Effect of Moisture on Terminal Velocity of Wheat Varieties

ALI RAJABIPOUR[1], AHMAD TABATABAEEFAR AND MEHDI FARAHANI
Agricultural Machinery Engineering Department, University of Tehran
[1]Corresponding author's e-mail: arajabi@ut.ac.ir ; atabfar@ut.ac.ir

ABSTRACT

Aerodynamic properties of wheat are important factors in pneumatic conveying, separating and cleaning machines. Among the properties, terminal velocity is very important. Terminal velocity of wheat measured with a designed vertical wind column. 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%. Wheat samples selected randomly and placed on the column screen. A "hot wire" anemometer at the local point measured the air velocity. 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. Linear regression modeling for different varieties of wheat was determined. There is a high correlation between the moisture content and terminal velocity of three varieties was as follows: For Mahdavi variety: $Vt = 6.65 + 0.03 \, Mc$ with $R^2 = 0.95$; for Marvdashat variety: $Vt = 5.67 + 0.04 \, Mc$ with $R^2 = 0.91$; for Pishtaz variety: $Vt = 5.53 \, Mc^{0.09}$ with $R^2 = 0.92$.

Key Words: Wheat; Terminal velocity; Moisture content

INTRODUCTION

Airflow and water flow are very important properties in material handling and processing of agricultural products. Agricultural engineers have used separation and handling of material by compressed air for many years. Knowledge about aerodynamic properties of agricultural materials is a necessity for hydrodynamic and aerodynamic behavior of material. Drag coefficient and terminal velocities of material are the most important parameters in aerodynamic as well as hydrodynamic behavior, which depends on acceleration of gravity and fluid flow. Terminal velocity is one of the most important parameters for separation of (MOG) chaff and wheat (grain, G) from each other. Terminal velocity for each element of agricultural materials for separation and handling is very important and therefore, is a very effective parameter for agricultural machine and system design (Rabani *et al.*, 2002; Tabatabaeefar, 2003).

Two different methods for determination of terminal velocity and drag coefficient have been studied; free fall method, by dropping a particle from a height and then measuring the time and heights. Then, by graphing, height versus time and differentiating at each time a velocity can be measured. By applying second Newton's law of particle free fall and from numerical methods, drag coefficient can be calculated (Keck & Goss, 1965). In this method, terminal velocity is measured either by digital instrumentation or by a camera and wind column.

In second method, particles positioned on a screen with controlled airflow, by increasing the airflow in gradual steps, the particle will float in a certain height. The measured air velocity at this height is equivalent to terminal velocity. This method is applied in wind column at either vacuum flow or pressured flow. Bilanski and Menzies (1968) have reported terminal velocities of alfalfa seed at different moisture contents. Bilanski and Lal (1965) have reported terminal velocity for wheat and chaff. They have also reported that the rotation of particles will reduce the terminal velocity and increase the drag coefficient. Chancellor (1960) has studied the airflow velocity of particle velocity on silage alfalfa in a wind column. Gilfillan and Growther (1959) have used a vertical column to separate stone from potato in high-speed airflow. Tabatabaeefar and Persson (1995) have reported terminal velocity for chaff and wheat grain. Aydin and Ozcan (2002) have reported the following relationship between moisture content (Mc) and terminal velocity (Vt) as follow:

$$Vt = 5.66 + 0.099 \, Mc$$

The objective of this research was to determine the physical properties of three-wheat variety and the terminal velocities of wheat grain verities at different moisture contents.

MATERIAL AND METHODS

Three different wheat varieties such as Pishtaz, Mahdavi, Marvdashat was collected from ministry of Jihad Agriculture and placed in a plastic container and the initial moisture content was measured.

Moisture content. A sample of 1 kg was randomly chosen from each variety of wheat. The initial moisture content, Mc_i, was determined from ASAE standard (ASAE Std., 1999) by using sampling of 25 g.

Physical Characteristics of Wheat Variety
Dimensions. Three samples of 35 seeds from each variety were randomly selected and then a 35 seed sample was

randomly selected. Three diameters (a, b & c) of each seed were determined by a Venire to an accuracy of 0.02 mm. Geometric mean diameters and sphersity of the seeds were calcuted from following equations as suggested by Stroshine (1998).

$$dg = \sqrt[3]{abc}$$

$$Sp = \frac{dg}{a}$$

Where *dg*: geometric mean diameter, mm; *a*: large diameter, mm; *b*: middle diameter, mm; *c*: small diameter, mm and *Sp*: sphersity.

Thousand-grain weight. Eight samples of 100 seeds was chosen and weighed by a digital scale with 0.001 g accuracy. Then eight sample weights were averaged. Thousand-grain weight was determined by multiplying the sample average weight by 10.

Bulk and particle density, porosity. Bulk density was determined from dropping seeds from a 15 cm height into a known volume of 500 cc and weighting the sample. This procedure was repeated three times for each variety.

Particle density was determined by placing Toluene fluid in a known volume of 100 cc. The particles were weighted and placed into the fluid. The displacement of volume was recorded three times and then averaged. Particle density was determined from the average weight divided by displacement volume. Porosity was determined from equation (5).

$$P = \left(1 - \frac{\rho_b}{\rho_s}\right) \quad (5)$$

Where *P*: porosity; ρ_b: bulk density, kg/ m^3; ρ_s: particle density, kg/ m^3

Vertical wind column. A vertical wind column was designed from others empirical experiences (Mehta, 1982). This wind column had an electrical motor, centrifugal fan (backward flow), diffuser with high angle, honey comb test area, test channel, as shown in Fig. 1. A test channel of a 20 cm square cross sectional area with 80 cm height was designed from previous design. Pressure loss for screen has been determined from equation (1). Void area for each screen was determined from equation (2).

$$\mathbf{k} = \frac{\mathbf{0.9(1-\beta)}}{\beta^2} \quad (1)$$

$$\beta = \left(1 - \frac{\mathbf{d}}{\mathbf{M}}\right)^2 \quad (2)$$

Where d: wire diameter, mm; M: wires space, mm.

Several screens were been used on the airflow with 0.5 mm opening, 0.75 mm opening and two layers of 1.5 mm opening and on the top of all another layer of 0.5 mm opening. The openings were 36%, 45% and 70%, respectively which gave a coefficient of pressure loss (from equation 1) of 12.43. Honeycomb of straw with 6 mm diameters with number of openings of 1415 around 28.27 mm^2. The length of straw was 70 mm with an aspect ratio of length to diameter of 12. For the honeycomb of straw, pressure loss, k_h, was determined from Pope *et al.* (1999) equation (3).

$$k_h = \lambda_h \left(\frac{L_h}{D_h} + 3\right)\left(\frac{1}{\beta_h}\right)^2 + \left(\frac{1}{\beta_h} - 1\right)^2 \quad (3)$$

Where L_h: cell length, mm; D_h: cell hydraulic diameter, mm; β_h: void area of honeycomb, mm^2; $_a$: a coefficient depends on Reynolds number.

The δ, wall thickness of straw was determined from Reynolds number, which is equal to the ratio of fluid flow velocity over viscosity of fluid, multiplied by δ. The Reynolds number was 106.7 and the thickness was 0.1 mm. The honeycomb pressure loss was 9.5 Pa.

The airflow rate was calculated from the velocity of air and the cross sectional area of channel with a pressure loss coefficient of 0.22. Minimum static pressure was 3 kPa and volume of air was 0.7 m^3 s^{-1}. A fan was chosen with the minimum specifications to be centrifugal with a power requirement of 3.5 kW. A vertical wind column was

Fig. 1. Vertical wind column

designed based upon the specifications as shown in Fig. 1.

Terminal velocity. A sample of 20 g was placed on the screen and the fan speed was gradually increased until the particle was floated in a level, at the level the air velocity was measured by a hot wire anemometer. This procedure repeated three times at different moisture content from 8 to 22%.

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, Mc_d. The amount of added water Wa, was determined from equation (4) as undere:

$$Wa = Mc_d - Mc_i * Ws/ 100 - Mc_d \qquad (4)$$

Where Ws = weight of sample and Mc_i initial moisture content. The added water sample was refrigerated for 24 h. It was then, placed in room temperature for about three h before the test.

Linear relationship models and coefficient of determination were determined for each variety by Excel software.

RESULTS AND DISCUSSION

Average initial moisture content, of each wheat variety, is shown in Table I to be around 7 to 8%. Two varieties have almost the same moisture content but Peshtaz variety had lower initial moisture content. Water was added to the samples in order to have the desired moisture content, Mc_d. The added water sample was refrigerated for 24 h to achieve uniform moisture through the sample base on the ASAE standard (ASAE Std., 1999) recommendation.

Physical properties of each variety as dimensions (a, b & c), geometric mean diameters (dg), sphersity (Sp), thousand-grain weight (W-1000), bulk density (Bd), particle density (Pd), and porosity were determined as shown in Table II. Geometric mean diameters (dg), is very close together for the three varieties. Sphersity (Sp) is the same for two varieties but is higher for the Marvdashat Wheat Variety. Higher Diameters, thousand grain weight, bulk density, particle density, and porosity belong to Peshtaz variety.

Maximum and minimum terminal velocity belonged to wheat variety of Mahdavi and Marvdashat, respectively. By increasing the moisture content of all wheat varieties, the terminal velocity increased.

Regression modeling for different varieties of wheat had shown correlation between the terminal velocity and

Table I. Initial moisture content (wb)

Wheat Variety	Moisture content
Peshtaz	7.3
Mahdavi	8.2
Marvdashat	8.1

Fig. 2. Terminal velocity vs moisture content for wheat varieties
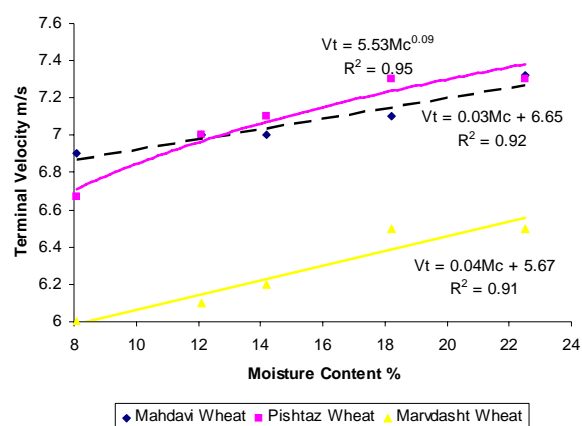
moisture content as follows:

For Mahdavi variety: $Vt = 6.65 + 0.03\ Mc$ with $R^2 = 0.95$

For Marvdashat variety: $Vt = 5.67 + 0.04\ Mc$ with $R^2 = 0.91$

For Pishtaz variety: $Vt = 5.53\ Mc^{0.09}$ with $R^2 = 0.92$

There is highly correlated relationship between the moisture content and terminal velocity of three varieties as shown in Fig. 2. There is a linear relationship between the moisture content and terminal velocity as shown by Aydin and Ozcan (2002) too.

It is shown (from Fig. 2) that with increase of moisture content for each variety of the wheat, the terminal velocity increases. The slopes of changes of terminal velocity for three wheat varieties are nearly the same. Comparing Marvdashat variety with other varieties, for all the range of moisture content, the terminal velocity is lower than the others are. However, the terminal velocity for Iranian cultivar is lower than the one reported by Tabatabaeefar and Persson.

In conclusion Peshtaz wheat variety had higher thousand-grain weight, bulk density, particle density, and porosity than others. Maximum and minimum terminal velocity belonged to wheat variety of Mahdavi and Marvdashat, respectively. By increasing the moisture

Table II. Physical characteristics of wheat varieties

Wheat variety	Dimensions(mm)			dg (mm)	Sp	W1000 (g)	Pd (kg-m^{-3})	Bd (kg-m^{-3})	Porosity
	a	b	c						
Peshtaz	7.27	4.9	2.57	4.02	0.55	45.448	1395.35	827.1	0.41
Mahdavi	7.19	3.0	2.60	3.97	0.55	38.204	1304.35	782.1	0.40
Marvdashat	6.51	3.5	2.62	3.98	0.61	35.833	1333.33	824.3	0.38

content of all wheat varieties, the terminal velocity increased. There is a high correlation between the moisture content and terminal velocity of three varieties.

REFERENCES

ASAE Standards, 1999. *Moisture measurement, un-ground grain and seeds*. Pp. 567–68. ASAE S352.2 Dec. 97

Aydin, C. and M. Ozcan, 2002. Some phsico–mechanical properties of Terebinth fruits. *J. food Eng*., 53: 97–101

Bilanski, W.K. and D. Menzies, 1968. Aerodynamic properties of Alfalfa particles. *Trans. ASAE,* 11: 829–31

Bilanski, W.K. and R. Lal, 1965. Behavior of threshed materials in a vertical wind tunnel. *Trans. ASAE,* 8: 411–6

Chancellor, W.J., 1960. Relation between air and solid particles moving upward in a vertical wind pipe. *Agric. Eng,* 41: 168–76

Gilfillan, G. and A.J. Crowther, 1959. The behavior of potatoes, stones and clodes in a vertical air stream. *J. Agric. Eng. Res.,* 4: 9 (Trans. ASAE; 11: 57–61)

Mehta, R.D., 1982. Design of a low speed wind tunnel, *Ph. D Thesis,* Imperial College of London. U.K

Pope, A., B. Jewel Barlow and H. William Rae, 1999. *Low speed wind tunnel testing*. John Wiley, New York, USA

Keck, H. and J.R. Goss, 1965. Determining aerodynamic drag and terminal velocity of agronomic seeds in free fall. *Trans. ASAE,* 8: 553–4

Rabbani, H., M. Behroozilar, S. Mohtasebi and A. Gerami, 2002. Aerodynamic properties of chick pea. *Ph. D Thesis*, Tehran University, Tehran, Iran

Stroshine, R., 1998. *Physical properties of agricultural materials and food products*, Purdue University Publishers, Indiana, USA

Tabatabaeefar, A., 2003. Moisture-dependent physical properties of wheat. *Int. Agrophysics J.,*17: 207–11

Tabatabaeefar, A. and S. Persson, 1995. Layer breakup and particle movement on a chaffer sieve. *Trans. ASAE,* 37: 1305–13