Mass Modeling of Thailand Varieties Pomelo Fruit (Khao-Nampueng Variety) with Overall Width

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Abstract. *Thailand has exported fresh pomelo fruits to its neighbor country. However, many lack knowledge of the physical characteristics of the important pomelo variety. That is necessary for the design and classification of the grading system. Generally, in the pomelo market, the pomelo fruits are graded according to their size, shape and variety. Usually, fruits are graded based on size observation such as No.1, No.2, No.3 and No.4 while based on whether fruits are properly mature. Manual grading with labor is a common method that pomelo growers graded when they harvest the fruits. This study aimed to find the most suitable model for estimating the pomelo fruit mass of Thailand especially the Khao-Nampueng variety with its physical characteristics. There are not specific studies that have investigated the mass modeling of this fruit variety yet.*

The results recommended that the mass model for overall fruits based on overall pomelo fruit width was the quadratic model: $M = -1.2659X^2 + 221.2X - 1824.1$ with $R^2 = 0.8856$. While the mass model for fruit without peel based on overall pomelo fruit width was also a quadratic model: $M = -13.216X^2 + 496.38X - 3701.1$ with $R^2 = 0.7175$. The predicted models can be useful for the design and classification of grading mechanisms for the Khao-Nampueng variety as the primary measurement before sending them to the market and transportation.

Received by	2 June 2022
Revised by	22 July 2022
Accepted by	22 September 2022

Keywords:

modeling, classification, grading, pomelo mass, pomelo width

1. Introduction

Thailand is the one country in Southeast Asia that has exported fresh pomelo fruits to its neighbor country such as Laos, Meayma, Vietnam, Malaysia, Indonesia, and especially China. Pomelo is a general economic fruit crop of Nakhon Pathom province. The main production area is located in Sam Phran and Nakhon Chi Sri districts. The main variety is “Thong Dee” and “Khao-Nampueng” [1]. Khao-Nampueng variety is commonly consumed by Thai people because there is a good taste, sweet with a slight sourness, without bitterness and tingling. The sweetness is about 10 degrees Brix and seedless [2].

Physical attributes of agricultural fruit products are graded based on their size, shape and weight of that ones. The knowledge of all these characteristics and their relationships can be applied to any form of handling, sorting, grading or packaging process [3]. Consumer decision in purchasing of Pomelo fruit is physical characteristics such as the similarly shaped fruits and the same mass. In addition, grading based on the fruit mass can help to reduce packaging and transportation costs, and also offer the most suitable packaging design [4].

Generally, in the pomelo market, the pomelo fruits are graded according to their size, shape and variety. Usually, fruits are graded based on size observation such as No.1, No.2, No.3 and No.4 while based on whether fruits are properly mature. Manual grading with labor is a common method that pomelo growers graded when they harvest the fruits because this method is low cost. However, manual grading requires a high level of experience and expertise. It takes a lot of practice to be accepted by farmers and merchants. Including the fact that farmers do not have much choice. That is why research in the field of pomelo grading is interesting because it can eliminate human error during the process. A more efficient and accurate grading system has therefore been proposed that enhances classification success or speeds up the process [5], [6].

Currently, most of the machines for sorting fruit size are industrial machines, which are expensive and complicated to use because that is difficult to use in pomelo fields. Therefore, new innovation should be studied to build a machine for fruit sorting by weight of fruit according to the variety of a normal shape. Consequently, it is important to study the relationship between mass and physical characteristics, which will contribute to the accuracy of the automatic classification of fruits [7].

Several pieces of research had been studied in the case of mass modeling of fruits with some physical characteristics. For example, The report of Seyedabadia et al. recommended dimensional mass model based on

cantaloupe fruits that width (W) was as nonlinear form as $M= 2.614W^{2.391}$, $R^2 = 0.957$, SSE = 0.118 [8]. Keshavarzpour and Rashidi offered the model to predict the apple mass based on outer dimensions, the mass model based on geometrical mean diameter (GMD) as M = -168.5 + 47.01 GMD with $R^2 = 0.77$ was preferred [9]. Moreover, Shahbazi and Rahmati offered a model for predicting the mass of grapefruit based on the fruit dimensional characteristics was Quadratic form based on the width of fruit as $M = 490.564 - 13.593W + 0.131W^2$, R2=0.919 [10]. In addition, they also recommended who want to design and development of persimmon fruits grading with the mass modeling based on length (L) of fruit as $M = 356.171 - 12.664L + 0.136L^2$, $R^2 = 0.960$ [11]. Sivabalan et al. (2019) presented the most appropriate mass modeling of coconut was concluded to be the one done with the minor diameter of the coconut (c). The modeling based on the projected area also had a good correlation with the mass of the coconut as $M = 98.877c - 421.82$, $R^2 = 0.4924$ [12]. Rashidi et al. recommended the egg mass model based on geometrical mean diameter as M = - 24.42 + 1.67 GMD with $R^2 = 0.595$ and the mass model based on length (L) and diameter (D) as M = - 27.81 + 0.69 L + 1.01 D with $R^2 = 0.619$ [13].

This study aimed to find the most suitable model for estimating the pomelo fruit mass of Thailand especially the Khao-Nampueng variety with its physical characteristics, which there are no specific studies that have looked at the mass modeling on this fruit variety yet. This information can be useful for the design and classification of grading mechanisms for Khao-Nampueng variety research that will do in the future.

2. Materials and Methods

Freshly harvested pomelo (Khao-Nampueng variety, KNP) fruits were used in this study bought from Nakhon Pathom province Thailand, during the period time of April - May 2022. 40 KNP fruits were randomly selected and checked the physical properties in the field. Selected samples had intact shells and an unmistakable appearance. The selected fruit was weighed not to exceed 12 hours after harvesting to prevent as much of a natural weight loss problem as possible. The data collection process did begin with weighing the fresh fruit. Then the fruits were cut in half vertically to measure the overall width (OW) as shown in Fig.1 and then the shell thickness was peeled off and weighed the fruits without the peel. Both weigh were carried out using a scale with a resolution of 0.01 kg. Then the OW was measured with a ruler along with a resolution of 0.1 cm.

Five model terms such as Linear, Quadratic, Power, Exponential and Logarithmic models were used for mass predication of KNP fruits based on measured physical properties as represented in the following Eq. (1) to Eq. (5) [14]:

$$M = b_0 + b_1 X \quad (1)$$

Fig. 1 Dimensional overall width (OW) of Khao-Nampueng variety.

$$M = b_0 + b_1 X + b_2 X^2 \quad (2)$$

$$M = b_0 X^{b_1} \quad (3)$$

$$M = b_0 e^{b_1 X} \quad (4)$$

$$M = -b_0 + b_1 \ln(X) \quad (5)$$

where, M is mass (g); X is the value of an independent (overall width) parameter which want to find its relationship with mass, and b_0, b_1, and b_2 are curve fitting parameters that are different in each equation. One evaluation of the goodness of proper is the value of the coefficient of determination (R^2). For regression equations in general, the nearer R^2 is to 1.00 indicated the better the reasonable [15]. Statistical Tool for Agricultural Research (STAR) software was used to analyze the data and determine regression models between the overall width.

3. Results and Discussion

3.1 Physical Properties of KNP Fruits

A summary of the physical properties of studied KNP fruits was shown in Table 1. These properties were found at specific moisture contents of about 80.33% wet basis. As seen in Table 1, all properties considered in this study, which were on the mass of KNP fruit that was found to be statistically significant at 1% probability level. According to the results, the mean values of each property which were studied in this research consisted of overall width, weight with peel, the weight of peel and weight without peel, which was 14.44 cm, 1,103.50 g, 410.13 g and 693.38 g, respectively.

Properties	Value			Significant level
	Average	Maximum	Minimum	
overall width (cm)	14.44	17.80	12.70	P<0.01
circumference (in)	17.84	22.00	15.7	P<0.01
weigh with peel (g)	1,103.50	1,640	750	P<0.01
weigh of peel (g)	410.13	730	260	P<0.01
weight without peel (g)	693.38	970	360	P<0.01

Table 1 Some physical properties of studied KNP fruits

3.2 Overall Fruit Mass Modeling based on Dimensions

Fig. 2 shows nonlinear and linear models of overall fruit mass based on overall pomelo fruit width. In comparing the R^2 value, the quadratic equation showed the best model that is $M = -1.2659X^2 + 221.2X - 1824.1$ with $R^2 = 0.8856$, in which R^2 is near to 1. In terms of other four models, the linear equation was $M = 183.7x - 1548.2$ with $R^2 = 0.8855$. The logarithmic equation was $M = 2698.4\ln(X) - 6092.2$ with $R^2 = 0.8837$. The power equation was $M = 1.8519X^{2.389}$ with $R^2 = 0.879$. The exponential equation was $M = 104.75e^{0.1618X}$ with $R^2 = 0.8655$. As the results of R^2, it indicated that regression is quite similar of around 0.88. Therefore, it can be seen that the quadratic equation has the proper model that can use for a model of overall KNP fruit mass based on overall pomelo fruit width in consisting with Seyedabadi et al. [8]. The results found that the equation for cantaloupe mass was based on fruit width. And similar to the model offered by Salihah et al. [16] which indicated the mass modeling of Malaysian varieties of pomelo fruit.

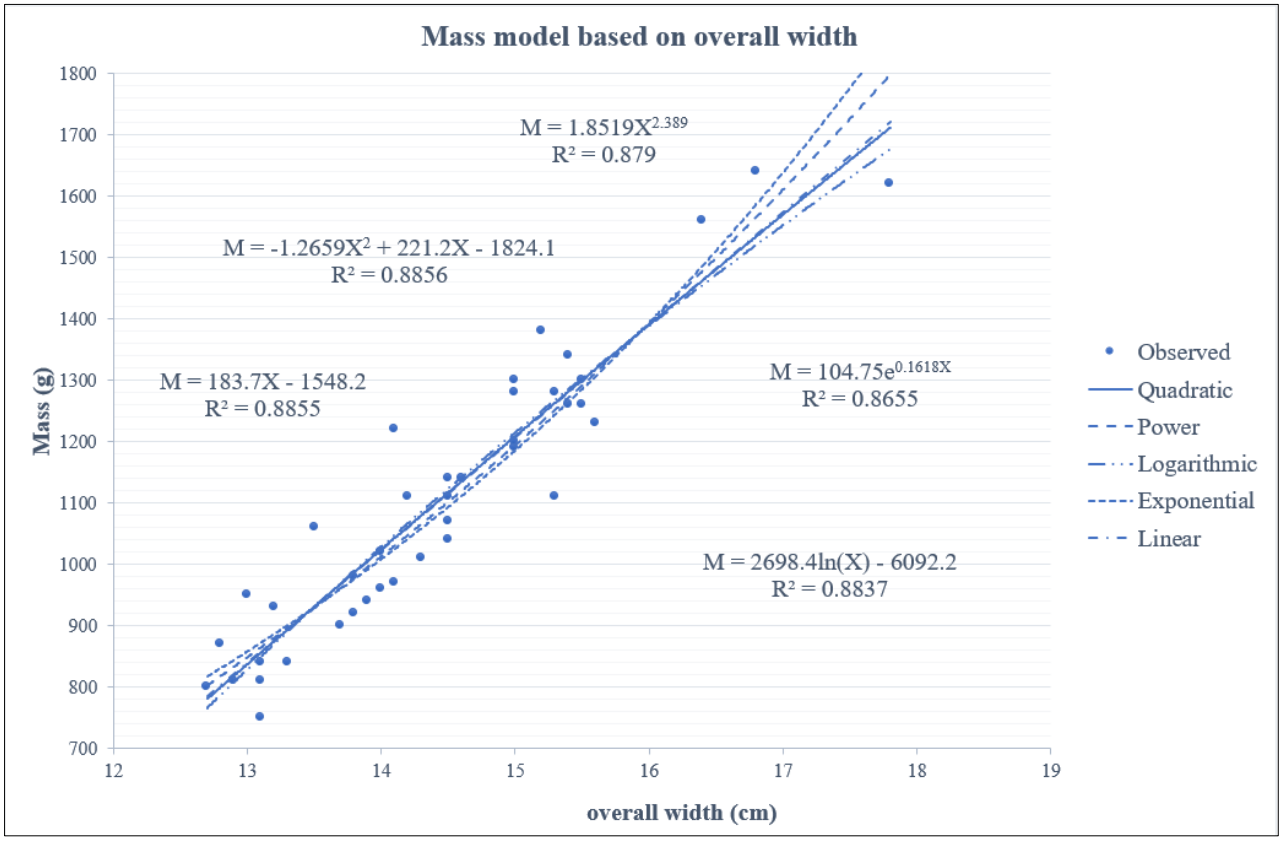

Fig. 2 Nonlinear and linear models of overall fruit mass based on overall pomelo fruit width.

3.3 Fruit without Peel Mass Modeling based on Dimensions

Fig. 3 shows nonlinear and linear models of fruit without peel mass based on overall pomelo fruit width. In comparison, the R^2 value of the quadratic equation illustrated the best model as the same with overall fruit mass modeling based on dimensions equal to $M = -13.216X^2 + 496.38X - 3701.1$ with $R^2 = 0.7175$ (close to 1). Another model, such as the logarithmic equation was $M = 1556.2\ln(X) - 3456.4$ with $R^2 = 0.7021$. The linear equation was $M = 104.89x - 820.78$ with $R^2 = 0.6898$. The power equation was $M = 1.3885X^{2.3213}$ with $R^2 = 0.6668$. The exponential equation was $M = 71.489e^{0.1558X}$ with $R^2 = 0.643$. Again, it can be concluded that the quadratic equation has the appropriate model that can use for the model of KNP fruit without peel mass based on overall pomelo fruit width. It also corresponds with Seyedabadi et al. [8] who presented the equation for cantaloupe mass based on fruit width with a similar to the model offered by Salihah et al. [16], of the mass modeling of Malaysian varieties of pomelo fruit.

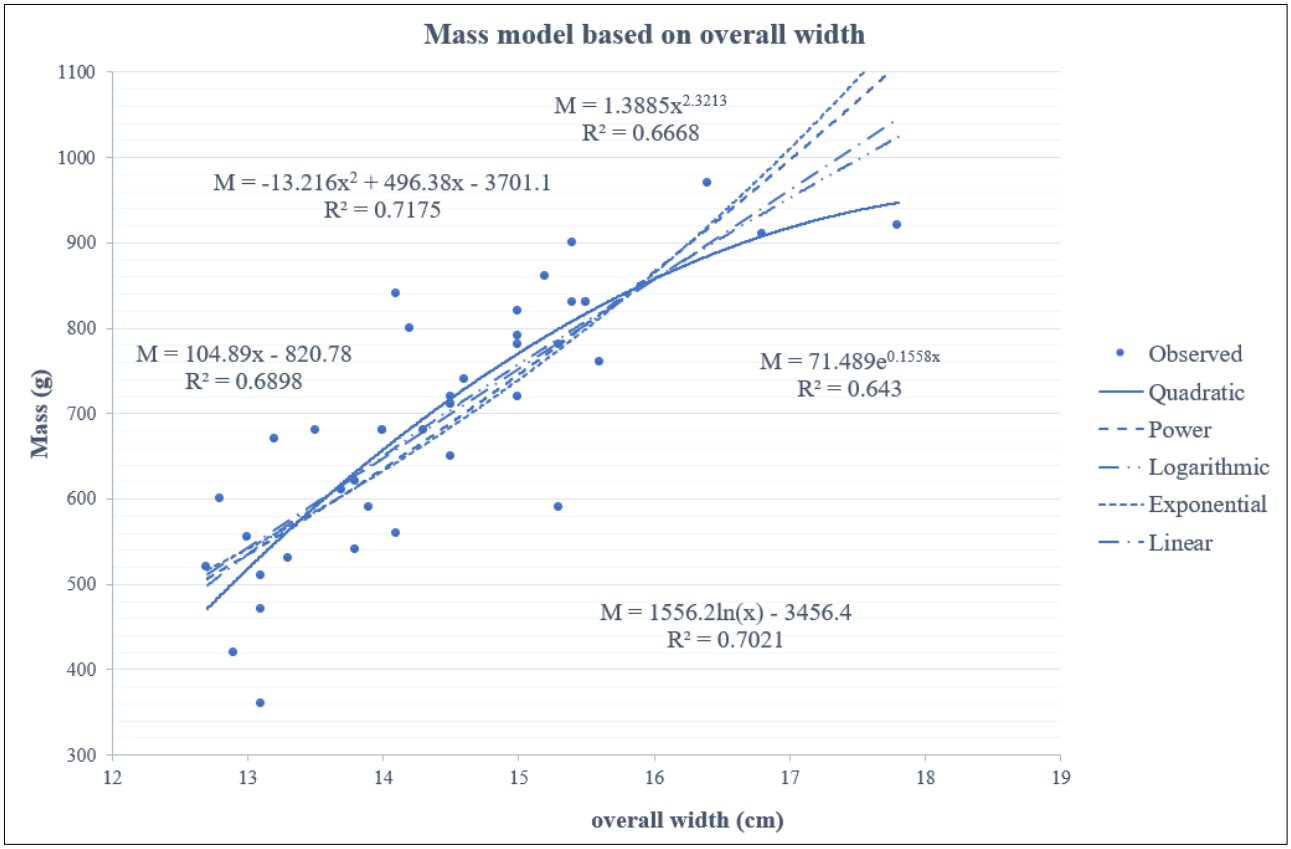

Fig. 3 Nonlinear and linear models of fruit without peel mass based on overall pomelo fruit width.

However, when the pomelo grower classifies and grades, they used a classification with the circumference of a KNP variety fruit. which can be calculated from the overall width. On the other hand, calculating the weight of the quadratic equation in overall width is difficult. Therefore, in this case, it is easier to use linear equations which was M = 183.7x - 1548.2 (R^2 = 0.8855) due to the values of R^2 were not much different with the quadratic equation (M = -1.2659X^2 + 221.2X - 1824.1 (R^2 = 0.8856)). This information can be useful for the design and classification of grading mechanisms for the Khao-Nampueng variety.

4. Conclusion

The mass models for the pomelo KNP variety were introduced in this research. The main obtained results are as follows:

- The recommended mass model for overall fruits based on overall pomelo fruit width was as quadratic model: M = -1.2659X^2 + 221.2X - 1824.1 with R^2 = 0.8856.
- The recommended mass model for fruit without peel based on overall pomelo fruit width was a quadratic model: M = -13.216X^2 + 496.38X – 3701.1 with R^2 = 0.7175.
- In some cases in the real field, the linear model, which is M = 183.7x - 1548.2 with R^2 = 0.8855, is an appropriate equation more than a quadratic equation.
- The predicted models can be useful for the design and classification of grading mechanisms for the Khao-Nampueng variety as the primary measurement.

Acknowledgments

The authors appreciated financial support from Kasetsart University Kamphaeng Saen Campus and technical assistance from the Department of Farm Mechanics Faculty of Agriculture at Kamphaeng Saen.

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