

*Full Length Research Paper*

# Terminal velocity of pistachio nut and its kernel as affected by moisture content and variety

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The terminal velocity data are necessary for the design of threshing, pneumatic conveying, fluidized bed dryer and cleaning the product from foreign materials. In this paper, terminal velocity of pistachio nut and its kernel for five major commercial Iranian pistachio varieties namely, Akbari, Badami, Kalle-Ghuchi, Momtaz and O'hadi were evaluated as a function of moisture content at five moisture contents levels in the range from initial moisture content at harvesting to completely industrial dried condition (37.6 - 4.0%w.b.). The results showed that terminal velocity of pistachio nuts varied from 9.8 - 12.44 m/s, whereas terminal velocity of kernels ranged between 8.30 - 11.10 m/s. The highest values of terminal velocity obtained for the nut and kernel of Kalle-Ghuchi variety that is, 12.44 and 11.1 m/s respectively, although the lowest values of terminal velocity were 9.6 and 9.06 which are related to Momtaz nut and Badami kernel. The effect of moisture content on terminal velocity of pistachio nuts and their kernels showed a linear increase with increasing moisture content.

**Key words:** Aerodynamics, terminal velocity, pistachio, moisture content, nut, kernel

## INTRODUCTION

The pistachio nut (*Pistachio vera* L.) is one of the popular tree nuts of the world and there has been a dramatic increase in production of pistachio in different regions of the world during the two last decades (Kashaninejad et al., 2005). Pistachio is mainly cultivated in some parts of the world such as Iran, Turkey, and USA. Based on FAO statistics (Food and Agriculture Organization, 2006), Iran produced about 190,000 Mt of pistachio nut in 2004, which is approximately 63.33% of the world's pistachio production. Iran exported 139,930 Mt of its pistachio nut in this year, and the total export revenue from pistachio nuts was about 556,550,000 US\$. Therefore, pistachio nut has great economic value for Iran. More than sixty pistachio varieties cultivate in different regions of Iran, but the O'hadi (or Fandoghi), Momtaz, Badami (or Sefid), Akbari and Kalle-Ghuchi are the major commercial varieties due to the good quality and adaptation with climate of Iran, which was selected for this research work.

Terminal velocity is very critical in the design of pneumatic conveyor, transporting pistachio nut and kernel us-

ing air to separate Pistachio nut and kernel from extraneous materials such as shells, hulls, leaves, blank pistachios and small branches. 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 and variety. Many valuable research works have been carried out about the aerodynamic properties of agro-food materials by Aydin and Calisir (2004) for cherry laurel; Aydin (2003) for almond nut and kernel; Bart-Plange and Baryeh (2003) for B cocoa beans; Aydin (2002) for hazel nut; Deshpande, et al. (1993) for soybean; Ogut (1998) for white lupin; Sherpherd and Bhardwaj (1986) for pigeon pea; and many others. Hsu et al. (1991) studied the physical and thermal properties of Kerman cultivar of pistachio nut. They determined length, width, height, bulk density and specific gravity of this variety. Kashaninejad et al. (2005) evaluated some moisture-dependent physical properties (including terminal velocity) of dried pistachio nut and its kernel only for O'hadi variety. Razavi et al. (2007a,b,c) also investigated comprehensively geometrical, gravimetric and frictional properties of pistachio nut and its kernel for five pistachio varieties as a function of moisture content. Literature review show that

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**Table 1.** Moisture content levels of pistachio nut and its kernel for five cultivars used in this study

Variety	Product	Moisture content (w.b.%)				
		Level 1	Level 2	Level 3	Level 4	Level 5
Akbari	Nut	31.3	28.5	18.0	8.0	5.0
	Kernel	31.3	26.5	15.0	7.0	4.0
Badami	Nut	33.9	24.5	18.0	8.5	5.5
	Kernel	33.9	20.0	14.0	7.0	4.5
Kalle-Ghuchi	Nut	37.6	34.5	27.5	13.0	5.0
	Kernel	37.6	33.0	24.5	9.5	4.5
Momtaz	Nut	34.0	22.0	16.5	9.5	4.5
	Kernel	34.0	19.0	15.5	8.5	4.0
O'hadi	Nut	36.3	25.0	19.5	8.0	4.0
	Kernel	36.3	20.0	13.0	5.0	3.5

there is no enough published work relating to moisture-dependent aerodynamic properties of pistachio nut and its kernel. Hence, the aims of this research were (i) to investigate the terminal velocity of five major Iranian varieties of raw pistachio nut and its kernel, at five moisture content levels in the range from initial moisture content at harvesting to completely industrial dried condition and (ii) to develop regression equations to predict terminal velocity of pistachio nut and its kernel for each variety as a function of moisture content.

## MATERIALS AND METHODS

### Sample preparation and moisture content determination

The samples were manually peeled and cleaned to remove all foreign matters as well as immature and broken nuts. The nuts were cracked and the kernels separated from the shells by hand (Razavi et al., 2007a). The initial moisture content of each pistachio variety was determined using oven method at  $103 \pm 2^\circ\text{C}$  until a constant weight was reached (Kashaninejad et al., 2005). To vary the moisture content of pistachio nut or kernel, the predetermined quantity of samples were dried down to the desired moisture content by a digital oven at temperature of  $70^\circ\text{C}$ . The average moisture content of five pistachio varieties (nuts and their kernels) at different moisture levels are given in Table 1.

### Terminal velocity measurement

The terminal velocities ( $V_t$ ) of pistachio nut and its kernel at different moisture content were measured using an air column. For each test, a sample (nut or kernel) was dropped into the air stream from the top of the air column with a 75 mm diameter tube; air was blown to suspend the material in the air stream. This apparatus was made in our department and by conductor of experiments. The air velocity near the location of the nut/kernel suspension was measured by an electronic anemometer (AM4205, Lutron company, Taiwan) having an accuracy of 0.1 m/s (Joshi et al., 1993; Singh and Goswami, 1996; Suthar and Das, 1996; Gezer et al., 2002; Mohsenin, 1978).

### Statistical analysis

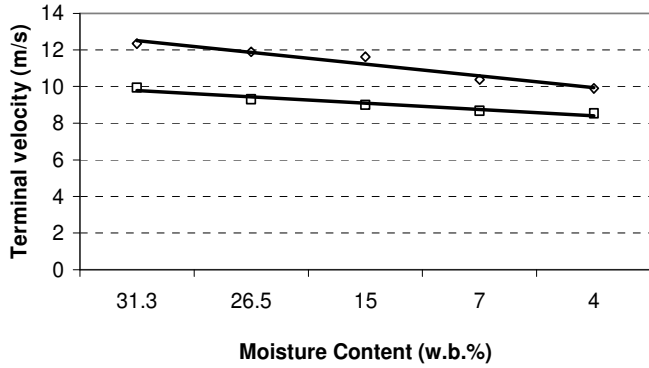
Determined at five moisture levels with at least five replications at

each level of moisture content. All the charts, regression equations and coefficient of determination ( $R^2$ ) were obtained using Microsoft Excel software (2003).

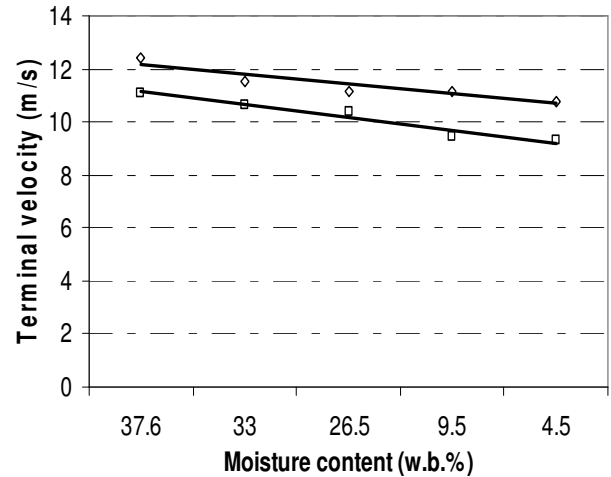
## RESULTS AND DISCUSSION

The variation of terminal velocity ( $V_t$ ) of pistachio nut and its kernel with moisture content are shown in Figures 1 - 5 for pistachio variety of Akbari, Badami, Kalle-Ghuchi, Momtaz and O'hadi, respectively. It can be seen, the terminal velocity of pistachio nut and its kernel for each variety increased as the moisture content increased. The terminal velocity of nuts was also higher than that of kernels in all varieties. These differences in results can be attributed to the increase in mass of the individual nut or the kernel per unit, when their frontal areas were presented to the air stream to suspend the material. The other reason is probably that the drag force is affected by the moisture content of particle. Kashaninejad et al. (2005) showed that as the moisture content increased from 4.10 to 38.10% (w.b.), the terminal velocity of pistachio nut and its kernel was found to increase. Joshi et al. (1993) for pumpkin seeds, Carman (1996) for lentil seeds, Singh and Goswami (1996) for cumin seeds, Suthar and Das (1996) for karingda seeds, Gupta and Das (2000) for sunflower seed, Gezer et al. (2002) for apricot pit and kernel, and Akar and Aydin (2005) for gumbo fruit also reported similar results.

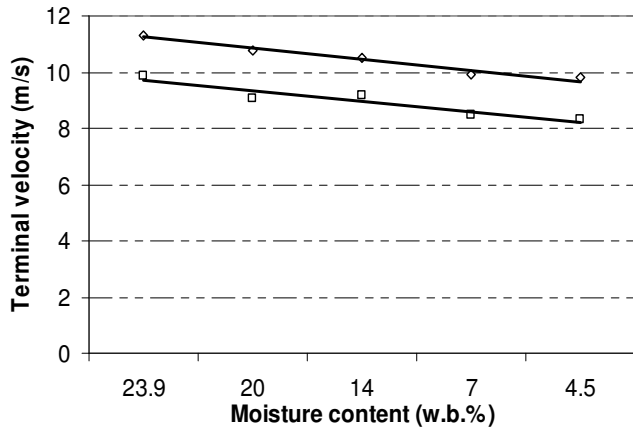
The values of terminal velocity of Akbari, Badami, Kalle-Ghuchi, Momtaz and O'hadi nuts at different moisture contents varied between 9.9-12.34, 9.8-11.3, 10.8-12.44, 9.45-10.36 and 9.8-12 m/s, respectively. However, the terminal velocity of pistachio kernels ranged from 8.54 - 9.94, 8.30 - 9.88, 9.30 - 11.10, 8.70 - 9.34 and 9 - 10 m/s, respectively. The results show that the nut and kernel of Kalle-Ghuchi had highest terminal velocity, whereas the lowest terminal velocity of pistachio nut and its kernel was found for Momtaz and Badami, respect-



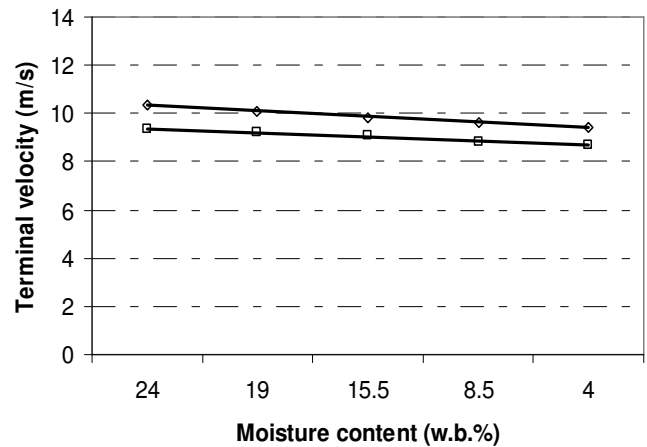
**Figure 1.** Effect of moisture content variation on the terminal velocity of pistachio nuts and kernel of Akbari variety (◇, nut; □, kernel).



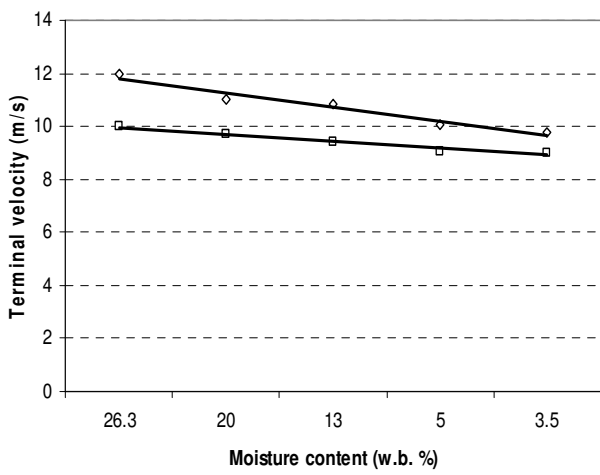
**Figure 3.** Effect of moisture content variation on the terminal velocity of pistachio nuts and kernel of Kaleh-Ghochi variety (◇, nut; □, kernel)



**Figure 2.** Effect of moisture content variation on the terminal velocity of pistachio nuts and kernel of Badami variety (◇, nut; □, kernel)



**Figure 4.** Effect of moisture content variation on the terminal velocity of pistachio nuts and kernel of Momtaz variety (◇, nut; □, kernel)

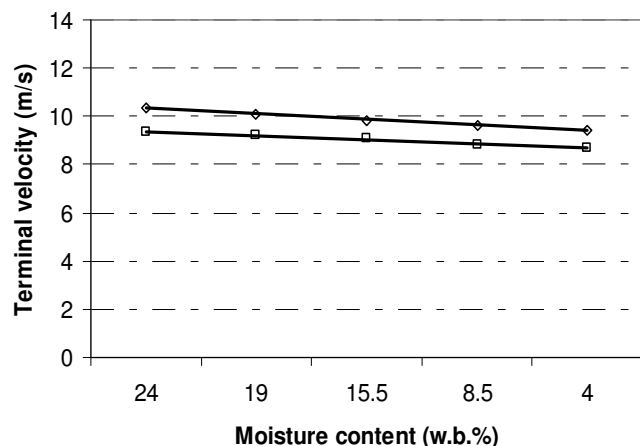


**Figure 5.** Effect of moisture content variation on the terminal velocity of pistachio nuts and kernel of Ohadi variety (◇, nut; □, kernel)

pectively.

Kashaninejad et al. (2005) observed the terminal velocity of pistachio nut and its kernel for O'hadi variety ranged from 7.19 - 7.93 and 6.45 - 7.32 m/s, respectively. Nimkar and Chattopadyay (2001) found that the terminal velocity of green gram increased from 10.1 to 12 m/s, when the moisture content was increased from 8.39 to 33.4% db. The terminal velocities of lentil seeds and apricot pits reported 11.0 – 12.1 m/s and 7.1 – 7.8 m/s, respectively (Carman, 1996; Gezer et al., 2002).

The mathematical equations and their  $R^2$  values obtained by fitting the experimental data of terminal velocity of pistachio nut and its kernel as a function of moisture content are listed in Tables 2 – 3 respectively. It can be found that there were positive relationships with very high correlation between terminal velocity and very high correlation between terminal velocity and moisture content in all cases studied. It can be also seen



**Figure 4.** Effect of moisture content variation on the terminal velocity of pistachio nuts and kernel of Momtaz variety ( $\diamond$ , nut;  $\square$ , kernel)

**Table 2.** Regression equations of terminal velocity of pistachio nut as a function of moisture content and variety

Variety	Nuts		
	$M_c$ (%w.b.)	Equation	$R^2$
Akbari	5.0-31.3	$V_t = 0.64M_c + 13.15$	0.94
Badami	5.5-33.9	$V_t = 0.39M_c + 11.63$	0.96
Kalle-ghuchi	5.0-37.6	$V_t = 0.37M_c + 12.53$	0.86
Momtaz	4.5-34.0	$V_t = 0.54M_c + 12.34$	0.94
O'hadi	4.0-36.3	$V_t = 0.23M_c + 10.56$	0.98
O'hadi*	4.1-38.1	$V_t = 0.019M_c + 7.29$	0.791

\* Ref.: Kashaninejad et al., 2005

**Table 3.** Regression equations of terminal velocity of pistachio kernel as a function of moisture content and variety.

Variety	Kernels		
	$M_c$ (%w.b.)	Equation	$R^2$
Akbari	4.0-31.3	$V_t = 0.64M_c + 13.15$	0.93
Badami	4.5-33.9	$V_t = 0.37M_c + 10.11$	0.88
Kalle-ghuchi	4.5-37.6	$V_t = 0.48M_c + 11.63$	0.94
Momtaz	4.0-34.0	$V_t = 0.26M_c + 10.23$	0.97
O'hadi	3.5-36.3	$V_t = 0.17M_c + 9.53$	0.96
O'hadi*	4.1-38.1	$V_t = 0.021M_c + 6.31$	0.692

\* Ref.: Kashaninejad et al., 2005

that similar results obtained by Kashaninejad et al. (2005) for pistachio variety of O'hadi (Tables 2 and 3).

These linear behaviors were in accordance with similar results reported for cumin seed (Singh and Goswami, 1996), Hacıhaliloglu apricot pit and its kernel (Gezer et al., 2002), hazelnut (Ozdemir and Akinci, 2004), gumbo

fruit (Aydin and Akar, 2005) and caper seed (Dursun and Dursan, 2005).

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