Quality Prediction of Mangosteen During Storage Using Artificial Neural Network

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ABSTRACT

In this research, multilayer perceptron neural network with back propagation algorithm was applied to predict mangosteen quality during storage at the most appropriate pre-storage conditions which performed the longest storage period. Each condition was combination of three pre-storage treatments involved pre-cooling at 20^{o}C, bee waxing concentration of 6% and strecth film single wrapping. To decide which combination gave best fruit quality on their prolonged storage, it was investigated by panelist preference used hedonic scale. Based on the experiment, pre-cooling at 20^{o}C followed by bee waxing concentration of 6% and strecth film single wrapping provided minimum quality changes over 40d. Those optimum data combination was used to predict quality changes during storage using neural network. The model was successfully trained used network architecture at 30,000 iterations; 14 nodes in hidden layer; learning rate constant 0.8 and momentum 0.7. It was represented by coefficient correlation (R^2) closed to 1 (more than 0.99) for each parameter, indicated that model was good to memorize data yet R^2 validation was poor. It defined that network architecture developed quality prediction model had not appropriated yet to predict mangosteen quality during storage using new data variants.

Keywords: *Quality prediction, Mangosteen, cold storage, artificial neural network*

1. INTRODUCTION

Mangosteen, The Queen of Fruit, has became one of the most popular tropical fruit in the world because of its exotically in shape, taste and color. The largest importer market of mangosteen from Indonesia are China (44.4%), Hongkong (35.47%), Singapore (8.54%), expand to Middle Eastern (6.14%) and Europe (0.39%). In Indonesia, mangosteen has become the main exported fruit commodity. Meanwhile, it is reported that a big shrinkage occurred in exported fruit which is stated by only 35%-40% accepted by importer country.

Fruits are perishable product since after harvested they still need energy for their existence as a living organism. Horticulture commodity still requires energy and substrate to metabolize cell even it has been attached from the tree. It is important to gain information about the quality development during distribution, shipment or due to await good market and reasonable price, but it also considered to consumer preference. Many fruit post harvest researches reported that storage accomplished with waxing enable to extend self life with minimum quality degeneration. Optimation of storage condition for each product has been widely studied with various treatments and methods.

Pre-cooling, waxing and coating, generally, as a means to remove heat field induced during harvesting to slow respiration, maintaining fruit to be more susceptible to microorganism attack and extend self life (Pantastico, 1986). Stretch film coating produced better quality than coating used polypropylene at 15^{o}C and LDPE at 5^{o}C (Lili, 1997). Single wrapping on mangosteen fruit could delay respiration rate by modifying internal atmosphere where during fruit development, decreasing O_2 concentration and increasing CO_2 concentration occurred. This also as water loss barrier especially on its shell (Utama *et al.*, 2000). All of treatments above should be cost efficient to maximize profit and minimize product deterioration. According to their availability to await a good market condition and supply good product, it should be developed a good technical post harvest handling. In this case, a controlled storage mechanism must be established in order to produce best product quality in desired term storage. Due to this, predicting product quality during storage is important to control quality changes.

Quality changes are dependent to storage and quality condition before its present time which has non-linear behavior and mathematical complexity to be represented. Recently, Artificial Neural Networks (ANN), which is heuristic models, is recognized as good tools for dynamic modeling. ANN modeling methods do not require parameters of physical models; have an ability to learn from experimental data and are capable to handle simple to complex systems with nonlinearities and interactions between decision variables (Lertworasirikul & Tipsuwan, 2008). Artificial Neural Network (ANN) has been applied to various aspects of predicting, modeling, clustering and recognizing pattern in a complex problem with high accuracy and generalization ability than regression linear method. In agricultural studies, it has been applied in cow feeding classification (Suroso *et al.*, 1999) and white crystal sugar prediction (Silvia, 2007).

This research was aimed to gain information of pre-storage treatment which enables to extend self life and developed mangosteen quality prediction during its storage.

2. MATERIAL AND METHODS

2.1 Research Material

The material of this study was mangosteen fruit grown in Wanayasa, Purwakarta district, Indonesia with maturity induce at 4-5 (CODEX, 2005; SNI, 2009). Fruits are edible, ripe stage when the skin at reddish purple, no latex remains on the skin and the flesh segments are separately easily from the skin. Back propagation neural algorithm was applied to predict mangosteen quality during storage (Rudiyanto, 2003).

2.2 Pre-storage Condition

Fruits were packaged into cartoon box placed at ambient temperature and transported to laboratory, Bogor right after harvested for four hours. Pre-storage treatments were carried out by pre-cooling, waxing and wrapping used single stretch film (Fig. 1) at 5^{o}C until fruits were not accepted by panelist.

Waxing was conducted to all treatments by immersing sample into bee wax solution of 6% concentration for 30 s and then to be drained off used blower for 3 min. 1 l wax emulsion of 6% was made by diluting 1 l of wax emulsion 12% in 1 l aqueous. 12% bee wax emulsion was made by mixing hot liquid bee wax 120 g, olead acid and amintryethanol 40 g and water 820 g (Suyanti, 1993). Coating treatment was conducted by using single stretch film wrapping. Each sample from three treatments were placed into chamber volume 3300 ml and stored at 5°C.

2.3 Quality Assessment and Hedonic Evaluation

Respiration rate was measured using Shimadzu analyze gaseous and periodically read every 3h during storage. SSC was measured using ATAGO digital refractometer stated by °Brix. Fruit firmness was measured using Rheometer CR-300, on mode set up 20, maximum load 10 kg, vertical pericarp surface 10 mm and pin diameter 5mm on 3 horizontal circumference points. Weight loss was measured using digital scale to determine the initial and the final weight in each day. Color was measured by applying image processing method. Mangosteen image was captured by Kodak Easy Share C613, captured distance at 18 cm from object, light intensity 2 lux, image resolution 800 x 600 pixels with light intensity level of RGB 256. Then, RGB was converted in to L, a*, b* value (Syaefullah et al, 2007). Each quality properties periodically measured every 3d. Hedonic test was conducted by 10 panelists who like mangosteen to rate the peel color, flesh color, texture, flavor and overall attributes of mangosteen using a seven-points hedonic scale (1 indicated very dislike to 7 indicated very like, and 4 indicated neutral), measured on day 1; 21; 30 and 40.

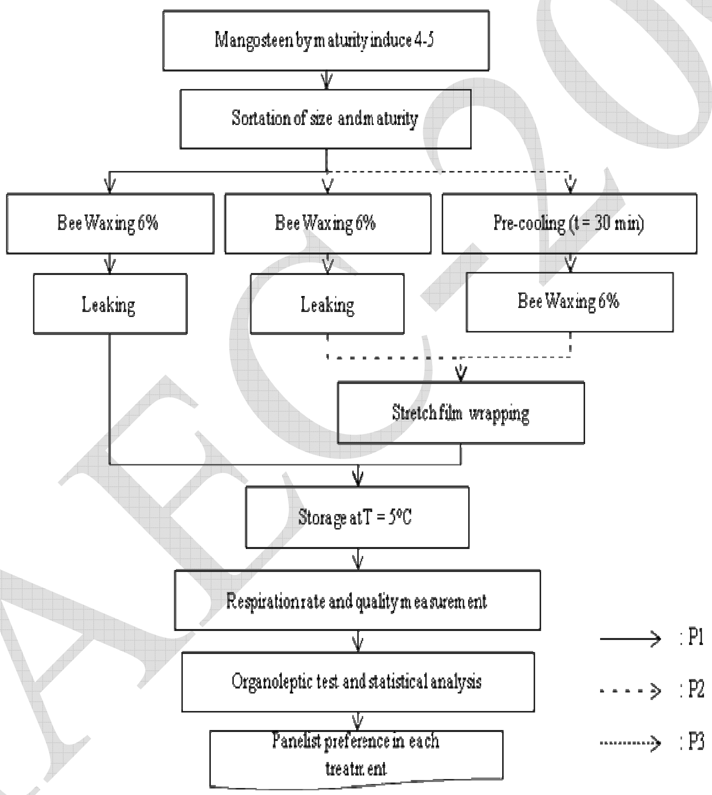


Fig. 1 Flow chart experiment of mangosteen pre-storage treatments (Mahmudah, 2008)

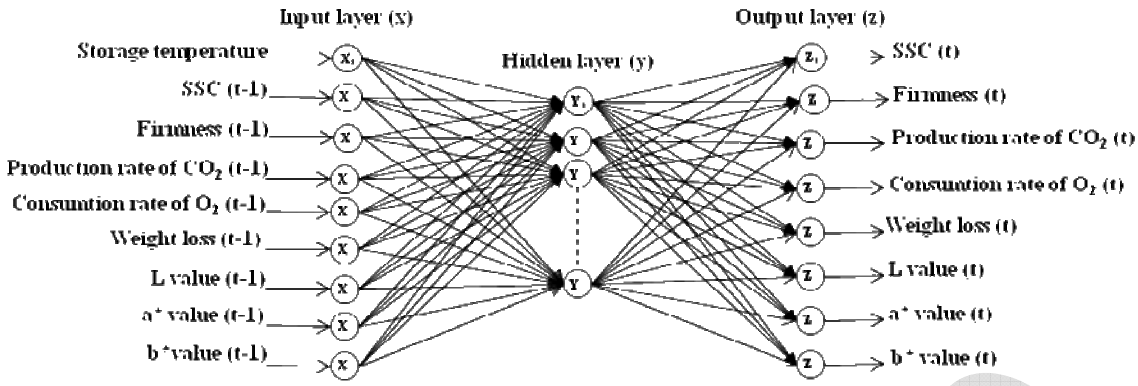


Fig. 2. Neural network to predict mangosteen quality during storage

2.4 Statistics

Single factorial completely randomized design was developed to examine three treatments (Gomez & Gomez, 1995), those were, P1: waxing at 6% concentration; P2: waxing at 6% concentration followed by stretch single wrapping; P3: pre-cooling, waxing at 6% concentration followed by stretch single wrapping. Each experiment was repeated twice for each treatment. Data were analyzed by ANOVA at α 0.05 then followed by Duncan Multiple Range Tests (DMRT).

2.5 Quality Prediction

Multilayer back propagation algorithm with one hidden layer and time delay neural network type was applied to predict quality of mangosteen during storage. Input layer represent storage period and quality parameter at (t-1), output layer represent storage period at (t) while hidden layer correlate input and output layer. Network architecture optimation defined by error closed to 0, conducted by trial error iteration on fixed architecture comprised minimum units of hidden layer, constantan learning rate 0.8 and momentum 0.7. Minimum nodes of hidden layer defined by Skapura (1996) formula (Equation 1) in Indrawanto *et al.* (2007).

$$n_h = \frac{1}{2}(n_i + n_o) + \sqrt{n_{dt}} \qquad \text{(Equation 1)}$$

Whereas:

n_h: minimum number of hidden layer nodes; ni: number of input layer nodes; n_o: number of output layer nodes and n_{dt}: number of data training.

Training was stopped when target error 0.0001 had been obtained. Neural network model which has error value less than 0.01 is appropriate to memorize data characteristic (Hermawan, 2006). Network performance was represented by coefficient correlation (R^2) between prediction output and actual output from observation (Hasbullah & Suhardiyanto, 2006) and it was calculated at iteration which obtained target error.

3. RESULT AND DISCUSSION

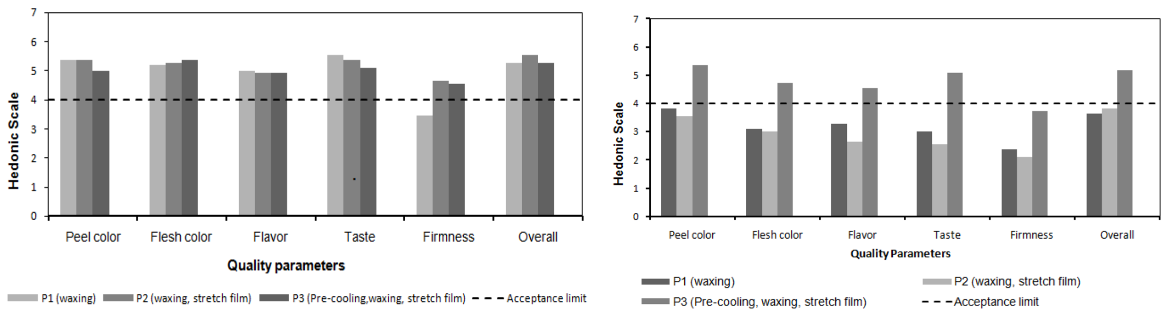
3.1 Pre-storage conditions

In this research, hedonic score which defined fruits consumer acceptance was determined by score higher than critical shelf life which stated by score 4. Less than 4 were no longer accepted to be consumed. Based on analytical statistic, there haven't seen significant relation between treatments and quality properties at day 30, except for overall properties. On day 30, all fruits quality properties in all treatments were still accepted except P1 for firmness quality (Fig. 3a). On day 40, it was seen that treatments were significant related to peel color, flesh color, firmness, flavor and overall. Based on DMRT, P3 was significantly different to other treatments on day 40 and also performed acceptance score for each hedonic attributes higher than other treatments. Generally, P3 performed less quality changes which are shown by Table 1.

Table 1 Quality value in each parameter on day 30 and day 40

Storage period (day)	SSC (°brix)			Fimness (kgf)			L value			a* value			b* value		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
30	18,85	19,50	19,10	3,61	1,26	3,11	31,70	31,73	31,71	7,90	8,70	10,47	-2,53	-1,87	-1,11
40	18,40	18,00	18,47	2,81	3,29	1,95	31,76	31,47	31,44	8,66	9,31	8,76	-1,70	-3,40	-3,87

Table 1 showed that P3 was the most appropriate method to extend shelf life, while the other treatments were only appropriate to extend shelf life up to 30d. Pre-cooling enabled to give positive effect to mangosteen quality. Pre-cooling at 20°C then stored at 5°C had the longest shelf life and enabled to preserve the taste and flavor of mangosteen fruit (Ramadhan, 2003).



(a) 30 days (b) 40 days

Fig. 3 Panelist hedonic score during storage

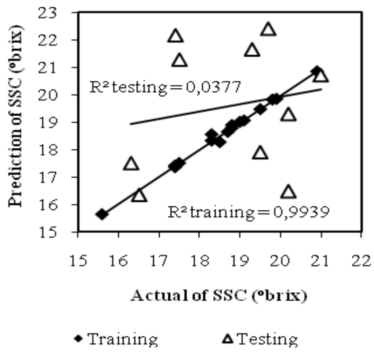
During storage, the lowest hedonic score was occurred at firmness quality. In mangosteen, chilling injury symptoms appeared by peel hardening. Fruit pericarp hardening physiologically occurred after maturity development, which defined by climacteric phase along with high hydration (Tongdee & Sawanagul, 1989 in Sarjana, 2000). The hardening of pericarp was developed by the increasing of pericarp firmness and lignin contents and the decreasing of total phenolics (Dangcham *et al*, 2008).

3.2 Quality prediction

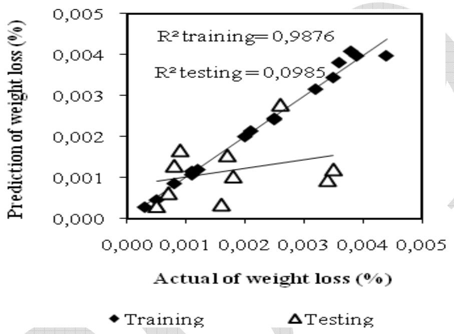
Fresh fruit storage method involved pre-cooling treatment at 20°C folowed by bee waxing concentration of 6% and stretch film single wrapping enabled to extend shelf life at the longest storage period with minimum quality changes and highest hedonic score. Due to this, quality changes data during storage used as input data to predict mangosteen quality.

During training process, there was decreasing error upon increasing iteration where at iteration 30,000 errors 0.0001 was obtained. Insignificant decreasing error were occurred during iteration 1,000; 10,000 and 30,000 (data not shown). Fig. 4 showed R^2 training which had value closed to 1 that described network good to recognize and memorize input data. On the contrary, R^2 validation was closed to 0 meant that network was poor to generalize input data. Thus, this network model couldn't be used to determine the mangosteen product quality during storage under pre-cooling, bee waxing and single film wrapping treatments.

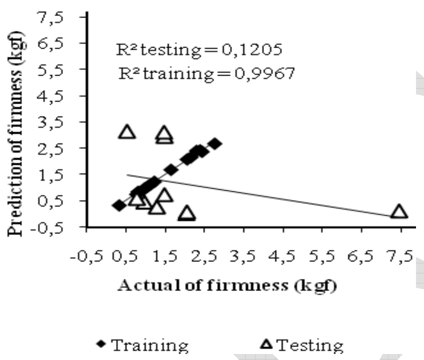
That pattern could be occurred when data set used was too small that caused quality changes pattern were not represented. Higher input data used impact to more data combination developed and caused prediction output closed to target value. Using 2,000 training set data and 500 testing set data, back propagation gradient descent with momentum, 20 number nodes of hidden layer, normalization input method with range value closed to 0 and standard deviation 1 could give accuration of validation 81.4% in predicting quality of edamame (Soedibyo et al, 2006). Based on actual data used in training and testing, it showed that standard deviation on testing were higher that consequently affected R^2. Standard deviation indicated deviation value to homogenous data; higher value influenced weighted data take more time and difficulties to identify data characteristic.



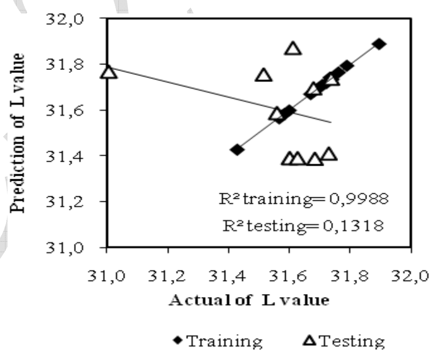
(a) Soluble solid content



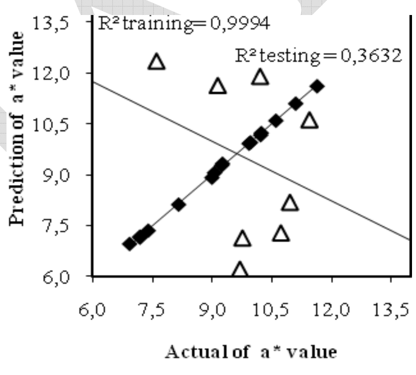
(b) Weight loss



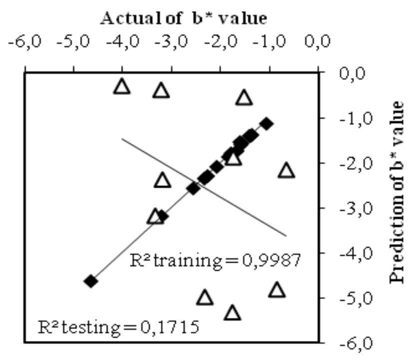
(c) Firmness



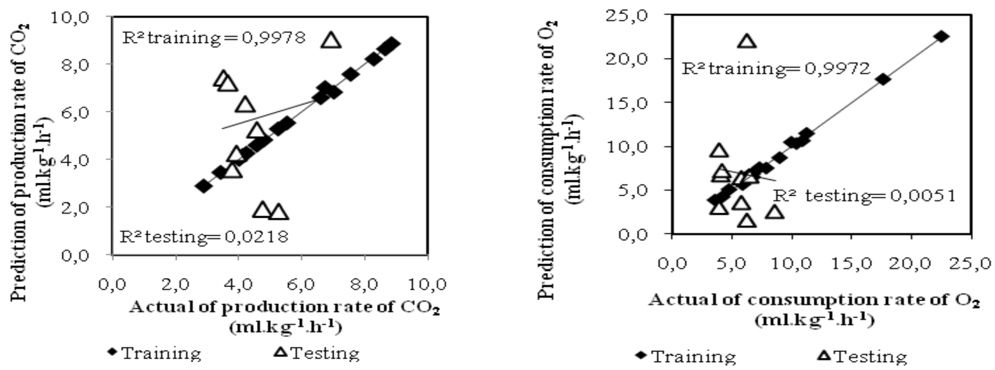
(d) L value



(e) a* value



(f) b* value



(g) Production rate of CO_2 (h) Consumption rate of O_2

Figure 4. Correlation of actual output and prediction output in each quality parameter

Decreasing error could be obtained by increasing training, but excessively iteration (over fitting) caused network couldn't recognize pattern characteristic yet network was enforced to develop weighted value closed to target value. This caused imbalance between memorization and generalization performance (Puspitaningrum, 2006). To avoid over fitting, an early stopping technique can be used (Meng, Y & Lin, B, 2008). To meet the requirement of the early stopping technique in predictive performance, training data (90% from entire data) is divided randomly into training subset (90%) and validating subset (10%).

The strength of a good ANN model is its ability to generalize the previously unseen cases, largely dependent on the quality of the data used in training; the more representative of the problem domain data are the better the generalization. A drawback of using ANN is the largely trial and error nature of finding the best network structure and determining the optimum values of any parameter associated with the chosen training algorithm by varying the number of hidden layers and the number of nodes within each layer, as well as controlling the learning rate and momentum parameters of the back propagation algorithm as training proceeds (Bryant and Shreeve, 2002).

4. CONCLUSION

Pre-storage condition with pre-cooling at 20^{o}C; waxing concentration 6% and stretch film coating could extend shelf life up to 40 days with the best panelist preferences. Network developed had not been appropriate yet to predict mangosteen quality during storage. It had a good performance of memorizing but not to generalize new input data.

5. ACKNOWLEDGEMENT

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