Prediction of Palm Oil Properties using Artificial Neural Network

Salwani Abdullah and Eow Chee Tiong

Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

Summary
The palm oil industry in Malaysia has witnessed a prolific growth in recent years. For the past few decades, Malaysia has led the world in terms of production and export of palm oil. Therefore, physical properties and thermodynamic facts of palm oil have become one of the predominant parts in related chemical industries. Efforts to obtain physical properties of palm oil have been made in order to ensure the quality of the product. Experimental work requires time and is not economic wise. Predictions via correlation methods and thermodynamic models are not practical because the methods are less accurate and high cost as well. In this study, models of Artificial Neural Network (ANN) are constructed to study the physical properties of major and minor components of palm oil. The network is built in conjunction with the data obtained from literature and several journals. The network utilized a feed-forward structure with back-propagation algorithm. The physical properties estimated include the liquid density of palm oil, the vapor and liquid mass fraction of palm oil, and the vapor and liquid equilibrium of fatty acids. The major components consist of triglyceride and fatty acids while the minor components are carotenoid, tocopherols, and tocotrienols. Estimations of the physical properties of palm oil using ANN gives smaller errors compared to other alternatives. As an overall, the lowest Root-Mean-Square (RMS) error acquired for the physical properties of palm oil is less than 1% (0.01). These error decisions have pointed out the suitability of ANN for this study.

Key words:
Prediction, Palm oil, Artificial Neural Network.

1. Introduction

Palm oil is produced from the fruit of the oil palm, or Elaeis Guineesis tree, which originated in West Guinea. The tree was introduced into other parts of Africa, South East Asia and Latin America during the 15th century. Malaysia currently accounts for 51% of world palm oil production and 62% of world exports, and therefore also for 8% and 22% for the world total production and exports of oils and fats. As the biggest producer and exporter of palm oil and palm oil products, Malaysia has an important role to play in fulfilling the growing global need for oils and fats in general [10][2][3][4][5]. [6] presented some experiments on palm oil deodorized condensates and supercritical carbon dioxide. A unique feature of the oil palm is that it produces two types of oil which is the palm oil from the flesh of the fruit, and palm kernel oil from the seed or kernel. For every 10 tonnes of palm oil, about 1 tonne of palm kernel oil is also obtained. In order to meet the manufacturer's requirements, several processing operations are used to produce the finished palm oil [7][8]. The first step in processing is at the mill, where the crude palm oil is extracted from the fruit. The various steps which consist of sterilization, stripping, extraction and purification are shown below [7].

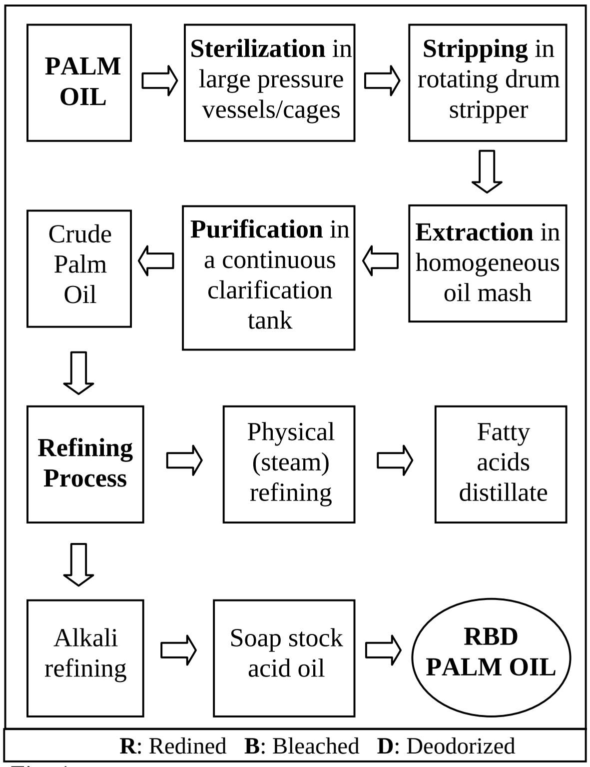

Fig. 1: Schematic diagram for palm oil processing

This paper is organized as follows: the description on the university course timetabling problems is discussed in the next section. The implementation of the hybrid method to

Manuscript received August 5, 2008.
Manuscript revised August 20, 2008.

course timetabling is discussed in Section 3 followed by a discussion on the experiments and results in Section 4. Brief conclusions are drawn in Section 5.

2. Problem Description

Predicting the physical properties of palm oil using experimental method contains high accuracy. However, it takes longer time and costs higher. The palm oil industry needs a method which is more efficient and workable that can be done within a shorter time and lower cost compared with the experimental method. Therefore, Artificial Neural Network (ANN) is taken as the best alternative for predicting the physical properties of palm oil which will take shorter time and lower cost.

3. Artificial Neural Network (ANN)

The fundamental processing element of a neural network is a neuron. This building block of human awareness encompasses a few general capabilities. Basically, a biological neuron receives inputs from other sources, combines them in some way, performs a generally nonlinear operation on the result, and then outputs the final result [9].

3.1. Artificial Neurons

Figure 2 shows the relationship of the four main parts of a simple neuron.

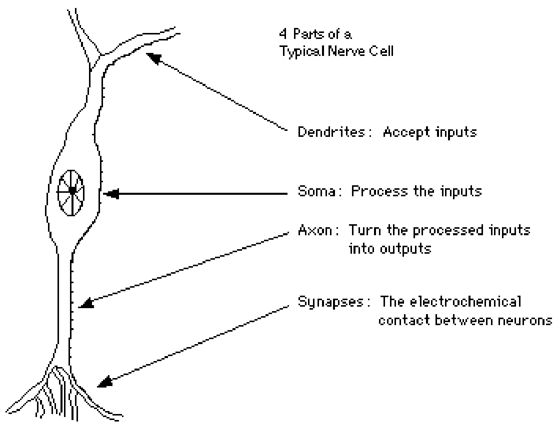

Fig. 2: Four main parts of a simple neuron

Within humans there are many variations on this basic type of neuron, further complicating man's attempts at electrically replicating the process of thinking. Yet, all natural neurons have the same four basic components. These components are known by their biological names – dendrites, soma, axon, and synapses.

Dendrites are hair-like extensions of the soma which act like input channels. These input channels receive their input through the synapses of other neurons. The soma then processes these incoming signals over time. The soma then turns that processed value into an output which is sent out to other neurons through the axon and the synapses.

Recent experimental data has provided further evidence that biological neurons are structurally more complex than the simplistic explanation above. They are significantly more complex than the existing artificial neurons that are built into today's artificial neural networks. As biology provides a better understanding of neurons, and as technology advances, network designers can continue to improve their systems by building upon man's understanding of the biological brain.

But currently, the goal of artificial neural networks is not the grandiose recreation of the brain. On the contrary, neural network researchers are seeking an understanding of nature's capabilities for which people can engineer solutions to problems that have not been solved by traditional computing [10].

3.2. Neural Network Structure

Neural network, as used in artificial intelligence, was considered as a simple nerve model processed in brain. The structure of neural network model contains 3 major layer namely the input layer, hidden layer, and output layer. The input layer is the layer which receives raw data or input from external source. This layer will send its output value and weight value to the next layer, namely the hidden layer.

In hidden layer, multiplication of weight and input will be made using the process called the summation function and transfer function. The hidden layer may consist of one or several layers depending on the suitability of data used. After processing data in hidden layer, the output will be sent to the final layer, namely the output layer [11]. Finally, in the output layer, determination of data accuracy will be analyzed. The results usually represented in the form of graph as depicted in Figure 3.

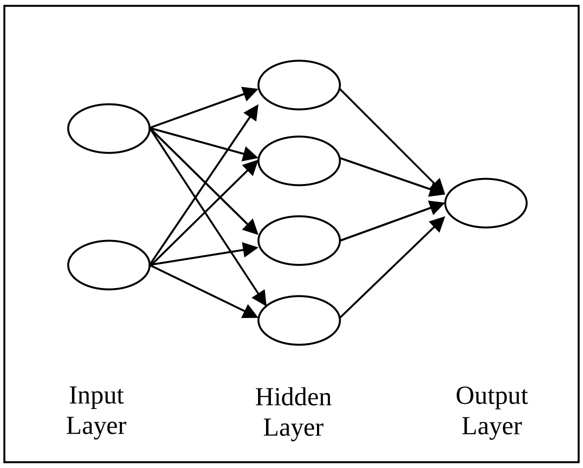

Fig. 3: A simple neural network structure

3.3. Major Components of an Artificial Neuron

An artificial neuron is a device with many inputs and one input. It is made up by four major components. These components are valid whether the neuron is used for input, output, or is in one of the hidden layers. Figure 4 illustrates a basic model of an artificial neuron and its components. The components of the nodes and their respective functions are discussed as follows [12][13]:

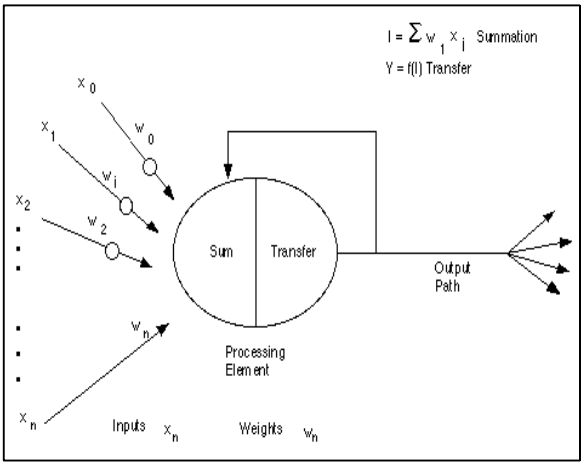

Fig. 4: A basic model of an artificial neuron

Weighting Factors:

A neuron usually receives many simultaneous inputs. Each input has its own relative weight which gives the input the impact that it needs on the processing element's summation function. These weights perform the same type of function as do the varying synaptic strengths of biological neurons. In both cases, some inputs are made more important than others so that they have a greater effect on the processing element as they combine to produce a neural response.

Summation Function:

The first step in a processing element's operation is to compute the weighted sum of all of the inputs. Mathematically, the inputs and the corresponding weights are vectors which can be represented as (i_1, i_2 . . . i_n) and (w_1, w_2 . . . w_n). The total input signal is the dot, or inner, product of these two vectors. This simplistic summation function is found by multiplying each component of the *i* vector by the corresponding component of the *w* vector and then adding up all the products. $Input_1 = i_1 * w_1$, $input_2 = i_2 * w_2$, etc., are added as $input_1 + input_2 + . . . + input_n$. The result is a single number, not a multi-element vector.

The summation function can be more complex than just the simple input and weight sum of products. The input and weighting coefficients can be combined in many different ways before passing on to the transfer function. In addition to a simple product summing, the summation function can select the minimum, maximum, majority, product, or several normalizing algorithms. The specific algorithm for combining neural inputs is determined by the chosen network architecture and paradigm [10].

Internal Thresholds:

The internal threshold is also one of the important factors which control the activation of the node. the nodes calculates it's weighting factor, sums the terms available, and then calculates the total activation, x_i by subtracting the internal threshold value, T_i. When the node has a high internal threshold, T_j is large and positive, which inhibits node-firing. Conversely, when the node has a low internal threshold, which excites node-firing, T_j is zero (or negative, in some cases). Mostly, but not necessarily all, nodes have an internal threshold. If no internal threshold is specified, T_j is assumed to be zero.

Transfer Function:

The result of the summation function, almost always the weighted sum, is transformed to a working output through an algorithmic process known as the transfer function. In the transfer function the summation total can be compared with some threshold to determine the neural output. If the sum is greater than the threshold value, the processing element generates a signal. If the sum of the input and weight products is less than the threshold, no signal (or some inhibitory signal) is generated. Both types of response are significant [10].

4. ANN Model

[14] presented process model using Neural Networks and tested on experimental datasets. [15] discussed simulation model of the phase behavior of palm oil.

Figure 5 shows the ANN model carried out in this study.

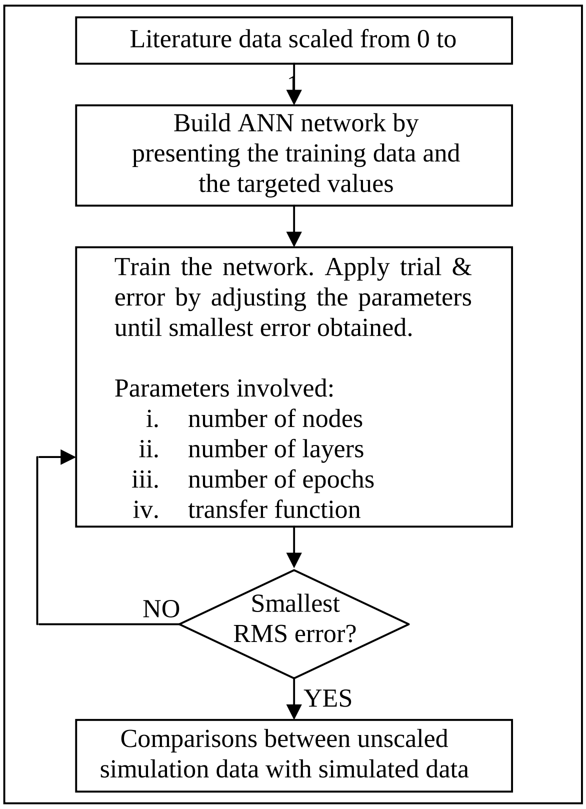

Fig. 5: ANN model

4.1. Root-Mean-Square (RMS) Error

Root-mean-square (RMS) error can be defined as the positive value for the mean-square error. RMS error is applied especially when an analysis involves numerous calculations that are very useful in estimations or predictions. The error can be calculated from the equation (1).

$$\text{RMS} = \sqrt{1/n\sum_{i=0}^{n}(q'-q)^2} \quad \textbf{(1)}$$

where n = number of data
q' = value from literature
q = value from the simulation

4.2. Data Scaling

Data scaling is another essential step for comparing the accuracy. The efficiency of the neural network can be evaluated with this RMSE equation. The smaller the RMS error, the network model indicates higher accuracy. A simple linear normalization functions within values of zero to one are shown in equations (2) and (3) respectively. Results obtained after this normalization were satisfactory for determining which alternative is more capable in estimating the physical properties of palm oil.

$$S = \frac{V - V_{\min}}{V_{\max} - V_{\min}} \quad \textbf{(2)}$$

$$V' = S(V_{\max} - V_{\min}) + V_{\min} \quad \textbf{(3)}$$

where S = scaled data
V = variable from the data set
V' = variable from simulation
V_{min} = minimum value in the data set among simulation and experimental values
V_{max} = maximum value in the data set among simulation and experimental values

5. Experiments and Results

Liquid densities for palm oil are predicted in accordance with temperature as the parameter input. The model which produces the smallest RMS errors during the simulation is taken as the best network model. Log-sigmoid transfer function and tan-sigmoid transfer function are used in the network.

The network was trained using Levenberg-Marquardt learning algorithm (trainlm). The feed-forward network consists of an input layer, 2 hidden layers and an output layer. The number of nodes in the input layer and output layer is one for the network because there is only one parameter input and one output parameter. Table 1 show that the network has 3 nodes in the first hidden layer and 4 nodes in the second hidden layer. The two hidden layers with the number of neurons are essential in improving the accuracy of the network prediction.

Table 1: Network architecture of liquid density of palm oil

Network Architecture			
1	2	3	4
logs 1	logs 3	logs 4	logs 1

The testing data and their predicted values are listed in Table 2. The simulation results obtained are presented as a plot of estimated values versus literature values in Figure 6. The predicted values are very accurate because of a perfect fit is obtained. This is proved by the R-squared value obtained which is 0.9987. This value, which is very close to 1, shows that the model is able to accurately predict the density of palm oil. The RMS error obtained is relatively small approximately 0.022809.

Table 2: Testing data and RMS error for liquid density of palm oil

Temp. (^{0}C)	Literature Data *(scaled)*	Simulation Data *(scaled)*	Literature Data *(unscaled)*	Simulation Data *(unscaled)*	RMS Error
30	0.7919	0.7907	915.00	914.91	0.022 809
70	0.25520	0.25440	876.30	876.24	
90	0.06657	0.02709	862.70	859.85	

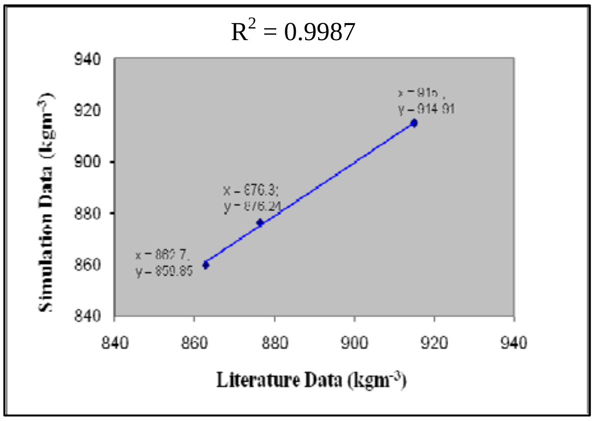

Fig. 6: Simulation data versus literature data for liquid density of palm oil

Figure 7 shows the simulation results obtained versus the tenmperature for liquid density of palm oil.

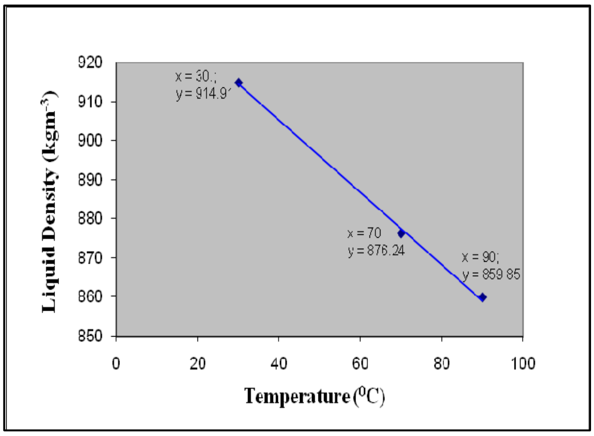

Fig. 7: Simulation data versus temperature for liquid density of palm oil

6. Conclusion

Artificial neural network offers an easier solution for predicting the physical properties of palm oil accurately especially in cases where the literature data for the components are very limited. Estimation of physical properties play an important role in improving and optimizing production by reducing raw material and making the process economically viable. ANN is capable of learning and generalizing from examples and experience to produce meaningful solutions. Thus, this makes ANN a powerful tool for predictions and the application of ANN should be highly implemented in manufacturing industries to optimize the production.

This study has highlighted the models for designing better network architecture for predicting the physical properties of palm oil. A single neural network can have poor generalization capabilities. The main reason is due to the case when the network is trained on a limited amount of data. But still, based on the results obtained, the RMS errors obtained for all the models developed are less than 1% which it can be concluded that the networks are reliable and could be an alternative to estimate the properties of palm oil in future.

References

[1] Ibrahim, A., *Selected Readings on Palm Oil and Its Uses*, Palm Oil Research Institute of Malaysia, Kuala Lumpur, 1993.

[2] Chandra, R.K., Kritchevsky, D. and Loke, K.H., “Health and Nutrition Aspects of Palm Oil”, *Selected Papers from the PORIM Palm Oil International*

Conference Kuala Lumpur, Malaysia, Pergamon Press Ltd., USA, 1992, pp. 32.

[3] Hamilton, R.J. and Rossell, J.B., *Analysis of Oilseeds, Fats and Foods*, Elsevier Applied Science Publishers, New York, 1986.

[4] Cocks, L.V. and van Rede, C., *Laboratory Handbook for Oil and Fat Analysis*, Academic Press, London, 1966.

[5] Berger, K.G., *Nutrition-Palm Oil*, Palm Oil Research Institute of Malaysia, Kuala Lumpur, 1983.

[6] Stoldt, J. and Brunner, G., "Phase Equilibria in Complex Systems of Palm Oil Deodorizer Condensates and Supercritical Carbon Dioxide: Experiments and Correlation", *The Journal of Supercritical Fluids*, 1999, pp. 14.

[7] Malaysian Palm Oil Council – MPOC,. http://www.mpoc.org.my, Accessed on 4th January 2008.

[8] Chong, Y.H. *Facts About Palm Oil*, Palm Oil Research Institute of Malaysia, Kuala Lumpur, 1987.

[9] Baughman, D.R. and Liu, Y.A., *Neural Networks in Bioprocessing and Chemical Engineering*, Academic Press Inc., USA, 1995.

[10] DACS – Data & Analysis Center for Software, https://www.dacs.dtic.mil, Accessed on 7th February 2008

[11] Demuth, H. and Beale, M., *Neural Network Toolbox User's Guide Version 4*, The MathWorks Inc., USA, 2001.

[12] Rafiq, M.Y., Bugmann, G. and Easterbrook, "Neural Network Design for Engineering Applications", *Computers & Structures*, 2001, pp. 79.

[13] Sridhar, D.V., Barlett, E.B. and Seagrave, R.C., "An Information Theoretic Approach for Combining Neural Network Process Models", *Neural Networks*, 1999, pp. 12.

[14] Lanoutte, R., Valade, J.L. and Thibault, J., "Process Modelling with Neural Networks Using Small Experimental Datasets", *Computers and Chemical Engineering*, 1999, pp. 167-176.

[15] Lim, C.S., Manan, Z.A. and Sarmidi, M.R., *Simulation Modelling of the Phase Behaviour of Palm Oil – Supercritical Carbon Dioxide*, JAOCS 2003.