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THE EFFECT OF MOISTURE CONTENT ON SOME PHYSICAL AND AERODYNAMIC PROPERTIES OF PEANUT AND ITS RESIDUES

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ABSTRACT

Physical and aerodynamic properties often required for designing the equipments for planting, harvesting, and pos-harvesting operations. Several physical and aerodynamic properties of peanut variety (Giza-4) were evaluated as a function of moisture content at four moisture contents levels (3.97, 15.89, 27.03, and 37.8% w.b.) for pods and (8.11, 17.9, 44.16, and 65.5% w.b.) for stalk pieces. The results showed a linear increase in mass from (0.68 to 1.66 gm) and from (1.67 to 2.58 gm) for stalk and pods respectively with increasing moisture content. The highest values of mean diameter and length were 0.46 and15.84 mm at moisture content 65.5 and 17.9% for stalk, whereas mean diameter and length were 1.61 and 3.68 mm at moisture content 37.8% for pods. Terminal velocity of peanut pods varied from 11.6 - 12.79 m/s, whereas terminal velocity of stalk ranged between 5.23 - 7.68 m/s. The highest values of terminal velocity obtained for pods and stalk were 12.79 and 7.68 m/s at moisture content 37.8 and 65.5% respectively, although the lowest values of terminal velocity were 11.6 and 5.23 at moisture content 3.97 and 8.11% for pods and stalks respectively. The effect of moisture content on terminal velocity of peanut pods and their stalk showed a linear increase with increasing moisture content.
Keywords: Aerodynamic property; Peanut; Moisture content; equipment design.

INTRODUCTION

Peanut (Giza-4) is an important annual plant. The requirements for peanut used directly or indirectly for human consumption increases in parallel with population increase. The peanut, also known as the groundnut, has become an important food and export crop in several countries, such as China, USA, Nigeria, Niger, and Egypt. Peanut is the fifth most important oilseed crop in the world after soybean, cotton seed, rape seed, and sunflower seed (Nwokolo, 1996). Approximately, 31500 tones of peanut seeds produced from about 26.000 feddans in Egypt. The properties of peanut are important to design the equipments and machines for sorting, separation, transportation, processing and storing. Designing of such equipments and machines without taking these in to consideration may yield poor results. For this reason the determination and consideration of these properties has an important role.

The proper air speed can be determined from aerodynamic properties of agricultural materials. These properties are terminal velocity and drag coefficient. If an object is dropped from a sufficient height, the force of gravity will accelerate it until the drag force exerted by the air, balances the gravitational force. It will then fall at a constant velocity called the terminal velocity (Mohsenin, 1970)

$$M.g = \frac{1}{2}\rho.V_t^{\,2}.C_d.A \rightarrow (1)$$

Where, M is mass of the object (kg), g is gravitational acceleration (m/s^2), Cd is drag coefficient, ρ is air density (kg/m^3), A is projected area (m^2), and Vt is terminal velocity (m/s).

From this equation, the drag coefficient of an object can be found from its terminal velocity

$$C_d = \frac{2M.g}{\rho.V_t^{\,2}.A} \quad \rightarrow (2)$$

Usually, a horizontal wind tunnel is used to measure drag coefficient of large objects. In this method, external parameters such as size and velocity are varied and values of drag coefficient are obtained over a wide range of Reynolds number. But for small particles (like grain seeds), the drag force cannot be measured directly by this method. So drag coefficient of agricultural materials are calculated from their terminal velocity (Eq.2) which is experimentally measured.

The separation of mixed components under an air stream is possible only when accurate air pressure is delivered and some of the components reach their terminal velocity (Bezrutskin *et al*., 1967; Gorial and O'Callaghan, 1991). Tado *et al*. (1999) found that the mean terminal velocity of paddy rice increased with the increase in moisture content. El-Awady and El-Sayed (1994) investigated the aerodynamic separation of the product components of the shelled peanut. They found that the air separation of unshelled, split and intact seed components from the shells is difficult due to the interference of the terminal velocity of the components. Carman (1996) measured the terminal velocity of lentil seeds at different moisture contents by free fall method. From the top of a dropping tube at various heights, a seed was allowed to fall. The duration of the fall was plotted as a function of vertical distance. The slope of the linear portion of the distance versus time curve indicated the terminal velocity of the seed. He found that as the moisture content of the lentil seed increased, its terminal velocity also increased linearly. The terminal velocity is affected by the density, shape, size and moisture content of samples (Kashaninejad *et al*., 2005). Therefore, it is necessary to determine the aerodynamic properties as a function of different factors such as moisture content. Khoshtaghaza and Mehdizadeh (2006) studied the effects of moisture content of wheat kernel on terminal velocity. The results showed that moisture content has significant effects ($p<0.01$) on terminal velocity. By increasing moisture content from 7 to 20 %(w.b.), its terminal velocity increased linearly from 6.81 to 8.63 m/s, respectively. Cetin (2007) reported that the terminal velocity of barbunia bean seed at various moisture levels increased linearly from 14.23 to 16.63 m s^{-1} as the moisture content increased from 18.33% to 32.43% (d.b.). Razavi *et al* (2007) reported that the effect of moisture content on terminal velocity of pistachio nuts and their kernels showed a linear increase with increasing moisture content. But there is limited information on properties of peanuts relating to moisture dependent which is inadequate to design equipment and machines in the scientific literatures for peanut to growed in Egypt.

The purpose of this study were (i) to investigate some physical and aerodynamic properties of peanut at four moisture content. (ii) to develop regression equations to predict terminal velocity of peanut pods and its stalk pieces as a function of moisture content.

THEORETICAL BACKGROUND

It is well known that the indexes characterizing the behavior of a particle in an air stream are its terminal velocity Vt, coefficient of drag Cd, and the coefficient of the air resistance Ca.

A particle under a vertical airflow, gravitational force Fg and drag resistance force Fd act on the particle as expressed in the following formulas after integration:

$$Fd = ca\ \rho a A\ (va - u)^2, \rightarrow (3)$$

where ρa: specific density of air, kg m^{-3}A: projected particle surface area, m^2; Va : velocity of airflow, m s^{-1}; u: velocity of the displacement of the particle, m s^{-1}; and va -u= Vt - relative velocity between airflow and the particle.

Under vertical airflow, the forces Fg and Fd are oppositely directed. Independently of the correlation of these forces, a particle will move down, if Fg>Fd, up, if Fg-Fd, in equilibrium if Fg=Fd when u =0, thus:

$$Vt = (Fg/ca\rho aA)^{1/2}. \rightarrow (4)$$

The terminal velocity of irregularly shaped particles is not constant, because of their movement in the airflow. The terminal velocity for spherical and non-spherical particles is expressed by Bezrutskin *et al*. (1967), respectively, as:

$$Vt = (4g\ \gamma m\ d/3ca\ \rho a)^{1/2} \rightarrow (4) \quad \text{and} \quad Vt = (g\ \gamma m\ dg\ /\ ca\ \rho a)^{1/2}, \rightarrow (5)$$

where: γm : specific mass density of the crop, kg m^{-3};
d :diameter of the crop particle, mm; and dg : geometric diameter, mm.

The values of the coefficients Cd and Ca are firmly in a complex relationship with the dimensions of the crops, state of the area of the crop and the relative velocity between air and the crop. For these reasons, the terminal velocity will be defined only experimentally; the coefficients Cd and Ca are defined by Bezrutskin *et al*. (1967), as:

$$Cd = g/\ Vt^2, \rightarrow (6) \quad \text{and} \quad Ca = Cd\ m/\ \rho a\ A, \rightarrow (7)$$

where: g : gravitational acceleration, m s^{-2} ρa : specific density of air, kg m^{-3}; and m : mass of particle, kg.

MATERIALS AND METHODS

Materials:-

This study was carried on peanut variety (*Giza-4*) which is usually planted in Egypt to predict the preliminary physical and aerodynamic properties of peanut pods and stalk pieces.

Sample Preparation:-

The peanut pods and stalk pieces samples were selected randomly to determine the average of mass (M), diameter (D) and length (L) of the samples (average of 100 samples) are given in Table1.

Mechanism description:-

Figures (1) illustrate the mechanism that was used for testing peanut aerodynamic properties. It consists of a rectangular transparent glass tube, 1.5 m long with a section of 155×155 mm from the bottom and 220×220 mm from the top, which was used to suspend the particles in an air stream. The air was supplied by a suction blower fan powered by an electric motor. A screen is fitted at the bottom of the transparent tube and a cyclone is fitted at the top of it. A flow straightener was attached with the lower screen to improve flow uniformity through the rectangular tube. The sample was placed on the lower screen. The terminal velocity of agricultural products can be obtained by measuring the air velocity required to suspend the particles in the vertical air stream. Air velocity was measured at the bottom of the tube. The air velocity changes according to changes in the cross - section of the tube.

Instrumention:-

1-Electric oven: - It was dried at 70° until a constant weight.

2-Electrical balance: - Digital electric balance of 200 grams was used to determine the mass with an accuracy of 0.0001g.

3- Caliper: - A sliding caliper with accurate nearest to 0.05 mm was used to measure length and diameter of peanut stalk pieces and pods.

4- Bags: - Plastic bags were used to collect samples.

3- Experimental procedure:-

3-1 Physical properties:-

The moisture content was determined at moisture levels of 3.97 to 37.8 % w.b for pods at 4 levels of moistures is about (3.97, 15.89, 27.03, and 37.8% w.b) and from

8.11 to 65.5% w.b. for stalks at 4 levels of moistures is about (8.11, 17.9, 44.16, and 65.5% w.b.) for each moisture content 3 replications. The moisture content (w.b., %) of grains were determined by oven method. The following equation was used to calculate the moisture content.

$$M.C._{w.b.} = \frac{W_i - W_d}{W_i} \times 100 \quad \rightarrow (8)$$

Where

M w.b. = Moisture content, wet basis, %.   Wi = Initial mass of sample, g.

Wd = Dried mass of sample, g.

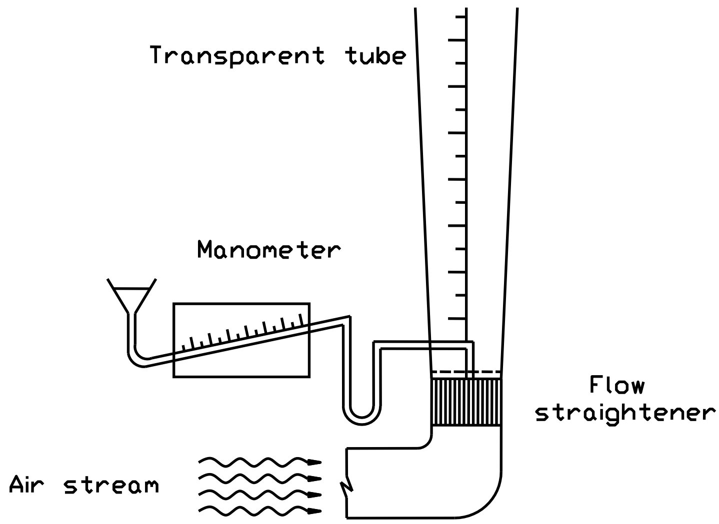

Fig. (1) The mechanism that was used for testing peanut aerodynamic properties.

Aerodynamic properties:-

The velocities of air stream were measured at different air speeds by an inclined manometer tube of 1:10 slope. The following equation was used to calculate the air velocity, (Awady and El-Sayed , 1989) :-

$$V = \sqrt{0.2\,g\,h\,\frac{\rho_w}{\rho_a}} \quad \rightarrow (9)$$

V=velocity of the air stream, m / s; g =gravitational acceleration, (9.81m /s2); H=inclined displacement of the manometer water, m; ρw=density of water in the manometer,10^3kg/ m^3, and ρa = density of air taken a 1.159 kg /m^3.

The following equations was used to calculate the drag force (df) and the coefficient of drag (Cd)

$$df = (\rho V^2 A)/2 \rightarrow (10)$$

$$Cd = 2mg/\rho V^2 A \rightarrow (11)$$

where: -m: the mass of particle, pod or stalk piece (kg); g: the acceleration of gravity (9.81 m/s^2); V: air terminal velocity (m/s), and A: particle area project to air (m^2).

Statistical analysis:-

Determined at four moisture levels with at least 100 replications at each level of moisture content. All the charts, were obtained using Microsoft Excel software (2003).

All obtained data was analyzed statistically by using a computer program (MINITAB) for estimating regression equations, coefficient of determination (R^2) and the probability.

RESULTS AND DISCUSSION

The Effect of Moisture on Physical properties

Data illustrated in Table (1) show The mean values and standard deviation of some physical properties such as the mass, diameter and length. The cumulative curves for mass, diameter and length of peanut pods and stalk pieces, at four levels of moisture content are shown in figures (2) and (3). The relationship between physical properties of stalk pieces and the moisture content can be represented as:-

For stalk pieces Mass,gm.. = 0.546 + 0.0160 M with a value for R^2 of 0.944
Diameter, mm. = 0.416 +0.000795 M R^2 of 0.755
Length, mm. = 15.9 - 0.00550 M R^2 of 0.886
And for pods Mass,gm. = 1.46 + 0.0250 M R^2 of 0.797
Diameter, mm. = 1.47 + 0.00391 M R^2 of 0.991
Length, mm. = 3.46 + 0.00566 M R^2 of 0.973

The Effect of Moisture on Aerodynamic properties

The terminal velocities of peanut in a vertical air stream were measured, and the velocity curves of the peanut pods and stalks are shown in Fig. 2.

Table 1. The mean values and standard deviation of some physical properties such as the mass, diameter and length

Moisture content w.b.,%		Characteristics	Average*	Min	Max	Std. Dev. (S.d.)	C.V.,%
pods	M1, 37.8 %	Mass, gm.	2.58	1.00	4.80	0.85	32.9
		Diameter, mm	1.61	1.20	2.03	0.17	10.6
		Length, mm	3.68	2.20	5.35	0.73	19.8
	M2, 27.03 %	Mass, gm.	1.93	0.69	4.19	0.69	35.8
		Diameter, mm	1.58	1.13	1.79	0.16	10.1
		Length, mm	3.60	2.15	5.37	0.65	18.1
	M3, 15.89 %	Mass, gm.	1.75	0.18	4.00	0.67	38.3
		Diameter, mm	1.53	0.87	1.90	0.14	9.20
		Length, mm	3.53	2.12	4.55	0.59	16.7
	M4, 3.97 %	Mass, gm.	1.69	0.50	3.37	0.74	43.8
		Diameter, mm	1.48	1.30	1.80	0.12	8.10
		Length, mm	3.49	2.12	4.26	0.54	15.5
stalk pieces	M1, 65.5 %	Mass, gm.	1.66	0.21	5.50	1.11	66.9
		Diameter, mm	0.46	0.29	1.10	0.12	26.1
		Length, mm	15.5	8.00	30.50	4.96	32
	M2, 44.16 %	Mass, gm.	1.14	0.20	3.30	0.74	64.9
		Diameter, mm	0.46	0.22	1.35	0.13	28.3
		Length, mm	15.7	8.20	30.5	3.89	24.6
	M3, 17.9 %	Mass, gm.	0.88	0.20	5.64	0.79	88.8
		Diameter, mm	0.44	0.22	1.62	0.16	36.4
		Length, mm	15.84	8.20	30.5	4.86	31.6
	M4, 8.11 %	Mass, gm.	0.68	0.20	2.30	0.45	66.2
		Diameter, mm	0.41	0.22	1.35	0.13	28.3
		Length, mm	15.8	8.20	30.5	3.89	24.6

- **average 100 samples.**

The average value of the terminal velocities was found to be increased from 11.6 to 12.8 m.s^{-1} and from 5.63 to 7.7 m.s^{-1} by increasing moisture content from 3.97 to 37.8 w.b. for pods and stalks, respectively. Hence, these values could be taken into consideration when developing devices for the separation of peanut parts. To remove lighter material from the peanut pods by an air stream, the velocity of airflow may not exceed 11.6 m s^{-1}. Meanwhile, to separate peanut pods from the heavier material, the airflow velocity may not be less than 12.8 m s^{-1} to achieve minimum pod loss.

The drag force value "(ρV^2A)/2" was calculated for peanut pods and stalk pieces at four levels of moisture content. The obtained data were plotted against the corresponding weight of particle, mg. for pods and stalk pieces. These relationships were found to be linear on plane scale curves as shown in figure (4).

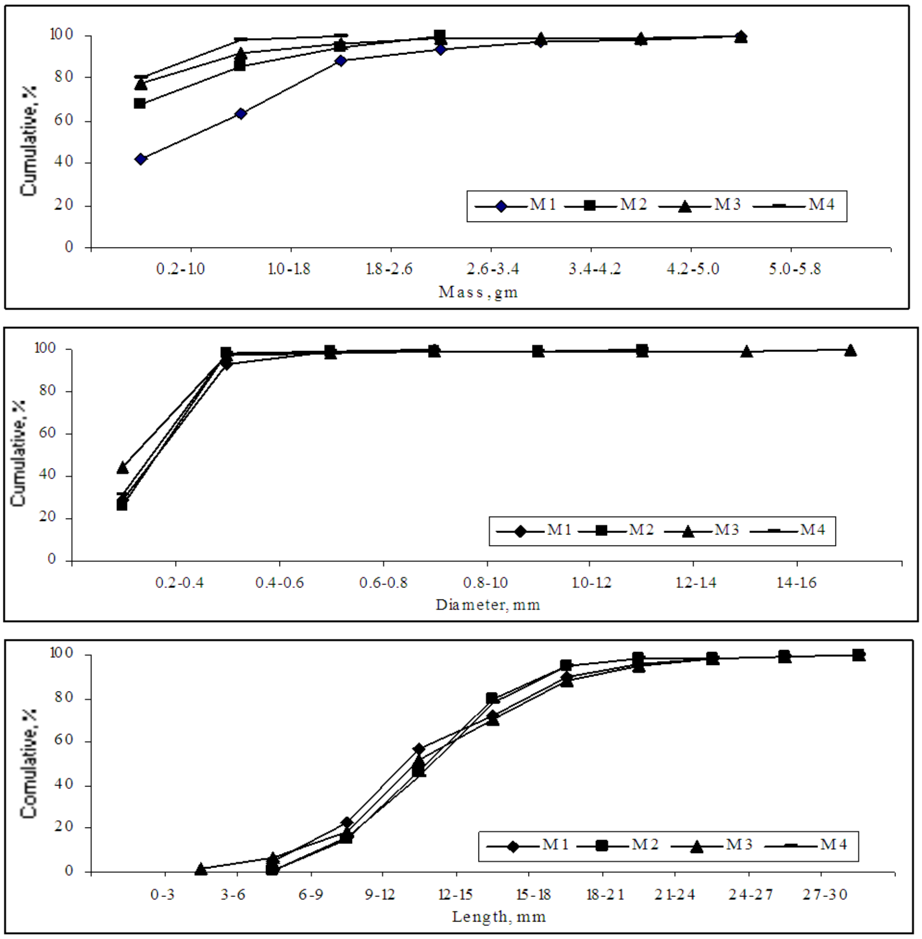

Fig. (2) Cumulative curves for mass, diameter and length of peanut stalk pieces, at four levels of moisture content.

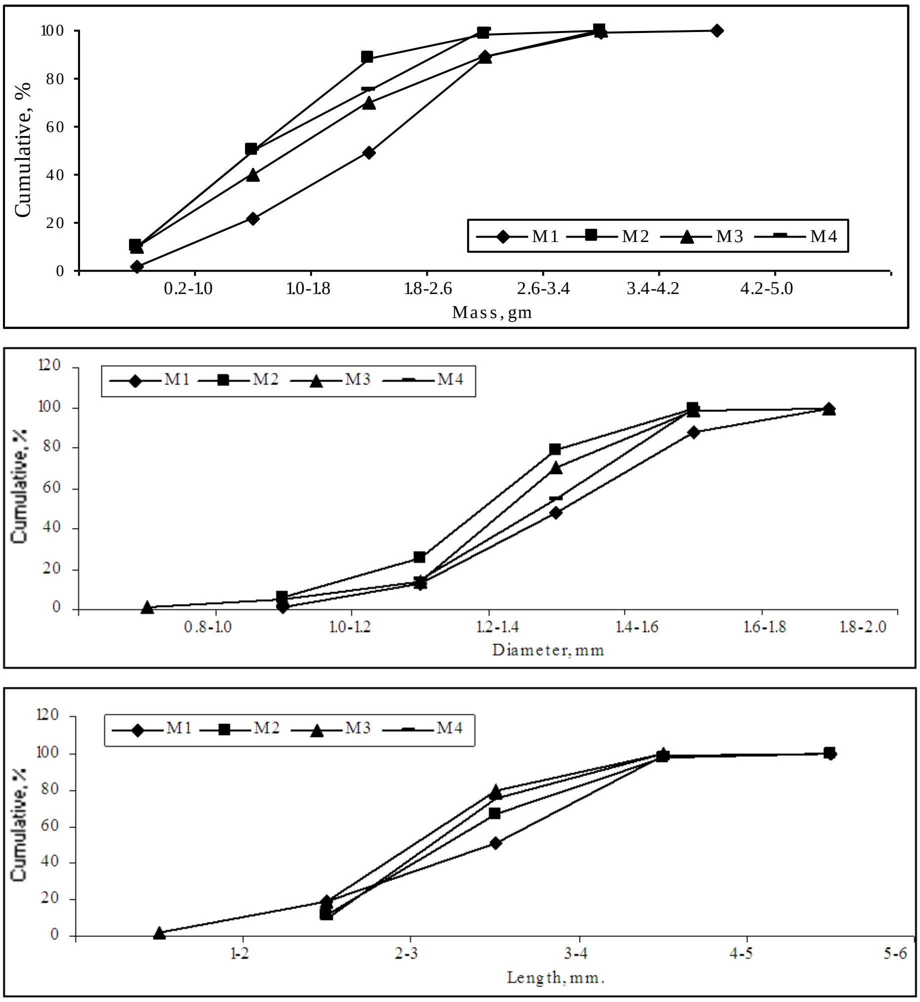

Fig. (3): Cumulative curves for mass, diameter and length of peanut pods, at four levels of moisture content.

The following equation were used to determine the coefficient of drag values of the drag coefficient for pods and stalk pieces under different levels of moisture content are illustrated in figure (5); it was found that, the "**Cd** " equal to 0.446, 0.396, 0.391 and 0.362 for pods at moisture content of 37.8, 27.03, 15.89 and 3.97% respectively meanwhile, the "**Cd** " was 0.695, 0.661, 0.565 and 0.471 for stalk pieces at moisture content of 65.5, 44.16, 17.9 and 8.11% respectively.

Cd = 0.351 + 0.00227 M with a value for R2 of 0.912

And for pods **Cd** = 0.472 + 0.00371 M R^2 of 0.898

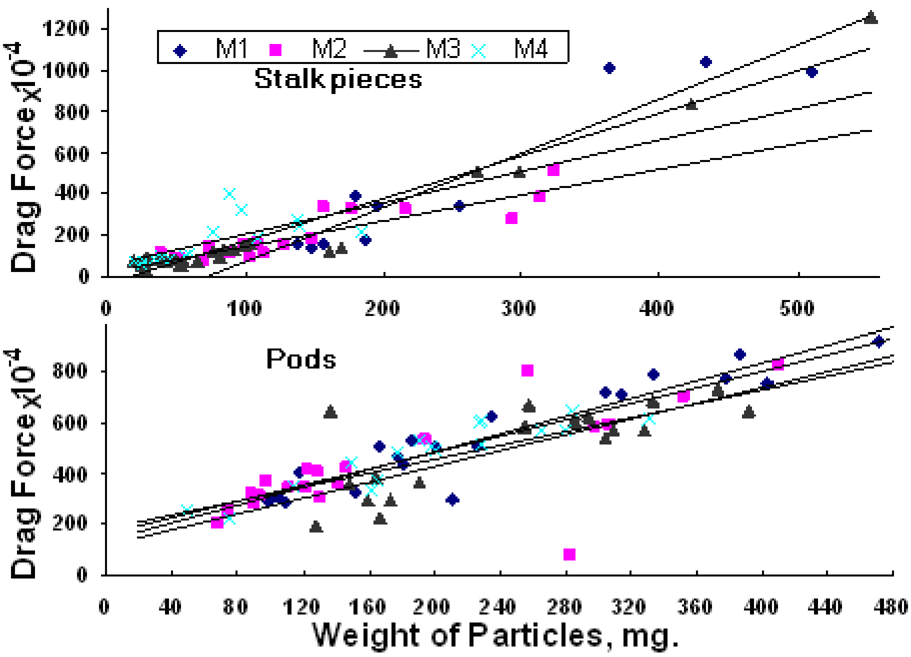

Fig. (4): Relation between drag force " ($\rho V^2 A$)/2 " and corresponding weight of particles, mg. for pods and stalk pieces at four levels of moisture content.

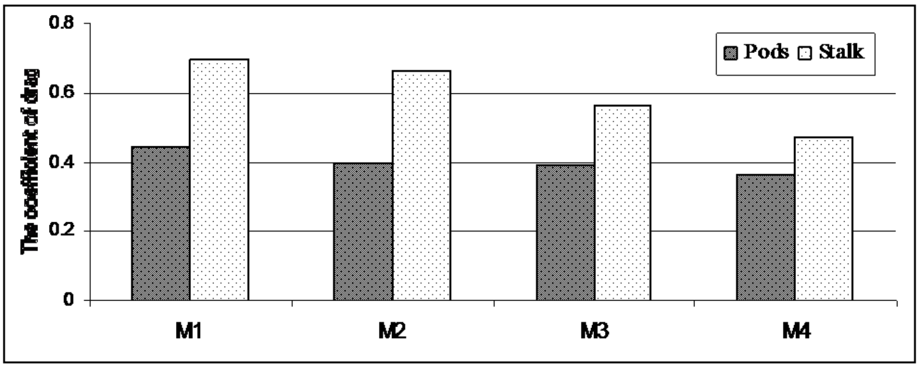

Fig. (5): Relation between different levels of moisture content and the coefficient of drag for pods and stalk pieces.

From the above, the terminal velocity (V) for peanut and stalk pieces can be predicted according to projected area (A), weight "mg" and coefficient drag (**Cd**) as follows

$$V = \sqrt{\frac{2mg}{C_d \rho A}}$$

Cumulative distribution curves of terminal velocity for pods and stalk pieces are shown in Figure (6). The terminal velocity is highly affected by the physical properties and moisture content of particle component. The mean value of terminal velocity was found 12.79 , 12.2, 11.9 and 11.6 m/s for pods at moisture content of 37.8, 27.03, 15.89 and 3.97% respectively meanwhile, the mean value of terminal velocity was 7.7, 6.19, 6.22 and 5.63m/s for stalk pieces at moisture content of 65.5, 44.16, 17.9 and 8.11% respectively.

$V = 4.83 + 0.0399\ M$ with a value for R^2 of 0.933

And for pods $V = 11.4 + 0.0342\ M$ R^2 of 0.96

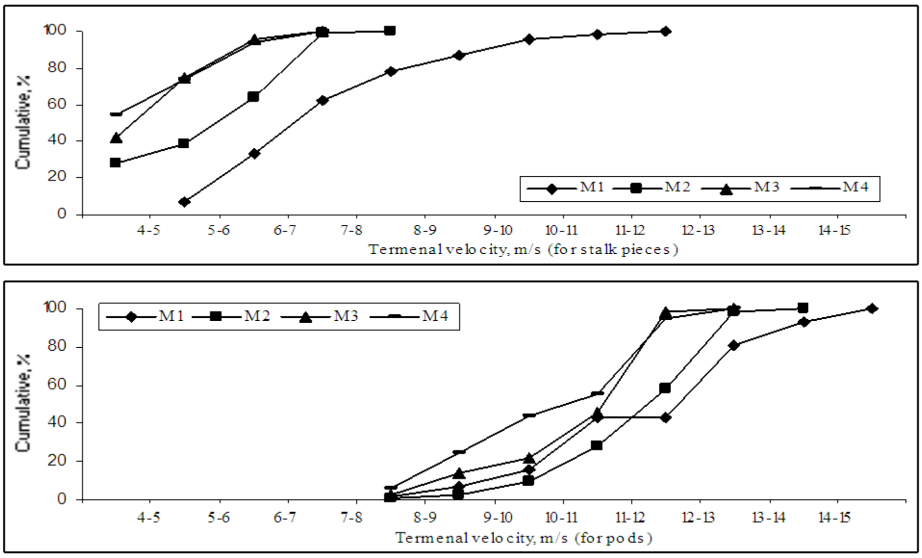

Fig. (6): Cumulative distribution curves of terminal velocity for pods and stalk pieces

REFERENCES

Awady, M. N. and El-Sayed, A. S. 1989. Characteristics of of anair-carrier sprayer from different outlet shapes. Misr J. Agri. Eng., 6(2): 125-132.

Bezrutskin I.P., Vassiliev S.A., Vaxhromeev V.A., Gladkov N.G., Nikolaev G.S., and Sissoev N.I., 1967. Cereal cleaning machines: Reference book of agricultural machinery for designer. In: Grain-cleaning separators. Vol. 2, Manufacturing unit, Moscow, 617-697.

Carman, K. 1996. Some physical properties of lentil seeds. Journal of Agricultural Engineering Research 63:87-92.

Cetin. M.2007. Physical properties of barbunia bean Phaseolus vulgaris L. cv. 'Barbunia seed. Journal of Food Engineering 80. 353–358. http://www.elsevier.com/locate/jfoodeng.

Gorial B.Y. and O'Callaghan J.R., 1991. Separation of grain from straw in a horizontal air stream. J. Agric. Eng. Res., 49(4), 273-284.

Kashaninejad M, Mortazavi A, Safekordi A, Tabil LG, (2005). Some physical properties of pistachio (Pistachio vera L.) nut and its kernel. J. Food Eng, 72 (1): 30-38.

Minitab Reference Manuel (release 15), Minitab Inc. State University Michigan.

M. Khoshtaghaza and R. Mehdizadeh, 2006. Aerodynamic Properties of Wheat Kernel and Straw Materials. Agricultural Engineering International: the CIGR Ejournal. Manuscript FP 05 007. Vol. VIII. March, 2006.

Mohsenin, N.N. 1970. The Properties of Plant and Animal Materials. New York: Gordon and Breach.

Nwokolo E. and Smartt J., 1996. Peanut (Arachis hypogaea L.). In: Food and feed from legumes and Oilseeds. Chapman and Hall: 1st edition, London; New York, 48-58..

Razavi Seyed M. A. , A. Rafe and R. Akbari, 2007. Terminal velocity of pistachio nut and its kernel as affected by moisture content and variety. Afr. J. Agric. Res. Vol. 2 (12), pp. 663-666, December 2007 Available online at http://www.academicjournals.org/AJAR.

Tado C.J.M., Wacker P., Kutzbach H.D., and Suministrado D.C., 1999. Aerodynamic properties of paddy. Agric. Eng. J., 8(2), 91-100.

تأثير المحتوي الرطوبي علي بعض الخواص الطبيعية والإيروديناميكية للفول السوداني ومخلفاتة

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يهدف البحث الى دراسة تأثير المحتوى الرطوبى على بعض الخصائص الطبيعية والايروديناميكية لمحصول الفول السودانى ومخلفاتة. حيث نحتاج لدراسة الخصائص الفيزيائية والديناميكية الهوائية المطلوبة في كثير من الأحيان لتصميم معدات للزراعة والحصاد وعمليات ما بعد الحصاد .تم تقييم العديد من الخصائص الفيزيائية والايروديناميكية لللفول السوداني ومخلفاتة أو عروشةوتم دراسة الصنف الجيزة (4 - كدالة للمحتوى الرطوبة في أربعة مستويات الرطوبة محتويات3.97) ،15.89، 27.03 ، 37.8 ٪ ، (لقرون و8.11)،17.9، 44.16 ، و 65.5٪ (لقطع ساق .وأظهرت النتائج علاقة خطية في الكتلة من 66،1-68،0) جم (ومن 58،2-67،1) جم (للساق وقرون على التوالي مع زيادة نسبة الرطوبة .وكانت أعلى قيم وطول قطرها يعني و 0.46 15.84ملم على محتوى الرطوبة 65.5 و 17.9 ٪ للساق، في حين تعني القطر والطول وكانت 3،68 1،61 ملم على نسبة الرطوبة37.8 ٪ لقرون .السرعة النهائية لقرون الفول السوداني متنوعة 12،79-6،11 م / ث، في حين أن السرعة النهائية للساق تراوحت بين-5،23 7،68متر / ثانية .وكانت أعلى قيم السرعة النهائية التي تم الحصول عليها لقرون وساق 12،79 و 7،68م / ث في محتوى الرطوبة 37.8 و65.5 ٪ على التوالي ، على الرغم من أن أدنى قيم السرعة النهائية كانت 11.6 و 5.23 في نسبة الرطوبة و8.11 3.97 ٪ للحاضن وسيقان على التوالي . وأظهرت تأثير الرطوبة على السرعة النهائية لقرون الفول السوداني وساق على زيادة خطية مع زيادة نسبة الرطوبة.

قام بتحكيم البحث

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