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Brix-acid Ratio Detection for Pomegranates Using Multivariate Equation

Sompong Nandee [1] and Sontisuk Teerachaichayut [1+]

[1] Department of Food Science, Faculty of Agro-Industry, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand.

Abstract. This research aims to use physicochemical properties to predict brix-acid ratio by establishment of an equation which can be used to consider harvesting period of pomegranate 'Dentawan variety'. Pomegranates from an orchard were used in this research. 90 to 132 days after flowering of samples were measured physicochemical properties such as soluble solids content (SSC), titratable acid (TA), moisture content of peel (MC), sphericity, fruit firmness and density. 100 samples were used for a training set and 50 samples were used for a test set. The brix-acid ratio or the ratio of soluble solids content and titratable acid (SSC/TA) was used as the maturity index. Calibration model of brix-acid ratio was established from multiple variables (MC, sphericity, fruit firmness and density) using multiple linear regression (MLR). The results showed density was the most important variable in the model for this research. The multivariate model obtained good performance by cross validation in the training set with the correlation coefficient (R) = 0.85 and the root mean squared error of calibration (RMSEC) = 4.58 and obtained a good result for prediction in the test set with R = 0.86 and the root mean squared error of prediction (RMSEP) = 4.44. Therefore, the multivariate equation can be used to predict the brix-acid ratio of pomegranates on trees. It will be useful for farmers to consider the suitable time of harvesting for pomegranates.

Keywords: Pomegranate, Maturity, Harvest, Multivariate

1. Introduction

Pomegranate (*Punicagranatum* L.) is one of prosperous fruits in Thailand due to peel, seed and pomegranate juice contain useful antioxidants that can be used to prevent of chronic disease such as cancer, atherosclerosis and alzheimer disease [1].

Physical properties of agricultural products such as size, mass, shape, volume, surface, density and color etc. are important to nondestructively consider for commercial trading and used to design harvesting tools for agricultural products [2]. Teerachaichayut *et al.* [3] reported that physical and chemical parameters were able to used for prediction of translucent flesh in mangosteens. The density is one of important physical properties due to two properties of mass and volumes are concerned. The firmness of fruits is related to maturity and their injury [4]. The index of maturity is normally use as the ratio of soluble solids content and titratable acidity. There are higher soluble solids content and lower titratable acidity in mature fruits when compared to young fruits [5]. Physicochemical properties of fruits are changed related to their maturity.

Pomegranate is non climacteric fruit therefore harvest period is important to control the quality of fruits. Farmers need to know a suitable time for harvesting of pomegranates. Hence, physicochemical properties of fruits on tree by counting days after flowering are investigated. The correlation of physicochemical properties and maturity index is considered to determine of the suitable time for harvesting of pomegranates.

2. Materials and Methods

2.1. Measurement of Physicochemical Properties.

+ Corresponding author. Tel.: +66(0)2-329-8000 ext.7267; fax.+66(0)2-329-8527
E-mail address: .ktsontis@kmitl.ac.th

Pomegranates (Dentawan variety) in the orchard at Khon Kaen Province, Thailand were considered. The development of fruits on trees was investigated by using multiple variables which measured from each fruit. The first day after flowering of each sample was labeled. Ten samples were harvested at every three days in an interval of 90-132 days after flowering. Physicochemical properties were measured in each sample.

The perpendicular dimensions of each pomegranate were measured by a vernier caliper namely a = length, b = width and c = thickness. Geometric mean diameter (GMD) and sphericity (ϕ) were calculated as suggested by Mohsenin [2]:

$$GMD = (a.b.c)^{1/3} \quad (1)$$

$$\phi = (100GMD)/a \quad (2)$$

Each sample was weighed using digital weighing scale (Sartorius, TE 1502S, Germany). For volume, each sample was weighed by submerging into water as outlined by Mohsenin [2]. Density of each sample was calculated by the ratio of mass and volume.

Firmness was determined using a hand penetrometer (N.O.W., FHR-5, Japan) equipped with a 2 mm diameter cylindrical probe and a penetration distance after contact of 5 mm and the value was expressed in kilogram (kg).

The moisture content of peel was determined by cutting about 2 grams of peel in each sample and then drying using a microwave (LG, MS2248BKB,Thailand), which is a standard technique explained by Gay *et al*. [6].

Pomegranate juice from flesh of each sample was extracted and filtered. The soluble solids content was measured by digital refractometer (ATAGO, PAL-1, Japan). It was approximate dissolved solid content in an aqueous solution in percentage by weight and expressed in degree Brix (^{o}Bx). The titratable acidity was determined using the 0.1 N NaOH titrated to pH 8.2 and expressed as percentage of citric acid.

2.2. Statistical Analysis

Brix-acid ratio was calculated as soluble solids content divided by titratable acidity and used as dependent variable. Independent variables were moisture content, sphericity, density and firmness. The calibration equation for brix-acid ratio was developed and cross-validated from samples in the training set using multiple linear regression. The performance of the model was tested on samples in the test set. The Unscrambler (CAMO, Oslo, Norway) was used for statistical analysis.

3. Results and Discussion

The appearances of pomegranates such as size, weight and color were different depended on days after flowering as shown in the figure 1. The young fruits were smaller and mostly red while mature fruits were bigger and became yellow. The characteristic of fruits were harvested at 90, 105, 120 and 132 days after flowering**.**

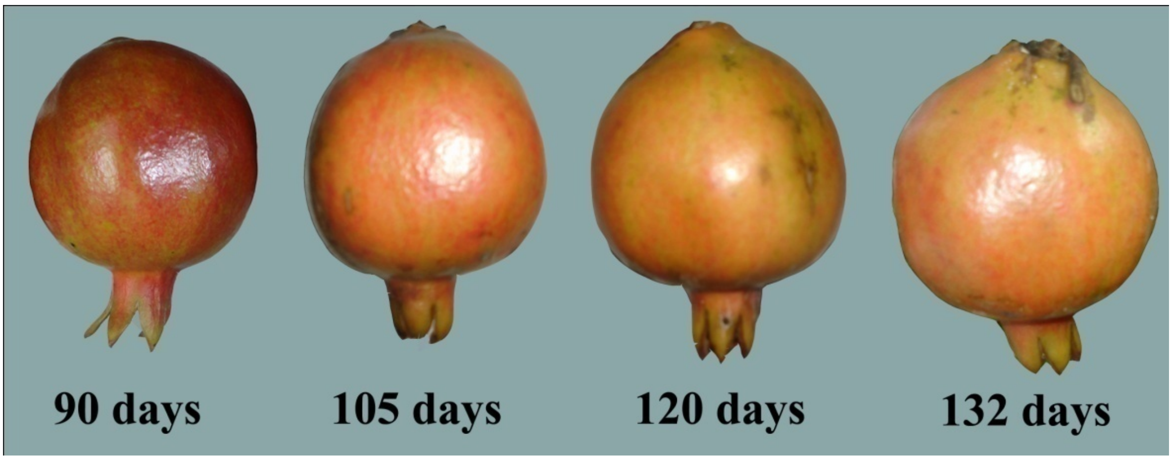

Fig.1: Appearance presentation of pomegranate 'Dentawan variety' in various days after flowering.

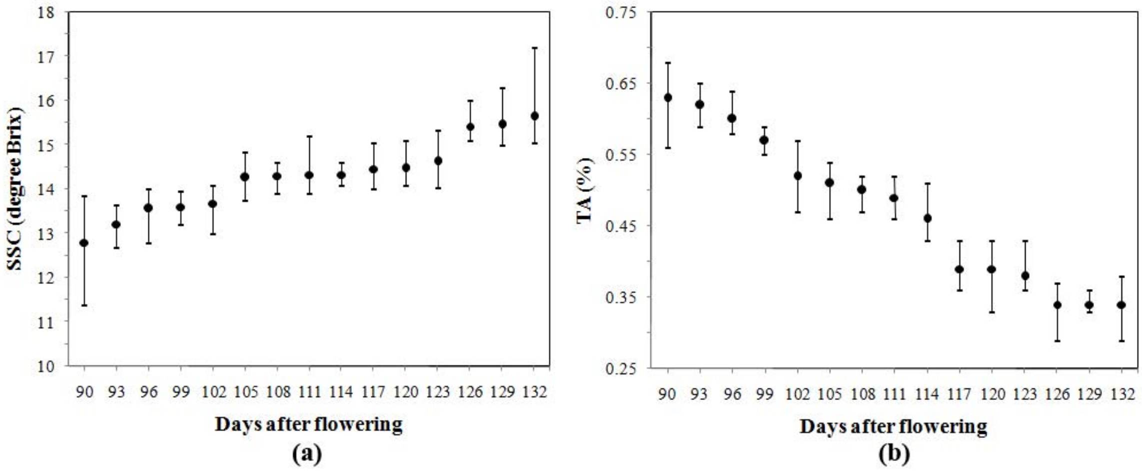

Fig. 2: Internal properties of pomegranate ‘Dentawan variety’ versus days after flowering (a) soluble solids content (SSC) and (b) titratable acidity (TA).

Averaged SSC and TA of pomegranates with days after flowering were calculated as shown in figure 2. Averaged SSC was increased while averaged TA was decreased when increasing of days after flowering. The results showed both averaged SSC and TA trended nearly constant at around 126 days after flowering.

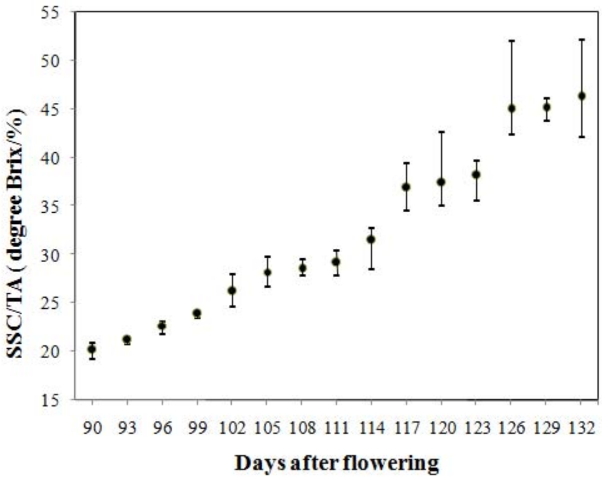

Fig.3: Ratio of soluble solids content and titratable acidity of pomegranate ‘Dentawan variety’ versus days after flowering

In figure 3, averaged brix-acid ratio was calculated related to days after flowering. It showed averaged brix-acid ratio was continuously increased and nearly constant at 126 days after flowering. This result showed that the suitable time for harvesting of pomegranate ‘Dentawan variety’ should be at the day of 126^{th} after flowering. Therefore optimal brix-acid ratio can be used to consider for harvesting time of pomegranates.

In Table 1, pomegranates were divided into two groups. One hundred fruits were used for samples in the training set and fifty ones were used for the test set.

Table 1: Characteristics of training set and test set of pomegranate ‘Dentawan variety’ for statistical analysis.

Sample set	Number of sample	SSC/TA	Max	Min	Averaged	SD value
Training	100	degree Brix/%	52.07	19.33	32.02	8.82
Test	50	degree Brix/%	52.24	19.77	32.12	8.75

The coefficients of multi-variables in the calibration model for brix-acid ratio from multiple linear regression were shown in Table 2. These results showed that density and fruit firmness were important variables of the calibration model for brix-acid ratio. Density was the most effective variable for prediction of maturity index for pomegranate.

Table 2: The coefficients of multiple variables in the calibration model for brix-acid ratio

Variables	unit	Mean	SD	Coefficient
Peel moisture content	%	68.10	4.21	0.71
Sphericity	%	100.80	4.25	0.30
Density	g/cm^3	1.01	0.01	112.94
Fruit firmness	kg	3.54	0.30	-32.28

Table 3: Statistical results obtained from the calibration model for brix-acid ratio.

Model	Number of variables	Training set			Test set		
		N	R	RMSEC	N	R	RMSEP
Brix-acid ratio	4	100	0.85	4.58	50	0.86	4.44

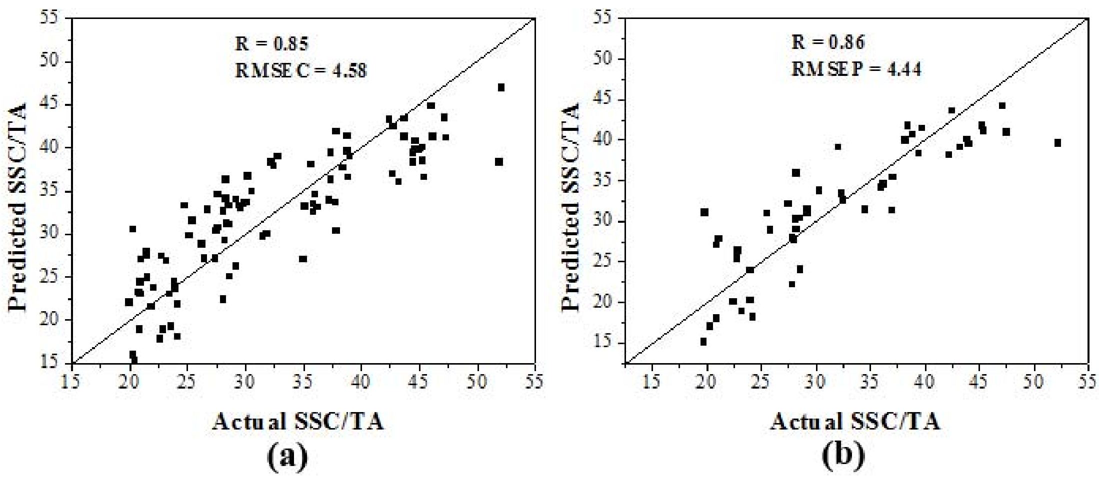

Fig. 4: Scattered plot of actual SSC/TA versus predicted SSC/TA for (a) the training set (b) the test set

In Table 3, the calibration model for brix-acid ratio obtained good statistical results in both of training set and test set (R = 0.85, RMSEC = 4.58 and R = 0.86, RMSEP = 4.44).

The scattered plots of the actual brix-acid ratio against the predicted brix-acid ratio were shown in Fig. 4(a) and Fig. 4(b). It showed that four variables were able to be used to develop the calibration model and obtained good accuracy of brix-acid ratio prediction for pomegranates. Although density and fruit firmness were destructive properties in this research, they could be measured by nondestructive or indirect methods such as NIRS, ultra sonic technique etc. However, the performance of the multivariate model could be improved by using more variables such as lightness, a, b etc. Hence, more variables could be considered to obtain better results in the next research.

4. Conclusion

Physicochemical properties of pomegranate 'Dentawan variety' such as moisture content of peel, sphericity, density and fruit firmness were able to be used to establish the multivariate equation for brix-acid ratio using multiple linear regression method. The performance of the model obtained good results for prediction. These results showed density of pomegranates was the most important variable for the model for brix-acid ratio prediction. Brix-acid ratio of pomegranates is able to use as the maturity index therefore the multivariate model has a good potential to use for farmers to investigate the suitable harvesting time of pomegranates.

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