THE ECONOMIC EVALUATION OF THE PRODUCTION OF OIL-PALM-SHELL-BASED PHENOL

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Abstract. Previous work done in the extraction of phenol from oil palm shells showed that it contained up to 80.1% purity of phenolic compounds. The oil-palm-shell-based phenol is applicable to replace petroleum-based phenol in preparation of phenol formaldehyde wood adhesives. Since the average price of petroleum-based phenol is around RM 3600/ton, this work was done to estimate the cost of oil-palm-shell-based phenol. In this present research, three oil-palm-shell-based phenol manufacturing plants were investigated. Their manufacturing capacities are 1000 ton/year, 10 000 ton/year, and 100 000 ton/year. All the designs are based on the results from simulator DESIGN II. From the economic analysis, the cost of the oil-palm-shell-based phenol is RM 1084, RM 1008, and RM 972 per ton respectively. It shows that the cost of the oil-palm-shell-based phenol is reduced when the productivity is high. The net profit after taxes for these plants is RM 361,530, RM 4,140,764 and RM 43,943,092 per year respectively. The plants require 3 years for starting–up and their operating life is 17 years with a depreciation of 10% per year. For undiscounted cash flow, the pay back period is 10.0, 8.4, and 7.8 years respectively including the first 3 years. For different discount rates, values of net present value and discounted break–even point vary. The discounted cash flow rate of return is 14.0%, 20.0%, and 25.0% respectively in these plants with related net present value becomes zero. The after tax rate return obtained are 71%, 169%, and 426% respectively.

Keywords: Phenol, oil palm shells, oil-palm-shell-based phenol, petroleum-based phenol

Abstrak. Kajian lepas yang telah dijalankan untuk mengekstrak fenol daripada tempurung kelapa sawit menunjukkan ekstrak itu mengandungi 80.1% ketulenan dan dibuktikan dapat menggantikan fenol-petroleum untuk menghasilkan resin fenol-formaldehyde. Memandangkan harga fenol adalah lebih kurang RM 3600/ton, maka pengiraan dibuat untuk menentukan harga fenol-tempurung-kelapa-sawit. Tiga jenis kilang yang berbeza akan dikaji, iaitu 1000 ton/tahun, 10 000 ton/tahun, and 100 000 ton/tahun. Semua pengiraan dijalankan dengan menggunakan penyelaku DESIGN II. Daripada analisis ekonomi, kos bagi ketiga-tiga kilang ialah masing-masing RM 1084, RM 1008, dan RM 972 setiap ton. Untung bersih selepas cukai ialah masing-masing RM 361,530, RM 4,140,764 dan RM 43,943,092 setiap tahun. Kilang itu memerlukan 3 tahun untuk memulakannya dan boleh beroperasi selama 17 tahun dengan penyusutan 10% setahun. Tempoh bayar balik ialah 10.0, 8.4, dan 7.8 tahun termasuk 3 tahun pertama. Peratus bayar balik selepas cukai ialah masing-masing 71%, 169%, dan 426%.

Kata kunci: Fenol, tempurung kelapa sawit, fenol-tempurung-kelapa-sawit, fenol-petroleum

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1.0   INTRODUCTION

Plant design engineers are frequently confronted with the problem of estimating the manufacturing cost of a product, especially the cost of equipment. The value of equipment cost should be reasonable to the investment. In order to determine such investment accurately, it is necessary to carry out a refined design and to submit the information to manufacturers for quotations. This step is a time-consuming process. In such cases, it is sufficient to make preliminary estimates only on the sizes of various equipment items involved and to estimate the cost of such items rather than to depend on quotations [1].

In this present research, three oil-palm-shell-based phenol manufacturing plants were investigated. The plants are assumed operating 24 working hours per day and 330 working days per year. Their manufacturing capacities are 1000, 10 000, and 100 000 ton/year.

All the designs are based on the results from simulator DESIGN II version 8.35. DESIGN II is a simulator program to model a specific process depending on the provided information. In this paper, only the 10 000 ton/year manufacturing plant is described in detail.

2.0   PROCESS ECONOMIC ANALYSIS

The sizes, capacities and cost of all equipments in the simulation will be determined. The equipment sizing and costing is based on the Guthrie design method covered in reference [2]. All the calculations are based on the result from simulator DESIGN II.

Equipment sizing plays an important role in plant design. It affects the profitability of a plant where the choice of material used and the size of the units determines the feasibility of a plant. For this purpose, flow rates, temperatures, pressures and heat duties from the simulation result are needed in the calculation. Several assumptions are made on each type of the unit before sizing and costing are carried out, i.e. materials of construction, horizontal or vertical vessel, and ratio of length to diameter.

The summary of the process equipment costs for all three different production yield are shown in Table 1. The annual production capability for these three plants will be 1000, 10 000 and 100 000 ton/year respectively.

The first part of economic evaluation is deciding on the exact cost of the equipment. Economic evaluation is the next step. The total of that exact cost is called a fixed capital that is the sum of capital invested on real equipment, which cannot be easily converted into another form of capital. Therefore, the Bare Module Cost (CBM) and the Total Bare Module Cost (CTBM) for the whole plant should be obtained. Bare Module method is used to estimate the cost of equipment used in the plant. All the equipment costs have been used to determine the gross roof capital (GRC) cost

Table 1   Summary of process equipment cost in RM

Equipment	1000 ton/year	10 000 ton/year	100 000 ton/year
Mixer	4,915.00	20,485.00	85,395.00
Extractor 1	16,975.00	70,765.00	295,020.00
Extractor 2	15,935.00	66,375.00	276,930.00
Flash separator	8,975.00	37,370.00	155,785.00
Condenser	10,645.00	142,600.00	636,960.00
Storage tank 1	33,010.00	105,630.00	396,105.00
Storage tank 2	33,010.00	105,630.00	396,105.00
Total CTBM, RM	**123,465.00**	**548,855.00**	**2,242,300.00**

for this plant. GRC makes up the major portion of total fixed capital cost (FCI). The gross-roof capital (GRC) is calculated as follows by using the formula [3]:

Contingency and Fees   =   0.18 CTBM
         =   RM 98,794.00

Total Module Cost, CBM   =   1.18 CTBM
           =   RM 647,649.00

Auxiliary Facilities   =   0.30 CTBM
        =   RM 164,657.00

Gross–roof Capital (GRC)   =   RM 98,794.00 + RM 647,649.00 + RM 164,657.00
           =   RM 911,100.00

2.1   Project Costing

Generally, the project costing considers the total investment required for the plant full operation that is total capital cost and total production cost.

2.1.1   Total Capital Cost

The total capital cost includes total fixed capital and working capital costs:

(i) Total fixed capital investment:
  (a) Purchased equipment cost.
  (b) All items of equipment installation and construction supervision.
  (c) All piping, instrumentation and control systems.
  (d) Buildings and structures.
  (e) Auxiliary facilities, i.e. utilities, land and civil engineering work.

(ii)   Working capital:

The additional investment needed to start-up and operate the plant to the point where income is earned. This includes the cost of:

    (a)   Start–up.
    (b)   Raw materials and intermediates in the process.
    (c)   Finished product inventories.
    (d)   Funds to cover outstanding accounts from customers.

   The summary of capital cost for the 10 000 ton/year production plant is shown in Table 2. The specifications are estimation methodology from reference [3].

Table 2   Estimation of fixed and total capital investment cost

Onsite	Specification	Total (RM)
Purchased equipment installation	30% GRC	273,330.00
Instrumentation and control (installed)	15% GRC	136,665.00
Piping (installed)	40% GRC	364,440.00
Electrical and material (installed)	8% GRC	72,888.00
Offsite		
Building	10% GRC	91,110.00
Yard improvements	1% GRC	9,111.00
Service facilities	5% GRC	45,555.00
Land	2% GRC	18,222.00
TOTAL 1		**1,011,321.00**
Engineering and supervision	5% GRC	45,555.00
Construction expenses	8% GRC	72,888.00
Contractor's fee	1.5% GRC	13,666.00
Contingency	10% GRC	91,110.00
TOTAL 2		**223,219.00**
TOTAL 3 = TOTAL 1 + TOTAL 2		1,234,540.00
Gross Roof Capital (GRC)		911,100.00
Fix Capital Investment (FCI)	TOTAL 3 + GRC	2,145,640.00
Working capital	12% FCI	257,477.00
Start up	8% FCI	171,651.00
Total Capital Investment, TCI	FCI + Working capital + Start up	**2,574,768.00**

2.1.2   Total Production Cost

After determination of the total capital cost, another important part is the estimation of costs for plant operating and selling the products. These costs can be grouped under the general heading of total production cost. Generally, total production cost

is divided into two categories, i.e. manufacturing costs and general expenses. The manufacturing cost includes direct and indirect production cost, general expenses and annual depreciation. Direct production cost includes raw material cost, utilities cost, operating labor cost, maintenance and others. The manufacturing cost of 10 000 ton/year of oil-palm-shell-based phenol is shown in Table 3. The specifications are estimation methodology from reference [3]. The cost of oil-palm-shell-based pyrolysis oil is estimated as RM 304/ton [4].

Table 3 Summary of manufacturing cost

Manufacturing expenses	Consumption rate	Specification	Total (RM)
Direct production cost:			
Pyrolysis oil	17820 ton/year	RM 304/ton	5,417,280.00
Ethyl acetate	4029 ton/year	RM 652/ton	2,626,908.00
Sodium bicarbonate	891 ton/year	RM 516/ton	459,756.00
Water	34854 m^3/year	RM 2.36/m^3	82,255.00
Cooling water	25321 m^3/year	RM 2.36/m^3	59,758.00
Electricity	2581250 kWh	RM 0.23/kWh	593,688.00
Maintenance and repairs		3% FCI	64,370.00
Operating supplies		0.5% FCI	10,730.00
Operating labor		0.0033 × 10,000,000 × 4	132,000.00
Direct supervision and clerical labor		15% operating labor	19,800.00
Laboratory charges		15% operating labor	19,800.00
Total 1			**9,486,345.00**
Indirect product cost:			
Overhead, storage		50% operating labor	66,000.00
Local taxes		1% FCI	21,456.00
Insurances		0.5% FCI	10,728.00
Total 2			**98,184.00**
Total manufacturing expenses, AME		Total 1 + Total 2	**9,584,529.00**
General expenses:			
Administration cost		10% overhead	6,600.00
Distribution and selling expenses		8% FCI	171,650.00
Research and development		5% FCI	107,280.00
Total general expenses, AGE			**285,530.00**
Total production cost, APC		AME + AGE	**9,870,059.00**
Annual depreciation, ABD		10% FCI	214,564.00
Total expenses, ATE		APC + ABD	**10,084,623.00**

2.2 Rate of Return

The rate of return of 10 000 ton/year of palm-shell-based phenol is shown as follows:

$$\text{Cost of extracted phenol} \quad = \quad \frac{\text{RM } 10,084,623.00}{10,000 \text{ ton}}$$

$$= \quad \text{RM } 1,008 \text{ / ton}$$

As the price of petroleum-based phenol is around RM 3,600.00, the oil-palm-shell-based phenol is assumed to sell at the price of RM 1,600.00.

Revenue from sales	=	RM 1,600.00 × 10,000 ton / year
	=	RM 16,000,000.00 / year
Annual profit	=	Revenue from sales – Total expenses
	=	RM 16,000,000.00 – RM 10,084,623.00
	=	RM 5,915,377.00 / year

The income tax is assumed 30% from the total annual profit

Income tax	=	0.3 × RM 5,915,377.00
	=	RM 1,774,613 / year

Net annual profit after income tax, A_{NNP}

	=	RM 5,915,377.00 – RM 1,774,613.00
	=	RM 4,140,764.00

$$\text{Rate of return} \quad = \quad \frac{A_{NNP} + \text{ABD}}{\text{TCI}} \times 100\%$$

where ABD	=	Annual depreciation
	=	RM 214,564.00
TCI	=	Total Capital Investment
	=	RM 2,574,768.00

$$\text{Thus, rate of return} = \frac{\text{RM } 4,140,764.00 + \text{RM } 214,564.00}{\text{RM } 2,574,768.00} \times 100\%$$

$$= \quad 169\%$$

2.3 Pay Back Period (PBP)

Pay Back Period (PBP) is the period of time required to recover back all fixed capital investment from the start up of the plant. The plant life is estimated to be 20 years including the first 3 years of construction of the plant. The undiscounted cash flow is shown in Figure 1. From Figure 1, the pay back period for undiscounted
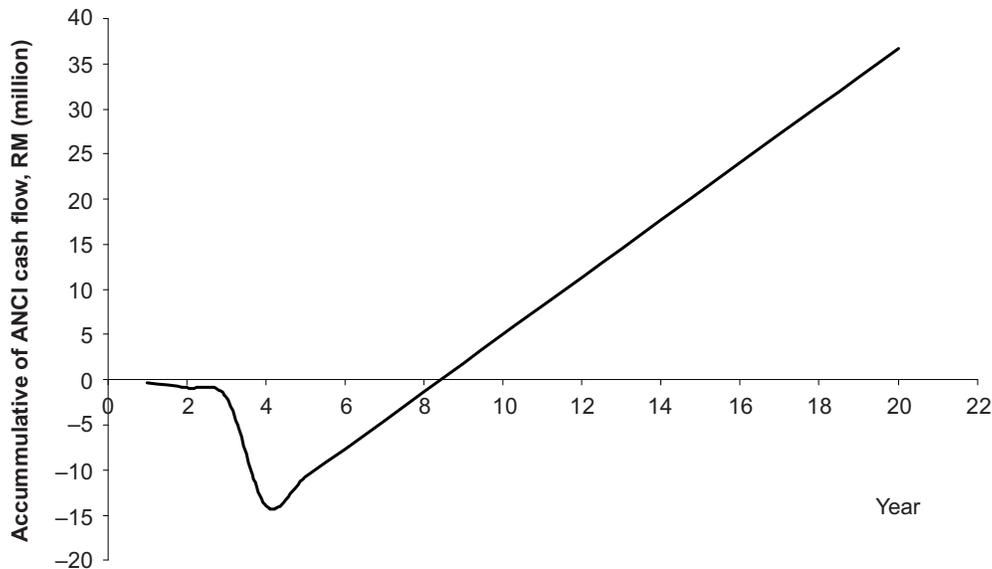
Figure 1   Cash flow for 7920 ton/year palm-shell-based phenol plant without discount rate

cash flow can be estimated as 8.4 years which includes the first 3 years set up period.

2.4   Discounted Cash Flow Analysis

The undiscounted cash flow analysis does not take account of time value of money. Therefore, for a more realistic analysis, the annual cash flows are multiplied by discount factors, f_d appropriate to the year, n and interest rate, i in formula, which is

$$f_d = \frac{1}{(1+i)^n}$$

yielding a cumulative discounted cash flow in terms of current Malaysian ringgit. The result depends on the interest rate that one assumes, in which in this case, three interest rates which are 10%, 15% and 20% were used. The new cash flow profiles can be plotted which is shown in Figure 2.

Discounted break-even period (DBEP) can be defined as the time from the decision to process until discounted cumulative cash flow becomes positive [3]. For this case, interest rate of 10% was considered a reasonable current interest rate to assess the plant profitability. From Figure 2, the DBEP at 10% is about 10 years.

Discounted cash flow rate of return (DCFRR) is the rate of return at which a net present value (NPV) of zero is obtained at the last year of the economic study. This
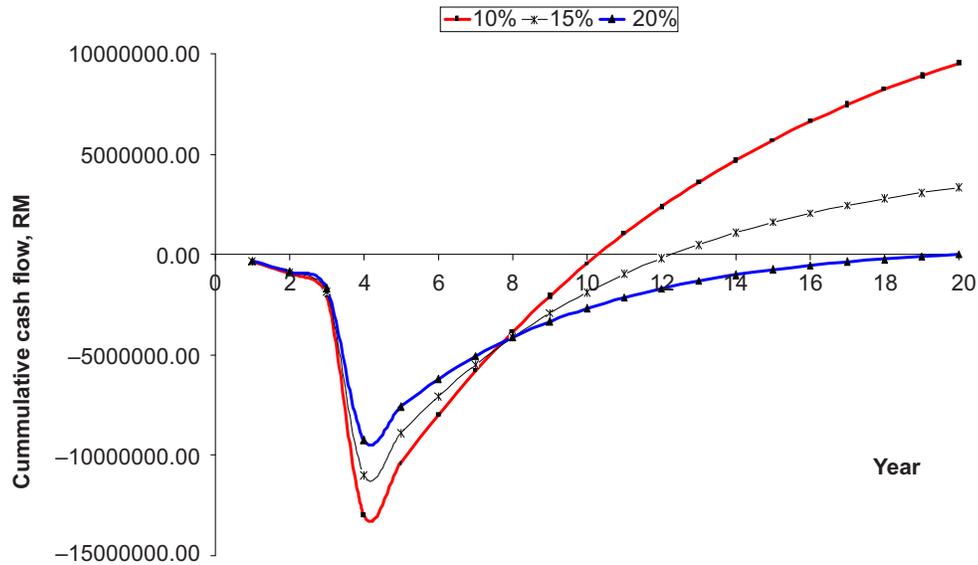
Figure 2   Cash flow for 7920 ton/year palm-shell-based phenol plant with different discount rates

value is designed to reflect the actual interest on investment. Because of this, it is useful for comparing alternate possibilities in which the DCFRR value should be higher than the interest rate available, otherwise the project is not profitable. From Figure 2, the DCFRR falls at around 20%. This value of DCFRR is considered high compared with the current interest rate which is assumed as 10%. Thus, this project is feasible due to its profitability.

2.5   Results and Discussions

Table 4 shows a summary of the costing results for three phenol-extraction plants. From the economic analysis, the Total Capital Investment (TCI) of these three plants are RM 579,194.00, RM 2,574,768.00 and 10,518,985.00 respectively. The annual total expenses (ATE) are RM 1,083,529.00, RM 10,084,623.00, and RM 97,224,155.00; and meanwhile, the annual revenue from sales are RM 1,600,000.00, RM 16,000,000.00, and RM 160, 000,000.00 respectively. The costs of the oil-palm-shell-based phenol are RM 1,084.00, RM 1,008.00, and RM 972.00 per ton for 1000 ton/year, 10 000 ton/year and 100 000 ton/year productivity respectively. It shows that the cost of the oil-palm-shell-based phenol is reduced when the productivity is high. The net profits after taxes (ANNP) for these plants are RM 361,530.00, RM 4,140,764.00 and RM 43,943,092.00 per year respectively.

Table 4   Summary of phenol extraction plant costing results

Specifications	1,000 ton/year	10,000 ton/year	100,000 ton/year
Total capital investment, TCI (RM)	579,194.00	2,574,768.00	10,518,985.00
Annual total expenses, ATE (RM)	1,083,529.00	10,084,623.00	97,224,155.00
Annual revenue from sales, AS (RM)	1,600,000.00	16,000,000.00	160,000,000.00
Annual net profit after taxes, ANNP (RM)	361,530.00	4,140,764.00	43,943,092.00
Cost of oil-palm-shell-based phenol per ton (RM)	1,084.00	1,008.00	972.00
Pay back period, PBP	10.0 years	8.4 years	7.8 years
Discounted cash flow rate of return, DCFRR	14.0%	20.0%	25.0%
Rate of return after taxes	71%	169%	426%

The plants are estimated to require 3 years for starting-up and their operating life is 17 years with a depreciation of 10%. For undiscounted cash flow, the pay back periods are 10.0, 8.4, and 7.8 years respectively including the first 3 years for starting-up the operation of these plants. The after tax rate of return obtained are 71%, 169%, and 426% respectively. The discounted cash flow rate of return (DCFRR) is 14.0%, 20.0%, and 25.0% respectively for these plants.

3.0   CONCLUSION

From the discounted cash flow rate of return (DCFRR), the values of 20.0% or 25.0% was determined which is high compared with the estimated current interest rate available, 10%. However, the value of 14.0% is considered quite low compared with the estimated current interest rate available, 10%. Hence, as conclusion, both of the 10 000 ton/year and 100 000 ton/year productivity oil-palm-shell-based extraction plant are feasible and profitable.

LIST OF SYMBOLS

f_d	-	discount factors
n	-	number of year
i	-	interest rate
C_{BM}	-	bare module cost
C_{TBM}	-	total bare module cost

GRC   -   gross roof capital
FCI   -   fixed capital cost
TCI   -   total capital investment
AME   -   total manufacturing expenses
AGE   -   total general expenses
APC   -   total production cost
ABD   -   annual depreciation
ATE   -   total expenses
ANP   -   annual net profit
ANNP   -   annual net profit after tax
PBP   -   pay back period
DBEP   -   discounted break-even period
DCFRR   -   discounted cash flow rate of return

REFERENCES

[1]   Douglas, J. M. 1988. *Conceptual Design of Chemical Processes*. New York: Mc Graw Hill.
[2]   Coulson, J. M., J. F. Richardson, and R. K. Sinnot. 1985. *Coulson & Richardson's Chemical Engineering Volume 6: Chemical Engineering Design*. 2nd ed. London: Pergamon Press. 212-245.
[3]   Ulrich, G. D. 1984. *A Guide to Chemical Engineering Process Design and Economics*. New York: John Wiley & Sons. 259-402.
[4]   Islam, M. N. 1999. Pyrolysis of Biomass Solid Waste and its Catalytic Treatment with Techno-Economic Analysis. Ph.D. Thesis. Universiti Teknologi Malaysia.