EFFECT OF RELATION BETWEEN MOISTURE CONTENT AND TERMINAL VELOCITY ON WHEAT AND BARLEY GRAINS

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ABSTRACT

Terminal velocity (T_V) is one of the important aerodynamic properties of materials, including seeds of agricultural crops that are necessary to design of pneumatic conveying systems, fluidized bed dryer and cleaning the product from foreign materials. Among the properties, terminal velocity is very important. This investigation aimed to provide database about the physical properties (length, width, thickness, volume, percent of sphericity, geometric diameter, arithmetic diameter, transverse surface area and flat surface area) and terminal velocity of crop grains at different moisture contents. Two different grains crop were tested such as wheat grains (Sakha 93-variety) and barley (Giza 130-variety). The wheat and barley grains were tested at different moisture contents of 9, 11, 13, 15 and 17 %.

The main results in this study can be summarized as follows:

- *Length, width, and thickness for wheat grains were 6.18 , 2.80 and 2.21 mm respectively. Meanwhile, length, width, and thickness for barley grains were 9.85, 2.49 and 3.52 mm respectively.*
- *Volumes for wheat and barley were 30.52 and 45.2 mm^3 respectively.*
- *Percents of sphericity for wheat and barley were 62.75 and 44.87% respectively.*
- *Geometric and arithmetic diameters for wheat and barley were 3.88, 4,21 and 4.42, 5.29 mm respectively.*
- *By increasing moisture content of all grains, the terminal velocity increased in general. The highest terminal velocities were 8.53 and 7.8 m/ s for wheat and barley grains respectively at moisture content of 17 %. Meanwhile, the lowest terminal velocities were 7.8 and 6.98 m/ s for wheat and barley grains respectively at moisture content of 9 %.*

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INTRODUCTION

Grains are mainly considered among the most important crops in Egypt. They are potentially usable for many industries. A knowledge of physical and mechanic undesirable materials such as light grains, weed seeds, chaff, plant leaves and stalks can be removed with air flow, when grains, fruits and vegetables are mechanically harvested. In addition, agricultural materials are routinely conveyed using air stream in pneumatic conveyers. If these systems are not used properly, they could cause problems. For example, in a combine harvester, if the air speed is low, the materials would not be separated from each other and there will be extra foreign material with the product. If air speed is high, the product will be exhausted along with extra material and product loss will increase. For conveying agricultural materials, the range of proper air streams should be used. With low air speed, there is stagnation in the system, or with high air speed, there is not only energy lost, but also grains may be broken. The proper air speed can be determined from aerodynamic properties of agricultural materials. These properties are terminal velocity and drag coefficient. Properties of grains which are important in their engineering, handling and storage. It is very important in specific machine design. Agricultural engineers have used compressed air for separation and handling of various materials for many years. Knowledge about aerodynamic properties of agricultural materials is useful for agricultural machine and system design. One of these properties is terminal velocity (T_v) of agricultural seeds as in addition to plant species, influenced by additional variables such as seed moisture (Behroozi-lar et al., 2003). Mohsenin (1986) mentioned that the physical properties of material such as shape, size, volume, and surface area are important in many problems associated with design or development of specific machine, analysis of the behavior of the product in handling of the material, stress distribution in the material under load, electrostatic separation of grain, light reflectance and color evaluation. One of the important design parameters in conveying of solid materials by air or water is the assumption for the shape of the materials. Accurate estimates of the frontal area and the related diameters are essential for the determination of terminal velocity, drag coefficient, and Reynold number.

Arora (1991) concluded that the engineering properties such as size, diam., vol., bulk density, particle density, porosity, terminal velocity, drag coefficient, and resistance coefficient. of 3 varieties of rough rice (Oryza sativa, L) at 5 m.c. (8.1, 14.20, 18.23, 23.40, 27.23) levels (d.b.). Physical properties were found to be related to m.c. physical properties were linearly dependent upon m.c. The aerodynamic properties (terminal velocity, drag-coeff. and resistance coeff.) also increased with an increase in moisture content. Separation of mixture of particles in a vertical air stream is only possible when the aerodynamic characteristics of the particles are so different that the light particles are entrained in the air stream and the heavy particles fall through it. Threshed crop material contains grains together with contaminants such as straw, chaff threshed heads, and weeds, each of the materials spans arrange of aerodynamic priorities (Gorial and O, Callaghan, 1991). Nimkar and hattopadhyay (2001) evaluated various physical properties of green gram as a function of moisture content in the range of 8.39 to 33.40 % d.b. The average length, width, thickness and thousand grain mass were 4.21 mm, 3.17 mm, 3.08 mm and 28.19 g at moisture content of 8.39 % d.b. The geometric mean diameter increased from 3.45 to 3.77 mm, whereas sphericity decreased from 0.840 to 0.815. Studies on rewetted grains showed that the bulk and true densities decreased from 807 to 708 kg m-3 and 1363 to 1292 kg m-3 , respectively, whereas the corresponding bulk porosity increased from 10.1 to 12.1 m.s-1. The static coefficient of friction varied from 0.344 to 0.625 over different material surfaces, while angle of repose varied from 26.6 to 31 deg within the studied moisture range. Ebaid et al. (2003) reported that, the terminal velocity values to suspended grain of rice (Giza 176 variety) was 8.275 m/s, the required terminal velocity to suspended the impurities from rice grain was 4.159 m/s. The terminal velocity values to suspended wheat grain (Sakha 69 variety) was 8.63 m/s, the terminal velocity values to suspended the impurities from wheat grain was 3.90 m/s. The terminal velocity values to suspended corn grain (Giza 2 variety) was 16.606 m/s, the terminal velocity values to suspended the impurities from corn grain was 13.957 m/s. The terminal velocity values to suspended soybean grain (Clark variety) was18.351 m/s, the terminal velocity values to suspended the impurities from soybean grain was 14.412 m/s. Ali et al., (2006) studied three different varieties of wheat as Pishtaz, Mahdavi and Marvdasht were tested. The wheat's verities were tested at different moisture contents of around 8, 12, 14, 18, to 22%. The highest terminal velocity was 6.9 m/ s for Mahdavi variety and the lowest terminal velocity was 6.0 m/ s for Marvdasht variety. By increasing moisture content, the terminal velocity of all wheat varieties increased.

The objective of this research was to determine some physical properties and terminal velocities for wheat and barley grains at different moisture contents. These properties help to develop appropriate technologies in design and adjustment of machines used during harvesting, separating, cleaning, handling and storing of agricultural materials and convert them into food, feed and fodder.

MATERIALS AND METHODS

In this study, the main experimental tests were done at Agricultural Engineering Research Institute, Dokki, Giza, Egypt in year of 2015. The experiments were conducted to determine some physical properties and terminal velocities for wheat and barley grains at different moisture contents.

Crop used in investigation.

Five hundred wheat grains "Sakha 93-variety" and barley "Giza 130-variety" were taken to determine the physical properties and terminal velocity.

Physical properties of grains.

Dimensions like (length, width, and thickness mm) moisture content %, volume mm^3, percent of sphericity %, Geometric diameter mm, arithmetic diameter mm, transverse surface area mm^2, and flat surface area mm^2 were determined according to El-Raie et al. (1996) as follows:

- $V = \pi/6\ (L*W*T)\ mm^3$ ----------------(1)
- $S = 100*(L*W*T)^{1/3}\ /L\ \ \%$ ------------(2)
- $Dg = (L*W*T)^{1/3}\ mm$ -----------------(3)
- $Da = (L+W+T)\ /3\ mm$ -----------------(4)
- $A_t = \pi/4\ (T*W)\ mm^2$ -------------------(5)
- $A_f = \pi/4\ (L*W)\ mm^2$ -------------------(6)

Where :

L = length, mm, W = width, mm,

T = thickness, mm, V = volume, mm^3 ,

S = percentage of sphericity,%, Dg = geometric diameter, mm, Da = arithmetic diameter, mm, A_t = transverse surface area , mm^2 and A_f =flat surface area mm^2 .

The aerodynamic properties of grain:

The terminal velocity of grains for wheat and barley were measured by the floating apparatus shown in fig. (1). The terminal velocity was measured when the material under test was floating in the air stream. This procedure repeated three times at different moisture content from 9 to 17 %.

Fig. (1): Floating apparatus for measuring terminal velocity

Moisture content.

Different moisture contents were achieved by adding water to the samples for the experiments. Water was added to the samples in order to have the desired moisture content "Mcd". The amount of added water "Wa" was determined from equation (7) as follows Ali et al. (2006):

$$Wa = (Mcd- Mci)* Ws/ 100 - Mcd \text{ ------------------ } (7)$$

Where:

" Ws"= weight of sample and

"Mci" = initial moisture content.

The added water sample was refrigerated for 24 h. It was then, placed in room temperature for about 3 h. before the test.

Terminal velocity.

A sample of 50 g was placed on the floating apparatus and the fan speed was gradually increased until the particle was floated in, then the air velocity was measured by anemometer. This procedure repeated three times at different moisture content from 9 to 17 %.

Instrumentations:

- Digital dial caliper: With range of 15 cm and accuracy of 0.05 mm was used to measure grain dimensions.
- Moisture content meter: A moisture content meter was used for measuring the grains moisture-content on wet basis.
- Anemometer instrument: An anemometer instrument was used for measuring the air speed, temperature and pressure. Its air speed ranged from 0 to 50 m/s.
- Floatation apparatus specification: It is used for measuring the terminal velocity. Operation theory is by vacuum. The maximum measuring value by the apparatus is 20 m/s and accuracy of 0.1 m/s.
- Electronic balance: An electronic balance was used for weighing grain samples. Its scale ranged from 0 to 5 kg and accuracy of 0.2 g.

RESULTS AND DISCUSSION

Effect of moisture content on terminal velocity:

Fig. (2) shows the relationship between moisture content and terminal velocity. By increasing the moisture content of all grains, the terminal velocity increased in general.

For instance by increasing moisture content from 9 to 17 % the terminal velocity increased from 6.98 to 7.8 m/s and from 7.8 to 8.53 m/s for barley and wheat grains respectively.

Increasing terminal velocity is may be due to increasing the weight of grains.

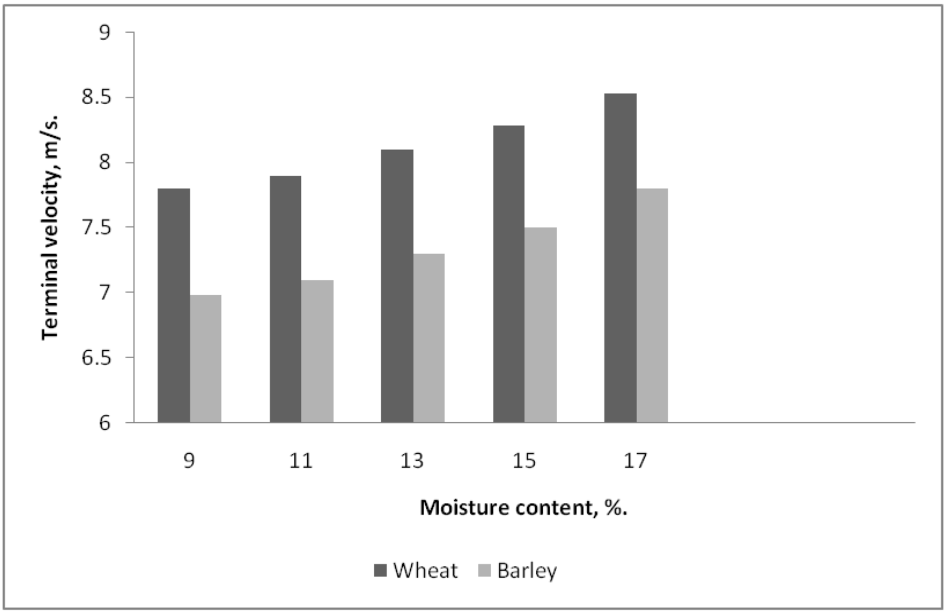

Fig. (2): Effect of moisture content on terminal velocity for paddy rice and barley grains.

<u>Physical properties of grains:</u>

The physical properties of wheat and barley were determined as follows:

<u>Dimensions grains:</u>

The averages of the length, width, thickness, geometric diameter, arithmetic diameter, volume, flat surface area, transverse surface area and sphericity of grain varieties are shown in table 1.

Maximum dimensions of wheat and barley grains are as follows:

Length (L) = 6.18 and 9.85 mm

Width (W) = 2.80 and 3.49 mm and

Thickness (T) = 2.21 and 3.52 mm respectively.

The frequency distributions for the length, width, and thickness were approximately normally distributed. The barley grains were longer and wider than wheat grains. This shows that wheat and barley grains may be separated according to their length.

<u>Shape and size of grains:</u>

If sphericiety is less than 0.9, the grains belongs to oblate group, if it is greater than 1.1 it belongs to oblong group, the remaining grains with intermediate index values are considered to be oblong (Buyanov and Voronyuk, 1985). Table (1) indicates that the grains sphericity were 44.87 and 50.40 for barley and wheat respectively.

Geometric diameter and arithmetic diameter of grains:

As seen in table (1), the mean values of geometric diameter for barley and wheat grains reported as 4.42 and 3.88 mm, respectively. Also, from table 2, the mean values of arithmetic diameter for barley and wheat were reported as 5.29 and 4.12 mm, respectively.

Volume, flat surface area, and transverse surface area:

The volume (V), flat surface area (A_f), and transverse surface area, (A_t) of wheat and barley grains, as also with other similar agricultural products, are useful values which are usually difficult and cumbersome to determine rapidly or by a direct measurement.

Table 1: Physical properties of wheat and barley grains.

Physical properties	Type of grains	
	Wheat	Barley
L	6.18	9.85
W	2.80	2.49
T	2.21	3.52
M.C	11.5	9.43
V	30.52	45.2
S	62.75	44.87
Dg	3.88	4.42
Da	4.12	5.29
A_t	7.41	6.88
A_f	16.36	19.26

Where:

L: length, mm,
W: width, mm,
T: thickness, mm,
M.c: Moisture content %,
V: volume, mm^3,
S: percent of sphericity, %,
Dg: Geometric diameter, mm,
Da: Arithmetic diameter, mm,
A_t: transverse surface area, mm^2 and
A_f =flat surface area mm^2.

CONCLUSION

The main results in this study can be summarized as follows: -

-Length, width, and thickness for wheat and barley grains were 6.18, 2.80 and 2.21 – 9.85, 2.49 and 3.52 mm respectively.

-Volume for wheat and barley was 30.52 and 45.2 mm^3 respectively.

-Percent of sphericity for wheat and barley was 62.75 and 44.87 % respectively.

- Geometric diameter and arithmetic diameter for wheat and barley were 3.88, 4,21 and 4.42, 5.29 mm respectively.

- By increasing moisture content of all grains, the terminal velocity increased in general. The highest terminal velocity was 8.85 and 7.8 m/ s for wheat and barley grains respectively at moisture content of 17 %. Meanwhile the lowest terminal velocity was 7.8 and 6.98 m/ s for wheat and barley grains respectively at moisture content of 9 %.

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<u>الملخص العربى</u>

تأثير العلاقة بين المحتوى الرطوبى وسرعة التعليق على محصولي القمح والشعير

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تعتبر سرعة التعليق (T_v) واحدة من اهم الخصائص الديناميكية الهوائية الهامة لفصل المواد، بما في ذلك بذور المحاصيل الزراعية وتنظيف المنتج من المواد الغريبة مما يؤدى لزيادة الانتاجية وبالتالى زيادة الدخل المتوقع. لذا هذا البحث يهدف إلى توفير قاعدة بيانات عن الخصائص الطبيعية (الطول، والعرض، والسمك، والمحتوى الرطوبى، والقطر الهندسي، والقطر الحسابي، مساحة عرضية، مساحة مسطحة) والسرعة النهائية للحبوب المحاصيل عند محتويات رطوبية مختلفة تتراوح من ٩ –١٧ %. حيث تم اختبار اثنين من الحبوب المختلفة المحاصيل مثل القمح والشعير. تم اختبار القمح (سخا ٩٣) والشعير (جيزة ١٣٠) في محتويات رطوبة مختلفة من حوالي ٩٪، ١١٪، ١٣٪، ١٥٪، ١٧ ٪.

وكان متوسط القيم لبعض الخواص كالتالي :

- الخواص الطبيعيه: وجد أن الطول والعرض والسمك لحبوب القمح هى ٦.١٨، ٢.٨٠، ٢.٢١ مم على التوالى. بينما كان الطول والعرض والسمك لحبوب الشعير هى ٩.٨٥، ٢.٤٩، ٣.٥٢ مم على التوالى. والحجم لحبوب القمح والشعير كان كالتالى ٣٠.٥٢، ٤٥.٢مم^3 على التوالى. ونسبة التكور لحبوب القمح والشعير كانت كالتالى٦٢.٧٥ ، ٤٤.٨٧ % على التوالى. والقطر الهندسى والحسابى لحبوب القمح والشعير كالتالى ٣.٨٨، ٤.١٢- ٤.٤٢، ٥.٢٩ مم على التوالى. ومساحة سطح الحبة، ومساحة السطح المسطح المنقول لحبوب القمح والشعير كانت كالتالى ٨.٤٤، ٠.٨٠، ٤١.٠٧، ٣.٦٠ مم^2 على التوالى ومساحة السطح المسطح لحبوب القمح والشعير كانت كالتالى ٧.٤١، ١٦.٣٦- ٦.٨٨، ١٩.٢٦ كج/م^3 على التوالى.
- وجد انه بزيادة المحتوى الرطوبة في جميع الحبوب زادت السرعة النهائية بشكل عام. وكانت أعلى سرعة تعليق ٨.٨٥ و ٧.٨ م / ث لحبوب القمح و الشعير على التوالي عند محتوى الرطوبة من ١٧ ٪ . في حين كانت أدنى سرعة تعليق ٧.٨ و ٦.٩٨ م / ث لحبوب القمح والشعير على التوالي عند محتوى الرطوبة ٩ ٪ .

(١)، (٢) أستاذ ورئيس بحوث وباحث اول على الترتيب، معهد بحوث الهندسة الزراعية.