Neural Network Model for Predicting and Classifying Exotic Tropical Fruits Based on Its Maturity and Ripeness

H.K. Purwadaria, I.W. Budiastra, A. Rejo, D.A. Nasution

Department of Mechanical and Biosystem Engineering, Bogor Agricultural University (IPB), Bogor, Indonesia (tpphp@indo.net.id)

Abstract

Durian and mangosteen are exotic tropical fruits of great economic value, however the fruit physical configuration make them difficult to manually predict their internal quality from outside. The objective of this study was to develop neural network model (NNM) to predict the maturity and ripeness of the fruits, and to classify the fruits into various grades. The NNM was developed using inputs from the relationship of ultrasonic characteristics (Mo-zero moment power, ultrasonic wave velocity, attenuation coefficient, and power spectral density) from the non-destructive evaluation, and physico-chemical parameters of the fruits from the lab analysis (hardness, total soluble solid, moisture content and total sugar). The results indicated that various NNM were required to be applied in detecting wholesome fruits from defect ones, and in classifying the fruits based on maturity, ripeness, and taste. The NNM has demonstrated capability of using the ultrasonic characteristics of durian and mangosteen fruits to detect their physico-chemical properties, to distinguish wholesome fruits from the defect ones, and to classify the fruits based on their maturity, ripeness, and taste. More effective NNM combining some or all stages of the model run was recommended to be pursued in the future. Fruit samples from different year and location would be tested to get more perfect model and results.

Keywords: NNM, internal quality assurance, durian, mangosteen, ultrasonic method

Introduction

Durian (Durio zibethinus Rumph. ex Murray) and mangosteen (Garcinia mangostana L) are exotic tropical fruits and of great economic value in Indonesia. Production of durian reached 595 thousand tons, and mangosteen 113 thousand tons in 2007. Furthermore, mangosteen has been the number one fruit export value so far amounting to 3.6 million USD in 2006. Durian, named as the king of fruit, is oval, and has width diameter of 15 – 30 cm, a skin thickness around 1.0-1.5 cm, spiky all over the surface, and internally segmented into 4-6 parts. Mangosteen, named the queen of fruit, is round, and has diameter of 6 – 7 cm, a fleshy pericarp of 0.8 cm, internally consist of 4-7 fingers, and commonly harvested at firm condition that only change slightly into softer texture when ripened. Due to their configuration and physical nature, their maturity, ripeness, and defects are difficult to detect and visualize from outside the fruits. Commonly, customers try at best to smell and to listen to the knocking noise of the durian skin, and to squeeze the mangosteen a little. However, the result is often disappointing to a level of 40 -50 % bad quality.

Evaluation to predict the internal translucent flesh disorder in intact mangosteen fruit by using short wavelength near infrared (SW-NIR) transmittance spectroscopy found that the hardening pericarp disorder influenced the accuracy of the classification [1]. Ultrasonic had been used for non-destructive quality evaluation of avocados and mangoes [2] and [3], and durian [4]. The developed system provided the assessment of some transmission parameters which had quantitative relations with the maturity, and hardness of the fruits, but not for the fruit ripeness and defects. Quantitative relations were developed to describe the linkage between ultrasonic parameters and the maturity, hardness and other quality-related properties in mango and avocado fruits. To ensure the internal prime quality for the consumer, ultrasonic method is considered the best since others do not give satisfied result such as NIR method. The attenuation of the ultrasonic waves, transmitted through the peel and the attached fruit tissue, is expected
to change as a result of the progressive ripening and change of pericarp texture due to physical defects of 
the fruit during the fruiting season and in the course of storage. 
Data obtained from the non destructive measurement needs to be analyzed immediately and effectively to 
support an on-line sortation system. Neural network has been applied for the classification of wheat 
kernel color [5], and the classification of seed – no seed lanzone [6]. The objective of this study was to 
develop neural network model to predict the maturity and ripeness of the fruits, and to classify the fruits 
into various grades. 

**Materials and Methods**

**Materials**

Durian fruits, cultivar *Aseupan*, were harvested from the farmer orchard at Rancamaya village, Ciawi, 
Bogor district at the maturity level of 117 – 120 days after anthesis, the average weight of one fruit was 
2.5 kg. Mangosteen fruits were harvested at various levels of maturity: 90-124 days after anthesis from 
the farmer groups of Wargi Mukti, Gandasoli village, Wanayasa, Purwakarta district, West Java. 

**Experimental Set Up**

The experimental apparatus for measuring the ultrasonic parameter in mangosteen was set up according 
to [7] as illustrated in Fig. 1. The components of the assembly were 1) an ultrasonic tester which 
composed of timing circuit, generator, pulse amplifier, and voltage amplifier, 2) a transmitter transducer 
T, 3) a receiver transducer R, 4) a digital oscilloscope, 5) an A/D converter, and 6) a personal computer. 
The set up for durian had slight modification in which the fruit and transducers were all dipped in water to 
allow good surface contact with the spiky surface configuration [4].

![Experimental setup](image)

**Ultrasonic and Physico-chemical Properties Measurement**

The ultrasonic characteristics of the fruits were determined such as Mo, the zero moment power, and the 
ultrasonic wave velocity that had relationship with the physico-chemical properties of fruits, i.e., specific 
density, hardness, moisture content, total soluble solid, and total sugar. 

**Neural Network Model (NNM)**

Neural network model (NNM) was then developed based on the established relationship between the 
ultrasonic characteristics and the physico-chemical properties of fruits which would determine the input 
variables and the expected outputs of the model. Back propagation was used in the NNM with one layer 
of input, hidden nodes, and output. At the end, the goal of the model was to be able to sort out the mature, 
ripe, and wholesome fruits from the immature, over ripe, and defect ones. Defects inside durian fruits was 
commonly in hardening and damages of tissue because of insect and diseases, while in mangosteen was 
because of transluscent finger, and gamboge – a yellow sap that hardened the tissue.
Results and Discussion

Durian

In durian, the results found out that Mo had good relationship with hardness ($r^2 = 0.815$), total soluble solid or TSS ($r^2 = 0.824$), moisture content or mc ($r^2 = 0.794$), and total sugar ($r^2 = 0.783$). Specific density of durian fruit was also in good relationship with mc ($r^2 = 0.800$), and total sugar ($r^2 = 0.810$). The NNM was applied in three stages: 1) inputting Mo and specific density to obtain four physico-chemical properties of fruit: hardness, TSS, mc, and total sugar (Fig. 2a), 2) inputting the four physico-chemical properties to distinguish the wholesome fruits from the defect ones (Fig. 2b), and 3) inputting the four physico-chemical properties to classify the durian fruits into partially mature, fully mature, ripe, and over ripe (Fig. 2c).

Figure 2. Various NNM applications a) to obtain the physico-chemical properties of durian fruit, b) to distinguish the wholesome fruits from the defect ones, and c) to classify the wholesome fruits into different maturity and ripeness levels.

The NNM training results for stage 1 indicated that the best number of node in the hidden layer was 10 with 5000 iterations and 0.0030 RMSE (Root Mean Square Error). The validation showed a range of accuracy from 91-100 % for hardness, TSS, mc, and total sugar. At the next two stages, RMSE of 0.00054 was obtained at 8 nodes in the hidden layer with 1000 iterations. The validation proved that an accuracy of 79 % was reached to detect wholesome fruits, and 71 % to identify the defect fruits. Even
though these results was still necessary to be improved, it had been much better than the 50 % probability to get defect fruits if manual sortation was utilized. Better results was gained for the classification of mature and ripe fruits, performing the accuracy of 94 % for partially mature, 82 % for fully mature, 100 % for ripe, and 60 % for the over ripe fruits. To get ripe, durian fruits were stored at room temperature for four days after the harvest. Lengthening the storage for the additional 2 days made the durian over ripe. The low accuracy in the classification of over ripe fruits indicated that there were changes of sugar to alcohol and other chemical components during the ripening process into significant amount that should have been analyzed and considered to be included in the NNM inputs.

**Mangosteen**

The results in mangosteen showed that the higher the hardness of the fruit would yield to higher ultrasonic wave velocity (mm/μs), while the different wave velocity separated the fruits into three groups of total sugar content : 1) low wave velocity (0.0150-0.01200 mm/μs) – high total sugar (14.0 – 20.0 g/100g), 2) medium wave velocity (0.01225 – 0.01275 mm/μs) – medium total sugar (10.0 – 12.0 g/100 g), and 3) high wave velocity (0.01300 – 0.01400 mm/μs) – low total sugar (2.0 – 2.5 g/100 g). Thus, the decreasing total sugar of the fruits yielded to increase of ultrasonic wave velocity.

The NNM was applied at three stages 1) distinguishing wholesome fruits from defect ones (Fig. 3a), 2) classifying the maturity of the fruits (Fig. 3b), and 3) classifying the fruits based on the sweetness level (Fig. 3c). The fruit maturity level was divided into five classification of harvest 0 (90-96 days after anthesis, daa), 1 (97-103 daa), 2 (104-110 daa), 3 (111-117 daa), and 4 (118-124 daa). Mangosteen fruits for export were commonly harvested at class 2, at 104-110 daa. Following stage 2, the wholesome fruits from class 2 were subjected for stage 3 to sort out the sweetness level suitable to market demand. The sweetness level was divided into three categories not sweet with total sugar less than 10.0 g/100g, rather sweet (total sugar 10.0-12.0 g/100g), and sweet (total sugar above 14.0 g/100g).

The NNM training for stage 1 found out a 0.0088 RMSE at 9 nodes in the hidden layer with 25 000 iterations. The validation resulted in an accuracy of 80 % wholesome fruits, and 100 % defect fruits, with 20 % of wholesome was detected as defect. This might create problem in losses of wholesome fruits. In stage 2, with 0.0064 RMSE at 21 nodes in the hidden layer for the training, the validation performed much better with all 100 % accuracy level for class 0, 1, 2, and 4 with the exception of class 3 for 33.3 % accuracy. Since the rest of class 3 was grouped as class 4, the two classes could be categorized into one group for domestic market. On stage 3, the NNM training was selected at 10 nodes with 0.0030 RMSE. The validation results indicated that the classification of not sweet was 100 % accurate, rather sweet was 66.7 %, and sweet 93.8 %. The undetected rather sweet fruits went into the not sweet group, while the undetected sweet went into rather sweet group.

**Conclusions**

The NNM has demonstrated capability of using the ultrasonic characteristics of durian and mangosteen fruits to detect their physico-chemical properties, to distinguish wholesome fruits from the defect ones, and to classify the fruits based on their maturity, ripeness, and taste. More effective NNM combining some or all stages of the model run was recommended to be pursued in the future. Fruit samples from different year and location would be tested to get more perfect model and results.
Figure 3. Various NNM applications a) to distinguish the wholesome mangosteen fruits from the defect ones, and b) to classify the wholesome fruits into different maturity levels, and c) ripeness level based on their sweetness.

References


