Kasetsart J. (Nat. Sci.) 46 : 318 - 324 (2012)

Prediction of Oil Content in Fresh Palm Fruit based on an Ultrasonic Technique

Sutthawee Suwannarat, Thanate Khaorapapong and Mitchai Chongcheawchamnan*

ABSTRACT

An ultrasonic technique was proposed to predict the oil content in fresh palm fruit by measuring the attenuation based on the ultrasonic transmission mode. Several palm fruit samples with known oil content determined by Soxhlet extraction (ISO9001:2008) were tested using ultrasonic measurement. Amplitude attenuation data results for all palm samples were collected. The Feedforward Neural Network (FFN) technique was proposed to apply to predict the oil content of the samples. The root mean square error and mean absolute error of the FNN model for predicting the oil content percentage were 5.8672 and 3.4731, respectively, with a correlation coefficient of 0.8891.

Keywords: ultrasonic testing, oil content, palm fruit, polynomial regression, neural network

INTRODUCTION

The oil palm plant (*Elaeis quineensis* Jacq.) is classified as a perennial plant which can yield more oil per unit area than any other oil plant (Sambantamurthi *et al*., 2000). The oil palm plant is very widely planted around the world, including parts of the ASEAN countries, Africa, Australia and South America. There is a huge demand for palm oil globally; in 2010, total world palm oil production was approximately 45 million t, worth more than USD 3.8 billion (Office of Agricultural Economics, 2010). In addition, with the global crisis in fuel supplies nowadays and the ever increasing need for alternative energy sources, it is possible that the increased trend in the demand for palm oil will be prolonged. Many countries have promoted oil palm plant production by launching several policies to facilitate and create stakeholder activity (Office of Agricultural Economics, 2010). One of the main policies is to promote a fair fresh palm fruit trading system.

Currently, the price of palm fruit is determined by the oil content in the fruit. Numerous reports have claimed that the oil content of a palm fruit is related to fruit ripeness and the fruit species (Sambantamurthi *et al*., 2000; Balasundram *et al*., 2006). *Elaeis guineensis* Jacq. *var. tenera* has been the most popular variety for planting since it is more productive than other varieties (Sambantamurthi *et al*., 2000). Several researchers (Abdullah *et al*., 2001; Balasundram *et al*., 2006; Alfatni *et al*., 2008) have reported that the ripeness condition of a Tenera palm fruit is related to the fruit color. However, there is no available, reliable and rapid measurement method for oil content determination. Consequently, trade in fresh palm fruit has not been based on actual

Intelligent Systems Laboratory, Department of Computer Engineering, Prince of Songkla University, Songkhla 90110, Thailand.
* Corresponding author, e-mail: mitchai@coe.psu.ac.th

Received date : 19/01/12 Accepted date : 03/02/12

product quality. Hence, to create a fair trading market, it is necessary to develop a rapid, reliable and accurate oil content determination system.

The conventional method used to determine the oil content is Soxhlet extraction. This method is well known, long established, and widely accepted for analyzing the oil content of fresh palm fruit (Balasundram *et al*., 2006). The process begins by extracting the mesocarp from fresh palm fruit and grinding with solvent. The whole process from preparation to extraction takes at least 48 hr per sample. This method is not yet suitable for oil content determination in the trading market because it is a slow and destructive process.

In general, there are various methods that can be classified as nondestructive. It was reported (Butz *et al*., 2005) that ultrasonic measurement is one of the most used methods for analyzing the quality of fruit and vegetables. The method can provide highly accurate and rapid measurement. It has been claimed that ultrasonic parameters from a sample are correlated to the quality-related physiochemical and mechanical properties (Mizrach, 2008). The attenuation parameters obtained from an ultrasonic measurement on avocado fruit samples were reported to be related to the oil content of the samples (Mizrach and Flitsanov, 1999). Suwannarat *et al*. (2011) proposed to determine the oil content of oil palm fruit using an ultrasonic technique. They used a second-order polynomial function for the model and the ultrasonic attenuation increased with increasing oil content. This knowledge was used in the current study to apply ultrasonic measurement based on the transmission mode and a neural network method to determine the oil content in fresh palm fruit with the results compared with the previous polynomial regression method.

MATERIAL AND METHODS

Thirty-six palm fruits with different ripeness conditions were sampled from *Elaeis guineensis* Jacq. *var.* tenera palm bunches collected from several crop areas around Songkhla province. Figure 1 shows the experimental setup under controlled temperature at (25 °C), with a pair of 40 kHz (*f*) ultrasonic transducers (consisting of an ultrasonic transmitter and receiver) positioned at an angle of 120 °. The distance between the transducer probes was measured by calipers to be 15 mm. Each test sample was firmly held with a sample holder. For ultrasonic transmission mode, an ultrasonic signal was emitted from an ultrasonic pulser through the probe, transmitted through the oil palm sample and collected by a receiving probe. The electrical parameters of the collected ultrasonic signal are related to the physical parameters of the test sample.

To collect the signal from the receiving probe, a digital storage oscilloscope (TDS210, Tektronix Corporation, Beaverton, OR, USA) was used to sample, digitize and finally transfer the received waveform to a personal computer using Tektronix translation software (Openchoice desktop application TDSPCS1 V2.1,Tektronix Corporation, Beaverton, OR, USA). A waveform in digital format using 2,500 samples for each measurement was preprocessed to remove noise. These waveform data were subsequently analyzed with a program developed in MATLAB™(The MathWorks, Inc. Natick, MA, U.S.A). The attenuation parameter (α) was calculated from Equation 1 (Krautkramer and Krautkramer, 1990):

$$A = A_0 e^{-\alpha d} \tag{1}$$

where *A*0 and *A* are the amplitudes of the transmitted and received waveform data, respectively and *d* is the distance between the transducer probes.

The parameters of each test sample were computed from the collected time-domain waveform. The spectra of the 36 waveforms were obtained with the Fast Fourier algorithm. Using Equation 1, the attenuation parameter of each

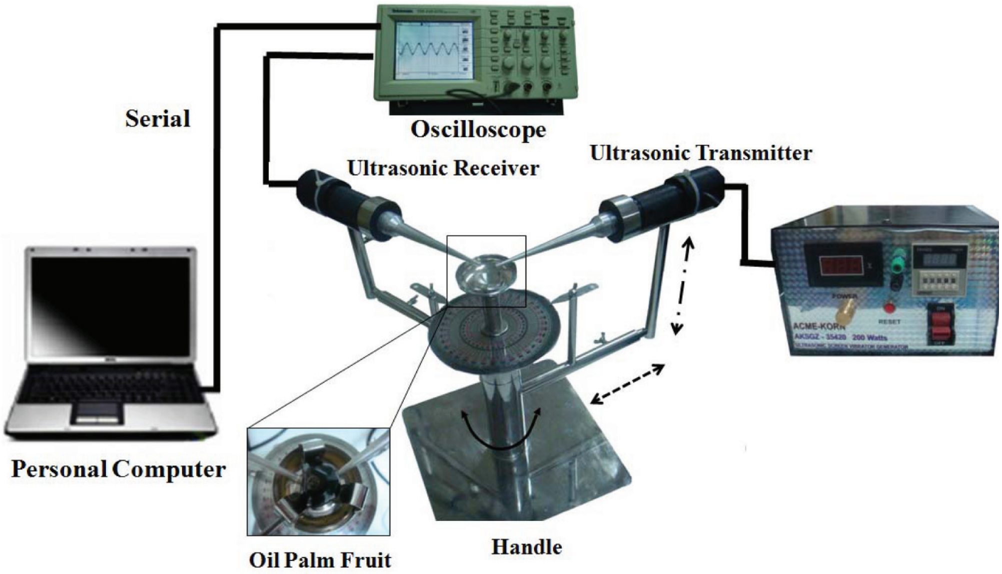

Figure 1 Ultrasonic system used in the study. (At the handle, horizontal solid line, horizontal dash line and vertical long dash line are the rotation point, horizontal translation direction and vertical translation direction, respectively.)

waveform was computed from the magnitudes of the transmitted and received spectra at 40 kHz.

After the ultrasonic measurement, some physical parameters and the oil content of all test oil palm fruits were measured at the Scientific Equipment Center (ISO9001:2008), Prince of Songkla University. A standard Soxhlet extraction method (Balasundram *et al*., 2006) was applied for determining the oil content in the samples.

Results were reported using mean, standard deviation, minimum and maximum values.

Mathematical model: neural network topology

A Feedforward Neural Network (FNN) with a back-propagation learning rule was used to develop a model. The attenuation parameter data with known oil content for the 36 test samples were classified into two sets, with 24 (66.67%) and 12 (33.33%) samples in the training and testing sets, respectively. The same training data set was applied to 15 network topologies. The network topology was chosen that provided the minimum error during the training process

A single hidden layer was chosen as the approximating function. During the testing process, a number of neurons in the hidden layer were thoroughly investigated to determine the appropriate number that provided the minimum error. For the single input network considered in this study, the activation functions in the hidden and output layers were the hyperbolic tangent sigmoid and linear, respectively.

The root mean square error (RMSE), mean absolute error (MAE) and correlation coefficient (R) were used to evaluate the performance of each network topology.

RESULTS

Table 1 summarizes the statistical calculations of the results of the physical and electrical parameters of the test samples. The oil content of the samples ranged from 20.19 to 87.72% whereas weights ranged from 8.98 to 20.57 g.

Table 1 Properties of fresh palm fruit.

Properties	No. of fruit	Mean	SD	Max	Min
Attenuation coefficient, α ($dB.mm^{-1}$)	36	2.47	0.26	3.08	1.99
Oil content (%w/w)	36	52.39	15.18	87.72	20.19
Weight (g)	36	15.00	2.99	20.57	8.98

Figure 2 shows the attenuation parameters of the propagated ultrasonic signals from the 36 samples plotted against the oil content obtained from the Soxhlet extraction method.

The ultrasonic signal was transferred through the fresh palm fruit; thus, the output for each sample had a different amplitude related to the oil content of the sample. It was found that the attenuation increased with oil content (Figure 2).

The statistical parameters used to evaluate the performance of each network topology are listed in Table 2. The FNN topology with three neurons in the hidden layer offered the best performance (RMSE = 9.6323, MAE = 7.7479, and R = 0.8241).

Hence the network topology with three neurons in the hidden layer (Figure 3) was selected.

Polynomial regression

Suwannarat *et al.* (2011) proposed an ultrasonic model to predict the oil content of oil palm fruit using a second-order polynomial regression describing the relation between ultrasonic attenuation and the oil content. In this paper, the model performance based on the FNN model was compared with that of the second-order polynomial regression. Twenty-four and twelve samples were defined for the training and testing sets, respectively. The results (RMSE, MAE and R) obtained from the polynomial regression technique on the training data set were 9.6591, 7.4105 and 0.8049, respectively. The second order polynomial equation is given by Equation 2:

$$y = -43.21x^2 + 266.1x - 336.5 \quad (2)$$

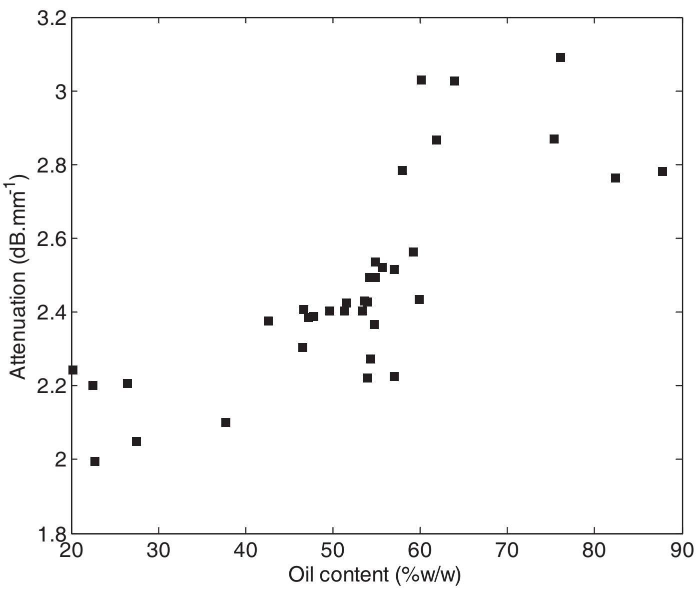

Figure 2 Ultrasonic attenuation versus oil content in fresh palm fruit.

Neural network and performance of polynomial regressions

The statistical parameters indicating the prediction performance of the model from the FNN model and polynomial regression model are summarized in Table 3. Although the R value is higher for the polynomial model, the RMSE and MAE are lower for the FNN model. Therefore, this information indicates that the FNN model showed better performance than the polynomial regression method.

Table 2 Statistical results for the FNN models.

Number of hidden nodes	RMSE	MAE	R
1	10.0688	7.7702	0.8049
2	9.9750	7.9322	0.8112
3	9.6323	7.7479	0.8241
4	9.8925	7.9653	0.8145
5	9.6688	7.8023	0.8233
6	9.9857	7.9259	0.8118
7	9.6624	7.7907	0.8238
8	9.9920	7.9265	0.8120
9	10.0123	7.9491	0.8111
10	9.7303	7.9037	0.8221
11	10.0161	7.9442	0.8115
12	9.7501	7.9223	0.8219
13	10.0233	8.3206	0.8214
14	10.0441	8.2964	0.8212
15	10.0467	8.3119	0.8214

RMSE = Root mean square error; MAE = Mean absolute error; R = Correlation coefficient.

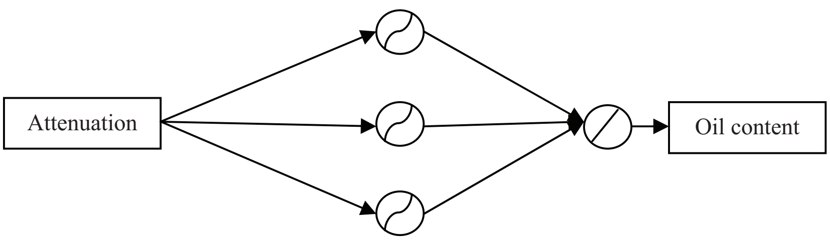

Figure 3 The selected FNN structure with 1 neuron in the input layer, 3 neurons (hyperbolic tangent sigmoid) in the hidden layer and 1 neuron (linear) in the output layer.

Table 3 Statistical results of FNN and polynomial regression models for the testing data.

Model	RMSE	MAE	R
FNN	5.8672	3.4731	0.8891
Polynomial	7.3253	5.8565	0.9295

RMSE = Root mean square error; MAE = Mean absolute error; R = Correlation coefficient.

Figures 4 and 5 show the scatter plots of the predicted oil content from the FNN and polynomial regression models, respectively, versus the actual oil content obtained from the Soxhlet extraction. Plots of the FNN and polynomial regression models are given by Equations 3 and 4, respectively.

$$y = 0.683x + 15.43 \quad (3)$$

$$y = 0.68x + 18.52 \quad (4)$$

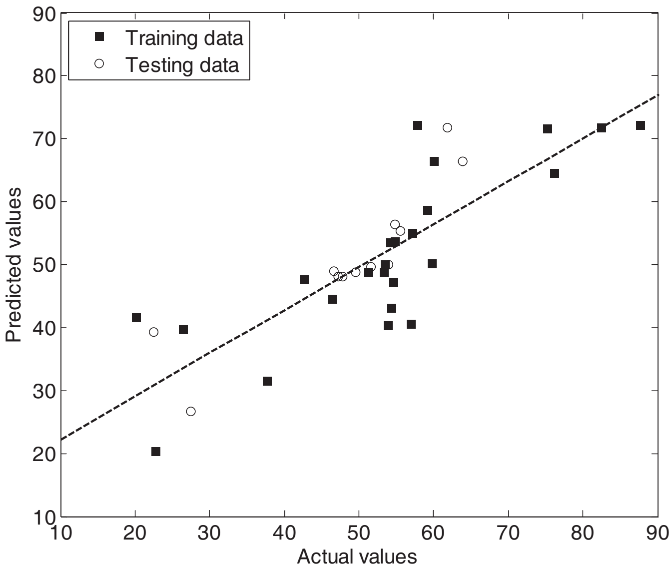

Figure 4 FNN model performance with testing and training datasets.

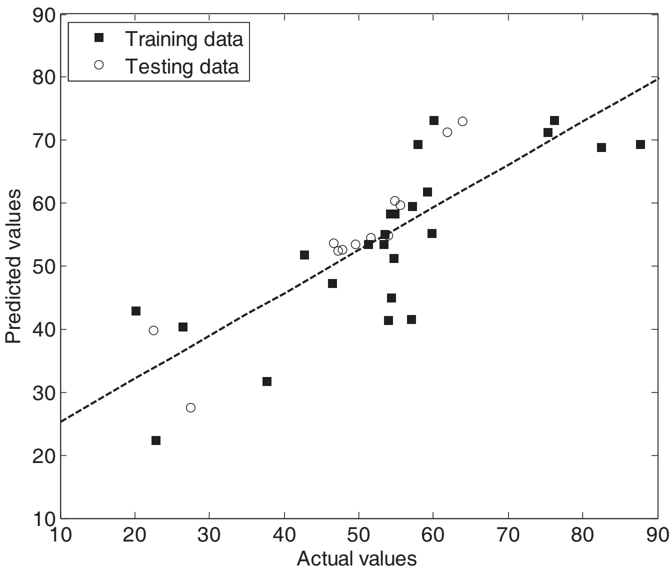

Figure 5 Polynomial regression model performance with testing and training datasets.

CONCLUSION

The feasibility of applying a transmission-mode ultrasonic approach for predicting the oil content in fresh palm fruits was tested. FNN topology with three neurons in the hidden layer was considered to best predict the oil content from the attenuation data.

It was concluded that the proposed technique shows promise for use in an oil content prediction system which could be very useful for the oil-palm trading market.

LITERATURE CITED

Abdullah, M.Z., L.C. Guan and B.M.N. Azemi Mohd. 2001. Stepwise discriminant analysis for colour grading of oil palm using machine vision system. **Food Bioprod. Process.** 79(4): 223–231.

Alfatni, M., A. Shariff, H. Shafri, O. Saaedand O. Eshanta. 2008. Oil palm fruit bunch grading system using red, green and blue digital number. **J. Appl. Sci.** 8(8): 1444–1452.

Balasundram, S.K., P.C. Robert and D.J. Mulla. 2006. Relationship between oil content and fruit surface color in oil palm (*Elaeis guineensis* Jacq.). **J. Plant Sci.** 1(3): 217–227.

Butz, P., C. Hofmann and B. Tauscher. 2005. Recent developments in noninvasive techniques for fresh fruit and vegetable internal quality analysis. **J. Food Sci.** 70(9): R131–R141.

Mizrach, A. 2008. Ultrasonic technology for quality evaluation of fresh fruit and vegetables in pre- and postharvest processes. **Postharvest Biol. Tec.** 48: 315–330.

Mizrach, A. and U. Flitsanov. 1999. Nondestructive ultrasonic determination of avocado softening process. **J. Food Eng.** 40: 139–144.

Krautkramer, J. and H. Krautkramer. 1990. **Ultrasonic Testing of Materials.** Springer-Verlag. Heidelberg, Germany. 521 pp.

Office of Agricultural Economics. 2010. Situation and trends in key agricultural year 2010, **Ministry of Agriculture.** Thailand.

Sambantamurthi, R., K. Sundram and Y.-A. Tan. 2000. Chemistry and biochemistry of palm oil. **Prog. Lipid Res.** 39: 507–558.

Suwannarat, S., T. Khaorapapong and M. Chongcheawchamnan. 2011. Oil content determination of oil palm fruit using ultrasonic. **The 15th International Computer Science and Engineering Conference.** Bangkok, Thailand.