PALM KERNEL OIL LEACHING

by

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ABSTRACT

This research is in its preliminary stage in which the efficiencies of the various methods of extraction were determined. The fundamental aspects of the process of extraction was also explored in an attempt to understand it better. Improved technique of analysis was investigaed.

To initiate the research it is essential to understand the process and develop correlations of the findings where possible for the bench and pilot scale extractor.

INTRODUCTION

The extraction of PKO in Malaysia is currently carried out in three process routes; mechanical extraction by screw pressing, direct solvent extraction by percolation or immersion and pre-expelling followed by solvent extraction. The problems affecting the mechanical oil extraction at the moment has been identified as repair and maintainances and energy. In solvent plant major cost is solvent loss and energy.[1]

Even after the most efficient pressing, an oil cake will retain an appreciable amount of an absorbed oil, usually 2.5 - 5% by weight. Solvent extraction is particularly valuable since it will reduce residual oil in the seeds to less than 1%.[2]

It is intended here to study the potential of solvent extraction in palm kernel oil and to improve the overall processing of this particular industry. This research is carried out using direct solvent extraction and is done on both bench and pilot scale extractors. Various solvents were used on the bench scale using sokhlet extractor. The method of percolation was done on the pilot scale extractor. Correlations for the percent oil extracted as a function of time was derived and compared to theoretical models.

BACKGROUND:

The mass transfer of palm kernel oil from the palm kernel into the bulk solvent is similar to that of any oilseeds during extraction.

Early work indicated that the rate controlling factor in the solvent extraction of seed flakes was probably the internal resistance of the flakes to the molecular diffusion of solvent and oil.[3]

The data of Karnofsky[4] on the extraction of soyabean flakes by percolation with hexane indicates that the extraction rate is in indirect proportion to the square of the flake thickness; doubling the thickness for example should quadruple the time required for the reduction of residual oil to the required level.

Later work by Othmer and Agarwal[5], using countercurrent batch extraction, has permitted the calculation of the oil in meal from measurements of the increased miscella concentration namely,

$$\frac{-dC}{dt} = k F^{3.97} C^{3.5}$$

The extraction rate is proportional to the 3.97 power of the flake thickness F and 3.5 power of the residual oil C.

Factors such as the change in viscosity and surface tension of the miscella (mixture of oil and solvent) and changes in the physical characteristics of the solids as extractions proceed can combine to substantially alter the retention of oil/solvent with solids.

The other major factor influencing the efficiency of extraction is the rate of extraction. In any practical stage the contact between solid on solvent is rarely long enough for equilibrium to occur and the reaction is rate controlled.[6]

An approximate rate law for extraction from cellular solids can be expressed as:-

$$\frac{c_R}{c_o} = k \exp -(D\ t\ / r_p^2)$$

where c_R = concentration of oil remaining at time t.
c_o = initial concentration of oil.
k,D = are constants related to area and diffusion coefficient.
r_p = flake thickness.

This shows that the solution reaches a saturated condition exponentially.

A paper by Othmer and Jaatinen [7] extends their work to other solvents and show that solvents other than hexane and acetone do not extract at a rate independent of miscella concentration.

Total Efficiency / recovery

Recovery (total efficiency) is described as the amount of material removed from a fixed mass of solid feed :

$$\text{Recovery (\%)} = \frac{\text{mass removed} * 100\ (\%)}{\text{total initial mass of component}}$$

If more than one component is removed then it is possible to define recovery for each component.

$$R_i(\%) = \frac{m_i}{M_i} \times 100\%$$

where m_i = mass of ith component removed
M_i = initial mass of ith component

EXPERIMENTAL:

Bench Scale Extraction

The bench scale sokhlet extractor is the partial immersion type. A weighted sample is put into a thimble and pure solvent will immerse the thimble to a certain level afterwhich the solvent will be drained out. The miscella will be heated to separate pure solvent. The oil extracted increases significantly with time.

The first part of the experiments were conducted using crushed palm kernel samples of different sizes specially prepared in the laboratory. The second part of the experiments were carried out on samples from various stages of the factory samples. In both cases, the tests were carried out on both moist and dried samples.

The test carried out are with the following objectives:

1. To identify the true oil content in the palm kernel and to identify the oil content in each of the samples.
2. To determine the effect of moisture on the extraction efficiency.
3. To determine the solvent loss with each sample types.

There are four sample types obtained from the Felda Isi Sawit:

a) crushed palm kernel,
b) flaked palm kernel,
c) pressed palm kernel, and
d) toasted palm kernel meals.

4. To determine the efficiency of each solvent type on a particular sample.

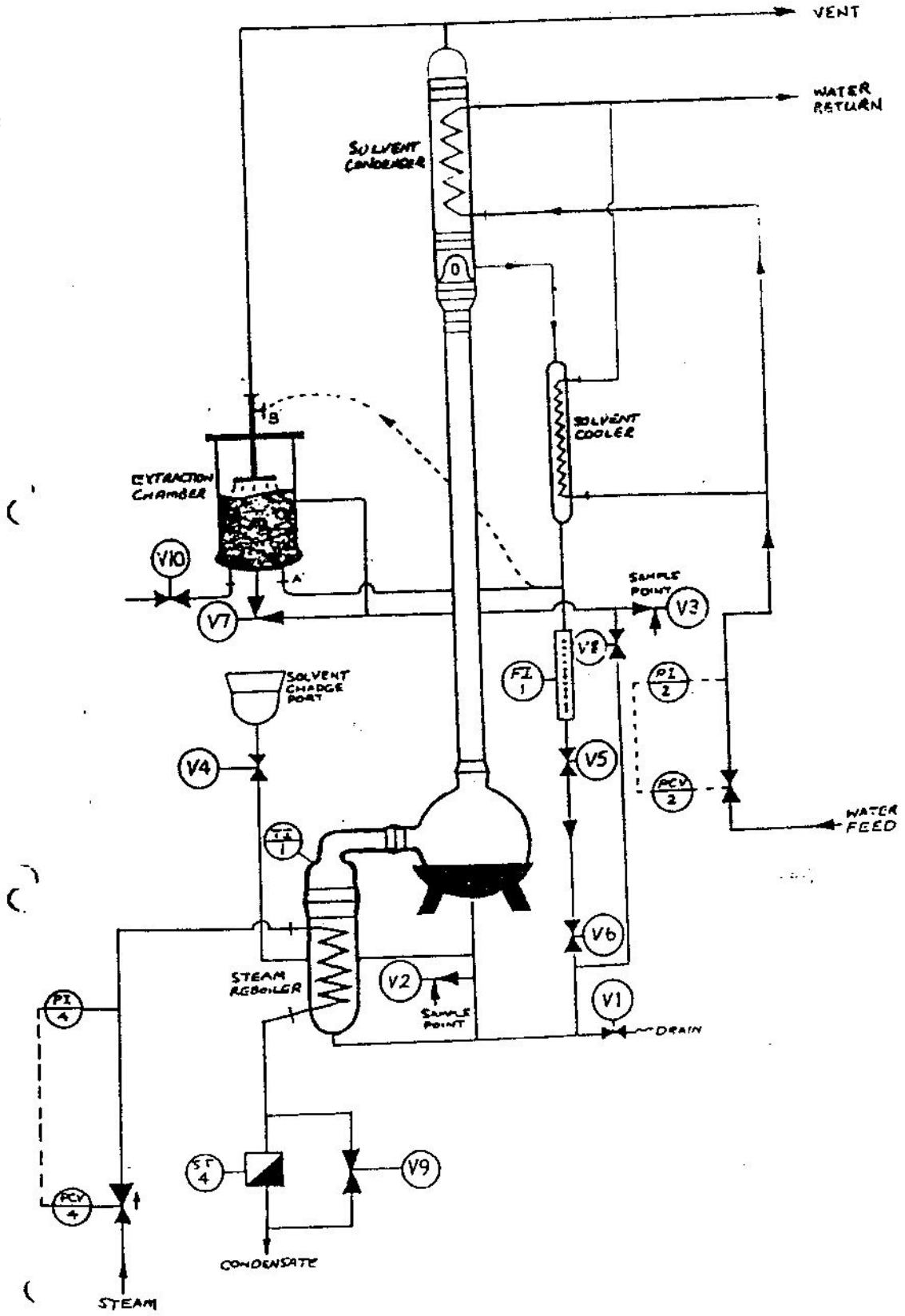


FIG. 1 : PILOT PLANT EXTRACTOR

The solvents used were :-

a. hexane;
b. iso-propanol;
c. acetone;
d. azeotropic isopropanol-hexane; (b.pt. 62.7 C)
e. azeotropic acetone - water (49.8 C).

Pilot Plant Extraction

The pilot scale extractor as in figure 1 was operated batchwisely in a percolation mode. A weighted sample was put into a woven bag and pure solvent was sprayed onto the bag of kernels.

The miscella was drawn out at specific intervals and the oil content was analysed. Only isopropanol solvent is used on the pilot extractor for safety reasons. Like sokhlet extractor the total oil extracted is a function of time.

The tests are carried on FELDA samples with the following objectives:

1. To compare the extraction efficiency for pilot scale extractor with the sokhlet extractor.
2. To study the variation of extraction with time and to determine the optimum operating time for this mode of extraction (percolation mode).
3. To develope a method of analysis of % oil extracted using uv.
4. To develope a correlation between the pilot scale extractor and the bench scale extractor.

RESULTS AND DISCUSSION

For this experiments % oil extracted is defined as follows:-

$$\% \text{ Oil Extracted} = \frac{\text{mass of oil extracted}}{\text{mass of total feed}} * 100$$

Results For Bench Scale Extractor

A correlation was obtained as a function of time and % oil extracted. It was found to be a simple fit of 5th order as follows:-

$$Y = At + Bt^2 + Ct^3 + Dt^4 + Et^5$$

where Y = % Oil extracted
t = time (hr.)
A,B,C,D and E are constants

In order to predict the % oil extracted on benc h scale using other solvents, a factor depending on the solvent used is obtained. The factor was based on the results using various solvents. Using hexane as a reference solvent the following factors were obtained:

Solvent	% oil	factor
hexane	43.59	1.04
isopropanol	41.93	1.00
acetone	45.89	1.09
isopropanol-hexane 23:77	42.81	1.02
acetone-water 59:49	44.81	1.07

The predictive % oil extracted was obtained by multiplying the factors to the above correlation. This is displayed in
Graph 1.

The true oil content in the sample types are graphically illustrated in Graph 2. This is important since the the efficiency of the various stages of the processes can be determined. The true oil content also varies for moist samples compared to the dried samples. The presence of water reduces the solvent extraction efficiency. Whether the solvent has affinity for water or water reduces the selectivity of the solvent for oil is yet to be determined.

Both the effects of crushed kernel sizes and the effect of solvent quantity are not conclusive in this experiments due to the small range of variation possible.

Graph 3 shows that solvent loss varies with sample types. This factor depends on the voidage spaces and the nature of the samples. The results indicated that the flaked samples retained a large quantity of solvents.

Both Graphs 1 and 6 indicate the % oil extracted vs. time for various types of solvents. The solvent with the highest efficiency is acetone and the least efficient is isopropanol. The difference of the % oil extracted is about 5%.

It takes about three hours before the values of % oil extracted reaches a steady state. After this period, the rate of extraction becomes very slow and the process requires a long time to produce a small

amount of oil. The maximum % oil extracted was found to be in the region 35 - 40% oil, which is low relative to the true oil content of the sample. The method of partial immersion used here is rather inefficient.

Results Of Pilot Scale Extractor

The optimum time of operation here is about 130min. The % oil extracted in this duration is within the range of 43 -47 % oil extracted. The efficiency is high for pilot scale extractor, since the % oil extracted is high relative to the true oil content. The method of operation of the pilot scale extractor is percolation in which only fresh solvent is used to leach out the oil from palm kernel.

The concentration of oil at a given time can also be determine using uv. A calibration chart was first established ie. a plot of absorbtion vs. % oil in solvent (Graph 4). Samples at each time interval was then tested using uv and the reading was obtained from a calibration chart.

A plot of comparison between % oil obtained by distillation with uv absorbance is illustrated in Graph 5. The results suggest that analisis of % oil extracted by distillation gives a higher and more accurate readings compared to the results obtained by uv absorbance. However, improved experimental techniques can save a lot of time and can give immediate results. This method of analisis has got a good prospect in future.

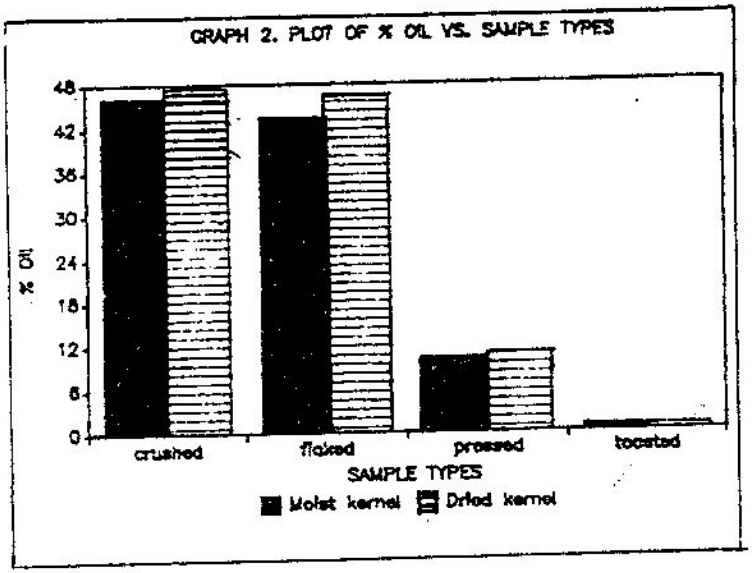
For the pilot scale extractor a correlation for predicting % oil extracted vs time was found to be a 3rd order equation:

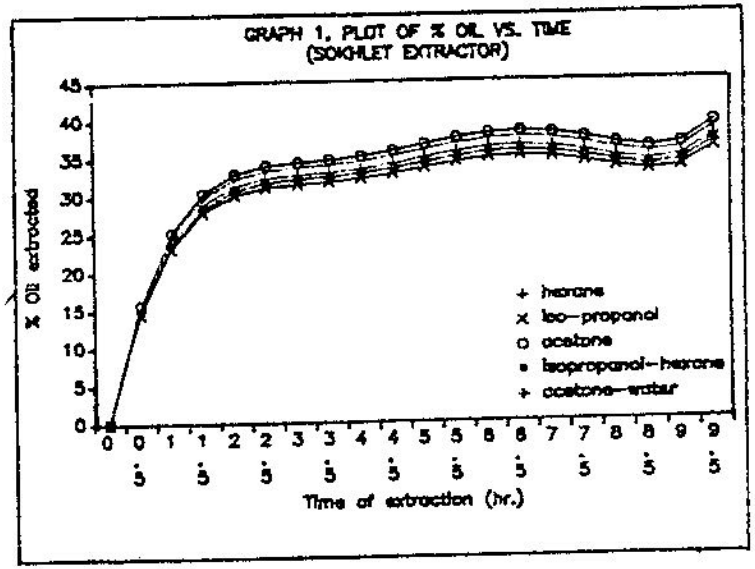
$$Y = At + Bt^2 + Ct^3$$

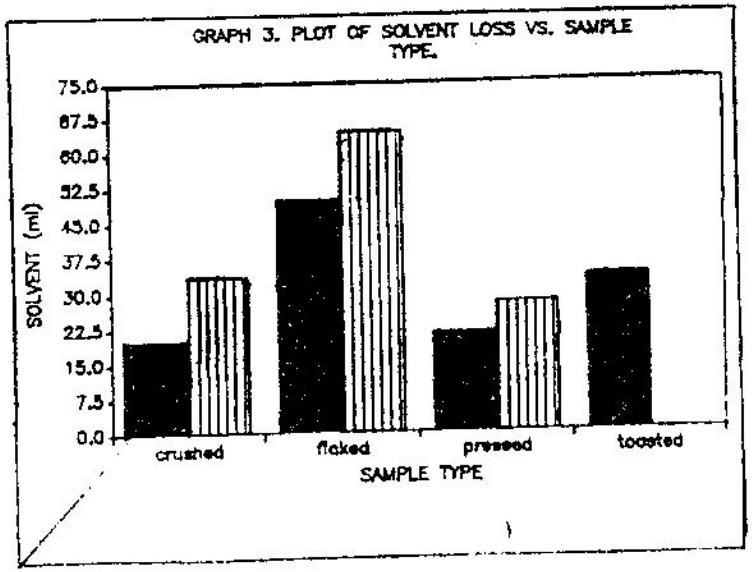
Where Y = % oil and t = time (min.)
A, B & C are constants.

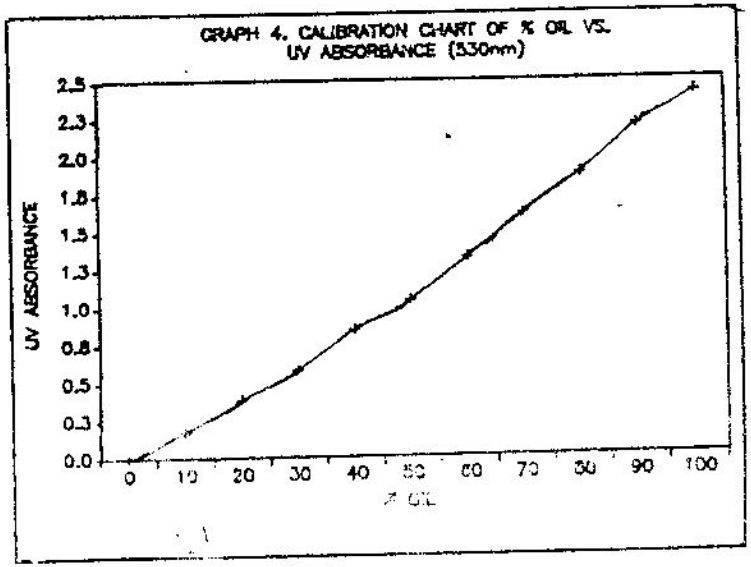
The results from the experiments in which various solvents types were used on bench scale were analysed to give predicting factors for extraction efficiency. This is graphically shown (graph 6).

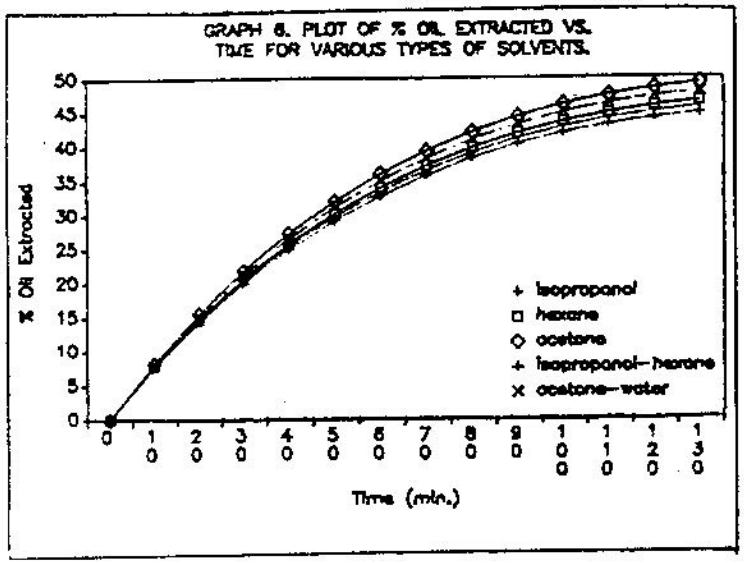
Graph 7 demonstrates the rate law for extraction from cellular solids. A plot of $ln\ (c_R / c_o)$ versus t gives a slope of $-D / r_p^2$ and an intercept of $ln\ k$. For this particular flake samples, c_o=47.27mass % or 0.4727kg oil/kg solids and flake thickness r_p^2 = 0.5mm.

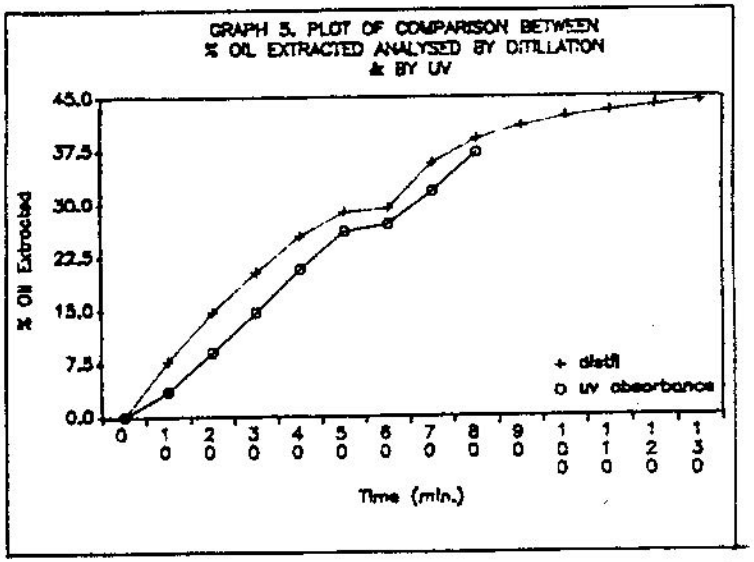

GRAPH 2. PLOT OF % OIL VS. SAMPLE TYPES
% Oil
48
42
36
30
24
18
12
6
0
crushed
flaked
pressed
toasted
SAMPLE TYPES
Moist kernel
Dried kernel

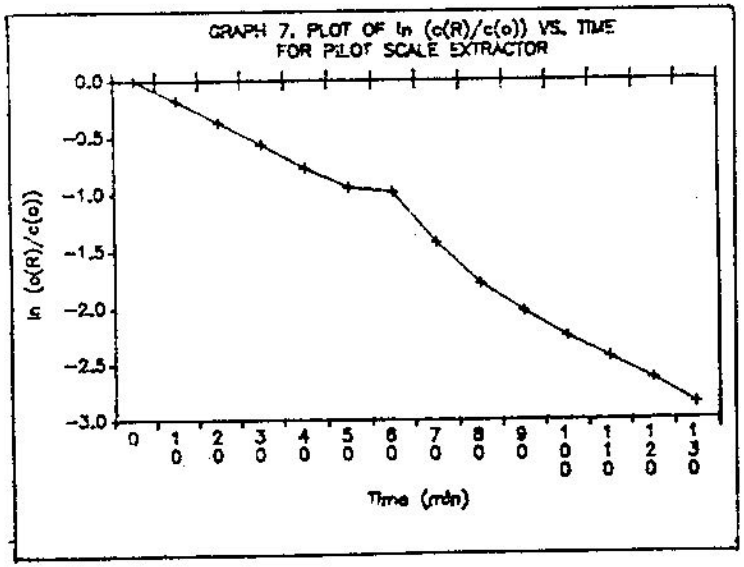

GRAPH 1. PLOT OF % OIL VS. TIME
(SOXHLET EXTRACTOR)
% Oil extracted
45
40
35
30
25
20
15
10
5
0
+ hexane
x iso-propanol
o acetone
• isopropanol-hexane
+ acetone-water
0 0 1 1 2 2 3 3 4 4 5 5 6 6 7 7 8 8 9 9
5 5 5 5 5 5 5 5 5 5
Time of extraction (hr.)

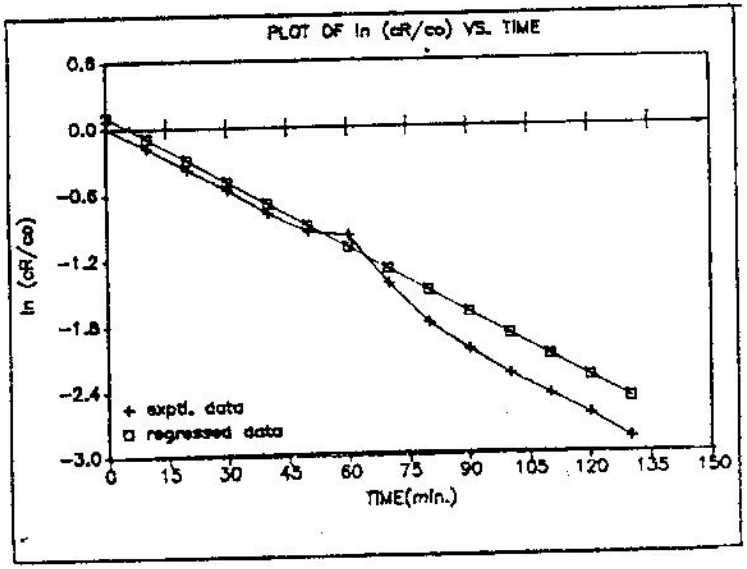

GRAPH 3. PLOT OF SOLVENT LOSS VS. SAMPLE TYPE.
SOLVENT (ml)
75.0
67.5
60.0
52.5
45.0
37.5
30.0
22.5
15.0
7.5
0.0
crushed
flaked
pressed
toasted
SAMPLE TYPE


GRAPH 4. CALIBRATION CHART OF % OIL VS.
UV ABSORBANCE (530nm)
UV ABSORBANCE
2.5
2.3
2.0
1.8
1.5
1.3
1.0
0.8
0.5
0.3
0.0
0 10 20 30 40 50 60 70 80 90 100
% OIL


GRAPH 6. PLOT OF % OIL EXTRACTED VS. TIME FOR VARIOUS TYPES OF SOLVENTS.
% Oil Extracted
Time (min.)
+ isopropanol
□ hexane
◇ acetone
+ isopropanol–hexane
× acetone–water


GRAPH 5. PLOT OF COMPARISON BETWEEN % OIL EXTRACTED ANALYSED BY DITILLATION & BY UV
% Oil Extracted
Time (min.)
+ distil
○ uv absorbance


GRAPH 7. PLOT OF ln (c(R)/c(o)) VS. TIME FOR PILOT SCALE EXTRACTOR
ln (c(R)/c(o))
Time (min)


PLOT OF ln (cR/co) VS. TIME
ln (cR/co)
TIME(min.)
+ expti. data
□ regressed data

The results show that the solute diffusivity D was found to be 5 E $-9m^2/s$.

CONCLUSIONS

1. The true oil quantity for each sample type is determined as follows:

a) crushed kernel	47.44%
b) flaked kernel	46.27%
c) pressed kernel	10.84%
d) toasted kernel	0.68%

However, the true oil quantity varies with different types of kernel species.

2. The moisture has the effect of lowering extraction efficiency in solvent extractors.

3. The extraction effiency is also affected by the types of solvents used. The results for solvents in the order of lowering extraction efficiency is acetone, acetone-water, hexane, isopropanol - hexane and isopropanol.

4. The correlations for predicting % oil extracted with time for both pilot and bench scale extractor were developed, the difference in the correlations is due to the varied modes of operation in both cases.

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