PROCESS MODELLING AND SIMULATION
OF CRUDE PALM OIL REFINING.

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1 SUMMARY.
Process Modelling, Simulation and Flowsheeting of Palm Oil Processes.

The aim of the paper is to discuss the development of a *microcomputer process modelling simulation and flowsheeting program for Palm Oil Distillation processes* i.e. Palm Oil Refining and Fatty Acids Fractionation.

The scope of this work encompasses the developments of the Properties Estimation, Short-cut Design, Rigourous Design and Flowsheet modules using a microcomputer spreadsheet program.

Chemical and physical properties of Palm Oil and derivatives were derived from 2 sources; literature and experiments. These data were input into a database-spreadsheet template to generate correlation and graphs. The Short-cut methods employ were the McCabe-Thiele Pseudo-Binary and Fenske methods to calculate number of trays. The Rigourous methods compare 3 methods; Lewis-Matheson, Thiele-Geddes and Tridiagonal-Matrix. Of which the Tridiagonal Matrix method was selected for further development. The Flowsheet method employs a dual level system by which the above Unit Operations modules are linked to a matrix of the linearised simultaneous equations representing the process flowsheet.

The initial results of this system were then compared with current distillation operating conditions and distillation techniques. It showed accuracy in simulating distillation processes and highlighted the influence of trace components on the vapor-liquid equilibrium of Fatty acids and Palm Oil. The techniques were also used to investigate the viability of alternatives distillation configurations in Palm Oil processes.

2 INTRODUCTION.
Palm Oil Refining, Fatty Acids Fractionation and Process Modelling.

This sections outlines the Malaysian Palm Oil and Oleochemicals industry, current practices and limitations as well as a brief look on the mathematical modelling techniques used in the research.

2.1 Palm Oil Refining and Fatty acids Fractionation.

Malaysia Palm Oil and Oleochemicals industry consist of 250 mills, 45 refineries and 5 oleochemicals plants with a total plant outlay of 2 billion ringgits. It produces 4.5 million tonnes of refined oil per year accounting for 20% of the world market. The mainstay of the industry are the refineries which refines and exports 90%

of Malaysian Palm Oil. To a lesser extent are the Fatty acids plants which uses Palm Kernel Oil as a oleochemical feedstock. producing 125,000 tonnes per year. In both plant. the vacuum steam distillation operation is responsible for the quality of the products.

In Palm Oil refining, the oil is steam-stripped under vacuum of odors and free fatty acids as well as the thermal degradation of β carotene red coloring. This a 5 trays, 280 c, 2 mmHG, isothermal column with steam injection at every plate. Similiarly, the fatty acids fractionation column is 19-30 trays and 300 c column.

2.2 Process Modelling, Simulation and Flowsheeting.

No Malaysian work has been reported on the rigourous mathematical modelling of Palm Oil and Palm Kernel Oil fatty acids distillation processes. What methods they are utilises the short-cut Vaporisation Efficiency formula to calculate free fatty acids stripping. In contrast, the Malaysian Petroleum industry employs modern process simulators e.g. *CHEMSHARE and PROCESS* to design and evaluate complex flow schemes.

The underlaying techniques in distillation modelling is similar in both applications but the problems of estimating large molecular chemicals properties, vapor-liquid deviations due to trace compounds and the Non-Newtonian fluid dynamics have hinder the development of mathematical models. As a result, optimisation is mostly done by Statistical methods. Another difficulty is on the quality consciousness of the industry and the inability to represent quality parameters such as colour and stability numerically. Last but not least, the processes are semi-continous relying on the attainment of quality parameters for each stage of process. Batch models are still being developed in this respect.

Notwithstanding this, the work intends to use current distillation models to simulate the processes and then to incorporate features such as time, quality and plate efficiencies. 2 techniques were chosen; the Tray to Tray and Tridiagonal Matrix calculations for comparison and ease of modifications. The program was developed on a micro computer spreadsheet which has complex matrices. iterative and graphics subroutines. What other subroutines are needed are programmed as macros and compiled within the spreadsheet. The most advanced feature is the auditing mode which enables errors to be detected immediately.

3 EXPERIMENT AND RESULTS.
Properties Estimation, Modelling and Simulation.

The experimental procedures consist of 3 main stages; properties database, mathematical modelling and simulation. The modules are developed in sequence and then integrated together using the build-in commands or the program project compiler. Although the spreadsheet module is the main applications used in this experiment, data can be transfer bidirectionally between the database, word-processing or communication modules. Project activities are scheduled using the program appointment scheduler. These features are still being developed.

3.1 Properties Estimation and Database.

A spreadsheet template was created to input literature and experimental data of Palm Oil. This is a free format structure so that a variety of datasets could be handled. In addition, the current spreadsheets has linear regression feature although new programs offers 3 types of regressions. Non-linear curve-fitting macros can be programmed but in this case, the data are linked via special file formats to dedicated statistical-graphics programs for rigourous analysis. The correlations are then graphed into standard engineering charts such as log-log graphs. A paper on the development of free format database is forthcoming. From this, a correlation of the properties against known parameters are developed e.g. Vapour Pressures vs Temperature or a correlation of constants e.g. Antoine Constants vs Temperatures.

3.2 Process Modelling.

The correlations generated are then passed into the design template. Preliminary design using *Short-cut algorithms. Fenske, McCabe-Thiele and Vaporisation Efficiency methods* were evaluated. The model was a 5 tray column with steam injection at all plates with a steam-ejected induced vacuum of 3mmHg operating at a range between 200 - 300 c. The column was assumed to be isothermal and isobaric for initial calculations. The crude Palm Oil feed composition is shown below.

FATTY ACIDS COMPONENTS	WEIGHT %
Palmitic	2.20
Myristics	0.06
Stearic	0.23

Oleic	2.00
Linoleic	0.51
Triglycerides	95.00

In addition to the number of trays calculations, Dew point, Bubble point, Feed Tray location, Minimum reflux ratio and plate composition estimation were also carried out. The Fenske-Underwood algorithm results was found to be sufficient for rigourous design giving 1.8 theoretical plates with a column efficiency of 36 %. On the other hand, the McCabe-Thiele using a Pseudo-Binary mixture of oil and an weighted averaged of free fatty acids vapour pressures produced an extraordinary large convex vapor-liquid curve which on estimation produces 2 theoretical trays. This gives an column efficiency of 40 %. Actual efficiency for vacuum column is below the average 50 % typically below 40 %[1] .

Mencari Bil.Plat

(Kaedah Mc-Cabe Thiele)
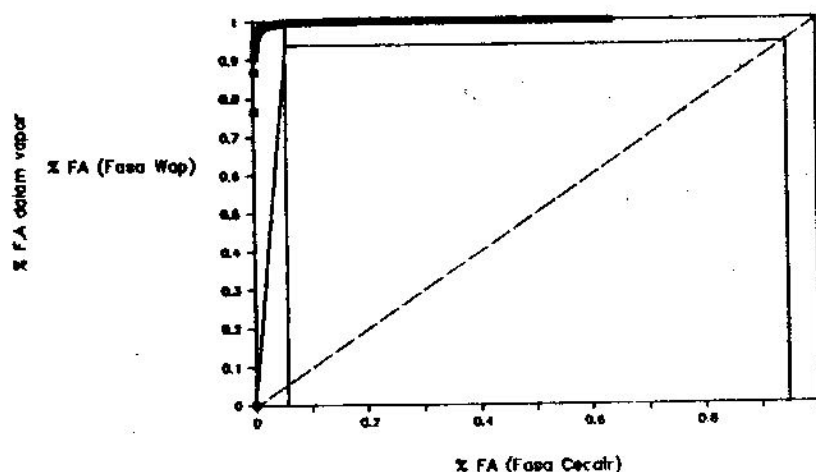
For rigourous design, the *Lewis-Matheson (L-M) plate to plate method* and the *Tridiagonal Matrix (T-M) method* were evaluated based on actual industrial specifications of free fatty acids less than 1%. For crude Palm Oil refining using L-M, 9 plates at 297 c and 19mmHg were estimated for 99.9% acid free oil. However, the T-M esti mated 5 plates at 3mmHg and 300 c was sufficient to lower ffa down to 99.9991 %. The actual number of plates is 5

1 Coulson, Richardson and Sinnot, "CHEMICAL ENGINEERING.", pg. 441, vol. 6, 1983, Pergamon.

with a column temperature of 280 - 270 ° operating at 2
mmHg. In reality, temperature above 280 ° are not toler-
ated because the oil will carbonised.

3.3 Simulation and Optimisation.

The next stage of the experiment was the simulation
and optimisation of the deacidification of Palm Oil
w.r.t. vacuum pressure, column temperature and steam
feed. This is compare with existing simulation method
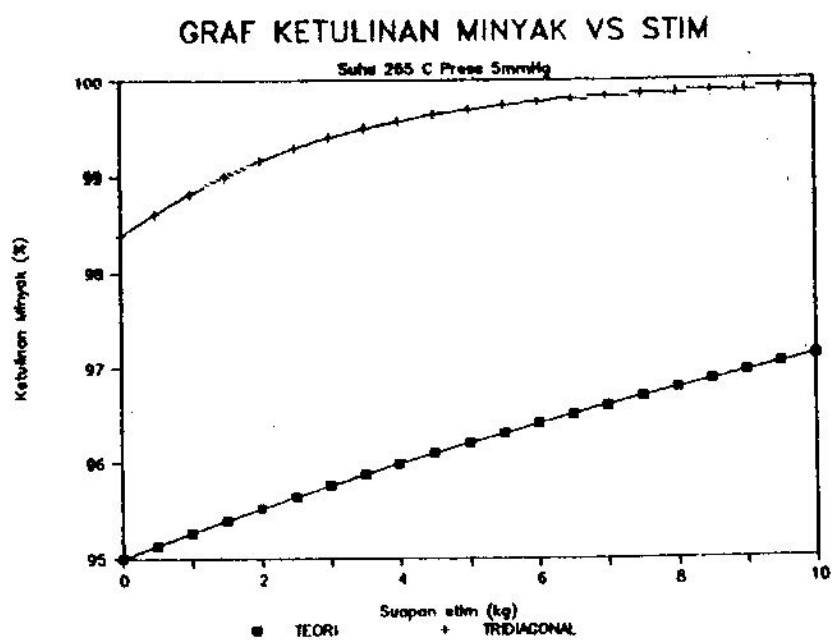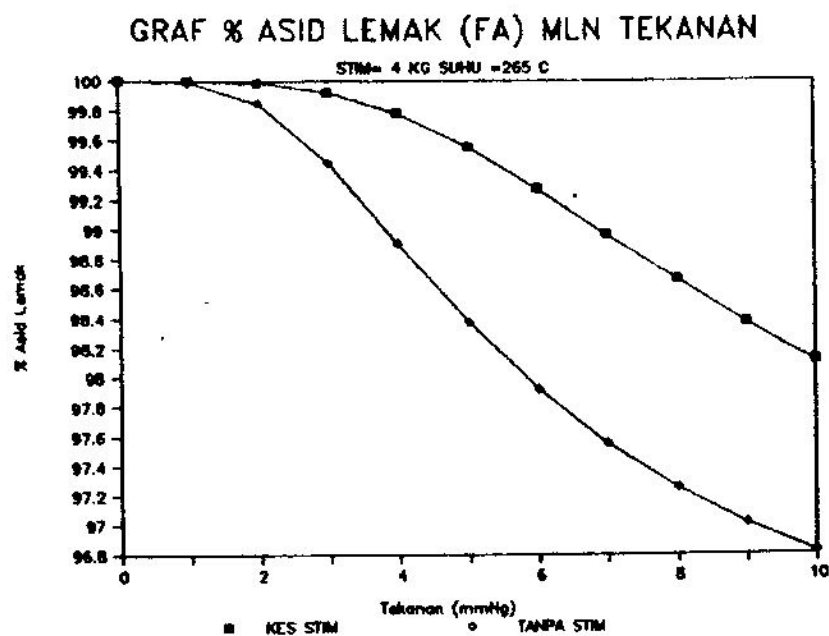such as the Vaporisation Efficiency method.

The relationship between percent free fatty acids
versus column temperature is non-linear indicating that
99.9 % oil purity was achieved at 270 ° with a 3.5 Kg
steam rate and 3.0 mmHg vacuum. However, the relationship
between column temperature versus vacuum pressure is lin-
ear for 100 % acids free oil.

GRAF TEKANAN MLN. SUHU
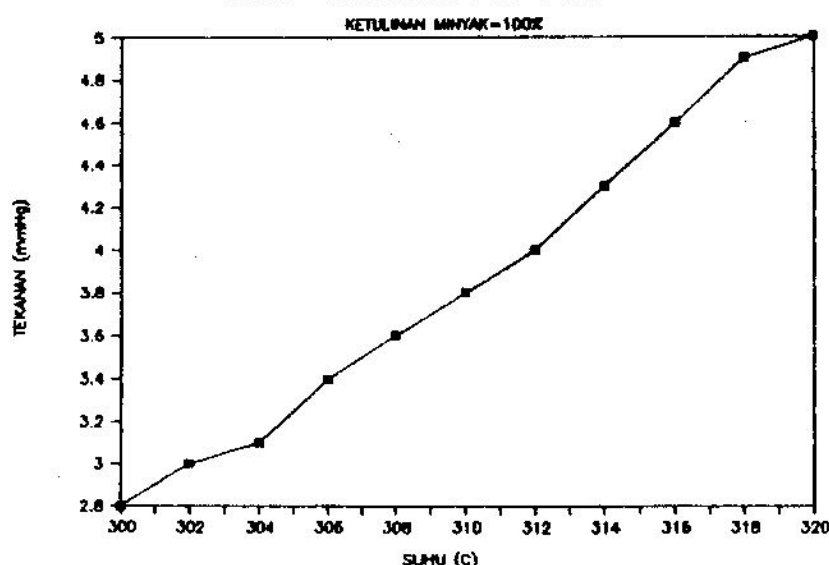
The advantages of using steam for stripping indicated
that at 265 °, 4 Kg steam rate, the best oil purity is 98
2 % compare to 96.8 % at 10 mmHg vacuum. There is a 1.40
% differences in oil composition due to steam being used.
However, this gap reduces as vacuum is increased when at
2mmHg the differences is less than 0.1 %.

The comparison between Vaporisation Efficiency and
the T-M methods indicate that at 100% oil purity, the
result of the T-M method is between 34 - 70 % more accu
rate than the Vapour Efficiency method.

GRAF % ASID LEMAK (FA) MLN TEKANAN

STIM= 4 KG SUHU =265 C

Tekanan (mmHg)

■ KES STIM   ○ TANPA STIM

GRAF KETULINAN MINYAK VS STIM

Suhu 265 C Press 5mmHg

Suapan stim (kg)

● TEORI   + TRIDIAGONAL

In summary, the T-M method gave the following operating conditions to achieve 99.9 % oil purity.

% OIL	PRESS	TEMP	STEAM
99.9054	3	265	3.50
99.9056	3	260	5.20

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99.9070	3	240	17.0
99.9090	2	240	7.50
99.9071	1	240	2.30

4 DISCUSSION.
Comparison, Problems and Opportunities.

As stated, the objective of the research was to develop rigourous, reliable and accurate mathematical models compared to existing techniques, to identify problems in the modelling stripping of free fatty acids and to formulate techniques to incorporate actual refining parameters into the models.

4.1 Comparison with existing techniques.

The model proved to be proved to be a more rigourous and accurate model in comparison with existing techniques.

It confirmed and quantified that the relationships between column pressures and temperature is non-linear and between column temperature versus vacuum pressure is linear[2].

For the comparison between various rigourous algorithms the T-M gave a more accurate answer than the L-M method. The error for number of plates was 80 % (comparing 9 to 5 plates).

For the comparison between Vaporisation Efficiency and the T-M methods indicate that at 100% efficiency, the result of the T-M method is between 34 - 70 % more accurate than the Vapour Efficiency method.

4.2 Problems and Opportunities in modelling.

The program suggest that the differences of oil purity achieved between deacidification of Palm Oil by steam and without steam is marginal below 2 mmHg at 265 c and at steam rate of 4 Kg. A difference of 0.2 % between steam and no steam at 2 mmHg and none below 1 mmHg vacuum. This indicated that at vacuum below 2 mmHg alternative processes may be economical for small volume, high value-added edible oils chemicals. An example is the use of Molecular Distillation to separate high purity Monoglyceride after a reaction between fats and Glycerol.

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2 Leong, L.W.. "STEAM DISTILLATION/PHYSICAL REFINING.", First Palm and Palm Kernel Oil Processing Course, July 1985, Palm Oil Research Institute Malaysia.

Experimental work on a pilot scale rig have revealed
that the presence of trace compounds (less than 1.0 %)
will distort the vapor-liquid equilibrium of the free
fatty acids and oil. The model is still unable to account
for this phenomena but emphasised the importance of
pre-treatment before refining. The model quantified the
degree of interference cause by the bad pre-treatment of
oil. Stochastic analysis have confirmed the effect of
pre-treatment on deacidification[3].

PLOT OF OIL PURITY VS VACUUM & STEAM

FOR PLATE 2nd ORDER STRIPPING EQ.
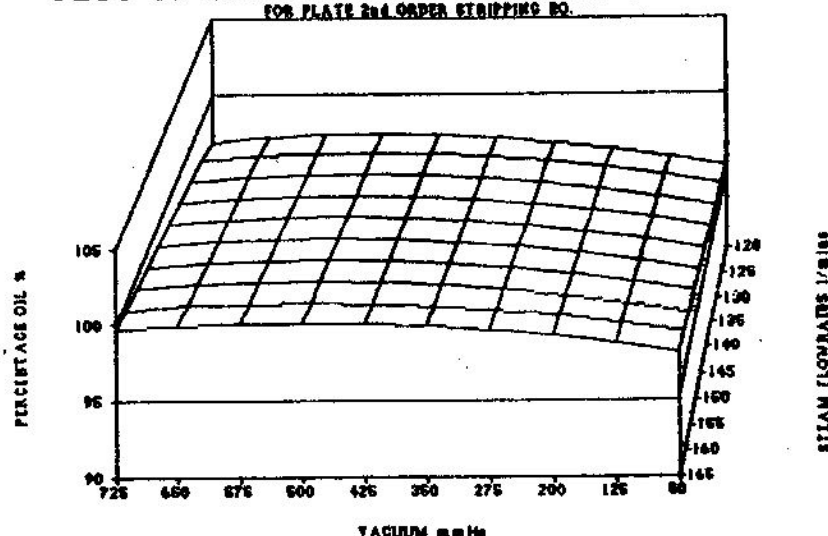
5 APPLICATIONS.
Process Optimisation, Flowsheeting and Integration.

Below are the downstream applications of these models
and its significance in the current and future edible oil
markets. In short, the ability to optimise existing plants,
to design new plants and to integrate processes in plants to
attain a higher Quality to Price Ratio for our oil offers
Malaysia a technological competitive edge against its com-
petitors. It also mean that we are able to respond faster,
manoeuvre more aggressively and produce a wider, integrated
range of edible oils for the changing markets.

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3 Lee, A.K. & Leong. W.T.,"Physical Refining: A preliminary
full scale optimisation trial.", Taiko Plantations, 1988
National Oil Palm & Palm Oil Conference, October 1988, Kuala
Lumpur.

5.1 Process Optimisation.

The most important application of the model is to optimise the distillation column w.r.t. to flexible feedstocks and multiple products specifications production scenarios.

The former scenario is common in Malaysia since we possess 4 types of oil feedstock i.e. Crude Palm Oil, Crude Palm Kernel Oil, Palm Olein and Palm Stearin originating from a single Oil Palm. Present plants are operated semi-continuously to cater for these feedstocks.

The latter scenario is becoming more and more critical to the survival of our industry. Malaysia refines a variety of edible oils for different markets i.e. Cheap and high volume oil for India and Pakistan, high quality and low volume oil for Europe and U.S.A. markets and specialised oils for Japan. The ability to use the same column to produce a large varieties of oils is a competitive edge.

5.2 Process Flowsheeting.

Apart from distillation models, others unit operations models were also developed i.e. heat exchangers, fatty acids splitter, and esterification column, using spreadsheet templates. Process Flowsheeting is therefore the systematic linking and integrating of the various models to simulate a process plant. Various techniques have been developed but we favour a Dual Level Flowsheeting System approach developed in U.T.M. called the SImultaneous Modular Unified System or SIMUS.

5.3 Process Integration.

The development of quantitative techniques to recover energy, schedule production runs, control product quality and automate critical processes. The earliest and current research has been on the recovery of heat from the process using the Pinch Design Method. This technique has now been adapted for the type of operations found in Malaysian plants.

The previous work was on the development of an Palm Oil Mill Energy Management System to control boiler steam fluctuations in the plant. The P.D.M. is linked interactively with the Process Flowsheet simulator and Steam Balance simulator to set energy targets, formulate minimum energy requirements networks and optimise the production schedule to minimise the energy fluctuations

in the mill[4] .

The current work is an extension of the above to Palm Oil Refineries to minimise the use of high pressure steam in the plant. For this work, the microcomputer based system is assisting in the modification of the CHEMSHARE program to simulate, design and rate refineries retrofits and to formulate production schedules.

Preliminary modelling works on the Oleochemical plants i.e. Fatty Acids Splitting and Methyl Esters plant have already begun with initial models being troubleshoot and tested for accuracy, reliability and portability.

6 CONCLUSION.

The work has confirmed current empirical and experimental research but more importantly it was able to quantified these findings more accurately and reliably. In some cases, new data on effect of trace chemicals on vapor-liquid equilibrium, pretreatment effect on column efficiency and properties of Palm Oil products are breaking new grounds in research. Strategically, the experience has proved that the process is capable of being modelled on the commercial process simulator CHEMSHARE and efforts are underway in this direction. Our next focus is to incorporate quality parameters, residence time and plate efficiencies into the models.