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Research Article/*Araştırma Makalesi*

Development of Adequate Mathematical Models to Predict the Mass of Potato Varieties From Their Some Physical Attributes

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Abstract: For the designing and developing of more economical machine and systems for agricultural materials some physical properties such as size, projected area, mass and volume are often used in postharvest applications. The relationships between mass and size dimensions, mass and projected areas and mass and volume and other physical attributes of agricultural materials must be taken consideration. In this study, the mathematical models for predicting the mass of potato tubers from their some physical characteristics were determined. For mass modeling of potato tubers, three different linear classifications were used as: 1- dimension models (single and multiple variable regression models of potato tuber dimensions), 2- projected area models (single and multiple variable regression models of projected areas), 3- models based on volume (estimation of potato tuber shape, ellipsoid or spheroid based on volume). The research was conducted with three potato cultivars (Jelly, Milva and Sante). Among single variable estimation models, for Jelly potato cultivar, the highest determining coefficient was obtained as R^2=0.925 based on length with a relation as M=3.864L-162.033 in the first classification of mass modeling. The best coefficient of determination for single and multiple variable estimation models based on projected area to prediction the mass of Jelly potato cultivar were obtained as R^2=0.819, R^2 =0.848 and R^2=0.858, respectively among potato cultivars, respectively. According to the results, there is a linear relation between mass and estimated volume, the shape of potatoes considered as ellipsoid volume was found to be the most appropriate the model. This model is recommended for any three potato cultivars.

Key Words: Potato, physical properties, linear modeling, dimension, projected area and volume

Patates çeşitlerinin bazı fiziksel özelliklerine göre kütle tahminlenmesi için matematiksel model geliştirme

Özet: Tarımsal materyallerin hasat sonu uygulamalarında, daha ekonomik makina ve sistemlerin tasarımı ve geliştirilmesinde boyut, projeksiyon alanı, kütle ve hacim dikkate alınan önemli fiziksel özellikler olarak sıkça kullanılmaktadır. Bu yüzden, kütle ile boyut, kütle ile projeksiyon alanı, kütle ile hacim ve diğer özellikler arasındaki ilişkiler dikkate alınmalıdır. Bu amaçla, ülkemizde kullanılan tescilli patates çeşitlerinden olan Jelly, Milva ve Sante çeşitlerinin kütle tahmin modelleri; patates yumrularının boyutları, projeksiyon alanları ve hacim ilişkisi dikkate alınarak belirlenmiştir. Modeller üç farklı sınıflamaya göre (1. model: yumruların boyutlarına gore tekli ve çoklu regresyon modelleri, 2. model: yumruların projeksiyon alanlarına gore tekli ve çoklu regresyon modelleri, 3. model: yumruların hacimlerine göre kütle tahminlemesi) belirlenmiştir. Tek değişkenli modeller arasında, Jelly patates çeşidine ait model, uzunluk boyutu dikkate alınarak M=3,864L-162,033 model denklemi ve R^2=0,925 ile en yüksek belirtme katsayısı elde edilmiştir. En iyi belirtme katsayısı tek ve çoklu değişkenlerde projeksiyon alanı değerlerine göre kütle modellemesi patates çeşitleri içerisinde Jelly patates çeşidinde sırasıyla R^2=0.819, R^2 =0.848 ve R^2=0.858 değerleriyle elde edlmiştir. Sonuçlara göre, kütle ve tahmin edilen hacim değerlerinde, patates şekline göre elipsoid hacime göre en uygun model bulunmuştur ki, bu model her üç patates çeşidi için de önerilebilir bir modeldir.

Anahtar Kelimeler: Patates, fiziksel özellikler, lineer modelleme, boyut, projeksiyon alanı ve hacim

1. Introduction

In Turkey, potatoes are widely cultivated as a fundamental crop for a long time and is cultivated on 174.000 ha with an annual production of 4,822 million tons (FAO, 2012). The physical properties of potatoes are to be known for design and improve of relevant machines and facilities for harvesting, storing, handling and processing. The size and shape of potatoes are important in designing of separating, sizing, storage and processing machines. Bulk density and porosity affect in designing of storage and transporting structures. The maturity level, colors, size, volume, projected area, mechanical defect, firmness are some of the importance factors considered for potatoes marketing.

Agricultural materails are often graded by size, but it may be more economical, which grades by weight. Thus, the relationship between weight and physical attributes is needed (Peleg et al. 1985; Khoshnam et al. 2007). Physical attributes of agricultural products (size, shape, mass, volume and projected area) are the most important parameters to determine the proper standards of design of sizing, grading, conveying, processing and packaging systems (Tabatabaeefar and Rajabipour 2005). Mass grading of agricultural materials can reduce packaging and transportation costs. For irregular shape agricultural materials, the sizing by weight of materails is recommended. Determining relationships among mass, dimensions and projected areas may be useful and applicable (Marvin et al. 1987; Stroshine, 1998; Rafiee et al. 2007).

Many researches have been conducted to find the mass modeling of the different agricultural products with some physical attributes by Tabatabaeefar (2002) for potato cultivars, by Shahi-Gharahlar et al. (2005) for loquat fruit (*Eriobotrya japonica* Lindl.), by Lorestani ve Tabatabaeefar (2006) for kiwifruit, by Rafiee et al. (2007) for bergamot fruit (*Mangifera indica L.*), by Sharifi et al. (2007) for orange, by Jahromi et al. (2008) for date fruit, by Gorji Chakespari et al. (2010) for apple cultivars and Mirzabe et al. (2013) for almond.

Gorji Chakespari et al (2010), predicted the mass of two Iranian apple varieties (Golab Kohanz and Shafi Abadi) using different physical characteristics in linear models as three different classifications: single or multiple variable regressions of apple dimensional characteristics, single or multiple variable regressions of apple projected areas and estimating apple mass based on its volume.

Lorestani and Tabatabaeefar (2006) examined the models for predicting mass of kiwi fruit based on dimensions, projected areas perpendicular to the major diameters and volumes.

Tabatabaeefar (2002) studied some physical properties of potato and as size and shape for the purposes of sorting, grading. Physical properties of common varieties of Iranian grown potatoes and relationships among their physical attributes were determined. The relationships among these physical attributes determined and a high correlation was found between volume and the diameters of mixed potatoes with a coefficient of determination, R^2=0.98.

Determination of relationship between mass with dimensions and projected areas may be useful and applicable (Pitts et al. 1987, Stroshine and Hamann 1994). To design and development of sizing mechanisms, mass modeling of potato tuber can be used. No detailed study concerning the mass modeling of potato tuber with some geometric attributes for Jelly, Sante and Milva potato cultivars. Therefore, the objective of this study is to determine the most suitable model for predicting potato tuber mass by its physical properties.

2.Materials and Methods

Potatoes were harvested from a research field during 2010 at Konya Province located in Middle Anatolia of Turkey. The potato cultivars used in the study are the international cultivars. Jelly cultivar is originated from Canada; Milva and Sante cultivars are from Netherland. Jelly that very high yield and tuber shape is oval to round.

Milva is intermediate cultivar and tuber shape is oval, and tuber size is large. Tuber characteristics of Sante that tuber shape uniformity is medium to uniform and tuber size of Sante is large (NIVAP, 2005). Harvested tubers were transferred to the laboratory. Physical properties of potato such as size, shape and surface area are very important for the purposes of quality for export, sorting, grading and packaging. Some of the most important processing steps after potato harvesting are seperating and grading according to size. Four hundred tubers were randomly selected to determine the potato tuber size for each potato cultivar. The linear dimensions, i.e. length, width and thickness and also projected areas, were determined by image processing method. Three mutually perpendicular axes were as L (the longest intercept), W (the longest intercept normal to L), and T (the longest intercept normal to L,*W*) of potato were measured to accuracy of 0.01 mm by dial-micrometer; when it was laid on a flat surface and reached its natural resting position. In order to obtain projected areas, scanner device for preparing media to taking a picture (Hawlett Packard 2400 S) was used. Potato tubers were placed on a scanner, and the boundary lines were traced by a printer. Then, three mutually perpendicular areas, PL, PW, PT of potato tubers were measured by a digital planimeter (Placom Roller-Type, KP90N; by positioning each potato tuber in the diameter directions. The mean of these three projected areas was suggested as a criterion for a sizing machine (Peleg, 1985; Sirisomboon et al. 2007). The tuber mass of potatoes were measured with a digital electronic balance with a resolution of 0.01 g. The surface area (SA) is the surface of the skin of potato tuber was peeled by knife and laid on a digital planimeter (Mohsenin, 1986).

The geometric mean diameter (D_g), sphericity (Φ) and volume (actual) of potato tubers were calculated using the following relationships (Mohsenin, 1986):

$$D_g = \left(LWT\right)^{1/3} \tag{1}$$

$$\Phi = \left[\frac{D_g}{L}\right] \times 100 \tag{2}$$

$$V_{ac} = \frac{\pi}{6}\left(LWT\right) \tag{3}$$

where L is the length, W is the width, and T is the thickness in mm.

To analyze data and estimated regression models between the parameters, a spreadsheet software, Microsoft EXCEL 2003, was used. A spreadsheet software, Microsoft Excel 2003 and SPSS Software (2000) were used to analyze the data and to estimated regression models between the parameters of either linear or polynomial form. The following three categories of models were suggested to estimate a potato tuber’s mass from measured dimensions (length, projected area, and volume):

First dimension estimated models (single and multiple variable regression models of potato tuber dimensions); regression model of mass with major (length, L), intermediate (width, W), minor (thickness, T) and all three size dimensions. A total of four models were estimated. A model with the highest coefficient of determination, R^2, and the least regression standard error (R.S.E.) was selected.

Second projected area models (single and multiple regression models of projected areas); regression model of mass with each potato tuber projected area along L, W and T (PL, PW, PT) and all three projected areas. A model with the highest coefficient of determination R^2, and the least R.S.E. was presented.

Three models based on volume (estimation of potato tuber shape, ellipsoid or spheroid based on volume); regression models of mass with potato tuber volumes (oblate spheroid (V_{ob}) and ellipsoid (V_{ell}) shapes) and measured actual volume (V_{ac}). A total of 11 models for all three categories for Jelly, Milva and Sante potato cultivars were estimated. A model with the highest coefficient of determination R^2, and the least R.S.E. was presented by Jahromi et al. (2007) ; by Jahromi et al. (2008).

For dimensional models classification, mass modeling was accomplished according to the independent variables with respect to one, two or three mutually perpendicular diameters (length, width and thickness) as following:

$M=k_1L+k_2$ (4)

$M=k_1W+k_2$ (5)

$M=k_1T+k_2$ (6)

$M=k_1L+k_2W+k_3$ (7)

$M=k_1L+k_2T+k_3$ (8)

$M=k_1W+k_2T+k_3$ (9)

$M=k_1L+k_2W+k_3T+k_4$ (10)

where: M is the mass of potato tuber (g); L, W, T are the longest, median and the smallest diameters, respectively (mm); k_i is regression coefficients.

For the projected area models classification, mass modeling was estimated as a function of one, two or three mutually perpendicular projected areas as following (Lorestani and Tabatabaeefar, 2006):

$M=k_1PL+k_2$ (11)

$M=k_1PW+k_2$ (12)

$M=k_1PT+k_2$ (13)

$M=k_1PL+k_2PW+k_3$ (14)

$M=k_1PL+k_2PT+k_3$ (15)

$M=k_1PW+k_2PT+k_3$ (16)

$M=k_1PL+k_2PW+k_3PT+k_4$ (17)

where: PL, PW, PT are the projected areas in diameter directions (cm^2).

For the third category, mass is related to volume and can be estimated as a function of the volume measured. At first, actual volume (V_{ac}) as stated earlier was measured, then the date shape was assumed as a regularly geometrical shape, i.e. oblate spheroid (V_{ob}) and ellipsoid (V_{ell}) shapes and thus their volume (cm^3) were calculated as following by Jahromi et al. (2008):

$M=k_1V_{ac}+k_2$ (18)

$M=k_1V_{ob}+k_2$ (19)

$M=k_1V_{ell}+k_2$ (20)

$M= k_1V_{ac}+ k_2V_{ob}+k_3$ (21)

$M= k_1V_{ac} + k_2V_{ell}+k_3$ (22)

$M= k_1V_{ob}+ k_2V_{ell} +k_3$ (23)

$M= k_1V_{ac}+ k_2V_{ob} + k_3V_{ell} +k_4$ (24)

where: V_{ob} is volume of oblate spheroid (cm^3); V_{ell} is volume of ellipsoid (cm^3).

Volume of oblate spheroid (V_{ob}, cm^3) volume of ellipsoid (V_{ell}, cm^3) of potato tubers were calculated using the following relationships (Mohsenin, 1986):

$$V_{ob} = \frac{4\pi}{3}\left(\frac{L}{2}\right)\left(\frac{W}{2}\right)^2 \quad (25)$$

$$V_{ell} = \frac{4\pi}{3}\left(\frac{L}{2}\right)\left(\frac{W}{2}\right)\left(\frac{T}{2}\right) \quad (26)$$

3. Results and Discussion

Physical properties

The length, width, thickness, geometric mean diameter, sphericity, surface area and volume of potato tubers for Jelly, Sante and Milva potato cultivars are presented in Table 1 (Altuntas et al. 2012). The length, width, thickness, geometric mean diameter, sphericity, surface area and volume of potato tubers were 78.6 mm, 56.0 mm, 47.2 mm, 58.8 mm, 76.0% and 113.2 cm^2 and 121.2 cm^3 for Jelly potato cultivar, respectively. The length, width, thickness, geometric mean diameter, sphericity, surface area and volume of potato tubers were 72.6 mm, 56.8 mm, 48.0 mm, 57.9 mm, 80.2% and 109.1 cm^2 and 114.0 cm^3 for Milva potato cultivar, respectively. For Sante cultivar, the length, width, thickness, geometric mean diameter, sphericity, surface area and volume of potato tubers were 65.5 mm, 56.9 mm, 44.9 mm, 54.8 mm, 80.2% and 98.1 cm^2 and 97.7 cm^3, respectively.

The mass of potato tubers for Jelly, Milva and Sante cultivars were 141.6 g, 125.0 g and 110.2 g, respectively. The size dimensions, geometric mean diameter, surface area, volume and mass of potato tubers were observed the significant differences for Jelly, Milva and Sante cultivars. Jelly was larger in size and geometric mean diameter compared to Milva and Sante cultivars, whereas, Sante cultivar was closer to sphere in shape than the other cultivars.

Golmohammadi and Purrahimi (2009) reported that significant differences were observed among Agria, Satina and Kayzer cultivars according to major diameter; shape characteristics, mass, and surface area of tubers. Satina was larger in size compared to two other cultivars. However, the Agria cultivar was closer to sphere in shape. Tabatabaeefar (2002) reported that, the mean tuber mass of potato tubers were 71, 219, 173 g for Vital, Agria and Ajacks potato cultivars, respectively. Golmohammadi and Purrahimi (2009) reported that significant differences were observed among Agria, Satina and Kayzer cultivars according to volume of potato tubers. A summary of selected physical characteristics of potato tubers for Jelly, Milva and Sante potato cultivars are shown in Table 1.

First category models, dimensions

First classification linear regression models based on the selected attributes for dimensions are presented in Table 2 for mass modeling for Jelly, Milva and Sante potato cultivars, respectively. The results of mass modeling were given by coefficient of determination predicted R^2 and R.S.E coefficients for the single, two and three variable classifications in Table 2.

In Table 2, the results of mass modeling in the single variable classification revealed that the highest coefficient of determination obtained as R^2 = 0.925, R.S.E.=21.900 (Nos. 1.1) estimation equation to length for Jelly potato cultivars, whereas, the highest coefficient of determination obtained as R^2 = 0.909, R.S.E.=19.183 (Nos. 2.2); and R^2 = 0.925, R.S.E.=17.531 (Nos. 3.2) estimation equations to width for Milva and Sante potato cultivars, respectively.

In the case of mass modeling based on multiple dimensions, Nos. 1.4, 2.4 and 3.4, respectively with two variables had the highest R^2 and lower R.S.E. as 0.958, 0.946 and 0.944 for Jelly, Milva and Sante potato cultivars than the single variable classifications, respectively.

In the case of mass modeling based on three multiple dimensions, Nos. 1.7, 2.7 and 3.7, respectively with three variables (L,W,T) had the highest R^2 and lower R.S.E. as 0.964, 0.961 and 0.951 for Jelly, Milva ands Sante potato cultivars, respectively. Then the best equations for three multiple variable estimated mass modeling were determined as M= 2.291L+2.059W+1.467T-222.986, R^2=0.964 for Jelly potato cultivar; M=1.665T+2.146W +1.699L-200.051, R^2=0.961 for Milva potato cultivar; M=1.463L+2.528W+1.461T-195.123 , R^2=0.951 for Sante potato cultivar, respectively. For mass modeling based on three multiple projected areas, R^2 coefficient of determination values of in total variatons were found with increase of 1%, 0.08% and 0.12% for Jelly, Milva and Sante potato cultivars, respectively.

Second category models, projected area

For mass modeling for Jelly, Milva and Sante potato cultivars, the second classification linear regression models based on the selected attributes for projected area are presented in Table 3 respectively. The results of mass modeling were given by coefficient of determination predicted R^2 and R.S.E coefficients for the single, two and three variable classifications in Table 3.

Table 1. *Selected physical properties of potato tubers for Jelly, Milva and Sante cultivars (Altuntaş et al. 2012).*

	Potato cultivar		
Physical properties	*Jelly*	*Milva*	*Sante*
Length (L, mm)	78.6±18.6	72.6±13.8	65.5±13.0
Width (W, mm)	56.0±11.2	56.8±11.6	56.9±12.5
Thickness (T, mm)	47.2±7.97	48.0±8.03	44.9±7.39
Mass (M, g)	141.6±77.0	125.0±61.5	110.2±61.5
Geometric mean diameter, (D_g, mm)	58.8±11.8	57.9±10.8	54.8±10.6
Sphericity (ϕ, %)	76.0±3.03	80.2±0.42	84.1±1.16
Surface area (SA, cm^2)	113.2±43	109.1±38.9	98.1±37.1
Volume (V_{ac}, cm^3)	121.2±65.0	114.0±58.0	97.7±53.8

Table 2. *Coefficient of determination (R) and regression standard error (R.S.E.) for linear regression models based on dimensions for Jelly, Milva and Sante potato cultivars*

Potato cultivar	Variable	Model No.	Linear Model	R^2	R.S.E.	Sig. M	Sig. RC
Jelly	L	1.1	M= 3.864L-162.033	0.925	21.900	*	* *
	W	1.2	M= 6.744W-236.117	0.902	25.008	*	* *
	T	1.3	M= 7.909T-231.667	0.756	39.499	*	* *
	L, W	1.4	M= 2.274L+ 3.094W-210.354	0.958	16.376	*	* * *
	L, T	1.5	M= 2.952L+ 2.598T-213.009	0.955	16.978	*	* * *
	W, T	1.6	M= 5.809W+ 1.362T-248.019	0.907	24.383	*	* * *
	L, W, T	1.7	M= 2.291L+2.059W+ 1.467T-222.986	0.964	15.202	*	* * * *
Milva	L	2.1	M= 4.006L-165.663	0.882	21.901	*	* *
	W	2.2	M= 5.197W-169.987	0.909	19.183	*	* *
	T	2.3	M= 6.230T-174.106	0.791	29.113	*	* *
	L, W	2.4	M= 1.833L+3.100W-183.968	0.946	14.836	*	* * *
	L, T	2.5	M= 2.685L+ 2.742T-201.417	0.939	15.748	*	* * *
	W, T	2.6	M= 3.909W+ 1.936T -189.880	0.930	16.884	*	* * *
	L, W, T	2.7	M= 1.665T+2.146W+1.699L-200.051	0.961	12.621	*	* * * *
Sante	L	3.1	M= 4.280L-170.045	0.884	21.907	*	* *
	W	3.2	M= 4.877W-167.427	0.925	17.531	*	* *
	T	3.3	M= 7.055T-206.800	0.818	27.415	*	* *
	L, W	3.4	M= 1.606L+3.228W-178.679	0.944	15.216	*	* * *
	L, T	3.5	M= 2.806L+2.979T-207.396	0.925	17.652	*	* * *
	W, T	3.6	M= 3.853W+1.767T-188.530	0.936	16.270	*	* * *
	L, W, T	3.7	M= 1.463L+2.528W+ 1.461T-195.123	0.951	14.247	*	* * * *

Sig. M= Significant of model Sig. RC=Significant of regression coefficient

Table 3. *Linear regression models based on the selected attributes for projected area for Jelly, Milva and Sante potato cultivars.*

Potato cultivar	Variable	Model No.	Linear Model	R^2	R.S.E.	Sig. M	Sig. RC
Jelly	PL	1.1	M=5.076PL-16.237	0.791	36.502	*	* *
	PW	1.2	M=5.241PW-27.988	0.813	34.523	*	* *
	PT	1.3	M=6.926PT-42.955	0.819	34.028	*	* *
	PL, PW	1.4	M=2.279PL+3.126PW-30.402	0.840	31.966	*	* * *
	PL, PT	1.5	M=2.238PL+4.213PT-40.248	0.847	31.306	*	* * *
	PW, PT	1.6	M=3.611PW+3.743PT-42.608	0.848	31.237	*	* * *
	PL, PW, PT	1.7	M=1.515PL+1.804PW+2.890PT -40.883	0.858	30.214	*	* * * *
Milva	PL	2.1	M=5.457PL-28.560	0.745	32.181	*	* *
	PW	2.2	M=5.408PW-31.711	0.805	28.141	*	* *
	PT	2.3	M=6.674PT-31.661	0.745	32.162	*	* *
	PL, PW	2.4	M=1.877PL+3.802PW-37.979	0.822	26.914	*	* * *
	PL, PT	2.5	M=2.910PL+3.569PT-40.653	0.795	28.841	*	* * *
	PW, PT	2.6	M=3.749PW +2.387PT-39.660	0.824	26.729	*	* * *
	PL, PW, PT	2.7	M=1.323PL+3.013PW+1.816PT-42.179	0.832	26.195	*	* * * *
Sante	PL	3.1	M=5.780PL-40.141	0.811	27.924	*	* *
	PW	3.2	M=5.518PW-32.057	0.762	31.336	*	* *
	PT	3.3	M=8.142PT-53.726	0.770	30.823	*	* *
	PL, PW	3.4	M=3.925PL+2.019PW-43.919	0.829	26.565	*	* * *
	PL, PT	3.5	M=3.796PL+3.162PT-52.187	0.831	26.410	*	* * *
	PW, PT	3.6	M=2.884PW+4.519PT-55.125	0.825	26.874	*	* * *
	PL, PW, PT	3.7	M=2.560PL+1.671PW+2.685PT-53.499	0.843	25.466	*	* * * *

The results of mass modeling based on the projected area are in the single variable classification revealed that the highest coefficient of determination obtained as R^2=0.819, (Nos. 1.3) R^2=0.805, (Nos. 2.2); and R^2=0.811, (Nos. 3.1) estimation equations to PT, PW and PL projected areas for Jelly, Milva and Sante potato cultivars, respectively (Table 3).

In the case of mass modeling based on multiple projected areas, Nos. 1.6, 2.6 and 3.5, respectively with two variables had the highest R^2 and lower R.S.E. as 0.848, 0.824 and 0.831 for Jelly, Milva and Sante potato cultivars. Mass modeling based on multiple dimensions with two variables (PW, PT) had the highest R^2 and lower R.S.E. for Jelly potato cultivar than the other potato cultivars.

In the case of mass modeling based on three multiple projected areas, Nos. 1.7, 2.7 and 3.7 with three projected area variables (PL,PW,PT) had the highest R^2 and lower R.S.E. as 0.858, 0.832 and 0.843 for Jelly, Milva ands Sante potato cultivars, respectively. Then the best equations for three multiple variable mass modeling were estimated as M=1,515PL+1,804PW+2,890PT-40,883, R^2=0.858 for Jelly potato cultivar; M=1,323PL + 3,013PW + 1,816PT - 42,179, R^2=0.832 for Milva potato cultivar; M=2,560PL + 1,671PW + 2,685PT - 53,499, R^2=0.843 for Sante potato cultivar, respectively. For mass modeling based on three multiple projected areas, R^2 coefficient of determination values of in total variatons were found with increase of 1%, 0.08% and 0.12% for Jelly, Milva and Sante potato cultivars, respectively.

Third category models, volume

The third classification linear regression models based on the selected attributes for volume for mass modeling for Jelly, Milva and Sante potato cultivars, are presented in Table 4 respectively. The results of mass modeling were given by coefficient of determination predicted R^2 and R.S.E coefficients for the single, two and three variable classifications in Table 4.

In Table 4, the results of mass modeling based on the volume are in the single variable classification revealed that the highest coefficient of determination obtained as R^2=0.978, (Nos. 1.3) R^2=0.975, (Nos. 2.3); and R^2=0.980, (Nos. 3.3) estimation equations to ellipsoid (V_{ell}) shape volume for each potato cultivar, respectively.

Table 4. *Linear regression models based on volumes with coefficient of determination (R) and regression standard error (R.S.E.) for Jelly, Milva and Sante potato cultivars*

Potato cultivar	Variable	Model No.	Linear Model	R^2	R.S.E.	M	KS
Jelly	V_{ac}	1.1	$M= -0.0000241V_{ac} +144.366$	0.000	79.922	-	* -
	V_{ob}	1.2	$M= 0.001V_{ob} +6.081$	0.972	13.310	*	* *
	V_{ell}	1.3	$M= 0.001V_{ell}-1.100$	0.978	11.818	*	- *
	V_{ac}, V_{ob}	1.4	$M= -0000125V_{ac}+ 0.001Vob +7.539$	0.972	13.319	*	* - *
	V_{ac}, V_{ell}	1.5	$M= 0.0000118V_{ac} + 0.001V_{ell}-2.483$	0.978	11.826	*	- - *
	V_{ob}, V_{ell}	1.6	$M= 0.0004V_{ob}+ 0.001V_{ell} +0.613$	0.985	9.823	*	- * *
	V_{ac}, V_{ob}, V_{ell}	1.7	$M= 0.0000017V_{ac}+ 0.0004V_{ob} + 0.001V_{ell} +0.408$	0.985	9.835	*	- - * *
Milva	V_{ac}	2.1	$M=-0.0000085V_{ac}+125.890$	0.000	63.686	-	* -
	V_{ob}	2.2	$M=0.001V_{ob}+16.327$	0.935	16.210	*	* *
	V_{ell}	2.3	$M=0.001V_{ell} +5.785$	0.975	10.064	*	* *
	V_{ac}, V_{ob}	2.4	$M=0.0000111V_{ac}+ 0.001V_{ob} +15.146$	0.935	16.226	*	* - *
	V_{ac}, V_{ell}	2.5	$M=-0.000000842 V_{ac} + 0.001 V_{ell}+5.874$	0.975	10.076	*	* - *
	V_{ob}, V_{ell}	2.6	$M=0.0000552 V_{ob} + 0.001V_{ell}+6.153$	0.975	10.033	*	* - *
	V_{ac}, V_{ob}, V_{ell}	2.7	$M=0.0000000157 V_{ac} + 0.0000552V_{ob} + 0.001 V_{ell}+6.151$	0.975	10.046	*	* - - *
Sante	V_{ac}	3.1	$M=0.00000102 V_{ac}+110.054$	0.000	64.463	-	* -
	V_{ob}	3.2	$M=0.001V_{ob}+11.389$	0.957	13.341	*	* *
	V_{ell}	3.3	$M=0.001V_{ell}-0.018$	0.980	9.042	*	- *
	V_{ac}, V_{ob}	3.4	$M=-000014V_{ac}+0.001V_{ob}+12.816$	0.957	13.347	*	* - *
	V_{ac}, V_{ell}	3.5	$M=0.00000146V_{ac}+0.001V_{ell}-0.168$	0.980	9.053	*	- - *
	V_{ob}, V_{ell}	3.6	$M=0.000068V_{ob}+0.001V_{ell}+0.733$	0.980	9.005	*	- * *
	V_{ac}, V_{ob}, V_{ell}	3.7	$M=0.000000095V_{ac}+ 0.000069 V_{ob}+ 0.001V_{ell}+0.723$	0.980	9.016	*	- - * *

In the case of mass modeling based on multiple volumes, Nos. 1.6, 2.6 and 3.6, respectively with two variables (V_{ob}, V_{ell}) had the highest R^2 and lower R.S.E. as 0.985, 0.975 and 0.980 for Jelly, Milva and Sante potato cultivars. Mass modeling based on multiple dimensions with two variables had the highest R^2 and lower R.S.E. for Jelly potato cultivar than Milva and Sante potato cultivars.

In the case of mass modeling based on three multiple projected areas, Nos. 1.7, 2.7 and 3.7 with three projected area variables ($V_{ac,}$ $V_{ob,}$ V_{ell}) had the highest R^2 and lower R.S.E. as 0.985, 0.975 and 0.980 for Jelly, Milva ands Sante potato cultivars, respectively.

Then the best equations for two and three multiple variable mass modeling were found similar as $M=0.613+0.0004V_{ob}+0,001V_{ell,}$ and $M=0.408+0.0000017V_{ac}+0.0004V_{ob}+0.001V_{ell}$ R^2= 0.985 for Jelly potato cultivar, respectively. Similarly, the best equations for two and three multiple variable mass modeling were found similar for Milva and Sante potato cultivars, giving the coefficient of determination (R^2) values as 0.975 and 0.980, respectively.

Tabatabaeefar (2002) determined mass versus relationships among these physical attributes and a high correlation found between volume and the diameters of mixed potato cultivars (Draga+Agria+Ajacks) potatoes with a coefficient of determination, R^2= 0.98. Mass and volume of the mixed potatoes had a very high coefficient of determination, R^2= 0.994, A coefficient of determination, R^2, between an average projected areas (criterion area, PT) 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 with R^2=0.993. However, a linear regression had a very high correlation, because of the shape of an Iranian potatoes is ellipsoidal.

Lorestani and Tabatabaeefar (2006) determined that the linear regression models of kiwifruits have higher R^2 than nonlinear models. Among the linear regression dimensions models, the model that is based on width dimension, and among the linear projected areas models, the model that is based on third projected area (PT), and the model that is based on measured volume, had higher R^2, that are recommended for sizing of kiwifruit.

Gorji Chakespari et al (2010), the linear models evaluated for first classification among single variable estimation models the model based on width (M=3.29W-116.25) had maximum coefficient of determination, R^2=0.91 for Golab Kohanz variety and the model based on thickness (M=3.29T-118.06) had maximum coefficient of determination, R^2=0.91 for Shafi Abadi variety, respectively. Among all of single variable estimation models, the mass model based on actual volume was the best model for both varieties. For multiple variable regression models the best models were based on three dimension and three projected areas for all observation.

4. Conclusions

Selected physical properties such as size dimensions, projected area along three dimensions (length, width and thickness) and volume and their relationships of mass of Jelly, Milva and Sante potato cultivars are presented in this study. From this study it can be concluded that:

1.The mean values of physical properties such as length, mass, geometric mean diameter, surface area and volume for Jelly potato cultivar were higher than that of the Milva and Sante cultivars.

2. Among the potato cultivars, the best single, two and three variable estimation models based on dimensions for prediction the mass of Jelly potato cultivar was estimated as M=-162.033+3.864L (R^2=0.925); M=-210.354+ 2.274L+ 3.094W (R^2 =0.958) and M=-222.986+ 2.291L+2.059W+1.467T (R^2=0.925). respective-ly. Jelly than that of Milva and Sante potato cultivars. Mass modeling based on dimensions with single, two and three variables had the highest R^2 and lower R.S.E. for Jelly potato cultivar than Milva and Sante potato cultivars.

3. Among the potato cultivars, the best single, two and three variable estimation model for the mass of Jelly potato cultivar based on projected area was estimated as: M= 6.926PT -42.955 with determination coefficients of 0.819 and corresponding models for Milva and Sante potato cultivars were M=3.611PW+3.743PT -42.608 (R^2=0.848) and M=1.515PL+1.804PW +2.890PT -40.883 (R^2=0.858) , respectively. Mass modeling based on projected area along

dimensions with single, two and three variables had the highest R^2 and lower R.S.E. for Jelly potato cultivar than that of Milva and Sante potato cultivars.

4. The shape of potatoes considered as ellipsoid volume was found to be the most appropriate single variable estimation model which predicts mass of potatoes based on estimated volume for any potato cultivar and these models are recommended. Among the potato cultivars, the best two and three variable estimation models for the mass of Jelly potato cultivar based on volumes were estimated as: $M=0.0004V_{ob} + 0.001V_{ell.} + 0.613$ (R^2=0.985) and $M=0.0000017V_{ac.}+ 0.0004V_{ob} +0.001V_{ell.} + 0.408$ (R^2=0.985), respectively.

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