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Physical Properties of Tangerine

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Abstract: Iran produces 3.5 million tones of citrus and is ranked 22nd in the world. Iranian tangerines are not exported because of variability in size and shape and lack of proper packaging. In this study, physical properties of three common cultivars of Iranian grown tangerines (Clementine (n=55), Onsho (n=55) and Page (n=55)) were determined. These physical properties included physical dimensions, mass, volume, geometric mean diameter, sphericity and projected areas. The aforementioned parameters were obtained from individual cultivars of tangerines as well as a mixture of cultivars. Relationships among these physical attributes were determined with a high correlation coefficient between them. For the mixed cultivars of tangerine the following results were determined for the volume, mass and projected areas. A logarithmic relationship between volume and the diameters of mixed cultivars of tangerines with a high coefficient of determination, $R^2 = 0.97$ was determined as shown in following equation: $\ln V = 0.97 \ln a + 1.32 \ln b + 0.7 \ln c - 7.75$. Mass and volume of the mixed tangerines had a very high coefficient of determination, $R^2 = 0.96$, as shown in equation: $M = 0.99V - 5.52$. Projected areas had a nonlinear relation with volume for the mixed cultivars of tangerines as: $Ac = 1.48V^{0.65}$ with $R^2 = 0.994$. A coefficient of determination, R^2, between average projected areas (criterion area, Ac) and the measured volume of tangerines was very high, close to one. The shape of the tangerine was spheroid.

Key words: Physical properties · tangerine · dimension · projected area · sorting

INTRODUCTION

Physical characteristics of agricultural products are the most important parameter in the design of grading, handling, processing and packaging systems. Among these physical characteristics, mass, volume, projected area, and centre of gravity are the most important ones in the handling systmes [1]. Other important parameters are width, length, and thickness [1, 2]. Knowledge of length, width, volume, surface area and centre location of mass may be applied in the designing of sorting machinery, in predicting surface needed when applying chemicals, shape factor (sphericity), and yield in the peeling operation (surface area) [3].

Researchers tried various, digital and mechanical methods to measure physical properties of agricultural products for example: sweet Potatoes [3], Neem nut [4], video analyzer of Potato [5-7] and Orange, Apple [8, 9], Physical properties of Bambara groundnuts [10], Hackberry [11], Apricot [12], Grains [13], Cocoa [14, 15], Breadfruit [16], Pistachio [17, 18], Soybean [19], Mucuna bean [20], Lentil [21], wild Plum [22], Pomegranate [23], Taro [24], Orange [25], Pear [26], Plum[27], Wtarmelon [28], Maize [29], Date Palm [30-33] and Tomato [34, 35].

The objective of this research was to determine physical properties of tangerine such as size and shape, and determining the relationship between them for the purposes of quality sorting, grading and packaging for export.

MATERIALS AND METHODS

Three different common commercial cultivars of Iranian tangerines were considered for this study. About 165 samples of tangerines were obtained from Agricultural Research, Education, and Extension Organization, from Citrus Research Institute placed in Northern Iran. The tangerines were picked up at random from their storage piles. Three different popular cultivars sampled were Clementine (n=55), Onsho (n=55) and page (n=55). The mass of each tangerine was measured to 0.01 g accuracy on a digital balance. Its volume was measured by the

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volume of the water displaced. A tangerine was submerged into the known water and the volume of water displaced was measured. Water temperature was kept at 25°C. Specific gravity of each tangerine was calculated by the mass of tangerines in air divided by the mass of displaced water.

Three mutually perpendicular axes; *a* major, (longest intercept), *b* intermediate, (longest intercept normal to *a*), and *c* minor, (longest intercept normal to *a, b*), of tangerine were measured by a computer vision area-meter (Dimmeter) with high accuracy [36].

Geometric mean diameter, GM, was determined from the cubic roots of three diameters, $(abc)^{1/3}$ and percentage sphericity was equal to the geometric mean diameter divided by the longest diameter? multiply by 100 as Mohsenin [2] suggested. The volume of tangerines was calculated assuming the shape of a prolate spheroid and an oblate spheroid and an ellipsoid applying the following equations, respectively, $V=0.52ab^2$, $V=0.52a^2b$, and $V=4.19$ (Geometric mean diameter/2)^3. An average projected area as a criterion for the sizing machine was proposed [2]. Three mutually perpendicular areas, *Pa, Pb, and Pc* were measured by a computer vision (Dimmeter) Area-meter with high accuracy.

An average area projected (known as the criterion area, *Ac*, cm^2) was determined from Eq. (1):

$$Ac = (Pa + Pb + Pc)/3 \quad (1)$$

Spreadsheet software, Microsoft EXCEL 2003, was used to analyze data and determine regression models between the parameters. A typical linear multiple regression model is shown in Eq. (2):

$$Y = a + b_1 X_1 + b_2 X_2 + ,..., + b_n X_n \quad (2)$$

where: Y - a dependent variable, for example mass, *M*, or a criterion area, *Ac*, or volume, *V*; X_1, X_2, X_3,..., X_n-independent variables, for example physical dimensions, *a, b, c*-major, intermediate and minor diameters, (mm), or volume, *V*, (cm^3); $b_1, b_2, ..., b_n$-regression coefficients, a-constant of regression.

For example, mass is related to volume and can be estimated as a function of the volume measured as shown in Eq. (3):

$$M = a + b_1 V \quad (3)$$

where: *V*-the volume measured of mixed cultivars (cm^3).

RESULTS AND DISCUSSION

The physical properties such as major, minor, intermediate diameter, mass, volume measured and shape resembled to geometric ones, specific gravity, geometric mean and percent sphericity, of three different cultivars, Clementine, Onsho, page and mixed cultivars are shown in Table 1.

Page variety had longer diameters and larger masses than the other two cultivars of tangerines. An average specific gravity of the Page variety was 0.97 higher than of other cultivars. The shape of the Iranian tangerines measured in this study is spheroid with a minimum probable error from the volume measured. Clementine variety had highest percent sphericity value (97%) and Onsho variety had the minimum value (93%).

Page variety is the biggest tangerine with a specific gravity of 0.97. Therefore, it may be used for export.

The mixed variety showed 95% shpericity, an average diameter of two diameters *a, c* was 1% less than the geometric mean diameter and with a similar coefficient of variation (8%). The volume measured was 1% higher than the calculated assumed shape of the spheroid ($V=4.19a^2b$).

Relationships among physical attributes were determined between the volume and mass of each variety and also for the mixed variety with the three diameters as shown in Table 2.

There was a strong relation between volume and diameter with a high coefficient of determination, R^2, as shown in Eq. (4):

$$\ln V = 0.97 \ln a + 1.32 \ln b + 0.7 \ln c - 7.75, \; R^2 = 0.97 \quad (4)$$

Natural logarithm of volume with three diameters of all cultivars and mixed variety was high. The relation between mass and the diameters was linear and the correlation was high for all cultivars and mixed variety.

Mass versus volume was plotted and there was a linear relation between mass and volume of the mixed variety of tangerine with a high coefficient of determination, $R^2 = 0.96$ as shown in Eq. (5):

$$M = 0.99V - 5.52. \quad (5)$$

Relation between the mean projected area and the volume of tangerines was determined from the plot and the coefficient of determination, between the two was very high and close to unity. A nonlinear regression

Table 1: Physical properties of tangerine cultivars

Variety	Physical attribute	Mean	Maximum	Minimum	Standard deviation	Coefficient of variation
Clementine	Major(mm)	61.45	73.70	54.20	4.07	6.62
Sample size: 55	Intermediate(mm)	60.32	72.60	52.70	4.03	6.68
	Minor diameter(mm)	57.50	67.30	79.90	4.37	7.54
	Mass(g)	82.13	124.70	60.60	13.22	16.09
	volume(cc)	89.74	138.20	63.90	16.42	18.29
	Specific gravity(g/cm^3)	0.92	0.96	0.86	0.03	3.06
	Geometric mean(mm)	59.72	70.07	52.48	3.92	6.57
	Percent sphericity	97.00	98.00	94.00	0.02	1.74
Onsho	Major(mm)	60.90	72.60	53.40	4.03	6.62
Sample size: 55	Intermediate(mm)	59.83	72.10	51.60	3.93	6.56
	Minor diameter(mm)	49.11	58.30	43.90	3.32	6.76
	Mass(g)	68.52	97.40	48.80	11.81	17.23
	volume(cc)	77.98	115.50	53.30	14.35	18.41
	Specific gravity(g/cm^3)	0.88	0.95	0.82	0.03	3.36
	Geometric mean(mm)	56.33	64.91	49.57	3.42	6.07
	Percent sphericity	93.00	96.00	88.00	0.02	1.95
Page	Major(mm)	65.33	74.30	53.90	4.31	6.59
Sample size: 55	Intermediate(mm)	64.15	73.20	53.00	4.21	6.57
	Minor diameter(mm)	56.33	64.20	47.10	4.25	7.54
	Mass(g)	103.82	147.30	61.70	18.37	17.70
	volume(cc)	107.04	152.30	63.10	19.26	18.00
	Specific gravity(g/cm^3)	0.97	1.01	0.93	0.01	1.36
	Geometric mean(mm)	61.80	69.62	51.88	4.11	6.65
	Percent sphericity	95.00	99.00	89.00	0.02	1.68
Mixed cultivars	Major(mm)	62.56	74.30	53.40	4.56	7.30
Sample size: 55	Intermediate(mm)	61.44	73.20	51.60	4.48	7.29
	Minor diameter(mm)	54.31	67.30	43.90	5.44	10.02
	Mass(g)	84.82	147.30	48.80	20.67	24.37
	volume(cc)	91.59	152.30	53.30	20.54	22.43
	Specific gravity(g/cm^3)	0.92	1.01	0.82	0.04	4.80
	Geometric mean(mm)	59.28	70.07	49.57	4.43	7.47
	Percent sphericity	95.00	99.00	88.00	0.03	2.69
	Ave. Diameter (a+c)/2	58.44	69.00	48.80	4.55	7.78

Table 2: Relationship between volume and mass with the three diameters of tangerine

	Volume $\ln V = k_1 \ln a + k_2 \ln b + k_3 \ln c + k_4$					Mass $M = K_1 a + k_2 b + k_3 c + k_4$				
Coefficient variety	k_1	k_2	k_3	k_4	R^2	k_1	k_2	k_3	k_4	R^2
Clementine	0.93	1.20	0.60	-6.70	0.99	0.65	2.07	0.58	-115.84	0.97
onsho	0.27	1.98	0.60	-7.21	0.97	0.53	1.98	0.68	-115.66	0.95
page	1.32	0.86	0.59	-6.80	0.99	1.74	1.55	1.12	-172.72	0.98
Mixed cultivars	0.97	1.32	0.70	-7.75	0.97	1.34	1.89	1.21	-180.44	0.89

equation for the mixed variety of tangerines was determined as shown in Eq. (6):

$$Ac = 1.48V^{0.65};\ R^2 = 0.994 \quad (6)$$

CONCLUSIONS

- Physical properties of three Iranian grown tangerine cultivars were examined. Page variety had the highest specific gravity. Onsho variety had the smallest sphericity.
- Page variety may be used for export.
- The tangerine shape resembled a spheroid.
- Volume and the diameters had a natural logarithmic relationship with the three diameters as shown in: $\ln V = 0.97 \ln a + 1.32 \ln b + 0.7 \ln c - 7.75$ with $R^2 = 0.97$.
- Mass and volume of the mixed variety of tangerine had a high correlation and a linear relationship $M = 0.99V - 5.52$.
- There was a power relationship between the criterion area and volume: $Ac = Ac = 1.48V^{0.65}$

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