PHYSICAL, MECHANICAL AND AERODYNAMIC PROPERTIES OF SOYBEANS FOR SEPARATION AND GRADING MACHINES

S. H. Dosoky*

ABSTRACT

I- Some physical, mechanical and aerodynamic properties, as: seed dimensions (length, width and thickness), mass, density, and projected area, terminal velocity were measured. Drag coefficient and Reynolds number for Soybeans (Giza 21) seed varieties were also estimated. These parameters must be considered for increase of separation accuracy of a product from its associated foreign materials. The dimensions of seed (length, width and thickness) ranged as: 4.9 – 8.39, 3.29 – 7.58 and 2.41– 6.52 mm respectively .The average data and coefficient of variation, the relation between (length, width and thickness) were estimated .Two screens 3 and 7 mm round hole sizes to separate > 84 % of the product were recommended, to separate large and small size contaminants. The seed mass of grain 0.218 g., with11.78 % c.v. Through the average value of 1000 kernels was 220 grams. The seed bulk density was 771 kg/m³. The bulk density is used and considered in hopper and conveying capacity. Seed projected area of soybeans varied from 36 to 54 mm² with average of 43 mm².

II- The terminal velocity of the seed was measured at 13.81 m/s . On the other side, the terminal velocity of the foreign materials for soybean was 5.38m/s. The air velocity for separator is recommended to be 10 m/s. Drag coefficient (Cd) of seed was estimated at 0.46, as it considered in separation of the foreign ,dead ,immature ,light and broken seed, which are different from those of good seed.

The (Re) calculated was 387 – 745, with an average of 597 which corresponds to laminar flow.

INTRODUCTION

Soybeans (Giza 21) variety is one of the important oil seed crops in Egypt. The cultivated area is about 120 thousands feddans. One feddan produces about 1.25 – 1.50 ton of seeds . The seed content is about 20% oil and 40% protein. (FAO 2010).

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*Lecture of Agric. Eng.; Faculty of Agric.; Al-Azhar Uni. (Cairo)

Soybeans are used as base of many manufactured food products.

The seed physical properties, such as dimensional (size) and, specific gravity are used in separation between the desirable and undesirable seeds, to give the most efficient operation.

Mohsenin (1984) mentioned that the physical properties of materials such as shape ,size and surface or projected area are important in many problems associated with design or development of specific machine. Analysis of the behavior of the product in separation of grain is among the important design parameters in conveying of solid materials by air on the assumption of the shape of the materials .Accurate estimation of frontal area and the related

diameters are essential for the determination of terminal velocity, drag coefficient ,and Reynolds number.

Awady and El Sayed (1994) stated that when air stream is used for separation of a product from its associated foreign materials, knowledge of terminal velocity of all the particles is involved for these reasons. Terminal velocity has been used as an important aerodynamic characteristic of

material in such applications as pneumatic conveying and separation from foreign materials.

Khairy and Nakib (1989) found that the differences between suspension or terminal velocity of hulled mixture components of sunflower seed were small and equal to 0.3, 0.8 and 1m/s for hulls, broken kernels, unshelled kernels resp. This is due to the slight differences of properties of the mixture components.

The aim of this work is to study some physical, mechanical and aerodynamic properties as seed dimensions (length, width and thickness) mass, density and projected area , terminal velocity. Drag coefficient and Reynolds number for Soybeans seed were estimated. These factors must be considered to increase separation accuracy by selection of air velocity relative to grain.

MATERIALS AND METHODS

• **Materials:**

Through the present study, some physical and mechanical properties of Soybeans (Giza 21) were investigated .The mentioned properties may be utilized as engineering parameters for the design and development of cleaning and grading machines, planters and handling equipment.

• **Instruments:**

1. Terminal velocity apparatus:

The apparatus used in this study is (as used by Awady and El Sayed ,1994) shown in the Fig.(1). It consists of an electric blower which discharges air into a transparent tapered tube fixed at outlet side of blower through an below. A screen is fitted at a bottom of the tube of 8×4 cm cross section. A choke

valve is built as the bottom of the cyclone to control the air flow rate. The choke valve is manually adjusted by the control lever.

2. Anemometer:

TRI-SENSE, Hygrometer, Anemometer, thermometer, model no. 37000-00 code – Parmer Instrument, Vernon Hills, USA made was used for measuring the air velocity.

3. Electronic digital vernier caliper:

Used for measuring the dimensions of grain and their associated foreign matters .The range of reading is 0.01 to 150 mm, with an accuracy of 0.05 mm.

4. Electric digital balances:

Two types of electric balances were used in this study to measure the mass of samples.

- The first type was used in determining particles mass with an accuracy of 0.1mg.
- The second one, with an accuracy of 0.1 gram was used in determining the mass of large samples.

5. Stop watch:

Used to measure the time in seconds during tests.

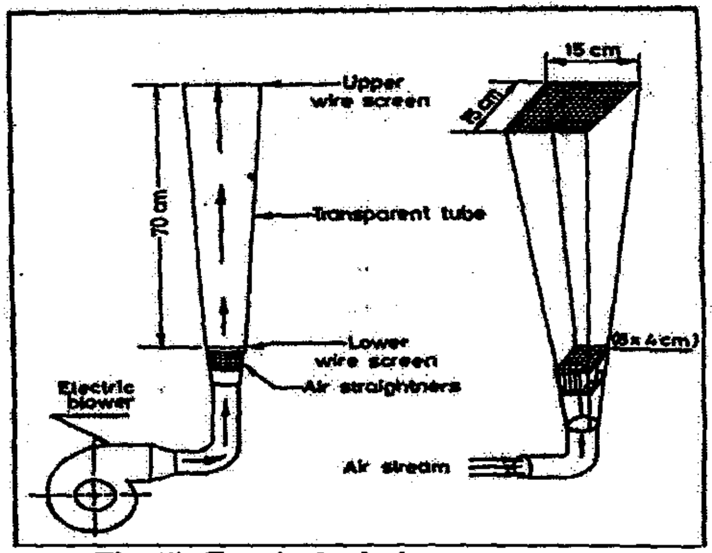


Fig. (1): Terminal velocity apparatus.

Methods:

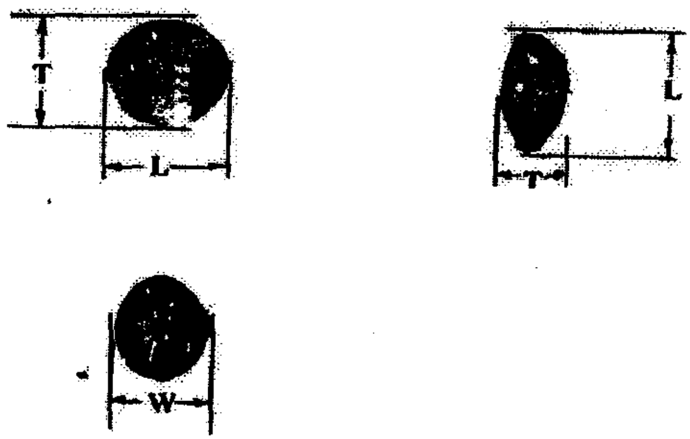
Physical and mechanical properties of seed :

The properties of seed have to be considered for designing or developing a local seed cleaning and grading machine, or planter. Some properties were studied for Soybeans (Giza 21) .The studied properties of the seed were : seed size (dimensions) length , width , real and bulk density ,projected area ,terminal velocity ,drag coefficient ,Reynolds numbers ,external friction angle ,and angle of repose ,moisture content and grain hardness.

Sample of about 500 grains was taken randomly from seed lots in order to determine the mentioned properties at air dry storage moisture content of (14-18%).

1. Seed dimensions: Fig (2)

Seed dimensions are considered in the design of disk pockets of mechanical precision planters and in proper adjustment of conveying system, cylinder clearance and screen opening .Dimensions of material under study were measured by electronic digital vernier caliper with an accuracy of 0.01 mm. The three dimensions measured for grains or seeds were the length (L), width (W) and thickness (T) in mm .Fig (2) shows the shape and the three mutually perpendicular dimensions L, W and T of seed.



c- Soybeans grain dimensions.

Fig. (2): Shape and the three dimensions, Length (L), Width (W), and thickness (T) of the studied grains.

2. Seed mass:

The seed mass (M) of the individual seed was determined in (g) using an electric digital balance with an accuracy of 0.1 mg.The measurement was replicated for 100 kernels which were taken randomly for each variety.

3. Mass of 1000 kernels:

Estimating mass of the seed is needed to facilitate bagging operation for screened commodity and also for precision planting operation .The same balance was used to determine the mass of counted samples of the investigated crop. Grain was counted manually .The work was replicated four times.

4. Seed real - density:

Density is considered in determining the capacity of the seed hopper and conveying unit of the seed cleaner .It is expressed as mass per unit volume.

Real density was measured for a random sample of 100 grains .Real volume of grain was measured as increasing in 5 ml. sodium nitrate solution.

5. Seed bulk density:

Property was calculated for the grains of the soybeans crops, dividing the mass by its bulk volume, which was measured by using graduate cylinder. The considered values are the average of four recorded replicates.

6. Air terminal velocity:

The determination of air terminal velocity and drag coefficient characteristics is needed to estimate the behavior of seed and other materials in air stream to establish blower design. The terminal is velocity required to suspend a particle in a vertical air stream in the test apparatus fig.(1).Terminal velocity of the investigated crops was measured ,where the particles under study were placed at the front of the blower on a net at the inlet side of transparent tube .After operating the blower, increasing the blower speed by closing gate slowly and gradually until the air steam suspends the particle in the vertical active part of the transparent tube. The measured air velocity in the case represents the terminal velocity of the particle. The velocity is recorded when the material was floating in the air stream.

7. Seed drag coefficient:

The drag coefficient (Cd) of the seed was calculated according to the following equation (Hexing, 1989, Awady and El Sayed ,1994).

$$Fd = \frac{1}{2} (Cd.Ap\ \rho_a\ V^2) = Mg.$$

Fd: the drag Force, M: Mass, G: gravity.

Ap: Frontal area of particle, ρ_a = air density.

V: relative air velocity and Cd: drag coefficient.

8. Reynolds number:

Reynolds number characterizes the nature of the flow: laminar, turbulent and transitional. It was calculated from the following equation :

$$N_{Re} = V_t\ d\ \rho_a / \mu$$

Where: N_{Re}: Reynolds Number, dimensionless.

V_t: terminal velocity of the particle m/s.

ρ_a: The density of the air 1.28 kg/m³.

μ: dynamic viscosity of air $18\times 10^{-6}\ \rho_a$

9. Seed projected area:

Projected area of sample of 100 grain was plotted to measure by using a digital photo camera and the seed picture was exported to " autocad " program. The value of projected area of seeds were measured with an accuracy of 0.001 mm. The results obtained determine the variation of the seed that was considered in the developed separating unit and precision planter.

RESULTS AND DISCUSSION

Separation for seed processing is based on differences in physical, mechanical and aerodynamic properties between desirable, undesirable seed or contaminating weeds or other crop seed.

1- Seed dimensions:

- Figs (3) and (4) show the grain dimensions, frequency and cumulative distribution of soybeans dimensions (length, width and thickness).

- The results shows the standard deviation, coeffient of variance, the range and arithmetic mean for grain dimensions (length, width and thickness) for hundred soybean seed (Giza 21) .The length of seed reneged between 4.9 and 8.39 mm with std. Dev (0.65) and C.V (9.85). The mean was 6.56 mm. The thickness of the seed ranged between 2.41 and 6.52 mm.

- Figs (5) and (6) show the relationship between length and width, and between thickness and width for soybean seeds. The grain length (L) varies directly with (W) according to the equation: $L = 1.367W + 1.483$.

The grain thickness (T) varies slightly with (W) according to the equation:

$T = 1.03W + 1.39$, since 84% of the seed ranged between > 6 and < 8 mm. in width ,passed through holes of top screen of 8mm and nut holes at bottom screen of 6 mm, as recommended to grade soybeans .

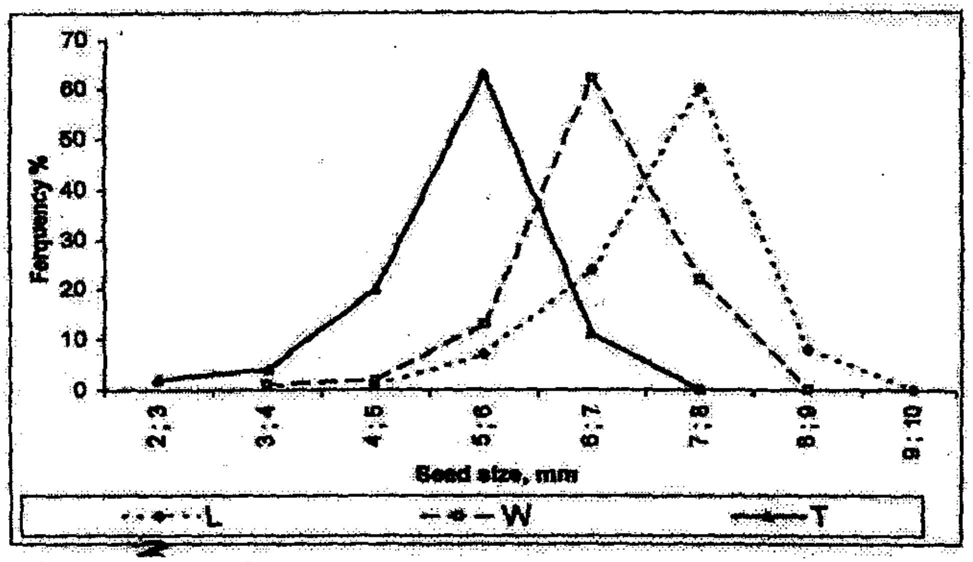


Fig . (3) : Frequency distribution curves of grain dimensions (length ,width and thickness) for soybeans (Giza 21)

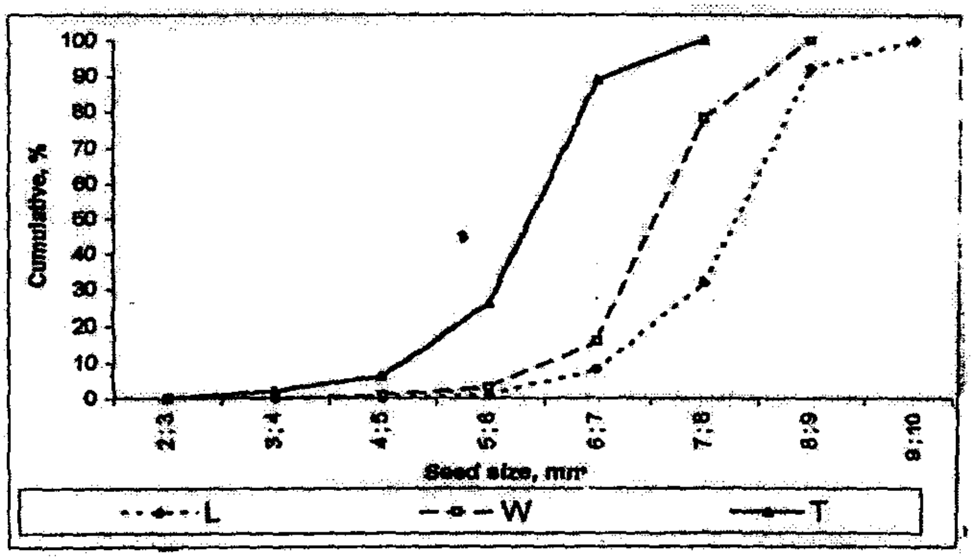


Fig . (4) : Cumulative distribution curves of grain dimensions (length , width and thickness) for soybeans (Giza 21

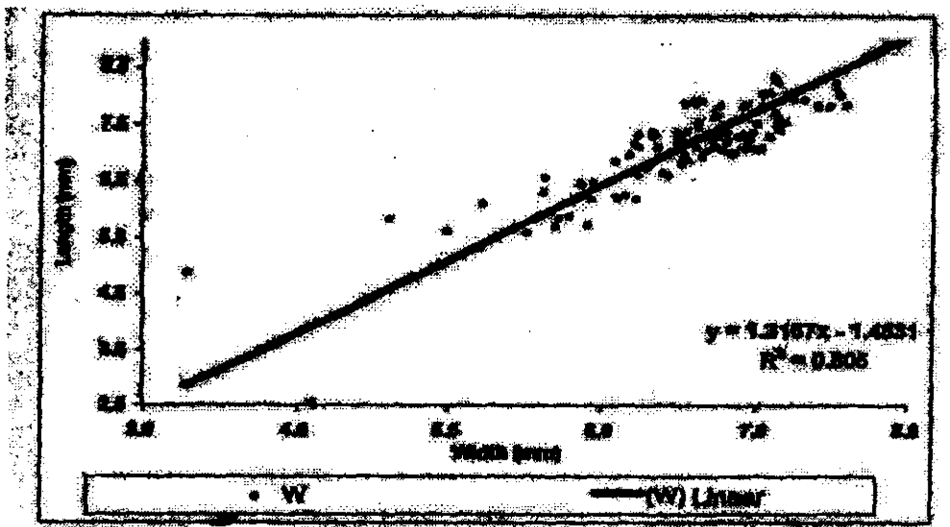


Fig . (5) : Relationship between length and width for soybeans (Giza 21) .

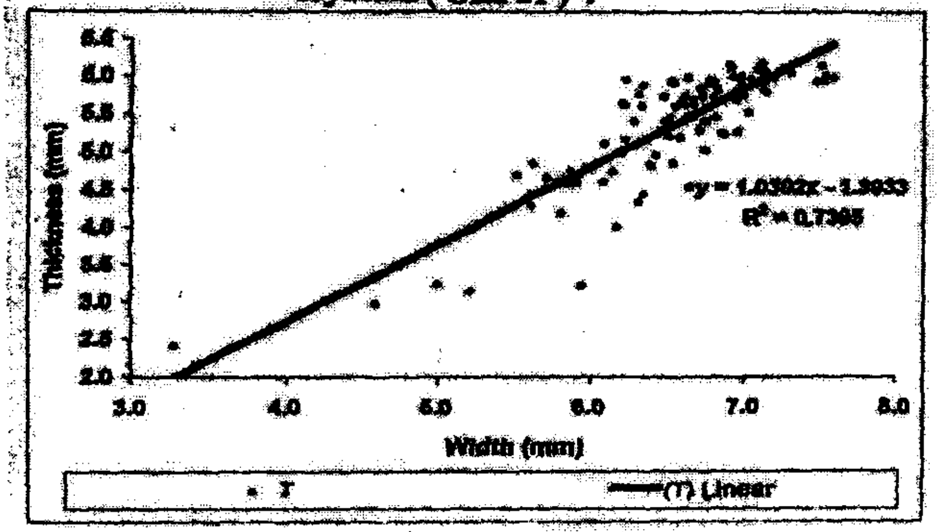


Fig . (6) : Relationship between thickness and width for soybeans seeds (Giza 21)

2- Seed mass (individual and 1000 kernels):

Data presented in fig (7) showed that the mass of individual grains of soybean (Giza 21) varied from 0.16 to 0.29 g with a mean of 0.218 gram and c.v. of 11.78% .The average value of 1000 kernels of four replicate was 220g. Moreover, the grain mass and projected areas are effective properties for aeromechanical separators. Estimating mass of seed is necessary in seed packing process, also to determine the required mass of seeds for planting a limited area, where the plants per area are calculated by the number of seeds.

Fig. (7) : Distribution curve of grain mass (g) for soybeans (Giza 21)

3- Seed real and bulk densities:

The values of the true and bulk densities were found to be 1358 and 771 kg/m^3. Density is considered in determining the capacity of seed hopper and conveying unit of the seed cleaner and seeder design.

4- Seed projected area:

Fig (8) shows the results of measurement of projected area of soybean seed in mm^2 of individual grains, which had been measured due their dimensions.

The grain projected area (A) varied from 36 to 54 mm^2 with mean of 43 mm^2 and c.v. of 9.42 % .The calculated grains projected area (A) was found to vary from 30 to 49 mm^2 with a mean of 37 mm^2 and c.v. of 17.50 %.The results are considered in developing of separating unit and precision planter design or development.

5- Terminal velocity:

The sample was placed on the screen of the terminal velocity apparatus .Air velocity was gradually increased at increments of 0.05m/s.The air velocity, as the particles floated was measured .The terminal velocity ranged from 9.6 to 14.6 m/s with average of 13.81 m/s and c.v. 10.86 % (fig.9). The terminal velocities of the individual weed, light and immature seeds are such lower than the velocity for the individual good seed. The terminal velocity for the contaminants in soybeans, which ranged between 2.35 and 8.35 with average of 5.38 and c.v. of 25%.

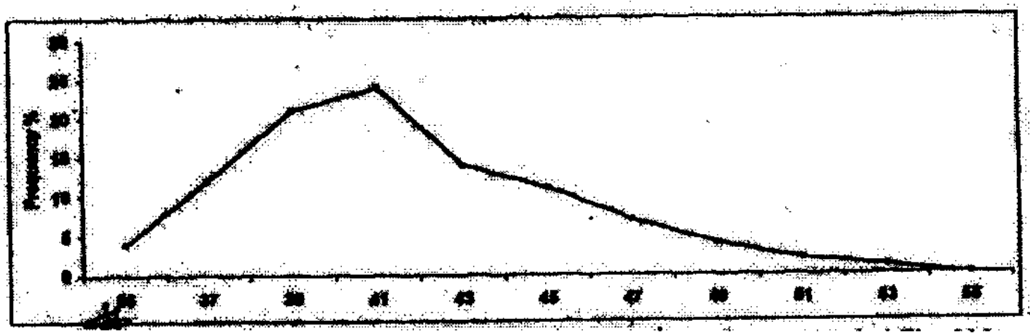


Fig. (8): Distribution curve of grain projected area for soybeans sample (Giza 21).

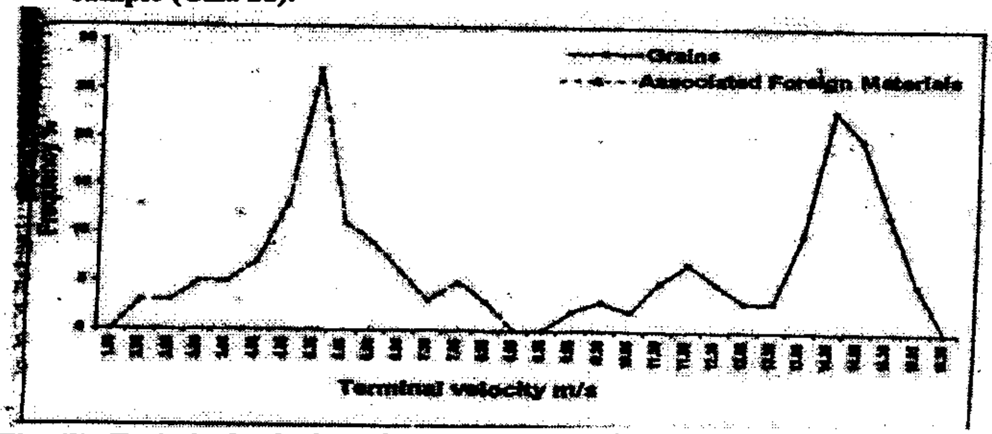


Fig. (9): Teriminal velocity – frequency curves for grains and foreign materials for soybeans (Giza 21).

6- Drag coefficient of seeds:

Drag coefficient of (Cd) for the sample of 100 grains was calculated, which ranged from 0.35 to 0.82 with average of 0.46 and c.v. 23.53%.

7- Reynolds number of seeds:

The effect of particle dimensions on terminal velocity can best be represented by the Reynolds number (R_e). The R_e plays an important role in characterizing the nature of the flow (laminar ,turbulent or transitional). R_e for soybeans ranged between 387 and 745, with average of 597 and c.v. 14.96. According to the value obtained flow, is turbulelent around the seed (much less than for flow inside pipes)

8- Relationship between the mass of particles and aerodynamic properties:

The obtained data for seeds were plotted against the corresponding terminal velocity of the seed for soybean. The relationship was found to be positive linear as shown in fig.(10). These results are supported by those obtained by Khairy and Al-Nakib (1989), Awady and El-Sayed (1994), who reported that the terminal velocity of the particle was highly affected by the mass .

Particle mass and drag coefficient :

The drag coefficient (Cd) value was calculated for soybeans under study under equilibrium state. The obtained data were plotted against the corresponding mass of particle (9). This relationship was found to be negative on curve as shown in fig (11). It is clear that the drag coefficient decreased as the seed mass increased. This result was in line with those obtained by Awady and El-Sayed (1994).

a. Particle mass and projected area:

The obtained result is shown in fig (12) for the crop under study. The relationship was found to be positive and linear. It is clear that the projected area is highly affected by the seed mass.

b. Particles terminal velocity and projected area:

The obtained data for seed projected area is plotted against the corresponding terminal velocity (m/s). This relationship was found to be positive and linear as shown in fig.(13) .It is evident from the data, that the terminal velocity of seed decreased as the projected area increased. This finding in agreement with those of Ahmed and Korayem (1988), Awady and El-Sayed (1994) who reported that the terminal velocity of the particle was highly affected by projected area of particle.

Particle drag coefficient and Reynolds number:

The seed drag coefficient (Cd) and Reynolds number (R_e) values for four crop grains of soybeans (Giza21) was calculated under equilibrium state. The obtained data for seed drag coefficient (Cd) were plotted against the corresponding (R_e). The relationship was found to be negative as shown in fig (14). It is evident from the data that the seed drag coefficient (Cd) decreases with increasing (R_e). The results are supported by those obtained by Sitkei (1986) , who reported that, the (R_e) of seed increased with decreasing drag coefficient.

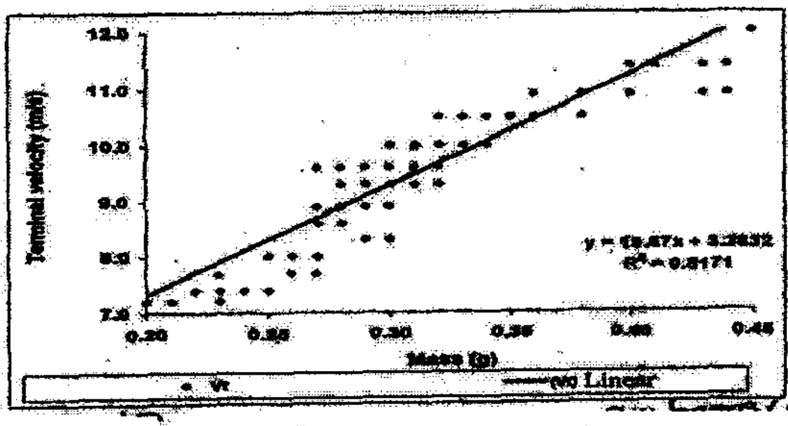


Fig. (10) : Terminal velocity , Vs. Mass for Soyabeans (Giza 21)

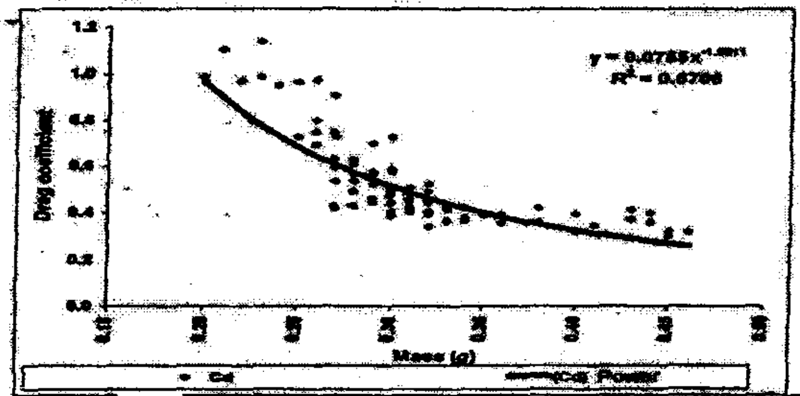


Fig. (11) : Drag coefficient , Vs. Mass for Soyabeans (Giza 21)

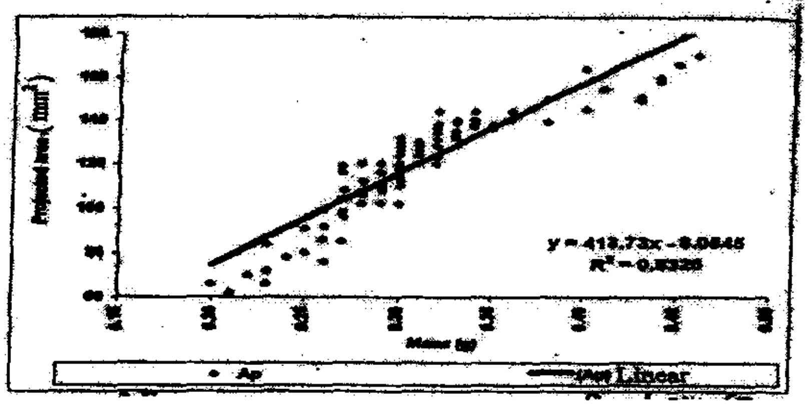


Fig. (12) : Mass Vs . projected area for Soybeans (Giza 21)

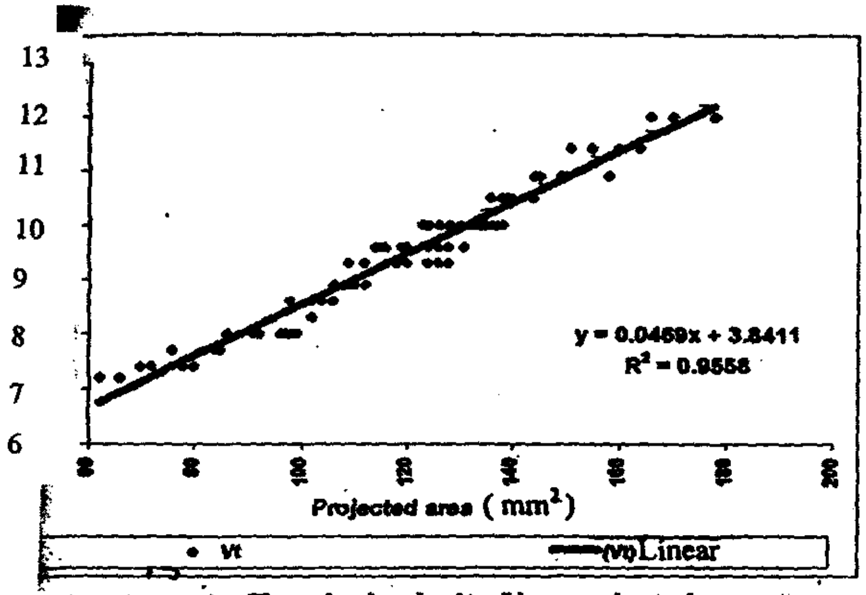


Fig . (13) : Terminal velocity Vs . projected area

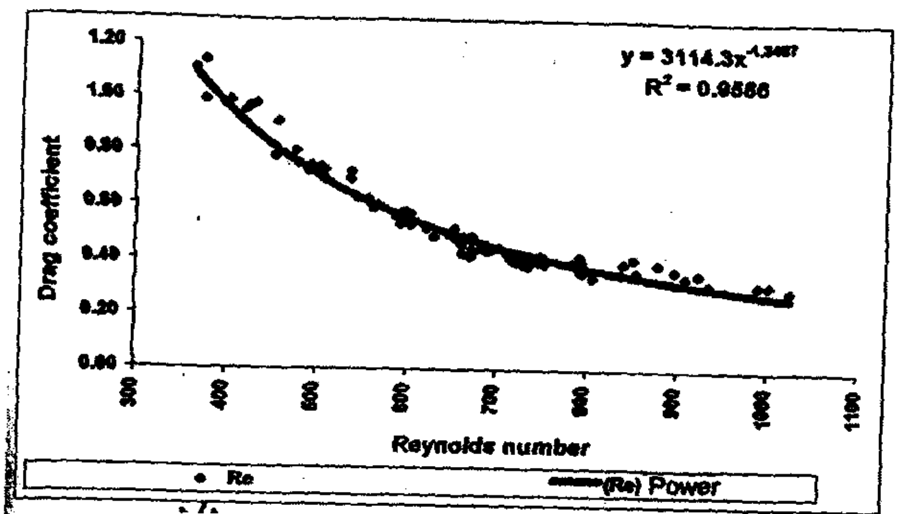


Fig . (14) : Drag coefficient , Vs . Reynolds number

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الملخص العربي

دراســـة بعـــض الخـــواص الفـــيزيائيـــة والمـــيكانيكيـــة والايـــروديناميـــة فـــى فصـــل وتـــدرج فـــول الصـــويـــا

د/ سمير حافظ دسوقى*

مقدمـــة:-

يهدف هذا البحث لدراسة العوامل لايجاد قاعدة بيانات تكون أساسا فى تصميم وتطوير ماكينات الفصل والتدرج وتؤخذ كذلك في الاعتبار عند التشغيل لمحصول فول الصويا .

تم قياس مقاسات حبوب فول الصويا من طول وعرض وسمك من مدى القياس ومعامل الاختلاف والمتوسط حيث كانت ٤،٩ – ٨،٣٩ مم للطول ، ٣،٢٩ – ٧،٥٨ للعرض و ٢،٤١ – ٦،٥٢ للسمك.

من هذه الأبعاد ودراسة المنحنى التراكمي لأبعاد الحبوب تم اختيار خاصية العرض للفصل عل أساسها ، فأختير غربال بفتحات مستديرة، حيث تم اختيار فتحات الغربال العلوى ٧مم و السفلى ٣مم والذى قام بفصل الشوائب والحبوب الشاذة والميتة ،واستبعدت نسبة مقدارها ٨٤% من الحبوب وهى نسبة الحبوب الجيدة.

- كما تم قياس وزن الألف حبة وكانت ٢٢٠ج/١٠٠٠ حبة وكذلك قيست الكثافة الظاهرية وكانت ٧٧١كج/م٣ وهى خاصية مهمة فى تقدير حجم العبوات وكذلك حجم صندوق التغذية فى الفصل والبذر .
- وقد قيست المساحة المسقطة فى مدى ٣٦ :٥٤ مم٢ بمتوسط ٤٣مم٢.
- و قيست السرعة الحدية للبذور حيث كانت ١٣،٨١م / ث .
- كما قدرت السرعة الحدية للشوائب الخفيفة والحبوب الميتة والغريبة فكانت ٥،٣٨ م / ث واقترحت سرعة فصل لتيار الحبوب ١٠ م / ث .
- كما قدر معامل رينولد للهواء حول حبوب بمتوسط ٥٩٧ والذى هو مضطرب بالضرورة.

**مدرس الهندسة الزراعية – كلية الزراعة – جامعة الأزهر بالقاهرة.