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# Aerodynamic Properties of Apricot Pits

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**Abstract:** Physical properties of agricultural materials are important for designing and manufacturing their harvest machines on farms and processing equipment in industry. Aerodynamic properties are related to their reaction to moving air as in piles or as a single seed/piece. The pressure drops occurring through apricot pit piles for the superficial air velocities ranging from 0.05 to 2.93 $m^3 \cdot m^{-2} \cdot s^{-1}$ were experimentally determined and mathematically modeled by using Modified Shedd's equation and Hukill-Ives equation. These experiments were replicated three times. The results of curve fitting suggested that both equations could be used adequately to predict the pressure drop of apricot pit piles with a high goodness of fitting ($R^2$>0.92). The terminal velocities of apricot pits, their kernels and hulls were experimentally determined by dropping one sample into upward air flow current inside the transparent cylindrical pipe. These experiments were replicated ten times. The terminal velocity values changed with the weight and projected area of these samples. The average terminal velocities of apricot pits, their kernels, and hulls were 10.99, 10.12, and 7.10 $m \cdot s^{-1}$, respectively. These results suggest that the apricot kernels can be cleaned easily from their hulls by pneumatic separation.

**Key words**: Apricot pit, air resistance, terminal velocity, superficial velocity

## 1. Introduction

Apricot (*Prunusarmeniaca* L.) is classified under the Prunus species of Prunaidea sub-family of the Rosaceae family of the Rosales group. Apricots are a commercially important fruit crop in Turkey which was one of the biggest producers in the world with 811609 tons comprising 19.7% of World total apricot production (FAO, 2013). In fact, 61.79% of dried apricots in the world markets are produced in Turkey (Anoymous, 2012). The most widely produced apricot type is Hacihaliloglu and mostly produced in Malatya region. Apricot pits contain two major parts: hard shell (stone) and kernel. The apricot kernel is encapsulated by its hard shell. Apricot kernels are rich in nutrition because they contain 17.38% protein, 48.70% crude oil, 3.68% Na, 1.06 ppm P, 0.58 ppm K, 0.11 ppm Ca, 0.24 ppm Mg, 42.8 ppm Fe, 42.35 ppm Zn, 1.10 ppm Mn, 2.09 ppm Cu. Apricot kernel is also used in the production of oils, benzaldehyde, cosmetics, active carbon, aroma perfume (Ozcan, 2000).

The airflow resistances of the beds/piles of agricultural materials in containers or silos are defined as the air pressure drop through those beds/piles when air is forced to flow through them. The pressure drop occurring through the beds/piles of agricultural materials depends on the superficial air velocity (flow rate per entrance area), bed depth, density, moisture content, the amount of other mixed material, and characteristics of shape and surface of the grain (Gunasekaran and Jakson, 1988). Modified Shedd's and Hukill and Ives's equations have been used widely to model airflow resistance of agricultural product. Shedd (1953) reported that the relationship between airflow resistance and superficial velocity was nonlinear for agricultural materials. Shedd concluded that pressure drop prediction using the logarithmic plot was sufficient only for a narrow range of air flow rate. Hukill and Ives (1955) reported an equation accounting for nonlinearity of Shedd's data set for entire range of air flow. Modified Shedd' s equation adequately predict airflow resistance of agricultural materials for narrow range of airflow ( 0.005-0.3 $m^3 \cdot m^{-2} \cdot s^{-1}$) while the equation of Hukill and Ives can predict airflow resistances of agricultural materials for wider superficial velocities (0.01-2 $m^3 \cdot m^{-2} \cdot s^{-1}$).

Airflow resistances of various agricultural material piles such as; cereals grain, oilseeds, vegetable seed, fruit seed, grass seed, and nut have been reported by numerous researchers (Nimkar and Chattopadhyay, 2002; Sacilik, 2004; Jayas et al.,1987; Chung et al., 2001; Sokhansanj et al., 1990; Giner and Denisienia, 1996; Nalladurai et al., 2002; Agullo and Marenya, 2005; Rajabipour et al., 2001; Kashaninejad and Tabil, 2009, Patil and Ward, 1988; Sokhansanj et al., 1990; Dairo and Ajibola, 1994; Giner and Denisienia, 1996; Nalladurai et al., 2002; Gunasekaran and Jackson, 1988). The superficial air velocity, moisture content and size of the seed were the effective parameters on air flow resistance (Jayas et al. 1987).

The terminal velocities of ackee apple (*Blighia sapida*) seeds, kernels and hulls were reported to be 9.95, 9.78 and 5.45 $m \cdot s^{-1}$, respectively at the moisture content of 9.88% (w.b.) (Omobuwajo et al., 2000). Terminal velocity values reported for African breadfruit seeds, their kernels, and hulls were 8.02, 7.71 and 2.90 $m \cdot s^{-1}$, respectively (Omobuwajo et al., 1999). The terminal velocity values for pine nuts, their kernels, and hulls were 8.23, 6.98 and 3.76 $m \cdot s^{-1}$, respectively (Ozguven and Vursavas, 2005). The study on the terminal velocities of sunflower was reported by Gupta et al. (2007). They found the terminal velocities of three different cultivars of sunflower as 2.93, 2.54, and 2.98 $m \cdot s^{-1}$ (at 6.2% moisture content d.b.) and the corresponding drag coefficients were 0.18, 0.20, and 0.17, respectively. An increase in moisture content resulted in corresponding increase linearly in terminal velocity and repose angle (Nimkar and Chattopadhyay, 2002).

Determination of physical properties (dimensions, weights, aerodynamic properties) of apricot pits and their kernels are needed for design of various processing equipment such as cleaner, grader, separator, and oil expeller. Similarly, information on aerodynamics properties such as terminal velocity and airflow resistance is needed for designing pneumatic conveying system and separation equipment. These parameters are also needed for designing an efficient drying and aeration system. Apricot pits are normally kept in silos or storage rooms for long time preservations and broken to get their kernels if needed. Therefore, the airflow resistances of apricot pits are needed for real storage applications while the terminal velocities of both apricot pits and kernels and hulls are needed for pneumatic separation and conveying applications. Therefore, the research objectives of this study were two folds. The first objective was to determine experimentally the air flow resistances of apricot pits at varying superficial air velocities (flow rate per entrance area), and to describe these experimental results by the selected mathematical models (Modified Shedd's equation, and Hukill and Ives equation). The second objective was to determine experimentally the terminal velocities of apricots pits and their kernels and hulls.

## 2. Materials and Methods

### *2.1. Experimental Material*

Hacihaliloglu apricot pits used in this study were obtained from a local market in Malatya, Turkey. The samples were manually cleaned from broken pits and foreign materials (dust, dirt, and stones). Apricot kernels were cleaned using an air screen cleaner for foreign matter. The initial moisture content of the apricot pit was determined using standard oven drying method at 103 ± 2 °C until a constant weight was reached (Kashaninejad et al., 2005).

### *2.2. Experimental Set Up*

The experimental unit consists of a centrifugal fan powered by a 4 kW electrical motor, air distribution room and cylindrical container (Figure 1a). A transparent cylindrical pipe of 8.5

cm inner diameter and 115 cm high was used for the terminal velocity tests of apricot kernel and pit (Figure 1b).

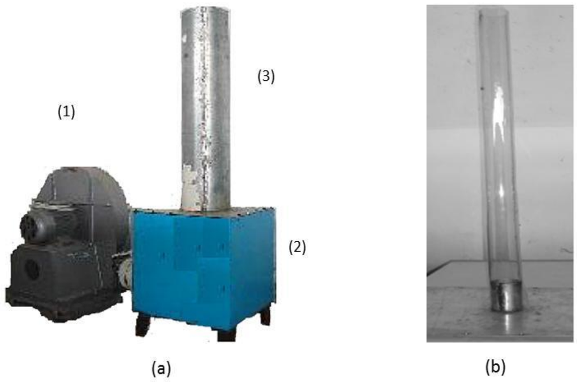


Figure 1.Experimental set up (a): 1, centrifugal fan; 2, air distribution room; 3, cylindrical container, (b): The transparent cylindrical pipe used for the test of terminal velocity.

An electronic variable-frequency drive (ABB Inc., Finland) was used to adjust the airflow rate of centrifugal fan by varying rotational speed (rpm) of the electric motor. The centrifugal ventilator had the capacity of 6 kPa pressure at 1000 $m^3h^{-1}$. The air distribution room was made from galvanized iron sheet with the dimensions of 55×55×55 cm.

Three perforated sheets were placed 5 cm away from each other and the top of distribution room to equalize air pressure and straighten the airflow stream coming from the fan. The perforated sheets had 116 holes of 5 mm diameter per 100 $cm^2$ total area. The cylindrical container of 25 cm outer diameter and 125 cm in height was made from galvanized iron sheet and its bottom was covered by a perforated sheet. A hole was drilled just above its bottom to insert pressure probe through it. A square iron sheet was welded around the bottom of cylindrical container to tighten it on the top of air distribution room. Another hole was drilled on the container at 100 cm high from its bottom to insert anemometer probe through it. The cylindrical container was used for the airflow resistance tests of apricot kernel and pit piles.

The pipe was placed on the top of the air distribution room via a connection part. The connection part consisted of a flange with a metal pipe in 8.5 cm outer diameter and in 10 cm height welded at its center. The bottom of pipe was covered by perforated sheet. Two holes were drilled on the pipe 2.5 cm and 30 cm away from its top. The upper hole was used to insert the anemometer probe while the lower hole was used to drop pits into air stream coming upward from the air distribution room.

### *2.3. Determination of Dimensions of Apricot Pits*

The length, width and thickness of 500 randomly selected pits were measured using a digimatic caliper having 0.01 mm accuracy. The geometric mean diameter ($D_g$), and sphericity ($\Phi$) of pits, were calculated by the following equations;

$$D_g = (L \times W \times T)^{1/3} \qquad (1)$$

$$\Phi = \left[ \frac{(L \times W \times T)^{1/3}}{L} \right] \times 100 \qquad (2)$$

Where:

L is length (mm), W is width (mm) and T is thickness (mm).

The true density of pit was measured by the liquid displacement method. The randomly selected sample whose total weight was measured was poured into a 100 ml glass cylinder filled with ethanol. The sample weight was divided by the displacement volume. Using true density of pit and bulk densities of pit piles, the porosities of these pit piles were calculated by the following equation;

$$P = \left( 1 - \frac{\rho_b}{\rho_t} \right) \times 100 \qquad (3)$$

Where:

$\rho_b$ and $\rho_t$ were the bulk densities of pit piles ($kg \cdot m^{-3}$), and the true density of pit ($kg \cdot m^{-3}$), respectively.

1000-seed weight was determined by weighing 500 randomly selected pits and multiplying it by two. All weight measurements were done by using a digital electronic balance with 0.01 g sensitivity (Sartorious BA3100P, Germany). To determine repose angle, a polyvinyl cylindrical pipe of 30 mm in diameter and 50 mm in height was placed on a clean surface and filled with pit samples. A cone shape of apricot pit samples was obtained by raising slowly and removing the cylinder. The radius and the height of the cone were measured. The repose angle was calculated using the following equation;

$$\alpha = \tan^{-1}\left(\frac{L}{R}\right) \quad (4)$$

Where:
L is the cone height (mm) and R is the cone radius (mm).

### *2.4. Determination of Airflow Resistance of Apricot Pit Piles*

The apricot pits were loosely filled into cylindrical container by free fall from the top of container. The pile was 33.9 cm in depth and had an evenly distributed upper surface. After free filing the container with apricot pit, the centrifugal fan was run at the selected lowest rpm of the electrical motor. Static pressure values at the bottom of piles were measured by using a probe made from the steel tube. One end of the tube was grounded into a taper and welded shut. A series of four holes with diameters of 0.12 cm were drilled into the probe at a 1.27 cm distance from the tapered end. These holes were 90° away from each other, and were used to measure average static pressure at a certain point. The probe was connected by a plastic tubing to a digital manometer whose range and resolution were 0 to 200 mbar and 0.01 to 0.1 mbar (Testo 520, Germany), respectively. The probe was inserted through the hole at the bottom of the container to measure static pressure values at the different points on the bottom of pile. The probe of hot wire anemometer was inserted through the hole that is 100 cm high from the bottom of the container. The probe was kept horizontally parallel to the upper surface of pile and used to measure the speed of airflow coming upward from the pile at different points on the same horizontal cross section of the container. The range and resolution of the hot wire anemometer (Testo 425, Germany) were 0 to 20 $m \cdot s^{-1}$ and 0.01 $m \cdot s^{-1}$, respectively. The static pressure and airflow speed values were read and written down one minute later after the start of the fan. After the static pressure and airflow speed measurements were completed, the rpm of the electric motor was increased to the second level. The measurements were completed for each rpm level of the electric motor. The same measurements were repeated for each rpm level of the electric motor by decreasing the rpm values, gradually. The static pressure and airflow speed values were averaged for each rpm level of the electric motor. Six levels of rpm of the electric motor were used in this experiment. After the completion of the first replication, the pits were emptied from the container and were refilled for the later replication. There were three replications for the airflow resistance tests of pit piles.

### *2.5. Mathematical Modeling of Airflow Resistance of Apricot Pit Piles*

Modified Shedd's equation and Hukill and Ives equation were used to describe mathematically the airflow resistance of the piles of apricot pits, due to their recognitions as a standard method and versatility.
Modified Shedd's equation was formulated as;

$$P = a \times Q^b \quad (5)$$

Where:
P: Pressure loss per unit of depth, $Pa \cdot m^{-1}$
Q: Superficial air velocity, $m^3 \cdot m^{-2} \cdot s^{-1}$
a and b: Model parameters
The Hukill and Ives equation was formulated as;

$$P = \frac{c \times Q^2}{\ln(1 + d \times Q)} \quad (6)$$

Where: c and d: Model parameters

Matlab nonlinear regression program was used to fit the experimental data to these models and determine the models parameters; a, b, c, and d. The coefficient of determination ($R^2$) and Root Mean Square Error (RMSE) of the model predictions were used to evaluate the fitting performance of the models.

### *2.6. Determination of Terminal Velocity of Apricot Pits and Kernels*

Randomly-selected ten apricot pits and their kernels and hulls were used for determination of terminal velocity. The selected apricot pits were cracked by using a hammer without damaging their kernels after measuring their terminal velocities. Their kernels and hulls were separated by hand. The transparent cylindrical pipe was used for the test of terminal velocity (Figure 1b). First, the fan was operated at its maximum speed. An apricot pit or kernel dropped into the pipe from the lower hole on the pipe (30 cm below from the top of pipe). If the sample was carried away from the pipe by the air stream in the pipe, the speed of the fan was gradually reduced. When the sample was moved up and down in the pipe, the speed of airflow was measured by the hot wire anemometer inserted into the pipe at the upper hole where 2.5 cm below from the top of pipe. The relative humidity and dry bulb temperature of ambient air were measured during tests by the digital Thermo Hygrometer (HI 8564, Hanna, Italy). The sensitivity values of temperature and relative humidity were 0.1 °C and 0.1%, respectively.

The drag coefficient ($C_d$) of a apricot pit, kernel or hull sample was calculated using the following equation:

$$C_d = \frac{2 \times M \times g}{\rho_{air} \times V_t^2 \times A_p} \quad (7)$$

Where:
$C_d$: Drag coefficient,
M: Mass of the apricot sample (kg),
g: Gravitational acceleration ($m \cdot s^{-2}$),
$\rho_{air}$: Air density ($kg \cdot m^{-3}$),
$A_p$: Projected area of apricot pit ($m^2$)
$V_t$: Terminal velocity ($m \cdot s^{-1}$).

The projected area of a pit or a kernel normal to the direction of the motion ($A_p$) was calculated by the following equation:

$$A_p = \left(\frac{\Pi}{4}\right) \times L \times W \quad (8)$$

The length and width of these apricot pits and kernels were measured by the digimatic caliper.

## 3. Results and Discussion

### *3.1. Physical Properties of Apricot Pits*

The average moisture content of the apricot pit was found as 8.73% (d.b.). Apricot pits have somewhat oval shape having a round and broad back side and flattened front side. The important dimensional and gravimetric properties of apricot pit were given in Table 1.

***Table 1.*** *Some physical properties of apricot pits*

| | |
|---|---|
| Length (mm) | 22.86 ± 1.8 |
| Width (mm) | 14.23 ± 1.25 |
| Thickness (mm) | 9.6 ± 0.88 |
| Geometric mean diameter (mm) | 14.59 ± 1.11 |
| Sphericity (%) | 63.95 ± 4.07 |
| Projected area ($mm^2$) | 256.42 ± 36.72 |
| 1000 seeds mass(g) | 1199.14 ± 4.47 |
| True density ($kg \cdot m^{-3}$) | 740.46 ± 31.36 |
| Bulk density ($kg \cdot m^{-3}$) | 548.72 ± 4.64 |
| Porosity (%) | 25.49 ± 3.13 |
| Angle of repose (°) | 66.13 |

The average length of apricot pit was 1.8 times bigger than its average width while its average width was 1.48 times bigger than its average thickness. The mean weight was 1.20 g. The average geometric mean diameter value (14.59 mm) and the average sphericity value (63.95%) indicate that an average apricot pit does not represent an exact sphere.

Sphericity is one of the important properties affecting terminal velocity for suspension of agricultural material in air. Sphericity values for different agricultural materials were reported by researchers: 65% for Hacihaliloglu apricot pit and 58.8% for its kernel at 6.79% moisture content d.b. (Gezer et al., 2002); 69.59% for almond nut and 55.17% for almond kernel at 2.77% moisture content d.b. (Aydin, 2003); 57.53% for pine nuts at 5.48% moisture content d.b. (Ozgüven and Vursavas, 2005); 86.34% for walnuts shelled (pit) at11.46% moisture content d.b. and 85.26% its kernel at 4.93% moisture content d.b. (Altuntas and Ekol, 2010). 63.95% sphericity found in this study for Hacihaliloğlu apricot pit was similar with the value of 65% reported by Gezer et al.(2002) for Hacihaliloglu apricot kernel and % 69.59 sphericity for almond nut by Aydin (2003). Sphericity were ranged from 0.916 to 1.064 for four different varieties of hazelnut nuts and ranged from 0.9 to 1.122 for their kernels (Ozdemir and Akinci, 2004).

The projected area of the pit normal to the direction of the motion was found as 2.564 $cm^2$ with the 0.367 $cm^2$ corresponding standard deviation based on the calculation using the length and width of the pit. Projected areas for many different agricultural materials were reported by researchers: 2.985 $cm^2$ for Hacihaliloglu apricot pit and 1.93 $cm^2$ for its kernel at 6.79% moisture content d.b. (Gezer et al., 2002); 3.74 $cm^2$ for almond nut at 2.77% moisture content d.b. by Aydin (2003); 1.512 $cm^2$ for pine nuts at 5.48% moisture content d.b. (Özgüven, 2005); 45.8 $cm^2$ for walnuts shelled (pit) at 11.46% moisture content d.b. (Altuntaş and Ekol, 2010). The projected areas of four hazelnut varieties varied from 2.068 to 2.656 $cm^2$ for nuts and ranged from 1.256 to 1.122 $cm^2$ for kernels (Ozdemir and Akinci, 2004). 2.56 $cm^2$ projected area found in this study for Hacihaliloğlu apricot pit was similar with 2.985 $cm^2$ reported by Gezer et al.(2002) for Hacihaliloglu apricot kernel and 1.68 $cm^2$ for almond nut by Aydin (2003). 1000 seeds mass, true density, bulk density ($kg{\cdot}m^{-3}$), porosity (%), and angle of repose (°) were also calculated using mean dimension values of randomly selected 500 apricot pits. 1000 seeds mass was 1199 g, with a 4.47 g corresponding standard deviation. True density and bulk density were 740.46 and 548.72 $kgm^{-3}$ with 31.36 and 4.64 $kg{\cdot}m^{-3}$ corresponding standard deviations, respectively. True density of Hacihaliloğlu apricot pit (1053 $kg{\cdot}m^{-3}$ at 6.79% moisture content d.b.) reported by Gezer et al. (2002) was higher than the value found in this study.

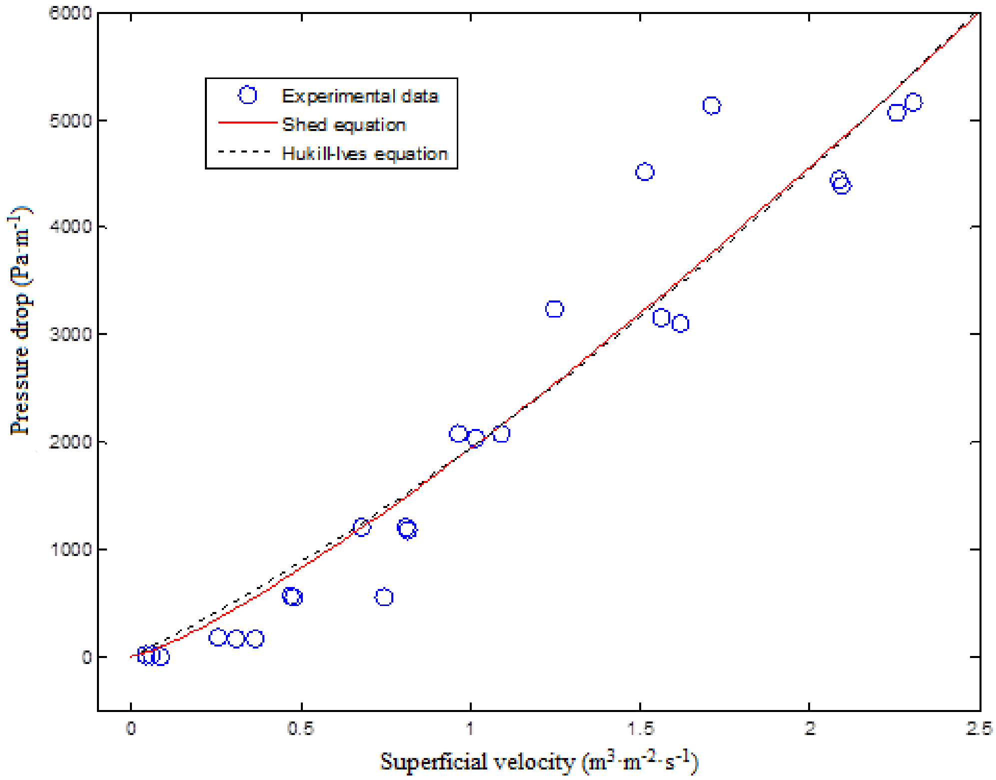


***Figure 2.*** *Experimental and model results of air flow resistance of apricot pit*

However, the bulk density (463 kg·m$^{-3}$) was lower than the value found in this study. Porosity and repose angle were found as 25.49% and 66.13°, respectively. Angle of repose for moth gram reported by Nimkar et al. (2005) ranged from 25.78° to 32.61° in the moisture content varying between 7.33 and 33.57% d.b.

***3.2. Air Resistance Determination of Apricot Kernel***

Increasing the amount of air passed through apricot pit piles per second resulted in nonlinear increase in pressure drop (Figure 2). It means that higher fan power is needed to pass the air through the piles at higher superficial air velocities. It was also observed that data points were dispersed more at higher increasing air flow rates (after the level of 1.5 m$^3$·m$^{-2}$·s$^{-1}$). This dispersion of data points could be caused by the uncontrolled variations occurring during filling process of apricot pits into the tank. The modified Shedd and Hukill and Ives equations were fitted to experimental data to predict the airflow resistance of apricot pit. The goodness-of-fit values for mathematical models were given in Table 2 for both equations.

***Table 2.*** *The goodness-of-fit values for mathematical models*

| | $R^2$ | RMSE | Pvalue |
|---|---|---|---|
| Modified | 0.93 | 517 | <0.0001 |
| Hukill | 0.92 | 537 | <0.0001 |

Their coefficients of determination ($R^2$) were very high and close to each other. Their RMSE values are also very small and close to each other. These results show that both equations can be used to predict adequately the pressure drop for a given superficial air velocity.

***Table 3.*** *The estimated values of model parameters*

| | Coefficients | Estimated | SE | tStat | pValue |
|---|---|---|---|---|---|
| Modified Shedd | A | 1939.6 | 149.490 | 12.97 | 8.75E-12 |
| | B | 1.2325 | 0.117 | 10.521 | 4.75E-10 |
| Hukill and Ives | C | 330.55 | 211.71 | 1.5613 | 0.13272 |
| | D | 0.47881 | 0.411 | 1.1664 | 0.25593 |

The estimated parameter values of modified Shedd's euqation and Hukill and Ives Equation were given along with their statistical parameters (t-stat, SE, pValue) in Table 3.

***3.3. Determination of Terminal Velocity of Apricot Kernel***

Ambient conditions during the experimental determination of terminal velocities were given in Table 4.

These values were used to calculate the drag coefficients of apricot pits, kernels and hulls. These values belong to a non-rainy day in Tokat, Turkey. The average width, length, and thickness values of apricot pits were 14.07, 22.74, and 9.70 mm, respectively. The average width, length, and thickness values of apricot pit kernels were 9.16, 15.16, and 5.55 mm, respectively. The average width, length, and thickness values of apricot pit hulls were 14.26, 21.45, and 1.96 mm, respectively (Figure 3).

***Table 4.*** *Results of terminal velocity experiments*

| | Pit | Kernel | Hull |
|---|---|---|---|
| Relative humidity of ambient air (%) | 60 | 60 | 60 |
| Dry bulb temperature of ambient | 25.3 | 25.3 | 25.3 |
| Elevation of Tokat (m) | 608 | 608 | 608 |
| Atmosphere pressure in Tokat (kPa) | 90.314 | 90.314 | 90.314 |
| Air density (kg·m$^{-3}$) | 1.1 | 1.1 | 1.1 |

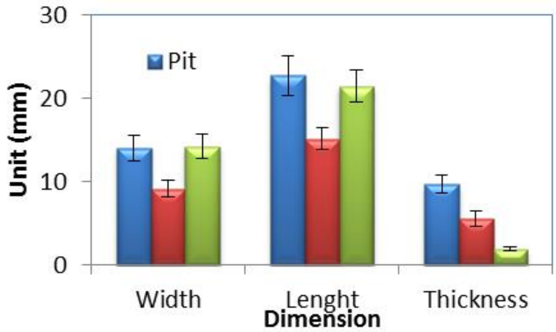


***Figure 3.*** *Mean values of major dimensions of 10 randomly selected apricot pits, their kernels and hulls (error bar represents the standard deviation)*

These results show that apricot pit kernels has a shape similar to its pits but with smaller dimensions. On the other hand, the pit hulls are very much thinner than their pits and kernels. The average weight of pits, kernels and hulls were 1.20, 0.38, and 0.47 g, respectively. These results show that the apricot kernel constitutes 31.7% of the apricot pit on the average. The average weight of pit hulls shows that apricot pits were mainly broken as big parts. If they had been broken into many parts, their average weight should have been smaller.

The terminal velocities required suspending the apricot pit, kernel, and hull in air were 10.99, 10.12, and 7.10 $m \cdot s^{-1}$, respectively. Their standard deviations are 0.64, 0.76 and 0.24, respectively. The terminal velocity values of apricot pits and their kernels are very close to each other but much higher than their hulls. These results show that the apricot kernels can be cleaned easily from their hulls by pneumatics separation. These results also show that the hulls have much lower terminal velocities than their seed and kernels. The average drag coefficient values of apricot pits, kernels and hulls were calculated as 0.69, 0.60 and 0.70, respectively. Their standard deviations were 0.08, 0.06, and 0.14, respectively. Kashaninejad et al. (2006) reported that the terminal velocity values ranged from 7.19 to 7.93 $m \cdot s^{-1}$ and 6.45 to 7.32 $m \cdot s^{-1}$ for the nuts and kernels of pistachio for O'hadi variety, respectively. The terminal velocities of pine nuts, their kernels and hulls were 8.23, 6.98 and 3.76 $m \cdot s^{-1}$, respectively (Ozguven and Vursavas, 2005). Ozdemir and Akıncı (2004) reported that terminal velocities of four hazelnut varieties ranged from 14.13 to 14.92 $m \cdot s^{-1}$ for the nuts and ranged from 14.54 to 15.45 $m \cdot s^{-1}$ for their kernels. The terminal velocity of kernels was found higher than that of their nuts. Terminal velocity values found in another study by Aydin (2003) were ranged 5.62 to 7.98 $m \cdot s^{-1}$ and 5.62 to 7.2 $m \cdot s^{-1}$ for almond nut and kernel, respectively. Altuntaş et al. (2010) reported that the terminal velocity values ranged from 14.17 to 15.50 $m \cdot s^{-1}$ for walnuts pit (shelled) based on the moisture content varying from 11.46% to 23.16% d.b. and ranged from 12.60 to 14.35 $m \cdot s^{-1}$ for walnuts kernel based on the moisture content varying from 4.93% to 32.25% d.b. These values for walnuts were similar but higher than the value found in this study. Gezer et al. (2002) reported that terminal velocities of Hacihaliloglu apricot pits and kernels were varied from 7.11 to 7.76 $m \cdot s^{-1}$ and from 5.37 to 6.68 $m \cdot s^{-1}$, respectively at moisture content varying between 6.95% and 38.76% (d.b.). Terminal velocities of Hacihaliloglu apricot pits and kernels obtained in this current study were higher than the values reported by Gezer et al. (2002).

The terminal velocities of different nuts (walnut, hazelnut, etc.) reported above ranged 5.62 to 15.5 $m \cdot s^{-1}$ for nuts and 5.62 to 15.45 $m \cdot s^{-1}$ for kernels. These variations is due to different physical properties of these nuts; such as, weight, density, sphericity, moisture content and projected area of an individual nuts under examination, as well as the different experimental conditions; such as, atmospheric pressure, temperature, humidity. One of the important results of these studies was that terminal velocities of hulls were lower than those of pit and kernel.

## 4. Conclusion

Modified Shedd's equation and Hukill and Ives's equation were well fitted to the experimental pressure drop data for the superficial air velocities in the range of 0.06 to 2.31, $m^3 \cdot m^{-2} \cdot s^{-1}$. Both equations can be used to design aeration systems for the storage and drying bins of apricot pits. The average terminal velocities (7.10 $m \cdot s^{-1}$) of apricot pit hulls are much lower than the average terminal velocity (10.12 $m \cdot s^{-1}$) of apricot pit kernels. This result shows that the apricot kernels can be cleaned from their hulls by pneumatics separation.

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