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Size and shape of potato tubers

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A b s t r a c t. Potatoes are little known products of Iran; yet they are comparaible in size, shape, and substance to any other potato in the world. They are, moreover, considerably cheaper than those grown in the Western Europe, North America, and Australasia. In this study, physical properties of four common varieties of Iranian grown potatoes were determined. These physical properties included physical dimensions, mass, volume, geometric mean diameter, sphericity, aspect ratio, $a/b+c$, and projected areas. The aforementioned parameters were obtained from individual varieties of potatoes as well as a mixture of varieties. In this study, relationships among these physical attributes were determined and a high correlation was found between volume and the diameters of mixed potatoes with a coefficient of determination, $R^2 = 0.98$, as shown in the equation $\ln V = 1.2 \ln a + 0.94 \ln b + 0.86 \ln c - 7.28$. Mass and volume of the mixed potatoes had a very high coefficient of determination, $R^2 = 0.994$, as shown in the equation: $M = 0.93V - 0.6$. A coefficient of determination, R^2, between an average projected areas (criterion area, A_c) and the measured volume of potatoes was very high, close to one and a nonlinear regression equation for the mixed varieties of potatoes was determined as: $A_c = 1.1V^{0.71}$ with $R^2 = 0.993$. This trend follows the same trend as shown in Mohsenin. However, a linear regression had a very high correlation, too. The shape of an Iranian potato is ellipsoidal.

K e y w o r d s: physical properties, potato, variety, projected area

INTRODUCTION

Physical characteristics of agricultural products is the most important parameter in the design of grading, handling, processing and packaging systems. Among these physical characteristics, mass, volume, projected area, and center of gravity are the most important ones in the handling systems (Peleg, 1985). Other important parameters are width, length, and thickness (Mohsenin, 1986; Peleg, 1985). Knowledge of length, width, volume, surface area and center 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) (Wright, 1986).

Stroshine *et al.* (1994) presented measurements of agricultural products and reported bulk density of 1.12 g cm^{-3} for potato the graded potato between 57 and 69 mm.

Researchers tried various, digital and mechanical methods to measure physical properties of agricultural products for example: faba beans (Freaser *et al.*, 1978), sweet potatoes (Wright, 1986), neem nut (Visvanathan *et al.*, 1996), image analysis of sweet potatoes (Tappan, 1984), video analyzer of potato (Sistler *et al.,* 1983), wheat and corn (Nelson, 1980), pigeon pea (Shepherd *et al.,* 1986), grain (Brusewitz, 1975; Datta *et al.*, 1988; Chung and converse, 1971; Lorenzen, 1959), potato (Marvin *et al.*, 1987; Khojastehpour, 1996; Safwat, 1971; Tabatabaeefar *et al.*, 2000b) and orange, apple (Tabatabaeefar *et al.*, 1999, 2000a).

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

MATERIALS AND METHODS

Four different and common commercial varieties of Iranian potatoes were considered for this study. 350 samples of potato were obtained from the Agricultural Research, Education, and Extension Organization, research institute. The potatoes were removed at random from their storage pile. Four different popular varieties sampled were Vital (NL), (53), Draga (PL), (98), Agria (DE) (99), and Ajacks (SE),(100) from different regions of the country with a total of 350 observations.

The mass of each potato was measured to 0.01 g on a digital balance. It was rounded to 0.1 g. Its volume was

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

Three mutually perpendicular axes; *a* (the longest intercept), *b* (the longest intercept normal to *a*), and *c* (the longest intercept normal to *a, b*), of potato were measured to accuracy of 0.1 mm by a micrometer (caliper); when it was laid on a flat surface and reached its natural resting position. 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 100 by the Mohsenin method. The volume of potato was calculated assuming the shape of a prolate spheroid and an oblate spheroid and an ellipsoid applying the following equations, respectively, V=4.19ab^2, V=4.19a^2b, and V=4.19 (Geometric mean diameter/2)^3. An average projected area as a criterion for the sizing machine was proposed (Mohsenin,1986). Three mutually perpendicular areas, PA_1, PA_2, PA_3, were measured on a ΔT Area-meter, a MK2 model from the United Kingdom by taking the area projected from each side. An average area projected (known as the criterion area, A_c, cm^2) was determined from Eq. (1):

$$A_c = (PA_1 + PA_2 + PA_3)/3. \quad (1)$$

A spreadsheet software, Microsoft EXCEL 98, 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, A_c, 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 varieties (cm^3).

RESULTS AND DISCUSSIONS

The physical properties such as major, minor, intermediate diameter, mass, volume measured and resembled, specific gravity, geometric mean, and percent sphericity, of four different varieties, Vital, Draga, Agria, Ajacks, and mixed varieties are shown in Table 1.

Draga and Agria varieties had longer diameters and larger masses than the other two varieties of potatoes. An average specific gravity of the Vital variety was 1.3 higher than of other varieties. The shape of the Iranian potatoes measured in this study is ellipsoidal with a minimum probable error from the volume measured. The percent sphericity for Draga, Ajacks and Vital varieties was similar, about 81%; but, Agria variety had the minimum value (71%) with the length to width ratio of 1.5 was the highest of all varieties; hence less spherical.

Draga variety is the biggest potato with a specific gravity of 1.07. Therefore, it may be used for export. Agria variety had a smaller range of variation for the specific gravity than others, with a coefficient of variation of 2%.

The mixed variety showed 80% shpericity, an average diameter of two diameters *a, c* was 3% less than the geometric mean diameter and with a similar coefficient of variation (18%). The specific gravity of the Iranian variety was 10 and 4% less than the one reported for the U.S. white potato and for Kerr Pink variety, respectively (Mohsenin, 1986). The length to width ratio of the mixed variety was 1.29 with the coefficient of variation of 16%. The volume measured was 2% higher than the calculated assumed shape of the ellipsoid (V= 4.19 (Geometer mean diatemeter/2)^3).

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):

$$\ln V = 1.2 \ln a + 0.94 \ln b + 0.86 \ln c - 7.28, \; R^2 = 0.98. \quad (4)$$

Natural logarith of volume with three diameters of Vital and Draga, and mixed variety was higher than Agria and Ajacks varieties but correlation was still very high. The relation between mass and the diameters was linear and the correlation was higher for Vital, and mixed variety. But for other varieties, correlation between mass and diameters was also high, around R = 0.92.

Mass versus volume was plotted and there was a linear relation between mass and volume of the mixed variety of potato with a very high coefficient of determination, R^2 = 0.994 as shown in Eq. (5):

$$M = 0.93V - 0.6. \quad (5)$$

Relation between the mean projected area and the volume of potatoes was determined from the plot and the coefficient of determination, $D = R^2$ 100%, between the

T a b l e 1. Physical properties of potato varieties

Variety	Physical attribute	Mean	Standard deviation	Maximum	Minimum	Coefficient of variation
Vital	Major (mm)	58.6	11.0	72.5	26.4	19.0
Sample size:53	Intermediate (mm)	48.9	9.0	65.0	23.5	19.0
	Minor diameter (mm)	41.7	7.7	55.4	22.0	19.0
	Mass (g)	71.1	28.7	123.3	8.5	40.0
	Measured volume (cc)	65.5	26.3	113.6	7.9	40.0
	Calculated volume (cc)	63.6	26.9	114.7	7.3	42.0
	Specific gravity	1.3	0.4	1.9	0.3	30.0
	Geometric mean (mm)	49.2	8.9	60.3	24.0	18.0
	Percent sphericity	80.0	10.0	90.0	70.0	6.0
Draga	Major (mm)	86.5	12.3	121.0	61.3	14.2
Sample size:98	Intermediate (mm)	75.0	10.0	101.0	57.0	13.0
	Minor diameter (mm)	57.0	7.0	78.0	40.0	12.0
	Mass (g)	219.0	77.0	445.0	94.0	35.0
	Measured volume (cc)	205.0	71.0	412.0	88.0	35.0
	Calculated volume (cc)	202.0	73.0	436.0	79.0	36.0
	Specific gravity	1.07	0.04	1.1	0.75	3.0
	Geometric mean (mm)	72.0	9.0	4.0	53.0	12.0
	Percent sphericity	83.0	5.0	94.0	72.0	6.0
Agria	Major (mm)	93.0	14.0	158.0	50.0	15.0
Sample size:99	Intermediate (mm)	62.0	6.0	81.0	42.0	10.0
	Minor diameter (mm)	48.0	4.0	63.0	41.0	9.0
	Mass (g)	173.0	42.0	271.0	80.0	24.0
	Measured volume (cc)	158.0	38.0	252.0	73.0	24.0
	Calculated volume (cc)	148.0	38.0	260.0	44.0	25.0
	Specific gravity	1.09	0.02	1.31	1.06	2.28
	Geometric mean (mm)	65.0	6.0	79.0	44.0	9.0
	Percent sphericity	71.0	6.0	88.0	50.0	8.33
Ajacks	Major (mm)	76.0	11.0	113.0	54.0	14.0
Sample size:100	Intermediate (mm)	60.0	5.0	77.0	46.0	9.0
	Minor diameter (mm)	51.0	6.0	70.0	39.0	12.0
	Mass (g)	137.0	37.0	257.0	78.0	27.0
	Measured volume (cc)	126.0	34.0	235.0	72.0	27.0
	Calculated volume (cc)	126.0	36.0	249.0	54.0	29.0
	Specific gravity	1.09	0.04	1.11	0.04	3.68
	Geometric mean (mm)	62.0	6.0	78.0	47.0	9.0
	Percent sphericity	81.0	7.0	98.0	63.0	8.15
Mixed Varieties	Major (mm)	80.0	18.0	158.0	26.0	23.0
Sample size:350	Intermediate (mm)	62.0	13.0	101.0	24.0	20.0
	Minor diameter (mm)	50.0	9.0	78.0	22.0	18.0
	Mass (g)	157.0	75.0	445.0	9.0	48.0
	Measured volume (cc)	145.0	70.0	412.0	8.0	48.0
	Calculated volume (cc)	142.0	69.0	436.0	7.0	49.0
	Specific gravity	1.08	0.03	1.31	0.75	3.0
	Geometric mean (mm)	63.0	12.0	94.0	24.0	18.0
	Ave. Diameter(a+c)/2 (mm)	65.0	12.0	102.0	24.0	19.0
	Percent Sphericity	80.0	8.0	98.0	50.0	10.0

T a b l e 2. Relationship between volume and mass with the three diameters of potato

Coefficient variety	Volume $\ln V = a + b_1 \ln a + b_2 \ln b + b_3 \ln c$					Mass $M = a + k_1 a + k_2 b + k_3 c$				
	b_1	b_2	b_3	a	R^2	k_1	k_2	k_3	a	R^2 100
Vital	1.2	0.78	0.93	-6.2	99.4	0.97	1.06	1.09	-84.2	94
Draga	1.17	0.88	0.78	-6.19	98	2.87	2.81	2.75	-256.5	84
Agria	0.82	0.75	1.03	-5.76	86	1.42	2.12	3.43	-256.6	84
Ajacks	0.92	0.65	0.86	-5.22	85	1.81	1.84	1.98	-214.3	85
Mixed varieties	1.2	0.94	0.86	-7.28	98	1.55	2.72	1.72	-222.3	90

two was very high and close to unity. A nonlinear regression equation for the mixed variety of potatoes was determined as shown in Eq. (6):

$$A_c = 1.1V^{0.71};\ D = 99.3\%. \quad (6)$$

The trend was the same as shown by Mohsenin (1986). However, the linear regression had a very high correlation, too.

CONCLUSIONS

1. Physical properties of four Iranian grown potato varieties were examined. Vital variety had the highest specific gravity. Agria variety had the smallest sphericity. The three diameters (minor to intermediate to major) of the varieties ranged from 41.7 to 93 mm which included fancy grade.

2. Draga variety may be used for export and it had higher length to width ratio than other varieties. Agria variety was more uniform since it had less specific gravity variation.

3. The potato shape resembled an ellipsoid.

4. Volume and the diameters had a natural logarithmic relationship with the three diameters as shown in: $\ln V = 1.2 \ln a + 0.94 \ln b + 0.86 \ln c - 7.28$ with $R^2 = 0.98$.

5. Mass and volume of the mixed variety of potato had a high correlation and a linear relationship $M = 0.93V - 0.6$.

6. There was a power relationship between the criterion area and volume: $A_c = 1.1V^{0.71}$.

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