Modelling of Palm Kernel Oil Extraction By using Super-Critical CO_2

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***Abstract*— A mathematical model is developed in order to study the effect temperature and pressure toward the extraction of palm kernel oil using a supercritical carbon dioxide. A sets of secondary data were obtained from previous studies which consist of a sets of temperature, pressure and amount of oil yield. In this study, the artificial neural network is used to simulate the effect of temperature and pressure towards the oil extraction. In order to obtain the desired output, the suitable number of neuron must be selected. To choose the suitable number of neuron, the sets of data were inserted into the neural network model and let to train by manipulating the variable from 1 neuron to 25 neuron. The result for mean squared error for each variable were then tabulated and compared. Based on the result, the least MSE was 18 neuron number. Then, by using the chosen neuron number the simulation were let to run and trained until the best regression is obtained. Regression R Values measure the correlation between outputs and targets. R value of 1 means a close relationship, 0 a random relationship. The regression obtained from the simulation is 0.958. This indicate that there are a good relation between the experimental and theoretical data. The data for experimental and theoretical were then compared and the error obtained is within the acceptable range which is 3.356%**

Keywords*— *Palm Kernel Oil, Super-Critical Carbon Dioxide, Artificial Neural Network, Regression, Oil Yield, Mean squared error

I. INTRODUCTION

Palm kernel is the edible seed of the oil palm trees. It is originally from Africa and become one of the main commodity crop for the nation. The fruit of the palm oil tree is known for its usefulness in producing palm kernel oil from the kernels and palm oil from the fleshy part of the fruits [1] the demand for the palm kernel are increasing and the palm kernel are introduced to other parts of the world such as Sri Lanka, Malaysia and Sumatra.

Palm kernel oil are widely used in food applications, oleochemical and energy, biomass and others. As for the food applications, the palm oil are commonly used for cooking oil. The characteristic of the palm oil made it suitable to be applied in making margarine and non-dairy creamer. On the other hand, there are plenty other applications of palm kernel oil in food industries. Besides that, the palm kernel oil are also used as a surfactant in the oleochemical. It were also widely used cosmetic and personal care product. Due to its benefits, the palm kernel oil has become very popular. The quality of the palm kernel oil are almost the same as the coconut oil. This make the palm kernel oil are chosen as the alternative for the coconut oil

Due to variety application of the palm kernel oil, the demand for the oil in Malaysia shown a rapid growth every year. More planted area for plantation of palm kernel tree were discovered. The production of the palm kernel oil managed to increase from 1.3 million tonnes in the year 1999 to 4.7 million tonnes in the year 2011. Malaysia currently accounts for 39 % of world palm oil production and 44% of world exports [2]. Hence, there are need to extract more palm kernel to fulfill the demand for palm kernel oil

In general, the method for palm kernel oil extraction are mechanical extraction and solvent extraction. However, due to the low yield, there is a need for a more effective oil extraction method. The cost of mechanical extraction is inexpensive, the process itself is not very efficient. The screw pressing only able to remove only 80% of the available oil. As for solvent extraction, solvent extraction causes losses in biological activity of extracted plant [3]. Besides that, the more solvent used for the process will increases the extraction time.

As an alternative, the extraction can be done by using a supercritical fluid. Supercritical fluid extraction offers an effective and cleaner mode of removing the residual oil [4]. The supercritical fluid extraction has been widely used in various application as an alternative to the mechanical method and the solvent extraction method. Most commonly used for supercritical fluid extraction is carbon dioxide and water. At supercritical states, carbon dioxide has been recognized as earth compatible solvents [5]

Pressure, temperature, and particle size are most important factors in influencing the quality of the supercritical fluid extraction [6]. However, to study the effect of temperature and pressure toward the extraction of palm kernel oil, a mathematical model are developed to observe the efficiency of extraction by increasing the parameters such as temperature and pressure. Mathematical model are used to design and scale up the process before it can be applied in the real process. The extraction process is simulate by the mathematical modelling. The simulation enable a generalization of a new process conditions. The mathematical modelling also help to formulate the idea and knowledge about the behavior of the extraction process [7].

Artificial Neural Network model was chosen for this study. An artificial neural network is a computational model based on the structure and functions of biological neural networks. The neural network model are widely applied in problems such as speech recognition, prediction of secondary structure, classification of cancers and gene prediction. In order to solve or predict the output of a problem, the artificial neural network will detect the pattern and relationship in the data. The knowledge about the problem will be gather by learning process. The model should be trained until it recognized the pattern through experience. The behavior of a neural network is determined by the transfer functions of its neurons, by the learning rule, and by the architecture itself [8]. The network are able to predict the output once it is trained and tested.

In this study, sets of secondary data of palm kernel oil extraction using super critical carbon dioxide (SC-CO2) were obtain from previous study by Özkal (2004). The secondary data are a range of temperature and pressure. The temperature and pressure were used as a parameters to be applied into the modelling. The effect of temperature and pressure for the palm kernel oil extraction are then studied.

II. METHODOLOGY

A. Sets of Secondary Data

The sets of secondary data were obtained from previous related studies by Ozkal (2004). The data are consist of a range of temperature and pressure. The data were then inserted into the mathematical modelling to study the effect of the parameters on oil extraction

Table 2.1: Secondary data for mathematical modelling [9].

Stand. Order	Pressure (bar)	Temperature (°C)	Oil Yield (g/g kernel)
1	300	40	0.065
2	300	50	0.042
3	300	50	0.059
4	300	50	0.083
5	300	50	0.059
6	300	60	0.088
7	375	40	0.055
8	375	40	0.079
9	375	40	0.114
10	375	40	0.145
11	375	50	0.061
12	375	50	0.071
13	375	50	0.089
14	375	50	0.091
15	375	50	0.094
16	375	50	0.119
17	375	50	0.146
18	375	60	0.079
19	375	60	0.104
20	375	60	0.156
21	375	60	0.164
22	450	40	0.108
23	450	50	0.096
24	450	50	0.132
25	450	50	0.187
26	450	50	0.177
27	450	60	0.217

B. Modelling by using Artificial Neural Network (ANN)

There are two steps done during the simulation. Firstly, the selection of neuron number and the modelling of palm kernel oil extraction. The ANN were set up and the sets of secondary data were inserted into the network. Next, the number of neuron 1 is used as an initial condition and let to be trained by using Levenberg-Marquardtz method. The simulation is done until the value of R>0.95. The value for mean squared error was recorded. The steps are then repeated until neuron 25. The result were then tabulated and compared. The least MSE error is chosen.

Next, by using the chosen number of neuron. The ANN were set up and sets of secondary data were inserted into the network. The network is set to be trained by using Levenberg-Marquardtz method. Training process were let to simulate. The training process is stop when the value of regression achieve a condition above 0.95. The result for the simulation were then displayed and discussed.

III. RESULTS AND DISCUSSION

A. Number of neuron selection

Number of neuron is very important in order to reduce error in the simulation. Minimum MSE value in the network is necessary to avoid error in predicting the output value. Hence, the result from the simulation were tabulated and compared. Based on figure 3.1, the least error were found at number of neuron 18. The value of mean squared error was 0.000051367. The number were then selected to be used for further simulation process

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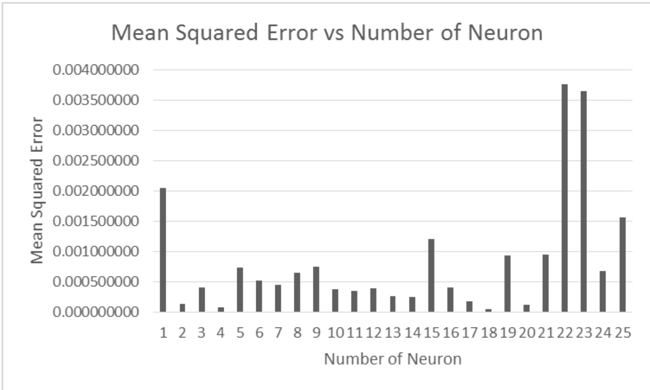

Fig 3.1: Mean squared error (MSE) for 1 neuron to 25 neuron

B. Yield extraction of palm kernel oil from the mathematical model

By using 18 as the number of neuron, the simulation were then and the best regression obtain. Figure 3.2 shows the regression obtained from the simulation was 0.95438.

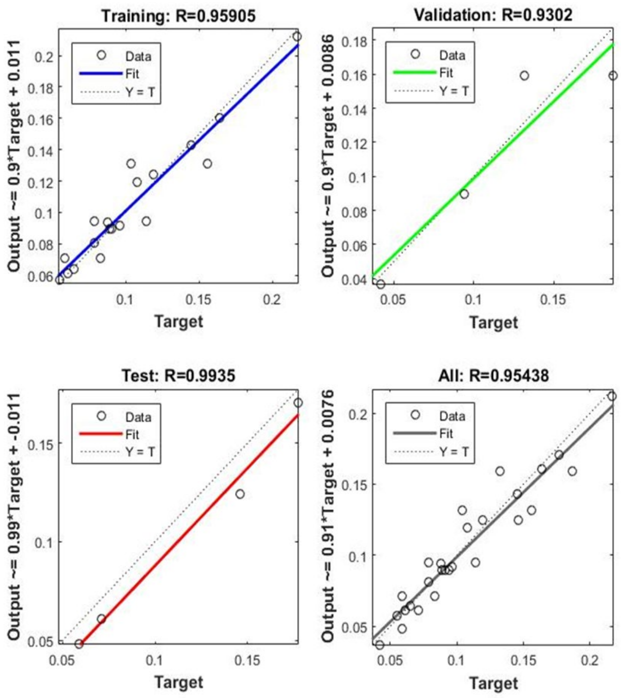

Fig 3.2: Regression value for 18 neuron number network

From the simulation, the output was the oil yield extracted at the condition based on the secondary data. Table 3.1 shows the theoretical oil yield extracted from the simulation. The value for theoretical oil yield were then compared with the experimental data. The percentage error for each value were then calculated and tabulated at table 3.2

Table 3.1: The theoretical value for oil yield from the Neural Network

Stand. Order	Pressure (bar)	Temperature (°C)	Oil Yield Model (g/g kernel)
1	300	40	0.0583
2	300	50	0.044
3	300	50	0.0538
4	300	50	0.0538
5	300	50	0.0603
6	300	60	0.0917
7	375	40	0.052
8	375	40	0.0821
9	375	40	0.0821
10	375	40	0.14
11	375	50	0.0626
12	375	50	0.0626
13	375	50	0.0913
14	375	50	0.0913
15	375	50	0.0913
16	375	50	0.1481
17	375	50	0.1481
18	375	60	0.084
19	375	60	0.1116
20	375	60	0.1116
21	375	60	0.167
22	450	40	0.1148
23	450	50	0.0923
24	450	50	0.1398
25	450	50	0.1398
26	450	50	0.1758
27	450	60	0.2153

The error are acceptable and there are correlation between both data. The average absolute relative deviations for the result were 3.3598 %. The value indicate that the error between both data are small. Figure 3.3 shows the relation between the experimental data and the theoretical data.

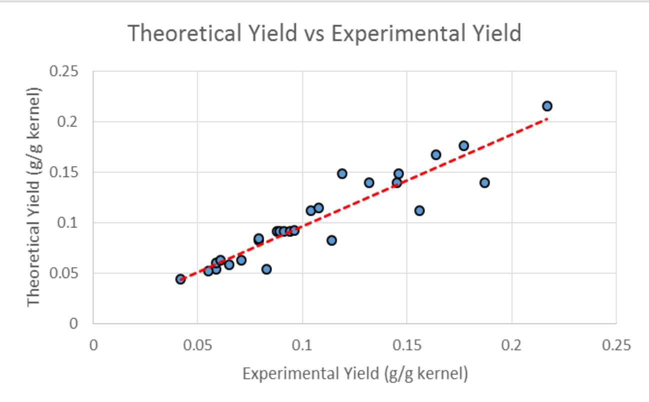

Fig 3.3: Graph of theoretical vs. experimental yield

Table 3.2: Percentage error between experimental and theoretical oil yield data

Experimental Oil Yield (g/g kernel)	Oil Yield Model (g/g kernel)	Percentage Oil Yield error (%)
0.065	0.0583	10.31
0.042	0.044	4.76
0.059	0.0538	8.81
0.083	0.0538	35.18
0.059	0.0603	2.20
0.088	0.0917	4.20
0.055	0.052	5.45
0.079	0.0821	3.92
0.114	0.0821	27.98
0.145	0.14	3.45
0.061	0.0626	2.62
0.071	0.0626	11.83
0.089	0.0913	2.58
0.091	0.0913	0.33
0.094	0.0913	2.87
0.119	0.1481	24.45
0.146	0.1481	1.44
0.079	0.084	6.33
0.104	0.1116	7.31
0.156	0.1116	28.46
0.164	0.167	1.83
0.108	0.1148	6.30
0.096	0.0923	3.85
0.132	0.1398	5.91
0.187	0.1398	25.24
0.177	0.1758	0.68
0.217	0.2153	0.78

C. *Effect of Temperature*

To study effect of temperature towards the oil extraction. Three different condition were set up separately. Each test were done by examining the value of oil extracted at constant pressure on a three different temperature. For each test, the pressure were kept at constant and the manipulated variables are the temperature. The pressure used were 300 bar, 375 bar and 450 bar. For each pressure, the temperature of 40, 50 and 60 °C were tested. The amount of yield extracted at different test were plotted and can be seen on figure 3.4, 3.5 and 3.6

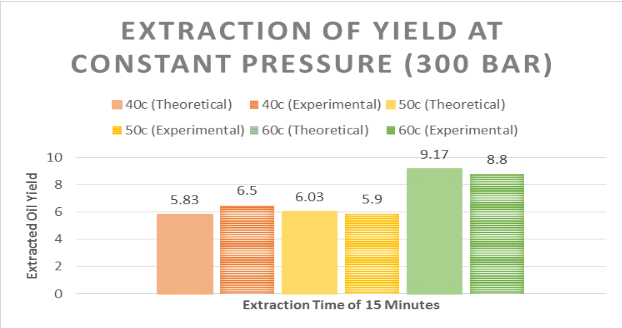

Fig 3.4: Extraction of yield at constant pressure of 300 bar for temperature 40 °C, 50 °C and 60 °C

Based on figure 3.4, the effect of temperature were tested on constant pressure 300 bar. The pattern shows that the value of oil yield extracted are increasing by increasing the temperature. From the figure, the lowest yield was extracted at 40 °C, 0.0583 g/g kernel and the highest was at 60 °C, 0.0917 g/g of kernel

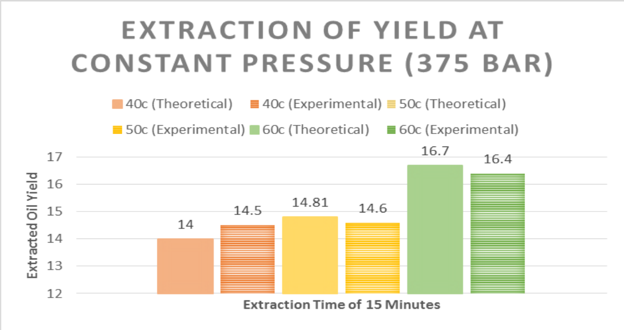

Fig 3.5: Extraction of yield at constant pressure of 375 bar for temperature 40 °C, 50 °C and 60 °C

The test were repeated on a constant pressure of 375 bar. From figure 3.5, the pattern also shows an increasing pattern in the amount of oil extracted by increasing the temperature. At 40 °C, the amount of oil extracted was 0.14 g/g kernel yield extracted, 0.1481 and 0.167 g/g kernel yield extracted for temperature 50 °C and 60 °C respectively.

Once again, the test were repeated at a constant pressure of 450 bar. The result for the test can be seen on figure 3.6. The highest value of oil was extracted at 60 °C with 0.2153 g/g kernel yield extracted and the lowest is at 40 °C with extraction of 0.1148 g/g kernel.

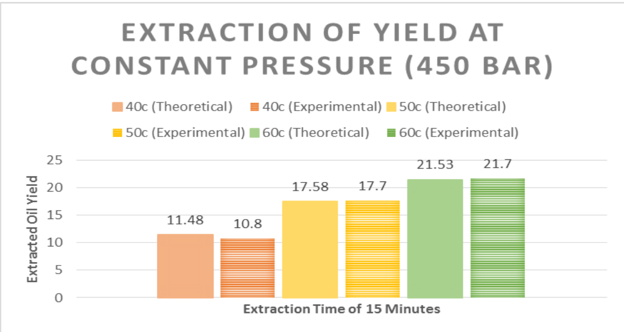

Fig 3.6: Extraction of yield at constant pressure of 450 bar for temperature 40 °C, 50 °C and 60 °C

To study the effect of temperature, the test were done on three different condition. Based on the result, it shows that at different pressure the highest temperature still gives the highest value of oil extraction compared to a lower temperature. The temperature of 60 °C shows the highest amount of oil extracted in all three conducted test. This was expected, due to increasing the temperature at a constant pressure will enhance the mass transfer in the kernel and increase the driving for during extraction. Hence, more yield will able to be extracted. Similar result were obtained from previous study by Bhupesh et.al (2006), the extraction yield increased with an increase in temperature value [10].

D. Effect of Pressure

To study effect of pressure towards the oil extraction. Three different condition were set up separately. Each test were done by examining the value of oil extracted at a constant temperature on a three different pressure. For each test, the temperature were kept at constant and the manipulated variables are the pressure. The extraction time were set to be 15 minutes.

Three different condition of temperature were set as constant which are 40, 50 and 60 °C respectively. For each temperature, a pressure of 300,375 and 475 bar were tested to study the effect of pressure towards the oil yield extraction. The results for each test were plotted on figure 3.7, 3.8 and 3.9.

Based on fig 3.7, temperature of 40 °C was set as constant variable. Based on the figure, the result shows an increment to the amount of oil extracted from 300 to 375 bar. Then, there were depletion in the oil extraction at 450 bar. However, this is due to the diffusivity of oil in supercritical condition decreases at high pressure over a constant temperature of 40 °C.. The duration of fast extraction decreases as pressure increased [11]. At pressure of 300 bar, the amount of oil yield extracted was 0.0583 g/g kernel. 0.14 g/g kernel was extracted at 375 bar and 0.1148 g/g kernel at 450 bar. The pressure is directly proportional to the amount of oil extracted at constant temperature of 40 °C.

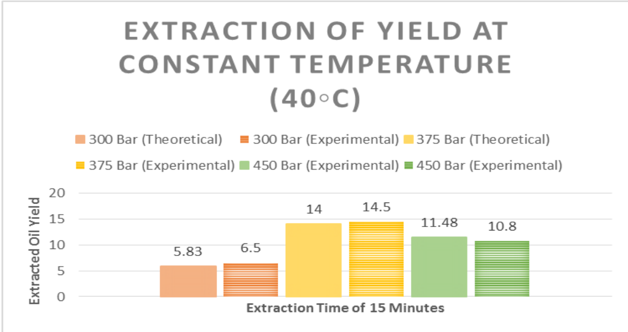

Fig 3.7: Extraction of yield at constant temperature of 40 °C for pressure 300,375 and 450 bar

Next, the same test were done at a constant temperature of 50 °C. The result for the test were illustrated on figure 3.8. Based on the result, the graph shows a positive pattern whereby it can be seen that the amount of oil extracted increased by increasing the pressure. From the graph, the amount of oil extracted was 0.0603 g/g kernel at 300 bar, 0.1481 g/g kernel at 375 bar and 0.1758 g/g kernel at 450 bar. Higher amount of yield were found at a higher pressure.

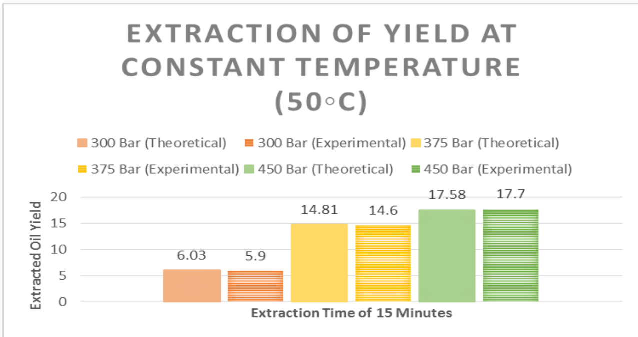

Fig 3.8: Extraction of yield at constant temperature of 50 °C for pressure 300,375 and 450 bar

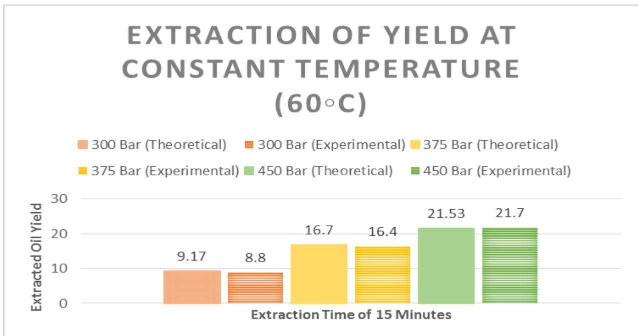

Fig 3.9: Extraction of yield at constant temperature of 60 °C for pressure 300,375 and 450 bar

The test were repeated once again of a constant temperature of 60 °C. The result for the test were plotted on figure 3.9. Figure 3.9

shows similarity with previous test. Positive pattern was seen on the chart. The pressure is directly proportional to the amount of yield extracted. From the figure, the highest yield were recovered at 450 bar and the lowest yield were recovered at 300 bar.

Based on all the result, it can be conclude that higher pressure are able to extract more oil from the kernel. The results shows that the highest value of oil extracted were at 450 bar. Similar to the temperature, the pressure also increase the driving force of the mass transfer. The increasing mass transfer speed up the extraction. Hence, more oil yield will be extracted in a constant duration. In a conclusion, the temperature and pressure are directly proportional to the extraction of oil yield.

IV. CONCLUSION

This study aim to obtain secondary data of palm kernel oil extraction using supercritical carbon dioxide (SC-CO2) from related journals and fit the data by using appropriate formula and mathematical model. Besides that, this study was also done to study the effect of temperature and pressure on the amount of oil extracted. The study was done by simulation the sets of secondary data obtained from related studies. The data were that inserted into the artificial neural network to be simulate. Result for the simulation were then recorded and studied. Based on the data, the Mean squared error (MSE) obtained is 0.00005136. The error in the simulation are very small. The regression for the simulation obtained was 0.958. It shows that there are a good correlation found between the theoretical and the experimental oil value. This indicated that there result obtained by using the simulation are good. To support the result, average error for the data were calculated. The error calculated were 3.356%. Then, then study were proceed to investigate the effect of pressure and temperature on oil extraction. Based on the result, it shows that at a higher temperature and pressure more amount of oil will be extracted at a duration of time. Similar results were seen on different condition during the study. It can be conclude that, the higher the temperate and pressure the higher the oil extracted.

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