International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:5, No:9, 2011

Predicting Oil Content of Fresh Palm Fruit Using Transmission-Mode Ultrasonic Technique

Sutthawee Suwannarat, Thanate Khaorapapong and Mitchai Chongcheawchamnan

***Abstract*—** In this paper, an ultrasonic technique is proposed to predict oil content in a fresh palm fruit. This is accomplished by measuring the attenuation based on ultrasonic transmission mode. Several palm fruit samples with known oil content by Soxhlet extraction (ISO9001:2008) were tested with our ultrasonic measurement. Amplitude attenuation data results for all palm samples were collected. The Feedforward Neural Networks (FNNs) are applied to predict the oil content for the samples. The Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) of the FNN model for predicting oil content percentage are 7.6186 and 5.2287 with the correlation coefficient (R) of 0.9193.

***Keywords*—** Non-destructive, ultrasonic testing, oil content, fresh palm fruit, neural network.

I. INTRODUCTION

OIL palm plant is classified as a perennial plant which can yield oil per unit area than any type of oil plants [1]. Oil palm plant is very widely planted around the world, these are some parts of ASEAN, Africa, Australia and South America. There is a huge demand for palm oil globally which is witnessed from the statistic data relating to the oil palm consumption. In 2010, the world total of palm oil production was approximately 45 million tons, creating such a large economy scale of more than 3.8 billions USD [2]. In addition, with the global crisis of fuel nowadays and the ever increasing need for alternative energy, it is believed that this increase trend of the palm oil demand will be prolonged. Many countries promote in palm plant production by launching several policies to facilitate and create many activities to stakeholders. One of the main policies is to promote a fair fresh palm fruit trading system.

The price value of a palm fruit currently is determined by oil content in the fruit. Numerous reports claim that oil content of a palm fruit relates to fruit ripeness and the fruit species. The Tenera specie has been the most chosen one for planting since it is more productive that other species. Several researchers reported that the ripness condition of a Tenera palm fruit is related to the fruit color. Since there is no available reliable and rapid measurement method for oil content determination, trading fresh palm fruit in the current market is not based on the actual product quality. Hence to create a fair trading market, it is necessary to develop a rapid, reliable as well as accurate oil content determination system

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

Generally there are various methods be classified in nondestructive technique. It was reported in [3] that ultrasonic is one of the mostly used methods for analyzing fruit and vegetable internal quality. The method can provide high accurate and rapid measurement. It was claimed that ultrasonic parameters from a sample are correlated to the quality-related physiochemical and mechanical properties [4]. Laterally attenuation parameter from ultrasonic measurement on Avocado fruit samples was reported to be relating to the oil content of the Avocado samples [5]. From this knowledge, we will apply an ultrasonic measurement based on the transmission mode to determine oil content in a fresh palm fruit.

This paper is organized as follows. The experimental setup and the experimental results are presented in section II. Detail of applying a neural network method for determining oil content in palm fruit samples based on the measured attenuation parameters will be discussed in section III. The performance prediction will also be and the paper will be concluded in section IV.

II. EXPERIMENTAL SETUP AND RESULTS

A. Experimental Setup

Several Ternara oil palm fruits were sampled from several palm bunches collected from several crop areas around Songkhla province. From the experimental setup shown in Fig. 1, a pair of 40 kHz (f) ultrasonic transducers composed of an ultrasonic transmitter and receiver was selected. These transducers are positioned at angle of 120 degree as shown in Fig.1. The distance between these probes (d) measured with a caliper is 15 mm. A test sample was firmly held with a sample holder. For the ultrasonic transmission mode, ultrasonic signal is emitted from an ultrasonic pulser through the probe, propagates through the oil palm sample and, is collected by a receiving probe. The electrical parameters of this collected

Sutthawee Suwannarat is with the Computer Engineering Department, Prince of Songkla University, Had Yai, Songkhla, Thailand, 90110 (e-mail: ssutthawee@gmail.com).

Thanate Khaorapapong is with the Computer Engineering Department, Prince of Songkla University, Had Yai, Songkhla, Thailand, 90110 (e-mail: kthanate@coe.psu.ac.th).

Mitchai Chongcheawchamnan is with the Computer Engineering Department, Prince of Songkla University, Had Yai, Songkhla, Thailand, 90110 (e-mail: mitchai@coe.psu.ac.th).

International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:5, No:9, 2011

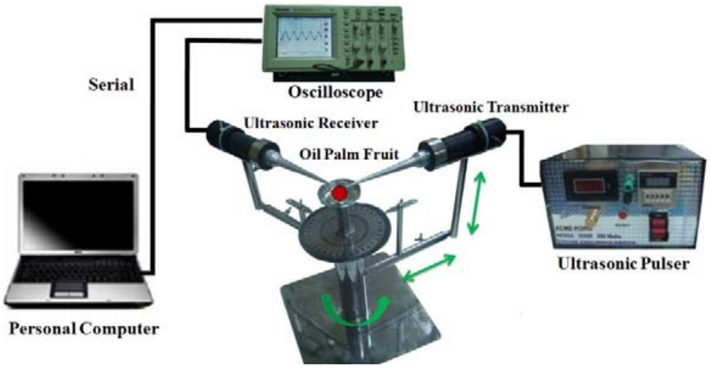


Fig. 1 Ultrasonic experimental setup

ultrasonic signal are changed according to the physical parameter of the test sample.

To collect the signal from the received probe, a digital storage oscilloscope (TSD210) sampled, digitized and finally transferred the received waveform to a personal computer using Tektronix translation software (furnished by Tektronix Corporation). A waveform in digital format of 2500 samples for each measurement was preprocessed for noise removal and subsequently analyzed with the developed program running on MATLAB (7.10). The attenuation parameter (α) can be calculated from (1) as shown [6],

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

Where A_0 and A are the amplitude of the transmitted and received waveform data, respectively. The phase shift (θ), in other word the phase delay, was calculated from (2). Where Δt is a time delay between transmitted and received signal.

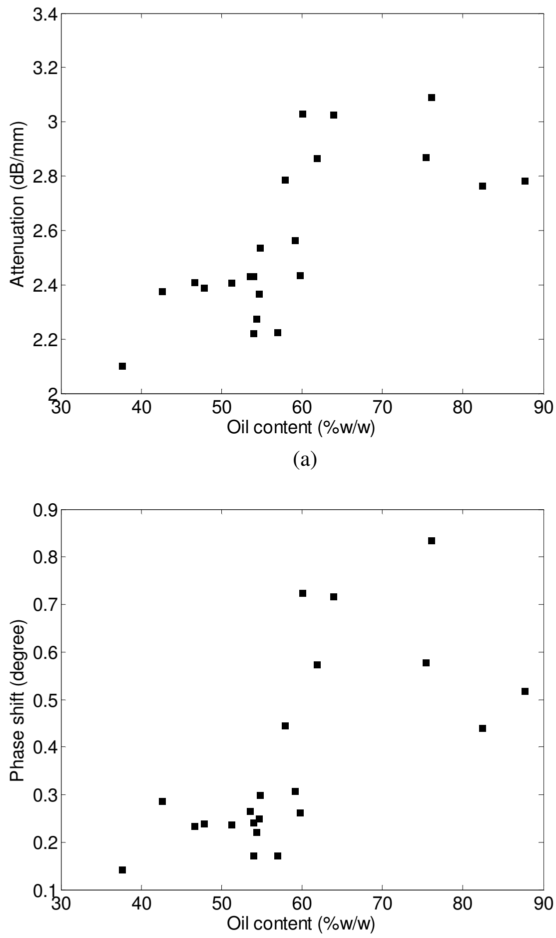
$$\theta = 360° f \Delta t \tag{2}$$

After the ultrasonic measurement, some physical parameters and oil content of all test oil palm fruits were brought to measure immediately at Scientific Equipment Center (ISO9001:2008), Prince of Songkla University. It should be noted that a standard Soxhlet extraction method was performed for oil content determination.

B. Physical and Electrical Results

Ultrasonic measurement was performed on several fresh palm fruits at temperature controlled laboratory. Twenty-two palm fruit of different ripeness conditions were our test samples. Table I summarizes statistical calculation results of some physical and electrical parameters of the test samples. Four statistical calculations (mean, standard deviation, minimum and maximum) are reported. The oil content of samples ranges from 37.67% up to 87.72%. Where the sample weight range from 8.98 g up to 20.57 g.

Fig. 2 (a) and (b) show the attenuation and phase shift parameters of the propagated ultrasonic signals from 22 samples. These two parameters of each test sample were computed from the collected time-domain waveforms. These waveforms were transformed to frequency domain by Fast



(a)

(b)

Fig. 2 (a) The ultrasonic attenuation and (b) phase shift in fresh palm fruit versus their oil content

TABLE I
PROPERTIES OF 22 FRESH PALM FRUITS

Model	Mean	STD	Max	Min
α (dB/mm)	2.56	0.29	3.08	2.09
θ (degree)	0.37	0.20	0.83	0.14
Oil content (%w/w)	58.78	12.28	87.72	37.67
Weight (g)	15.64	2.94	20.57	8.98

Fourier algorithm and the amplitude and phase shift of each waveform are obtained from the waveform spectrum. From Fig. 2 (a0 and (b), both graphs plot the ultrasonic signal parameters defined in (1) and (2) against the oil contents obtained from the Soxhlet extraction method. Evidently, the phase shift parameter is almost independent with the oil content. This suggests to overlook the phase shift parameter and takes only attenuation parameter into account for modeling oil content prediction.

The ultrasonic signal is transferred through fresh palm fruit, the output will have difference amplitude and phase shift related to their oil content. Fig. 2 show the attenuation and phase shift that increase with advancing oil content. However, the phase shift range value on x-axis is narrow; it cannot be used for prediction the oil content of the fresh palm fruit.

III. Neural Network Topology and Performances

In this research, Feedforward Neural Network (FNN) with back-propagation learning rule is proposed to apply for our model. This section describes the most appropriate network topology that provides the best prediction performance. Here, we divide 22 test samples to two sets which are the training and testing sets of attenuation parameters with known oil content percentages. In this paper: 15 (68.18%) and 7 samples (31.82%) are defined for training and the testing sets, respectively. The same training data set is applied to several network topologies for training network. The network topology that provides minimum error during the training process is chosen. Finally the testing set data will apply to validate the selected network topology.

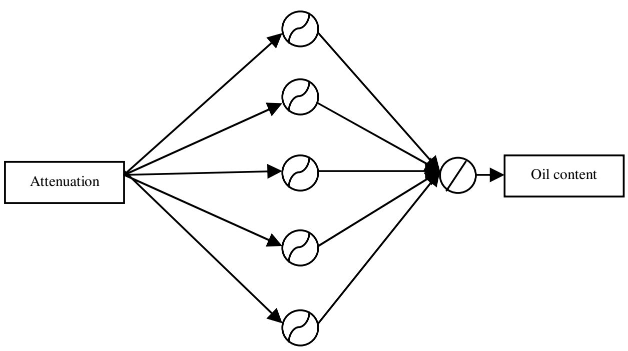


Fig. 3 A selected FNN structure with 1 neuron in the input layer, 5 neurons in the hidden layer and 1 neuron in the output layer.

TABLE II
THE RMSE, MAE, AND R STATISTICS OF THE FNN MODEL

Number of hidden nodes	RMSE	MAE	R
1	7.7203	6.6225	0.7522
2	6.9906	5.7472	0.8018
3	6.7296	5.3931	0.8196
4	6.7322	5.3798	0.8195
5	6.0663	4.4427	0.8542
6	6.7331	5.3745	0.8195
7	7.7481	6.3823	0.7501
8	7.7465	6.3842	0.7502
9	7.7452	6.3862	0.7503
10	7.7426	6.3932	0.7506
11	7.7433	6.3896	0.7505
12	7.7425	6.3910	0.7505
13	7.7418	6.3923	0.7506
14	9.9651	7.4524	0.6364
15	9.9624	7.4494	0.6367

We choose a single hidden layer for approximating function. During the testing process, the neuron number in the hidden layer is thoroughly investigated to determine the appropriate number that provides the minimum error. For our single input network, the activation functions in the hidden and output layers are the hyperbolic tangent sigmoid and linear respectively.

In this paper, Root Mean Square Error (RMSE), Mean of Aboslute Error (MAE) and correlation coefficient (R) are used to evaluate the performance of each network topology. These statistical parameters are listed in Table II. It is shown that the FNN topology 5 neurons in the hidden layer offers the lowest RMSE (6.0663), the lowest MAE (4.4427) and the highest R (0.8542). Hence the network topology with 5 neurons in the hidden layer shown in Fig. 3 is selected in this paper.

The model provides RMSE, MAE and R with this testing data set of 7.6186, 5.2287 and 0.9193, respectively. The statistical parameters indicating the prediction performance of the model from the training and test set are summarized in Table III. Fig. 4 shows the scatterplot of the predicted oil content from the FNN model and the actual oil content from the Soxhlet extraction. The square and circle symbolize the data obtained from training set and testing set. The line equation for the plot is given by

$$y = 0.98x + 3.27 \quad (3)$$

TABLE III
THE RMSE, MAE, AND R STATISTICS OF FNN MODEL FOR TESTING DATA AND TRAINING DATA

Model	RMSE	MAE	R
FNN of testing set	7.6186	5.2287	0.9193
FNN of training set	6.0663	4.4427	0.8542

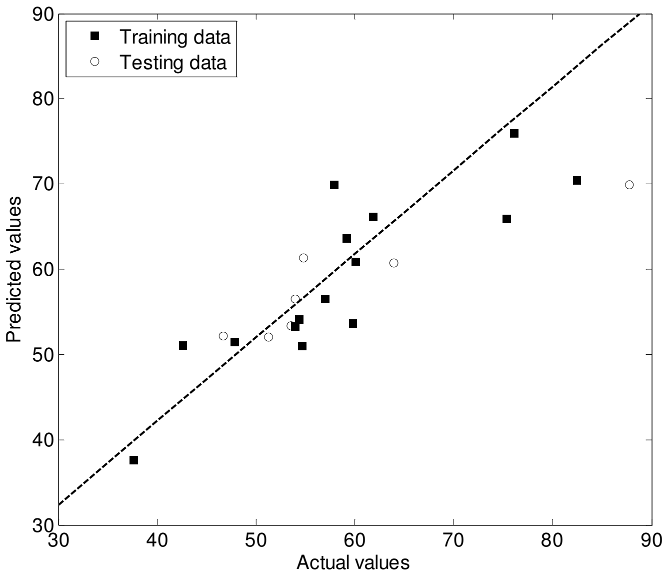


Fig. 4 The scatterplots of the FNN model performances with the testing and training data

IV. Conclusions

The main objective of the paper is to show the feasibility of applying transmission-mode ultrasonic approach for predicting oil content in fresh palm fruits. It has been found that only the attenuation parameter is sufficient for prediction oil content. To predict the oil content from the attenuation data, FNN topology with five neurons in the hidden layer has been proposed to model.

The oil content determination by using ultrasonic testing technique with FNN was promising. The obtained RMSE, MAE and R results of the proposed FNN on testing data are 7.6186, 5.2287 and 0.9193 respectively. From this result, it has been shown that by using the nondestructive ultrasonic operated in transmission mode can predict oil content in a fresh palm fruit. This leads to conclude that the proposed technique can be highly possibly used for oil content prediction system for oil-plam trading market.

References

[1] R. Sambantamurthi, K. Sundram, Y.-A. Tan, "Chemistry and biochemistry of palm oil," *Progress in Lipid Research*, vol. 39, pp. 507-558, 2000.

[2] Office of Agricultural Economics, *Situation and trends in key agricultural year 2554*, Ministry of Agriculture, Thailand, 2011.

[3] P. Butz, C. Hofmann, B. Tauscher, "Recent developments in noninvasive techniques for fresh fruit and vegetable internal quality analysis," *J. FoodSci*, vol. 70, no. 9, pp. 131–R141, November 2005.

[4] A. Mizrach, "Ultrasonic technology for quality evaluation of fresh fruit and vegetables in pre- and postharvest processes," *Postharvest Biology and Technology*, vol. 48, pp. 315-330, 2008.

[5] A. Mizrach, U. Flitsanov, "Nondestructive ultrasonic determination of avocado softening process," *Journal of Food Engineering*, vol. 40, pp. 139–144, 1999.

[6] J. Krautkramer, H. Krautkramer, *Ultrasonic testing of materials.*, Springer-Verlag, Heidelberg, Germany, 1990.