

*Research Paper*

## **Artificial neural network model for estimating the surface area of fresh guava**

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**Abstract:** In this research, one-hidden-layer feed-forward artificial neural network (ANN) model was developed for estimating surface area of fresh guava. The input parameters of the network were major diameter, intermediate diameter, minor diameter and sphericity while the output of the network was surface area. The performance of the network was demonstrated in mean relative error (MRE) and mean absolute error (MAE) values which were compared with those of simple linear regression models. It was found that the optimum ANN model required 20 nodes. In addition, the lowest MRE and MAE values of the ANN model were 0.05% and 0.12 cm<sup>2</sup> cm<sup>2</sup>, respectively which were found to be lower than those of simple linear regression models.

**Keywords:** artificial neural network, fruit, post-harvest, modelling, ANN, MRE, MAE

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### **Introduction**

Guava (*Psidium guajava* L.) is the most valuable cultivated species of the Myrtaceae family. In Thailand, guava is a popular tropical fruit and it can flower and produce fruit throughout the year. In addition, it is high in dietary fibre and vitamin C. It has been reported that more than 90% of guava is used for fresh consumption while the remainder is processed for guava juice, jams and jelly, pickled guava, dried seasoning guava and guava paste (Thaipong and Boonprakob, 2005).

An understanding of the physical properties of agricultural products is necessary, due to their importance in designing process equipment, i.e., absorption, peeling, drying, extraction, surface coating and chemical reactions. One of the important physical

properties is surface area. The surface area can be used to calculate the storage and shipping space, spray and gas applications, respiration rates, packaging design, etc. In

addition, surface area plays an important role in determining of the amount of coating to be applied to processed food products to extend shelf-life, heat transfer, water vapour, gases and nutrients moving in and out of food products (Eifert *et al.*, 2006). The conventional method used in this research for measuring surface area is the tape method which is considered as the standard method.

Artificial neural networks (ANN) have been inspired by the nervous biological architecture systems which consist of the relative simple systems working in parallel to make quick decisions. An ANN has one input layer containing one or more nodes for each independent variable, one or more hidden layers and one output layer containing one or more nodes for each independent variable (Goncalves *et al.*, 2005). The ANN model is a simple and accurate approximation of a complex process; therefore, the ANN has been very useful as an alternative to replace the conventional methods (Sablani and Rahman, 2003; Poonnoy *et al.*, 2006). Mathematical models which are linear regression equations were used for comparison with the ANN model in order to investigate the appropriate model for determining surface area.

The objective of this research was to develop one-hidden-layer feed-forward artificial neural network (ANN) model for estimating surface area of fresh guava.

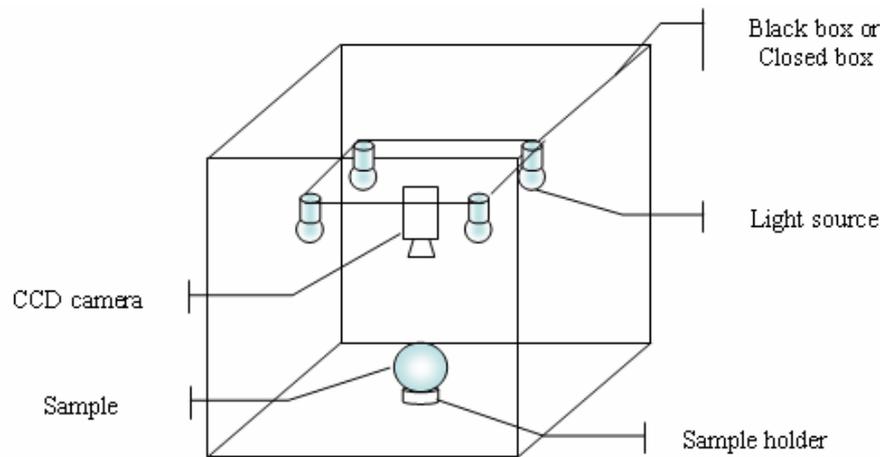
## **Materials and Methods**

### ***Sample Preparation and Surface Area Determination***

Guava samples were purchased from a local market. Surface area determination of fresh guava was performed using the tape method which starts with cutting the tape by a razor knife into several small pieces ranging from 2 to 4 centimeters. Each section of tape was placed all over the surface area of fresh guava, then all sections were removed and placed on a sheet. Following this, a planimeter (Ushikata 360dII) was used to measure all perimeters of these sections to obtain the total surface area of fresh guava.

### ***Diameter Determination using Image Processing***

The machine vision system was applied to obtain the diameter of fresh guava. This system consisted of a light box, a sample holder and CCD camera as shown in Fig 1. Test objects were placed on a sample holder and were held in a fixed position. One each of the top and side views of the object were taken, the objects being turned by hand. The amount of light entering the CCD array of the camera was controlled by pre-setting the white balance with a white paper (Sabliov *et al.*, 2002). The objects were turned in dimensions of major diameter, intermediate diameter and minor diameter by hand. The acquired images were obtained from triggering the CCD camera and a sequence of images recorded in the memory card.



**Figure 1. The system layout.**

### ***Mathematical Model***

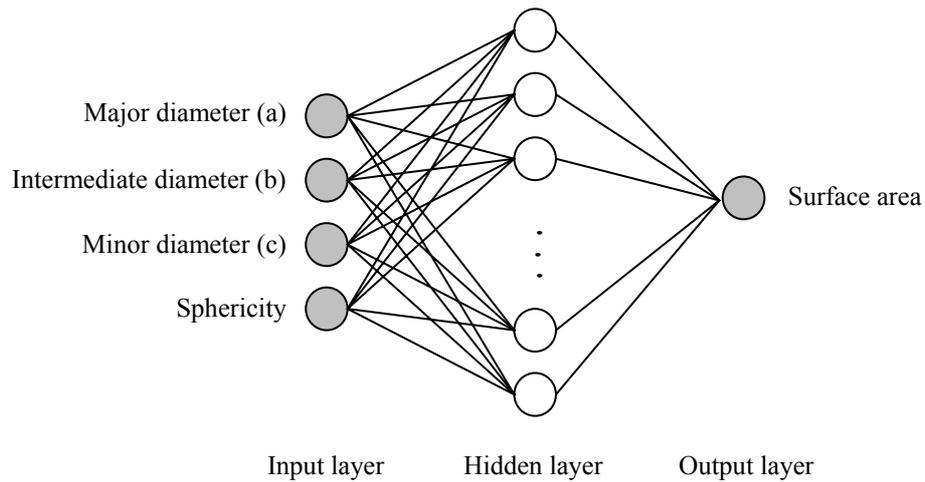
A simple linear regression model was developed and applied to describe the correlations among diameters of agricultural products. The major diameter, intermediate and minor diameter were input parameters. The output was surface area. The simple linear regression equation is shown in Eq. 1.

$$Y = a + bX \quad (1)$$

where, Y is the surface area (cm<sup>2</sup>), a is an intercept, X is the dimension of fresh guava (cm) and b is the slope.

### ***Artificial Neural Network Model***

One-hidden-layer feed-forward artificial neural network model was developed using MATLAB<sup>®</sup> (version 7.0). The input parameters of the network used were major diameter, intermediate diameter, minor diameter and sphericity, while the output parameter of the network was surface area. The network architectures were created with one hidden layer while numbers of nodes in hidden layers ranged from 2 to 30. The node increment used was 2 nodes and the transfer function was logarithmic transfer function. In addition, a linear transfer function, Pureline, was applied in all nodes of the output layer. The architecture network of one-hidden-layer feed-forward artificial neural network model is shown in Fig 2.



**Figure 2. The architecture network of one-hidden-layer feed-forward artificial neural network model.**

### *Selection of Optimal ANN*

The prediction performances of the ANN model were compared using mean relative error (MRE) and mean absolute error (MAE) as expressed in the following equations.

$$MRE = \frac{1}{N} \sum_{i=1}^N \Delta D_R \quad (2)$$

$$MAE = \frac{1}{N} \sum_{i=1}^N \Delta D_A \quad (3)$$

where  $\Delta D_R = |(D_p - D_T) / D_T|$ ,  $\Delta D_A = |D_p - D_T|$ ,  $D_p$  = the predicted output value from ANN model,  $D_T$  = the target output value or experimental output value and  $N$  = the number of samples.

The lowest MRE and MAE values were chosen to obtain the optimal ANN model.

## **Results and Discussion**

### *Mathematical Model*

In this study, the regression equations of each diameter are as shown in Table 1 and simple linear regression plots are shown in Figures 3-5. It was observed that the surface area determination based on the major diameter gave the highest correlation ( $R^2 = 0.871$ ) as compared with the surface area determination based on the intermediate diameter and minor diameter ( $R^2 = 0.813$ , and  $0.642$ , respectively).

**Table 1.** Regression equations of each diameter for determining surface area.

Type of diameter	Number of samples	Equation	R <sup>2</sup>
Major	42	Y = 41.33X – 124.34	0.871
Intermediate	42	Y = 40.39X – 103.37	0.813
Minor	42	Y = 31.01X – 5.55	0.642

Once the correlations of surface area were obtained, the predicted values of surface area from the regression models were compared with those from the conventional method (the tape method). From Table 2, the regression model for predicting surface area based on the major diameter gave the lowest MRE and MAE (0.72% ± 3.95%, 1.83 cm<sup>2</sup> ± 10.25 cm<sup>2</sup>, respectively). The MRE and MAE from the regression models based on intermediate diameter (5.72% ± 5.80%, 14.65 cm<sup>2</sup> ± 14.82 cm<sup>2</sup>, respectively), and minor diameter (15.23% ± 7.13%, 38.97 cm<sup>2</sup> ± 17.50 cm<sup>2</sup>, respectively) are also reported in Table 2. These results show that the regression models using the major diameter to calculate surface area was more accurate than the other regression models which used intermediate diameter and minor diameter to calculate the surface area. This may be because the major diameter is the largest value of all. The value of the major diameter was shared to other dimensions in order to adjust the shape to approximate the real shape of the fruit. Conversely, intermediate and minor diameters were not adequate values to adjust the shape to approximate the fruit. Therefore, the surface area of guava using the major diameter was the most suitable value to calculate surface area, rather than intermediate and minor diameter.

**Table 2.** Prediction error of surface area from the tape method and regression models.

Method	Mean of surface area ± SD (cm <sup>2</sup> )	MRE ± SD (%) (Compared with conventional method)	MAE ± SD (cm <sup>2</sup> ) (Compared with conventional method)
Conventional (Tape method)	255.94 ± 21.06	-	-
Regression (S <sub>a</sub> )	257.77 ± 26.13	0.72 ± 3.95	1.83 ± 10.25
Regression (S <sub>b</sub> )	241.29 ± 27.33	5.72 ± 5.80	14.65 ± 14.82
Regression (S <sub>c</sub> )	216.96 ± 28.30	15.23 ± 7.13	38.97 ± 17.50

S<sub>a</sub> = surface area calculated using major diameter

S<sub>b</sub> = surface area calculated using intermediate diameter

S<sub>c</sub> = surface area calculated using minor diameter

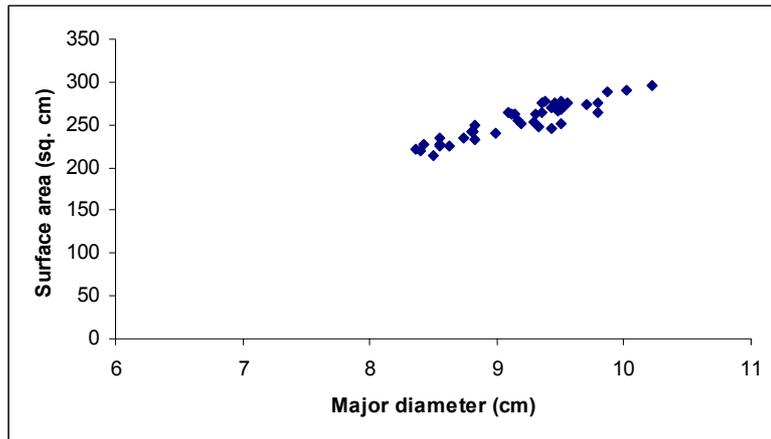


Figure 3. Correlation of major diameter (cm) versus surface area (cm<sup>2</sup>).

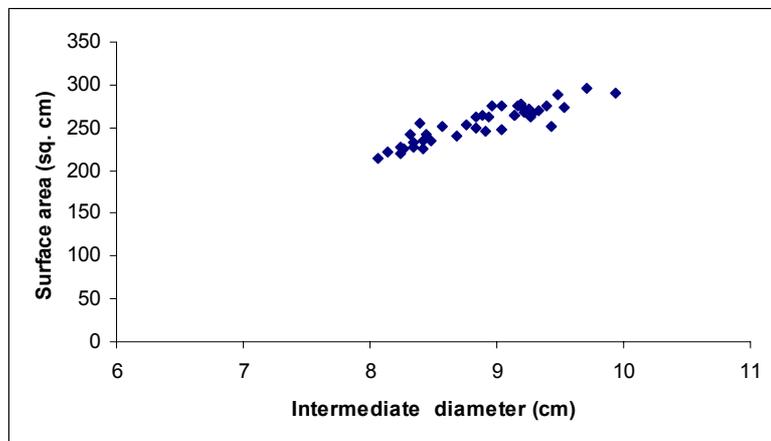


Figure 4. Correlation of intermediate diameter (cm) versus surface area (cm<sup>2</sup>).

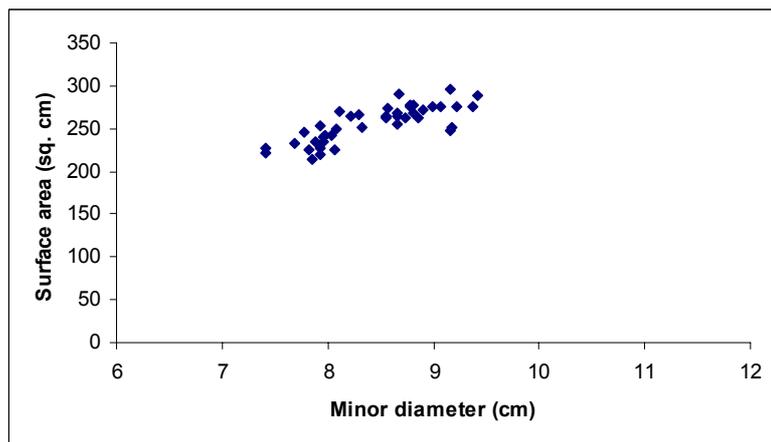


Figure 5. Correlation of minor diameter (cm) versus surface area (cm<sup>2</sup>).

### Artificial Neural Network Model

The 20 nodes of one-hidden-layer artificial neural network were obtained and applied to predict surface area of fresh guava. From the experiment, it was found that the artificial neural network model could predict surface area accurately. Table 3 shows that the ANN model gave the lowest MRE and MAE values (0.15% and 0.39 cm<sup>2</sup>, respectively). These MRE and MAE values were lower than those obtained from the regression models. It is concluded that the developed ANN model may be beneficial for predicting surface area since the ANN model is simple and provides results that are more accurate when compared with the regression method.

**Table 3.** Prediction error of surface area using the tape method and artificial neural network model.

Method	Mean of surface area $\pm$ SD (cm <sup>2</sup> )	MRE $\pm$ SD (%) (Compared with conventional method)	MAE $\pm$ SD (cm <sup>2</sup> ) (Compared with conventional method)
Conventional (Tape method)	251.40 $\pm$ 27.55	-	-
Proposed (ANN)	251.79 $\pm$ 27.83	0.15 $\pm$ 0.26	0.39 $\pm$ 0.66

### Conclusion

In this research an ANN model was developed and compared with the regression models for predicting surface area of fresh guava. The optimal ANN model with 20 nodes of logarithmic transfer function could well predict surface area. It was found that the ANN model gave the lowest MRE and MAE values (0.15% and 0.39 cm<sup>2</sup>, respectively) which were lower than those from the regression models. The MRE and MAE values of the regression models based on major diameter were 0.72% and 1.83 cm<sup>2</sup>, respectively; based on intermediate diameter were 5.72% and 14.65 cm<sup>2</sup>, respectively; and based on minor diameter were 15.23% and 38.97 cm<sup>2</sup>, respectively. Therefore, it could be concluded that the ANN model was a better tool for predicting surface area of fresh guava than the regression models.

### Acknowledgement

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