Modeling of terminal velocity of orange to characterize suitable sorting process

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***Abstract*-In this study, the possibility of using terminal velocity of orange through water as a means of hydro-sorting was studied. Terminal velocity of orange was experimentally determined by using of water column method. The best model for terminal velocity of Valencia variety as a function of water and fruit densities, shape factor and fruit volume were modeled as $V_t = 9.34(\rho_w - \rho_f)^{0.33} V^{0.45} S_h^{0.35} - 4.79$ with determination coefficients of 0.87. It was found that the differences between water and fruit density gave a major effect and their volume and shape factor had small effect on terminal velocity. It can be resulted that in an online sorting system; orange fruits with approximately similar volume can be sorted based on their densities. It can be concluded that in the sorting systems, difference in terminal velocities of oranges can be used as a suitable factor for designing the sorting system devices.**

KEYWORDS: hydro-sorting, orange, terminal velocity, physical properties

I. INTRODUCTION

Citrus is an important source of income for the producing countries. Among the citrus fruits, orange is the most important one economically and industrially. It is consumed in different forms such as fresh fruit, thin dried slices or concentrated juice [1].

Iran is ranked as the 7th orange producer in the world [2]. Iran's orange export amounted to be 31710 tons, in 2004 year Even though Iran has been among the oldest citrus producing countries of the world, unfortunately, there has not been considerable progress achieved either in its industrial processing or in its export qualities, causing it not to be of a good standing in the international markets. Fruit packaging installations have been founded in five northern regions in Iran include of Ramsar, Shahsavar, Noshahr, Chaloos and Amol to process and pack citrus in advanced modern ways, but unfortunately grading and packaging is not yet done in the most suitable and proper way.

As world markets for fruit and produce become more sophisticated and technology continues to provide means to evaluate product quality, there is a corresponding market pull for produce with higher, or at least specified, quality levels. Electrical sizing mechanisms are overly expensive and mechanical sizing mechanisms are slow to react [3]. In recent years, the search to find rapid and non-destructive techniques for usage of physical attributes for size sorting, quality grading etc have attracted many researches [4]. As well Fruit graders that employ near-infrared technologies are costly and more importantly, the calibrations and maintenance they need tend to remain outside the skills of packing house staff [5]. Density, a fine indicator of fruit dry matter [6, 7] therefore becomes an interesting tool for fruit quality sorting and grading because of its naturally lower cost and simpler operation.

Hydrodynamic properties are very important characters in hydraulic transport and handling as well as hydraulic sorting of agricultural products [8]. Terminal velocity of fruits is a maximum velocity that each fruit can reach in particular medium [9]. According to Jordan and Clerk an approach to fruit sorting is to utilize the terminal velocity of fruit moving in a fluid that has a density above or below the target density [5]. Mirzaee et al. Reported that apricot fruits with approximately constant volume can be sorted based on their densities[10]. This is due to the fact that fruits with approximately constant volume and different densities have different terminal velocities and can be separated accordingly [11].

The main object of this study was modeling of terminal velocity of Valencia variety of orange in water column to determine if there was potential for terminal velocity methods as a viable sorting unit operation.

II. Material and methods

Valencia orange variety was obtained from orchard located in Gorgan, north of Iran. The 25 fruits of this variety were tested in the Biophysical laboratory and Biological laboratory in Gorgan University of Agriculture Science & Natural Resources, Iran. The samples were transferred to the laboratory in polyethylene bags to reduce water loss during transport. All of the experiments were carried out at a room temperature. Fruit mass was determined with an electronic balance with 0.01 gram sensitivity. Fruit volume and density were determined by the water displacement method [12]. Oranges' picture was taken by Area Measurement System Delta T-England apparatus. Then, projected areas (AP) were calculated by applying the software written in Visual Basic. A glued Plexiglas column was used with a height of 100 centimeter and a cross-section of 40 × 40 centimeter. The column was constructed with a diameter five times more than that of the fruit [13]. The column was filled with tap water to a height of about 90 centimeter.

In order to conclude the terminal velocity of the fruit, a digital camera, JVC with 30 frames per second, recorded the moving of fruits from releasing point (in bottom) to the top of water column, at the same time. Each fruit was tested three times. Then, video to frame software was used to change video film to images with the aim of calculate terminal velocity of fruits by knowing the fact that each picture takes 0.033 second. Subsequently, information on the trajectory of fruit moving through the water was plotted in a Microsoft Excel Worksheet. Terminal velocity of orange was modeled using SPSS20 software and according to KHAT 2 theory [9]:

$$V_t = BX\left[S_h^{\left(\frac{1}{2-n}\right)}\left(\rho_w - \rho_f\right)^{\left(\frac{-1}{2-n}\right)}\left(V^{\left(\frac{-n-1}{3(2-n)}\right)}\right)\right] \quad (1)$$

The (1) can be generalized as [9]:

$$V_t = A\left(\rho_w - \rho_f\right)^{-b} V^{-c} S_h^{d} + E \quad (2)$$

Where parameters A, b, c, d and E are constant factors and take appropriate values. Parameter E is added to reducing errors, Vt is terminal velocity (cm.s^{-1}), ρw is water density (g.cm^{-3}), ρf is fruit density (g.cm^{-3}), V is fruit volume (cm^3) and S_h is shape factor that is defined as [5]:

$$S_h = A_p / V^{2/3} \quad (3)$$

Where Ap is Projected area (cm^2).

III. Results and Discussion

The model was optimized by adjusting various combinations of the five parameters, to maximize the determination coefficient. In order to assess the impact of volume, shape factor and density of samples on the terminal velocity models 1 to 5 were tested. Based on the results shown in Table 1, with removal parameters volume and shape factor in model 2 and 3 compared with model 1 with all parameters, the coefficient of determination slightly reduced rate. Also this result can be showable in model 4 by eliminating both volume and shape factor parameter, slightly reduction in R^2 But by eliminating the density parameter model 5, R^2 greatly reduced. For Valencia orange variety the effectiveness of all parameters including shape factor, volume, and water and fruit densities for determining the terminal velocity is shown in model 1 with R^2 of 0.87:

$$V_t = 9.34\left(\rho_w - \rho_f\right)^{0.33} V^{0.45} S_h^{-0.35} - 3.91$$

Table1. Different models developed with different parameters and corresponding determination coefficients for Valencia orange variety.

MODELR	*A*	*b*	*c*	*d*	*E*	R^2
1	9.34	-0.33	-0.45	-0.35	-4.79	0.87
2	11.25	-0.25	-0.38	0	-13.89	0.86
3	104.44	-0.21	0	-0.29	-25.3	0.85
4	79.64	-0.29	0	0	-11.9	0.84
5	1.29	0	-0.71	0.06	-20.9	0.25

In order to quantify effectiveness of characters among differences between fruit and water densities, volume and shape factor of samples, they were individually plotted versus terminal velocity showed in Figs. 2 and 3, for Valencia varieties. For Valencia variety, Fig. 1 with more regular plots than those of Figs.2 and 3 shows the higher effectiveness of differences between water and Valencia variety densities on terminal velocity than those of volume and irregular shape factor.

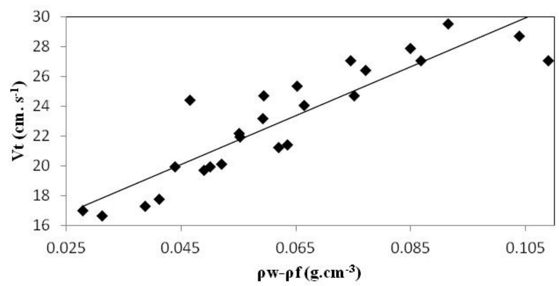

Figure 1. Terminal velocity versus differences between water and orange density for all experiments (R^2=0.81).

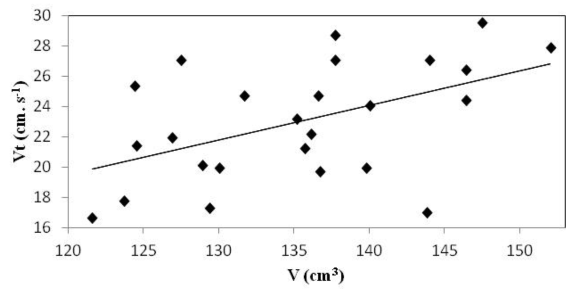

Figure 2. Terminal velocity versus orange volume for all experiments (R^2=0.24).

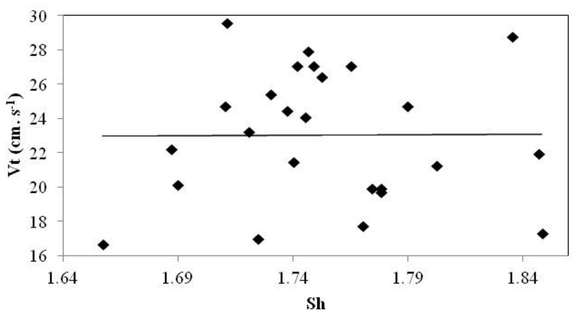

Figure 3. Terminal velocity versus orange shape factor for all experiments (R^2=0.00).

IV. Conclusions

1. The best model for terminal velocity of Valencia orange variety found to be in the form of Eq. (2) as a function of water and fruit densities, shape factor and fruit's volume.
2. It was found that the differences between water and fruit densities of Valencia variety were found the most effective on their terminal velocity. Orange fruits with approximately constant volume can be sorted on their densities. This is due to the fact that fruits with almost constant volume and different densities have different terminal velocities and can be separated.

It can be concluded that in the sorting systems, difference in terminal velocities of oranges can be used as a suitable factor for design the sorting system devices.

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