Middle-East Journal of Scientific Research 14 (10): 1337-1344, 2013
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2013.14.10.3569

Prediction of Plum Mass Based on Some Geometrical Properties

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Abstract: Plums are often graded on the basis of size, but it may be more suitable and economical to develop a system which grades by mass. Thus, a relationship between plum mass and some geometrical properties of plum is needed. In this study, eighteen linear regression models for predicting plum mass based on some geometrical properties of plum such as major diameter (a), intermediate diameter (b), minor diameter (c), geometrical mean diameter (GMD), first projected area (PA_1), second projected area (PA_2), third projected area (PA_3), criteria area (CAE), estimated volume based on an ellipsoid assumed shape (V_{Ell}) and measured volume (V_M) were suggested. Models were divided into three main classifications, i.e. first classification (outer dimensions), second classification (projected areas) and third classification (volumes). Paired samples t-test was used to compare the plum mass values predicted using selected models with the plum mass values measured by digital balance. Also, to check the discrepancies between the plum mass values predicted by selected models with the plum mass values measured by digital balance, root mean squared error (RMSE) and mean relative percentage deviation (MRPD) were calculated. The paired samples t-test results indicated that the plum mass values predicted by selected models were less than the plum mass values measured by digital balance. Results of the study indicated that in order to predict plum mass based on outer dimensions, the mass model based on three diameters as $M = -95.37 + 0.824\,a + 1.231\,b + 1.261\,c$ with $R^2 = 0.912$, RMSE = 1.6 g and MRPD = 2.1% can be recommended. Moreover, to predict plum mass based on projected areas, the mass model based on three projected areas as $M = -22.10 + 1.141\,PA_1 + 1.148\,PA_2 + 2.479\,PA_3$ with $R^2 = 0.911$, RMSE = 1.5 g and MRPD = 1.9% can be suggested. Besides, to predict plum mass based on volumes, the mass model based on estimated volume as $M = 2.846 + 1.089\,V_{Ell}$ with $R^2 = 0.901$, RMSE = 1.4 g and MRPD = 1.9% can be utilized. These models can also be used to design and develop sizing machines equipped with an image processing system.

Key words: Plum · Mass · Geometrical properties · Modeling · Prediction · Iran

INTRODUCTION

A plum is a drupe fruit of the genus *Prunus*. The subgenus is distinguished from other subgenera (peaches, cherries, bird cherries, etc.) in the shoots having a terminal bud and solitary side buds (not clustered), the flowers in groups of one to five together on short stems and the fruit having a groove running down one side and a smooth stone (or pit). The commercially important plum trees are medium sized, usually pruned to 5-6 meters height. The tree is of medium hardiness. Without pruning, the trees can reach 12 meters in height and spread across 10 meters. They blossom in different months in different parts of the world; for example, in about January in Taiwan and about April in the United States. Fruits are usually of medium size, between 1 to 3 inches in diameter, globose to oval. The flesh is firm, juicy and mealy. The fruit's peel is smooth, with a natural waxy surface that adheres to the flesh. The fruit has a single large seed. Plum has many species and taxonomist differ on the count. Depending on taxonomist, 19 to 40 species of plum exist. Plum fruit tastes sweet and/or tart; the skin may be particularly tart. It is juicy and can be eaten fresh or used in jam-making or other recipes. Plums come in a wide variety of colors and sizes. Some are much firmer-fleshed than others and some have yellow, white, green or red flesh, with equally varying skin color [1]. Plums are produced around the world and China is the world's largest producer. The ten largest producers of plums are China, Romania, USA, Serbia, Chile, France, Iran, Turkey,

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Italy and India. The second to tenth rankings change almost every year due in part to the alternate bearing nature of plum trees. Iran products nearly about 269,139 tons of plum and is ranked 7th in the world [2]. But, Iranian plums are not exported because of variability in size and shape and lack of suitable packaging [3].

Similar to other fruits, plum size is one of the most important quality parameters for evaluation by consumer preference. Consumers prefer fruits of equal size and shape [4, 5]. Sorting can increase uniformity in size and shape, reduce packaging and transportation costs and also may provide an optimum packaging configuration [6]. Moreover, sorting is important in meeting quality standards, increasing market value and marketing operations [7]. Sorting manually is associated with high labor costs in addition to subjectivity, tediousness and inconsistency which lower the quality of sorting [8]. However, replacing human with a machine may still be questionable where the labor cost is comparable with the sorting equipment [9]. Studies on sorting in recent years have focused on automated sorting strategies and eliminating human efforts to provide more efficient and accurate sorting systems which improve the classification success or speed up the classification process [10, 11].

Physical and geometrical properties of products are the most important parameters in design of sorting systems. Among these properties, mass, outer dimensions, projected areas and volume are the most important ones in sizing systems [12]. The size of produce is frequently represented by its mass because it is relatively simple to measure. However, sorting based on some geometrical properties may provide a more efficient method than mass sorting. Moreover, the mass of produce can be easily estimated from geometrical properties if the mass model of the produce is known [13-17]. For these reasons, modeling of plum mass based on some geometrical properties may be useful and applicable. Therefore, the main objectives of this research were to determine suitable mass model(s) based on some geometrical properties of plum and to verify selected mass model(s).

MATERIALS AND METHODS

Experimental Procedure: One of the most common commercial cultivars of plum in Iran, i.e. Golden Drop (Fig. 1) was considered for this study. One hundred randomly selected plums of various sizes were purchased from a local market. Plums were selected for freedom from defects by careful visual inspection, transferred to the laboratory and held at 5±1°C and 90±5% relative humidity until experimental procedure. In order to obtain required parameters for determining mass models, the mass of each plum was measured to 0.1 g accuracy on a digital balance. By assuming the shape of plum as an ellipsoid, the outer dimensions of each plum, i.e. major diameter (a), intermediate diameter (b) and minor diameter (c) was measured to 0.1 cm accuracy by a digital caliper. The geometric mean diameter (GMD) of each plum was then calculated by equation 1.

Fig. 1: Plum (*Prunus domestica* cv. Golden Drop)

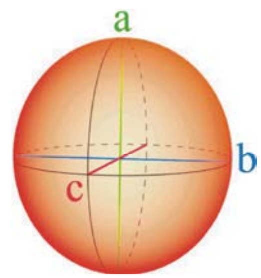

Fig. 2: The outer dimensions of a plum, i.e. major diameter (a), intermediate diameter (b) and minor diameter (c) by assuming the shape of plum as an ellipsoid

$$GMD = (abc)^{1/3} \quad (1)$$

Three projected areas of each plum, i.e. first projected area (PA_1), second projected area (PA_2) and third projected area (PA_3) was also calculated by using equation 2, 3 and 4, respectively. The average projected area known as criteria area (CAE) of each plum was then determined by equation 5.

$$PA_1 = \pi\, ab/4 \quad (2)$$

$$PA_2 = \pi\, ac/4 \quad (3)$$

$$PA_3 = \pi\, bc/4 \quad (4)$$

$$CAE = (PA_1+PA_2+PA_3)/3 \quad (5)$$

Table 1: The mean values, standard deviation (S.D.) and coefficient of variation (C.V.) of mass and some geometrical properties of the 100 randomly selected plums used to determine mass models

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
Mass (M), g	42.5	58.2	51.5	3.87	7.51
Major diameter (a), mm	39.3	45.0	41.9	1.29	3.07
Intermediate diameter (b), mm	42.7	47.9	45.5	1.17	2.57
Minor diameter (c), mm	41.5	46.8	44.7	1.21	2.72
Geometrical mean diameter (GMD), mm	41.3	46.0	44.0	1.11	2.52
First projected area (PA_1), cm^2	13.3	16.6	15.0	0.77	5.14
Second projected area (PA_2), cm^2	13.0	16.3	14.7	0.77	5.24
Third projected area (PA_3), cm^2	13.9	17.4	16.0	0.82	5.14
Criteria area (CAE), cm^2	13.4	16.6	15.2	0.77	5.03
Estimated volume (V_{Ell}), cm^3	36.9	51.0	44.7	3.37	7.54
Measured volume (V_M), cm^3	38.0	57.7	47.1	4.05	8.60

Table 2: The mean values, standard deviation (S.D.) and coefficient of variation (C.V.) of mass and some geometrical properties of the fifteen randomly selected plums used to verify mass models

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
Mass (M), g	58.4	68.4	61.4	2.93	4.77
Major diameter (a), mm	42.7	46.4	44.4	1.29	2.90
Intermediate diameter (b), mm	46.8	49.7	48.1	0.74	1.54
Minor diameter (c), mm	46.3	48.8	47.4	0.68	1.44
Geometrical mean diameter (GMD), mm	45.5	48.1	46.6	0.76	1.63
First projected area (PA_1), cm^2	15.9	17.9	16.8	0.66	3.93
Second projected area (PA_2), cm^2	15.8	17.6	16.5	0.61	3.67
Third projected area (PA_3), cm^2	17.1	19.1	17.9	0.50	2.80
Criteria area (CAE), cm^2	16.3	18.2	17.1	0.55	3.24
Estimated volume (V_{Ell}), cm^3	49.3	58.2	53.1	2.60	4.90
Measured volume (V_M), cm^3	51.6	63.1	57.3	3.43	5.99

In addition, the volume of ellipsoid assumed shape (Fig. 2) or estimated volume of each plum (V_{Ell}) was calculated by using equation 6.

$$V_{ell} = \pi\, abc/6 \tag{6}$$

Table 1 shows mass and geometrical properties of the plums used to determine mass models. Also, in order to verify selected mass models, mass and geometrical properties of fifteen randomly selected plums of various sizes were determined as described before. Table 2 shows mass and geometrical properties of the plums used to verify selected mass models.

Regression Model: A typical multiple-variable linear regression model is shown in equation 7:

$$Y = k_0 + k_1X_1 + k_2X_2 + \ldots + k_nX_n \tag{7}$$

where:

Y = Dependent variable, for example mass of plum

$X_1, X_2, \ldots, X_n$ = Independent variables, for example geometrical properties of plum

$k_0, k_1, k_2, \ldots, k_n$ = Regression coefficients

In order to estimate plum mass based on geometrical properties, eighteen linear regression models were suggested and all the data were subjected to linear regression analysis using the Microsoft Excel 2007 (Table 3). Models were divided into three main classifications, i.e. first classification (or outer dimensions), second classification (or projected areas) and third classification (or volumes).

Statistical Analysis: Paired samples t-test was used to compare the plum mass values predicted by selected models with the plum mass values measured by digital balance. Also, to check the discrepancies between the plum mass values measured by digital balance with the plum mass values predicted by selected models, root mean squared error (RMSE) and mean relative percentage deviation (MRPD) were calculated using the equations 8 and 9, respectively [18-25]:

Table 3: Eighteen linear regression mass models and their relations in three classifications

Classification	Model No.	Model	Relation
Outer dimensions	1	$M = k_0 + k_1\ a$	$M = -45.50 + 2.316\ a$
	2	$M = k_0 + k_1\ b$	$M = -86.05 + 3.025\ b$
	3	$M = k_0 + k_1\ c$	$M = -77.88 + 2.893\ c$
	4	$M = k_0 + k_1\ GMD$	$M = -94.25 + 3.313\ GMD$
	5	$M = k_0 + k_1\ a + k_2\ b$	$M = -93.93 + 0.896\ a + 2.373\ b$
	6	$M = k_0 + k_1\ a + k_2\ c$	$M = -89.40 + 0.977\ a + 2.236\ c$
	7	$M = k_0 + k_1\ b + k_2\ c$	$M = -88.40 + 1.666\ b + 1.435\ c$
	8	$M = k_0 + k_1\ a + k_2\ b + k_3\ c$	$M = -95.37 + 0.824\ a + 1.231\ b + 1.261\ c$
Projected areas	9	$M = k_0 + k_1\ PA_1$	$M = -17.37 + 4.601\ PA_1$
	10	$M = k_0 + k_1\ PA_2$	$M = -16.54 + 4.622\ PA_2$
	11	$M = k_0 + k_1\ PA_3$	$M = -18.71 + 4.393\ PA_3$
	12	$M = k_0 + k_1\ CAE$	$M = -21.56 + 4.799\ CAE$
	13	$M = k_0 + k_1\ PA_1 + k_2\ PA_2$	$M = -17.56 + 1.626\ PA_1 + 3.038\ PA_2$
	14	$M = k_0 + k_1\ PA_1 + k_2\ PA_3$	$M = -22.33 + 2.112\ PA_1 + 2.642\ PA_3$
	15	$M = k_0 + k_1\ PA_2 + k_2\ PA_3$	$M = -21.47 + 2.216\ PA_2 + 2.525\ PA_3$
	16	$M = k_0 + k_1\ PA_1 + k_2\ PA_3 + k_3\ PA_3$	$M = -22.10 + 1.141\ PA_1 + 1.148\ PA_2 + 2.479\ PA_3$
Volumes	17	$M = k_0 + k_1\ V_{Ell}$	$M = 2.846 + 1.089\ V_{Ell}$
	18	$M = k_0 + k_1\ V_M$	$M = 12.46 + 0.829\ V_M$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(M_{Mi} - M_{Pi})^2}{n}} \quad (8)$$

where:
RMSE = Root mean squared error (g)
M_{mi} = Plum mass measured by digital balance (g)
M_{Pi} = Plum mass predicted by selected mass model (g)
n = Number of samples

$$MRPD = \frac{100 \times \sum_{i=1}^{n} \frac{|M_{Mi} - M_{Pi}|}{M_{Mi}}}{n} \quad (9)$$

where:
MRPD = Mean relative percentage deviation (%)

RESULTS

The p-value of independent variable(s) and coefficient of determination (R^2) of the linear regression models are shown in Table 4.

First Classification Models (Outer Dimensions): In this classification plum mass can be predicted using linear regression models No. 1-8 (Table 3). As indicated in Table 4, among the first classification models, model No. 8 had the highest R^2 value (0.912). Also, the p-value of independent variables (a, b and c) was 9.63E-10, 3.75E-06 and 5.30E-07, respectively. Based on the statistical results model No. 8 was selected as the best model of first classification models. Model No. 8 is given in equation 10.

$$M = -95.37 + 0.824\ a + 1.231\ b + 1.261\ c \quad (10)$$

Second Classification Models (Projected Areas): In this classification plum mass can be predicted using linear regression models No. 9-16 (Table 3). As demonstrated in Table 4, among the second classification models, model No. 16 had the highest R^2 value (0.911). Moreover, the p-value of independent variables (PA_1, PA_2 and PA_3) was 0.113250, 0.129671 and 1.63E-11, respectively. Again, based on the statistical results model No. 16 was chosen as the best model of second classification models. Model No. 16 is given in equation 11.

$$M = -22.10 + 1.141\ PA_1 + 1.148\ PA_2 + 2.479\ PA_3 \quad (11)$$

Third Classification Models (Volumes): In this classification plum mass can be predicted using linear regression models No. 17 and 18 (Table 3). As measuring the volume of an irregularly shaped object (plum) using water displacement method is often difficult, model No. 17 was primarily preferred. Moreover, as demonstrated in Table 4, between the third classification models, model No. 17 had higher R^2 value (0.901) and lower p-value (5.32E-51) of independent variable (V_{Ell}). Once more, based on the statistical results model No. 17 was chosen as the best model of third classification models. Model No. 17 is given in equation 12.

$$M = 2.846 + 1.089\ V_{Ell} \quad (12)$$

Table 4: The p-value of independent variable(s) and coefficient of determination (R^2) of the linear regression models

	p-value										
Model No.	a	b	c	GMD	PA_1	PA_2	PA_3	CAE	V_{Ell}	V_M	R^2
1	5.76E-21	---	---	---	---	---	---	---	---	---	0.595
2	---	3.51E-40	---	---	---	---	---	---	---	---	0.835
3	---	---	4.19E-39	---	---	---	---	---	---	---	0.827
4	---	---	---	9.86E-52	---	---	---	---	---	---	0.904
5	2.97E-09	2.22E-28	---	---	---	---	---	---	---	---	0.886
6	3.48E-11	---	3.26E-29	---	---	---	---	---	---	---	0.890
7	---	1.41E-07	1.77E-06	---	---	---	---	---	---	---	0.870
8	9.63E-10	3.75E-06	5.30E-07	---	---	---	---	---	---	---	0.912
9	---	---	---	---	8.25E-41	---	---	---	---	---	0.840
10	---	---	---	---	---	1.71E-42	---	---	---	---	0.852
11	---	---	---	---	---	---	2.92E-45	---	---	---	0.870
12	---	---	---	---	---	---	---	1.09E-51	---	---	0.904
13	---	---	---	---	0.073004	0.000995	---	---	---	---	0.857
14	---	---	---	---	4.96E-09	---	1.66E-13	---	---	---	0.909
15	---	---	---	---	---	5.53E-09	9.03E-12	---	---	---	0.909
16	---	---	---	---	0.113250	0.129671	1.63E-11	---	---	---	0.911
17	---	---	---	---	---	---	---	---	5.32E-51	---	0.901
18	---	---	---	---	---	---	---	---	---	1.34E-31	0.754

DISCUSSION

Among the eighteen linear regression models (models No. 1-18), models No. 8, 16 and 17 were selected based on the statistical results and paired samples t-test was used to compare the plum mass values predicted by three selected models with the plum mass values measured by digital balance. In addition, to check the discrepancies between the plum mass values predicted by three selected models with the plum mass values measured by digital balance, RMSE and MRPD were calculated.

Comparison of Model No. 8 with Measuring Method: The plum mass values predicted by model No. 8 were compared with the plum mass values measured by digital balance and are shown in Table 5. The paired samples t-test results indicated that the plum mass values predicted by model No. 8 were significantly less than the plum mass values measured by digital balance (Table 6). The mean of plum mass deference between two methods was -1.13 g (95% confidence interval: -1.823 g and -0.431 g; P = 0.9981). The standard deviation of plum mass difference between two methods was 1.26 g. RMSE and MRPD were also used to check the discrepancies between the two methods. The amounts of RMSE and MRPD were 1.6 g and 2.1%, respectively. Thus, plum mass predicted by model No. 8 may be 1.6 g or 2.1% less than plum mass measured by a digital balance. Small amounts of RMSE and MRPD confirmed that linear regression model M = -95.37 + 0.824 a + 1.231 b + 1.261 c with $R^2 = 0.912$ may be used to predict mass of plum based on three diameters. Moreover, as it is indicated in Fig. 3, our attempts to relate mass values predicted by model No. 8 (M_P) to mass values measured by digital balance (M_M) using a linear equation resulted in good agreements ($R^2 = 0.825$) as equation 13:

$$M_M = 1.129\ M_P - 6.701 \quad (13)$$

It means that measured mass (M_M) can be computed in two steps. At first step predicted mass (M_P) can be calculated based on three diameters using model No. 8 (equation 10). Second step is calculating measured mass (M_M) based on predicted mass (M_P) using equation 13.

Comparison of Model No. 16 with Measuring Method: The plum mass values predicted by model No. 16 were also compared with the plum mass values measured by digital balance and are shown in Table 5. Again, the paired samples t-test results showed that the plum mass values predicted by model No. 16 were significantly less than the plum mass values measured by digital balance (Table 6). The mean of plum mass deference between two methods was -0.87 g (95% confidence interval: -1.542 g and -0.191 g; P = 0.9922). The standard deviation of plum mass difference between two methods was 1.22 g. RMSE and MRPD were also used to check the discrepancies between the two methods. The amounts of RMSE and MRPD were 1.5 g and 1.9%, respectively. Thus, plum mass predicted by model No. 16 may be 1.5 g or 1.9% less

Table 5: Geometrical properties of the fifteen plums used in evaluating selected mass models

Sample No.	Geometrical properties of plum a(mm)	b(mm)	c(mm)	PA_1(cm^2)	PA_2(cm^2)	PA_3(cm^2)	V_{Ell}(cm^3)	Plum mass (g) Measured by digital balance	Predicted by model No. 8	Predicted by model No. 16	Predicted by model No. 17
1	43.4	47.0	46.8	16.0	16.0	17.2	50.0	58.4	57.2	57.3	57.2
2	43.2	46.8	46.5	15.9	15.8	17.1	49.3	58.5	56.5	56.5	56.5
3	42.7	47.6	47.4	15.9	15.9	17.7	50.4	58.9	58.1	58.2	57.7
4	42.8	48.5	47.2	16.3	15.8	18.0	51.2	58.9	59.0	59.2	58.6
5	43.5	48.5	47.0	16.6	16.0	17.9	51.9	59.1	59.4	59.6	59.3
6	45.1	47.7	46.3	16.9	16.4	17.3	52.1	59.4	58.8	59.0	59.6
7	43.1	48.3	47.9	16.3	16.2	18.1	52.1	59.9	59.9	60.1	59.6
8	44.1	47.7	47.7	16.5	16.5	17.8	52.5	60.8	59.7	59.9	60.0
9	46.4	48.2	47.5	17.6	17.3	18.0	55.6	61.1	62.0	62.4	63.4
10	43.7	47.9	47.2	16.4	16.2	17.8	51.7	61.9	59.1	59.3	59.2
11	45.5	48.6	47.9	17.4	17.1	18.3	55.4	62.3	62.3	62.6	63.2
12	46.1	48.6	47.1	17.6	17.0	18.0	55.2	63.6	61.7	62.1	62.9
13	45.0	48.8	48.3	17.2	17.1	18.5	55.5	64.6	62.6	63.0	63.3
14	45.5	48.5	48.0	17.3	17.2	18.3	55.5	64.9	62.4	62.8	63.3
15	45.8	49.7	48.8	17.9	17.6	19.1	58.2	68.4	65.1	65.7	66.2

Table 6: Paired samples t-test analyses on comparing plum mass determination methods

Determination methods	Average difference (g)	Standard deviation of difference (g)	p-value	95% confidence intervals for the difference in means (g)
Model No. 8 vs. measuring	-1.13	1.26	0.9981	-1.823, -0.431
Model No. 16 vs. measuring	-0.87	1.22	0.9922	-1.542, -0.191
Model No. 17 vs. measuring	-0.71	1.29	0.9752	-1.425, -0.002

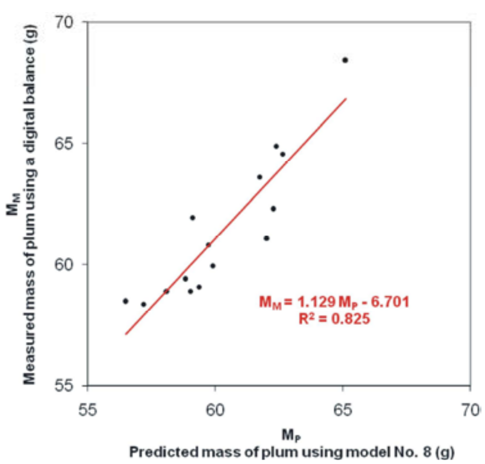

Fig. 3: Measured mass of plum (M_M) using a digital balance based on predicted mass of plum (M_P) using model No. 8

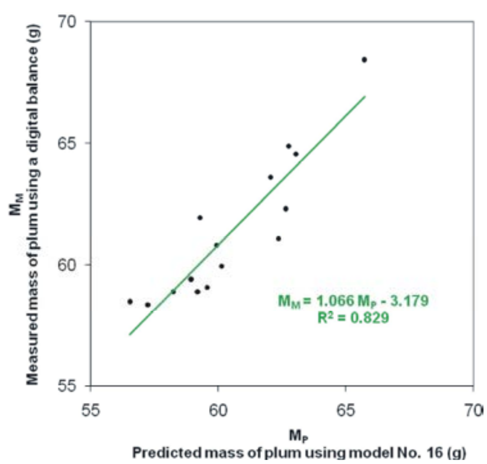

Fig. 4: Measured mass of plum (M_M) using a digital balance based on predicted mass of plum (M_P) using model No. 16

than plum mass measured by a digital balance. Again, small amounts of RMSE and MRPD confirmed that linear regression model M = - 22.10 + 1.141 PA_1 + 1.148 PA_2 + 2.479 PA_3 with R^2 = 0.911 may be used to predict mass of plum based on three projected areas. In addition, as it is indicated in Fig. 4, our attempts to relate mass values predicted by model No. 16 (M_P) to mass values measured by digital balance (M_M) using a linear equation resulted in good agreements (R^2 = 0.829) as equation 14:

$$M_M = 1.066\ M_P - 3.179 \qquad (14)$$

It means that measured mass (M_M) can be computed in two steps. At first step predicted mass (M_P) can be calculated based on three projected areas using model No. 16 (equation 11). Second step is calculating measured mass (M_M) based on predicted mass (M_P) using equation 14.

Comparison of Model No. 17 with Measuring Method: The plum mass values predicted by model No. 17 were also compared with the plum mass values measured by digital balance and are shown in Table 5. Once more, the

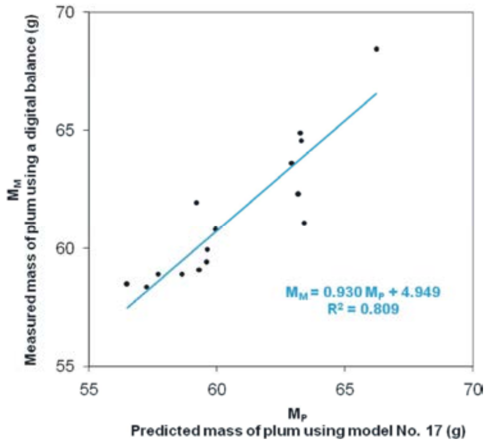

Fig. 5: Measured mass of plum (M_M) using a digital balance based on predicted mass of plum (M_P) using model No. 17

paired samples t-test results indicated that the plum mass values predicted by model No. 17 were significantly less than the plum mass values measured by digital balance (Table 6). The mean of plum mass deference between two methods was -0.71 g (95% confidence interval: -1.425 g and -0.002 g; P = 0.9752). The standard deviation of plum mass difference between two methods was 1.29 g. RMSE and MRPD were also used to check the discrepancies between the two methods. The amounts of RMSE and MRPD were 1.4 g and 1.9%, respectively. Thus, plum mass predicted by model No. 17 may be 1.4 g or 1.9% less than plum mass measured by a digital balance. Once more, small amounts of RMSE and MRPD confirmed that linear regression model $M = 2.846 + 1.089 V_{Ell}$ with $R^2 = 0.901$ may be used to predict mass of plum based on estimated volume. Besides, as it is indicated in Fig. 5, our attempts to relate mass values predicted by model No. 17 (M_P) to mass values measured by digital balance (M_M) using a linear equation resulted in good agreements ($R^2 = 0.809$) as equation 15:

$$M_M = 0.930 M_P + 4.949 \quad (15)$$

It means that measured mass (M_M) can be computed in two steps. At first step predicted mass (M_P) can be calculated based on estimated volume using model No. 17 (equation 12). Second step is calculating measured mass (M_M) based on predicted mass (M_P) using equation 15.

CONCLUSIONS

In order to predict plum mass based on outer dimensions, the linear regression model based on three diameters as $M = -95.37 + 0.824 a + 1.231 b + 1.261 c$ with $R^2 = 0.912$ was preferred. In addition, to predict plum mass based on projected areas, the linear regression model based on three projected areas as $M = -22.10 + 1.141 PA_1 + 1.148 PA_2 + 2.479 PA_3$ with $R^2 = 0.911$ was selected. Moreover, to predict plum mass based on volumes, the linear regression model based on estimated volume as $M = 2.846 + 1.089 V_{Ell}$ with $R^2 = 0.901$ was chosen.

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