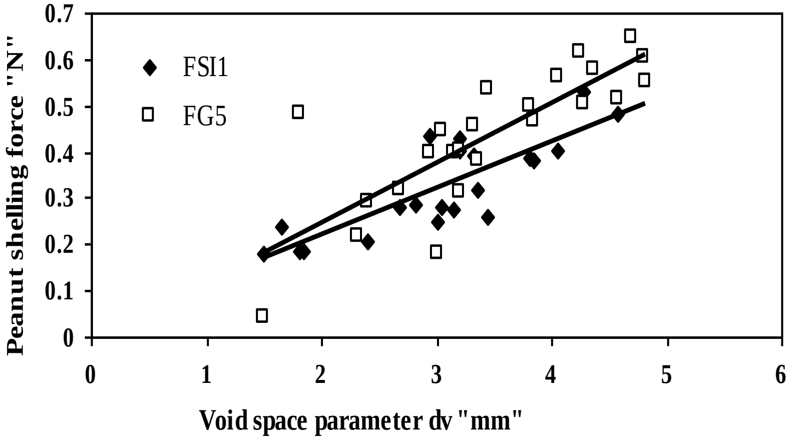


Fig.(6) Correlation between the force required for peanuts shelling and void space parameter Vsp at moisture content of 3.5 %.

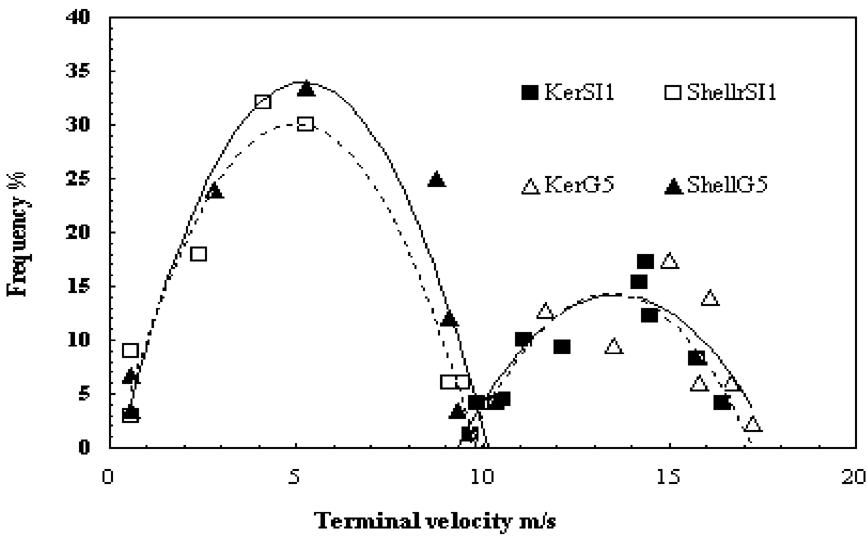


Fig.(7) Frequency distribution of terminal velocities of shells and kernels for the two varieties tested.

Table(1) Minimum, maximum, averages and standard deviation for shelling force 'Fs', void space parameter 'Vsp', friction angle ' ϕ^o' , repose angle 'θ^o' for hulled peanuts at two levels of moisture contents Mc % db and terminal velocities V_t of kernels and shells.

variety	Parameter		Mc%db	Min.	Max.	Avg.	St. dev.
SI1	Fs "N"		16	0.356	0.75	0.581	0.104
			3.5	0.160	0.521	0.323	0.103
	ϕ^o	Steel	16	38	33	35.3	2.5
		Rubber	16	42	43	42.6	0.5
		Wood	16	33	36	34	1.7
		Steel	3.5	30	32	31	0.5
		Rubber	3.5	36	38	37	0.25
		Wood	3.5	36	32	34	1.2
	θ^o		16	26.7	29	28.2	1.33
			3.5	26	33	30.8	3.6
	Vsp "mm"		16	1.18	4.85	2.99	0.86
			3.5	1.49	4.818	3.302	0.989
	V_t m/s	Kernel	16	9.8	17.3	13.31	1.81
		Shells	16	0.55	9.95	5.20	3.58
G5	Fs "N"		16	0.252	0.650	0.467	0.128
			3.5	0.05	0.648	0.434	0.149
	ϕ^o	Steel	16	36	38	37	1.2
		Rubber	16	38	42	40.3	2.8
		Wood	16	34	37	35.7	1.8
		Steel	3.5	30	33	32	1.2
		Rubber	3.5	36	38.5	37.7	1.53
		Wood	3.5	33.2	35.8	34.6	1.52
	θ^o		16	29.2	32.7	30.8	1.8
			3.5	31.6	37.6	34.6	1.52
	Vsp "mm"		16	1.59	4.918	3.402	0.99
			3.5	1.28	4.89	3.00	0.96
	V_t m/s	Kernel	16	9.5	17.8	14.07	3.66
		Shells	16	0.55	10.3	5.45	4.22

SUMMARY AND CONCLUSION

This work was carried out to study some mechanical properties of two different Egyptian verities namely: Ismailia1 "IS1" and Giza5"G5" that affecting design and development of handling, storage, shelling and cleaning machines such as shelling force, friction angle, repose angle, and terminal velocities of both kernels and shells.

From the present study we concluded that:

1 **Shelling force F_s "N":** **T**he average values of shelling forces were 0.581, 0.467 N and 0.323, 0.434 N for the Is1and G5 varieties at moisture contents of 16 and 3.5%db respectively. The shelling forces of peanuts were also correlated to void space parameter "v_{sp}" in mm at moisture contents of 16 and 3.5 % db for both studied varieties. The following linear form was found to be satisfied:

$$Fs = m\, v_{sp} + C$$

Where, m and c are constants. The coefficients of determination were 65, 69 % and 59,60 % for moisture contents of 16 and 3.5%db for both tested varieties respectively.It is clear that the shelling force is affected by peanut variety. The shelling force increased at peanuts moisture content of 16 % db. As the moisture content decreases to 3.5 %db, the shelling force also decreased. This results agree with Chen et al. (1989).

2 **Terminal velocity of kernels and shells:**. It was found that the terminal velocities of a half a hull shell to the very small shells were 0.5-10.15 m/s for both tested varieties. Meanwhile, the terminal velocities of kernels were 9.4-17.8 m/s for both tested varieties. So, a vertical air stream of 9.8-9.9 m/s sufficient to separate 98.5 and 96.5 % of shells, fine particles and dust for Is1 and G5 varieties respectively. This trend agrees with Awady and El-sayed (1994). Meanwhile, variations of terminal velocity values may be due to higher levels of moisture contentand variety difference.

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4 **Repose angle" θ^{o} ":** The repose angles "θ^{o}" for hulled peanuts were evaluated at two different levels of moisture content i.e. 16 and 3.5 % db for all varieties tested . The repose angle increases as the moisture content increases. For flat plate belt conveyor, it is recommended that the inclination angle should be less than the repose angle. When the IS1

variety is conveyed, the inclination angle should be less than 28.2 and 30.8^o for the two levels of moisture content respectively. It is also recommended that the inclination angle for conveying G5 variety should be less than 30.8 and 34.6^o for the two levels of moisture content respectively.

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الملخص العربى

بعض الخواص الميكانيكية لقرون وحبوب الفول السودانى

د/ طارق حسين غانم د/محمد احمد السيد شيتيوى

يعد محصول الفول السودانى أحد أهم وأكبر محاصيل التصدير الزيتية. ففى السنوات الأخيرة لوحظ تدهور فى جودة الفول السودانى المنتج فى مصر بسبب الأفلاتوكسينات ونمو الفطريات والذى يرجع الى سوء التداول والتخزين والحاجة الماسة للتقشير حيث يقل زمن التجفيف والحيز اللازم للتخزين. لذا فقد تم دراسة بعض الخواص الميكانيكية المؤثرة على عمليات التداول والتخزين والتقشيروالتنظيف. تمت القياسات بكلية الزراعة جامعة الأزهر على نوعين من قرون الفول السودانى وهى صنف اسماعيلية١ وجيزة ٥ - وهى من الأصناف العالية الانتاج والمقاومة للأمراض- عند محتوى رطوبى على اساس جاف ١٦
و ٣,٥ % على الترتيب وكانت النتائج كالأتى:

١ أوضحت النتائج ان متوسط القوة اللازمة لتقشير قرون الفول السودانى ٠,٥٨١ و ٠,٤٦٧ نيوتن للصنف اسماعيلية١ وجيزة ٥ عند محتوى رطوبى على أساس جاف ١٦ % . كما كانت القوة اللازمة لتقشير القرون ٠,٣٢٣ و ٠,٤٣٤ نيوتن عند محتوى رطوبى على أساس جاف ٣,٥٪ لكلا الصنفين على الترتيب.

٢ وباستخدام الانحدار تم التوصل الى علاقة خطية بين القوة اللازمة للتقشير ومعامل فراغ القرن(الفراغ بين القرن والحبة)علىالصورة:

$$Fs = m\, v_{sp} + C$$

حيث Fs هى القوة بالنيوتن و v_{sp} معامل الفراغ و C وm ثوابت المعادلة. كما تراوح معامل الآرتباط بين ٠,٥٩-٠,٦٩ .

٣ وبدراسة السرعة النهائية للقشر والحبوب تبين أن السرعة ٩,٨-٩,٩ م/ث كافية للتخلص من٩٨,٥ و ٩٦,٥ من القشور وكذلك الأتربة والجزيئات المتناهيةفى الصغر لكلا الصنفين على الترتيب.

٤ وعند تداول القرون بواسطة المزلقات يراعى ان تزيد زاوية الميل عن ٣٢-٣٧° وعن٣١-٣٢ ° عند محتوى رطوبى على اساس جاف ١٦٪ و ٣,٥ % لكلا الصنفين على الترتيب.

٥ وعند تداول القرون بواسطة السيور يجب الا تزيد زاوية ميل السير عن ٢٨,٢-٣٠,٨ ° و عن ٣٠,٨ – ٣٤,٥ ° عند محتوى رطوبى ١٦ و ٣,٥ %على أساس جاف لكلا الصنفين على الترتيب.

أستاذ مساعد الهندسة الزراعية ومدرس الهندسة الزراعية –كلية الزراعة - جامعة الأزهر،على الترتيب.