Palm Kernel Crusher Plant Operation and Economic Feasibility

Andrew Yap Kian Chung* and Rohaya Mohamed Halim*
*Malaysian Palm Oil Board (MPOB), 6 Persiaran Institusi, Bandar Baru Bangi, 43000 Kajang, Selangor, Malaysia.
E-mail: andrew@mpob.gov.my

ABSTRACT

Palm kernels are produced in a palm oil mill but will usually be sent to a palm kernel crusher plant with a maximum of 6% dirt and 7% moisture content. Mechanical screw press extraction is most common in used to produce crude palm kernel oil (CPKO) complying with Malayan Edible Oil Manufacturers' Association (MEOMA) specifications. The average palm kernel oil extraction rate is about 45.63% and the crusher plant's energy expenditure decreases as mill capacity increases. Although oil production cost varies due to production conditions, palm kernel oil production cost is the lowest among the major oil crops. The profit margin of palm kernel mill increases with plant capacity.

Keywords: Gross margin, net present value, payback period, return on investment.

INTRODUCTION

Fresh fruit bunches (FFB) are sent to the palm oil mill to thresh out the fruitlets as shown in *Figure 1* before crude palm oil (CPO) is extracted from the mesocarp.

Figure 1. Fruitlet and fresh fruit bunch (FFB).

The nuts will then be further processed to recover the kernel. The general mill mass balance is shown in *Figure 2*. Due to its small quantity, palm kernels with maximum of 6% dirt and 7% moisture are sent to the palm kernel crushing plant for further processing to produce crude palm kernel oil (CPKO) with properties as shown in *Table 1* (Pantzaris and Mohd Jaaffar Ahmad, 2001). *Figure 3* shows the market price trend for palm kernel and CPKO (MPOB, 2021). *Table 2* shows the production costs of several oil crops, which vary due to production conditions (ABC Machinery, 2021).

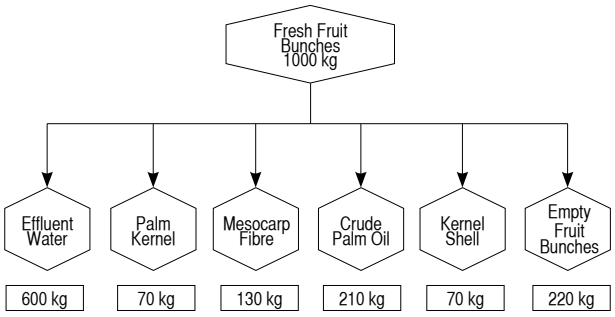

Figure 2. General mill mass balance.

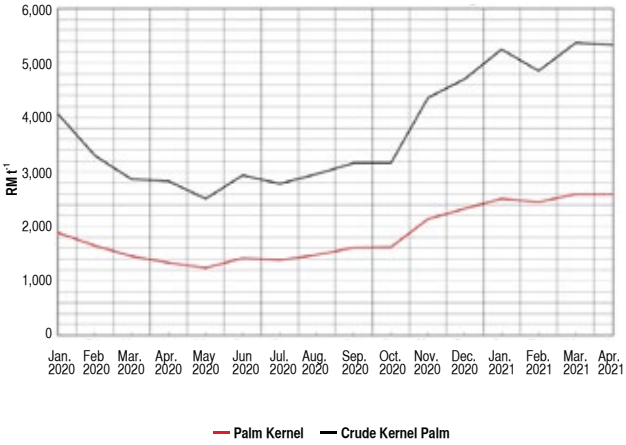

Figure 3. Palm kernel and crude palm kernel oil (CPKO) price trend.

TABLE 1. CRUDE PALM KERNEL OIL PROPERTIES

Fatty Acid	[%]	Iodine Value (Wijs)	16 – 23
Caproic acid	0.2	Slip Melting Point [°C]	25.9 – 28.0
Caprylic acid	3.3	Density at 15 °C [g ml^{-1}]	0.925 – 0.935
Capric acid	3.5	Refractive index at 40 °C	1.4500 – 1.4580
Lauric acid	47.9	Saponification value [mg KOH / g]	242 – 254
Myristic acid	16.3	Unsaponifiable [g]	≤ 10.0
Palmitic acid	8.5	Colour (5 1/4" Lovibond) R	3.4 – 4.5
Stearic acid	2.4	Colour (5 1/4" Lovibond) Y	30 – 32
Oleic acid	15.4	Dynamic Viscosity [mPa s]	43 at 30 °C
Linoleic acid	2.4	Dynamic Viscosity [mPa s]	29 at 40 °C
Arachidonic acid	0.1	Dynamic Viscosity [mPa s]	20 at 50 °C
Malayan Edible Oil Manufacturers' Association (MEOMA) Product Specifications			
Free Fatty Acid, FFA (as lauric acid)		5.00% maximum	
Moisture and Impurity, M & I		0.50% maximum	
Iodine Value (Wijs), IV		19 maximum at time of shipment	

Various palm kernel oil extraction processes are available but mechanical screw press is the most commonly used method in Malaysia. It consists of three basic steps, kernel pre-treatment, screw-pressing, and oil clarification (*Figure 4*) (Ihediwa and Ndukwu, 2017). *Figure 5* shows a typical mechanical screw press used for palm kernel oil extraction, which consists of an interrupted helical threaded worm that revolves within a stationary perforated cylinder known as a cage or barrel.

Small mills usually use screw-presses with a capacity of less than 10 t $unit^{-1}$ day^{-1} to crush the kernels directly without any pre-treatment following process route (A) (*Figure 4*). Double pressing is required to ensure efficient oil extraction.

Process route (B) (*Figure 4*) partially pre-treat the kernel, followed by screw-pressing whereas plants with larger capacities (50-500 t day^{-1}) usually pre-treat the kernel completely before screw-pressing as described under process route (C).

TABLE 2. SEVERAL OIL CROPS PRODUCTION COSTS COMPARISON

Oils	Production Country	Per Tonne Oil Processing Cost (USD)
Palm Kernel Oil	Indonesia	185
Palm Kernel Oil	Malaysia	240
Soybean Oil	United State of America	400
Rapeseed Oil	Canada	648
Rapeseed Oil	European Community	900

Kernel pre-treatment is necessary for efficient kernel oil extraction. The kernels must be cleaned and free from foreign materials which may damage the screw-presses. Magnetic separators could be used to remove metal debris while vibrating screens are used to eliminate sand, stones, and other undesirable materials.

Cleaned kernels are smashed into small fragments by a swinging hammer grinder, breaker rolls, or a combination of both to increase the kernels' surface area, thus facilitating flaking in a roller mill. Each vertically mounted roller revolves at 200-300 rpm and the kernel cake thickness are

progressively reduced from the top roller to the bottom to initiate cell walls rupture. Kernel flakes' thickness ranged from 0.25 mm to 0.4 mm.

The kernel flakes are conveyed to a saturated steam-heated stack cooker complete with a mechanical stirrer for steam conditioning so that:

- the kernel meal moisture content is adjusted to optimum level;
- cell walls are further ruptured after initiated by rolling;
- crude kernel oil viscosity is reduced;
- protein in the meal is coagulated to facilitate oil separation from protein materials.

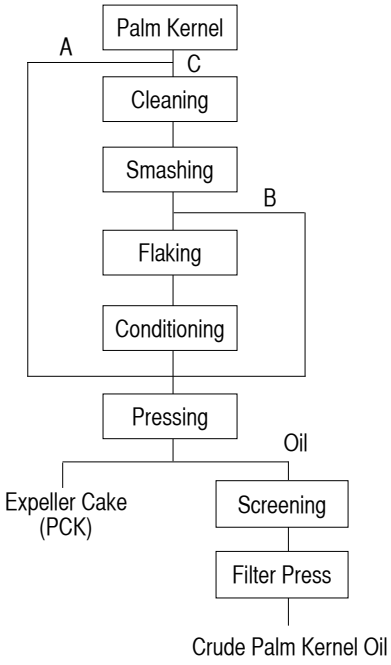

Figure 4. Mechanical palm kernel crushing process flow chart.

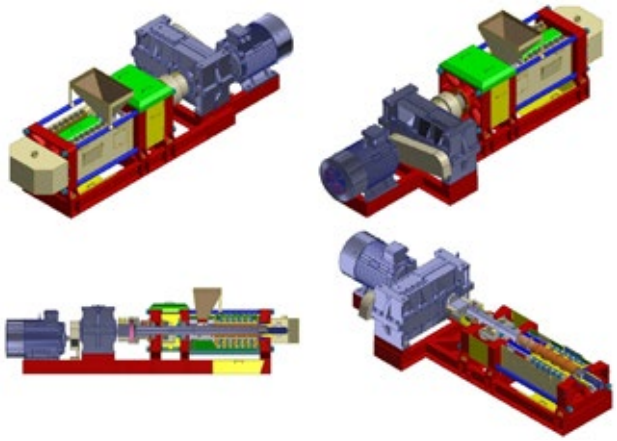

Figure 5. Mechanical screw press for palm kernel oil extraction.

The kernel meal is agitated at each stage and flows down from the top compartment of the heated stack cooker. Temperature and moisture content are important control variables, normally 3% moisture content at 104°C to 110°C.

The duly cooked meal is fed into a screw press and forced through the barrel by the revolving worm action. The worm diminishes displaced axial volume from the feeding end to the discharge end, thus compressing the meal while passing through the barrel to a reservoir. The expelled crude palm kernel oil is drained through the barrel lining bars perforation, while the palm kernel cake is discharged through an annular orifice and conveyed for bagging or bulk storage. The extreme temperature could damage the oil and cake quality thus, the worm shaft is always cooled with circulating water while the barrel is externally cooled by recycling some cooled oil.

The expelled oil invariably contains a certain quantity of impurity that needs to be removed. A decanter or vibrating screen is used to remove large solid impurities. Filter press is then used to remove the remaining solids and fines in order to produce clear CPKO comply that with Malayan Edible Oil Manufacturers' Association (MEOMA) specification prior to storage (*Figure 6*). *Figure 7* shows a typical palm kernel crusher plant process flow diagram. The average palm kernel oil extraction rate is 45.63% and *Figure 8* shows the palm kernel oil extraction rate trend in Malaysia (MPOB, 2021).

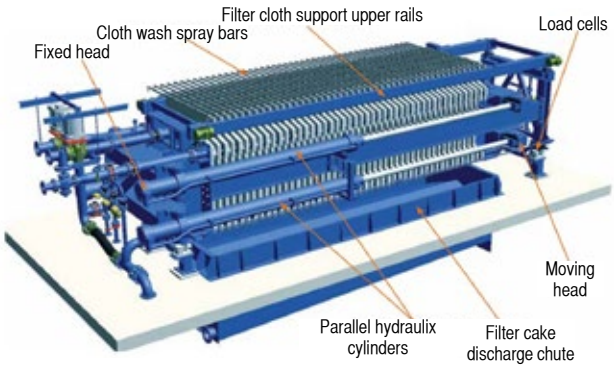

Figure 6. Typical filter press structure for crude palm kernel oil clarification.

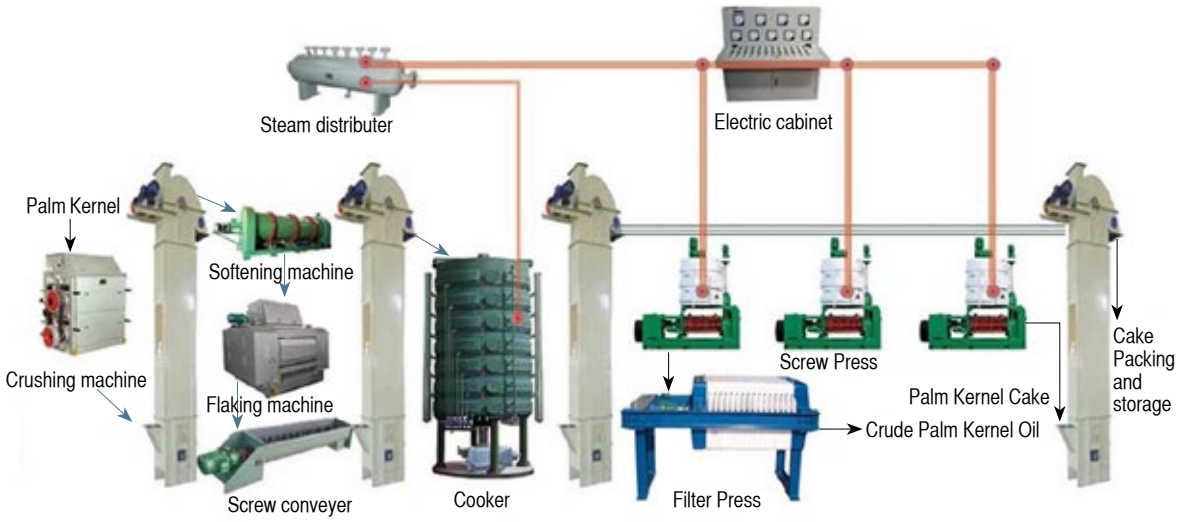

Figure 7. Typical palm kernel crusher plant process flow diagram.

Direct energy utilisation evaluation showed that the unit energy requirement for PKO output decreases as mill capacity increases and the total energy expenditure for small, medium, and large palm kernel oil mills were 350.89 MJ t^{-1} PKO, 230.70 MJ t^{-1} PKO and 181.74 MJ t^{-1} PKO respectively (Jekayinfa and Bamgboye, 2004).

The cost for palm kernel crushing plant setup varies depending on size and capacity. Generally, at least about USD3000 will be required which is equivalent to about RM12 383 in the year 2021, and most of the money is spent on starting up. Thus, project funding for the palm kernel oil production business plan plays a key role towards the final success. However, plants with a small capacity is not able to generate significant economic revenue. A medium- capacity mill, 20 t kernel day^{-1}, with initial capital expenditure (CAPEX) of about RM1500 000 is recommended for potential small and medium industry (SMI) entrepreneurs.

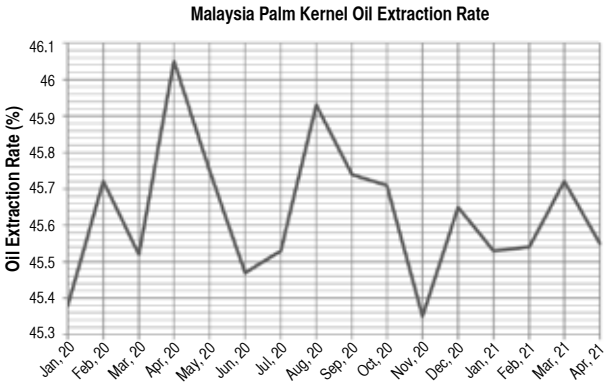

Figure 8. Malaysia Palm Kernel Oil Extraction Rate.

DISCUSSION

The price gap between palm kernel and CPKO as shown in *Figure 3* indicates the business gross profit margin. The business feasibility study should base on the worst scenario where the price gap is minimum. Based on the pricing status on May 2020 CPKO was sold at RM2510 t^{-1} while palm kernel was offered at RM1244 t^{-1}. The palm kernel cake could be sold at RM620 t^{-1} currently for animal feed purposes. The average crude palm kernel oil extraction rate is 45.63% based on the data shown in *Figure 8*. *Table 3* shows the business gross margin.

TABLE 3. PALM KERNEL CRUSHING PLANT GROSS MARGIN ANALYSIS

Particular	Quantity	Amount [RM]
Palm Kernel	1000.0 kg	1244.00
Crude Palm Kernel Oil (CPKO)	456.3 kg	1145.31
Palm Kernel Cake	543.7 kg	337.10
Gross Margin		**238.41**
MPOB Cess	RM16/t CPKO	7.30
Average Energy Expenditure	RM0.40/kWh	11.70
Estimated Gross Profit		**219.41**

The energy expenditure calculation was based on medium-scale crusher plant thus; 105.26841 MJ will be consumed to process one tonne of palm kernel. Knowing that 1 MJ = 0.277778 kWh, the energy expenditure is equivalent to 29.241225 kWh. Palm kernel mill is defined as 'Industrial Consumer' under tariff D by Tenaga

Nasional Berhad (TNB), the sole electric energy provider in Malaysia. The first 200 kWh per month is RM0.38 kWh^{-1}, followed by RM0.44 kWh^{-1} for each exceeded unit. Thus, the rate of RM0.40 kWh^{-1} was used for the convenience of calculation.

The following is based on assumption that the project needs to be fully funded by SME Business Loans from Malaysian banks with an average interest of 10% per annum and the 20-tonne plant has 10 years of design life. For the convenience of calculation, RM200 gross profit per tonne kernel processed and 300 days operation per annum was adopted. Thus, annual gross profit is 200 x 20 x 300 = RM1 200 000. Based on gross profit, the net present value (NPV) is

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)t}$$

where R_t is net cash flow during a single period = RM1200 000; i is discount rate = 10% p.a., and n is the plant design life = 10 years.

were mainly the palm kernels transportation from the palm oil mills to the kernel crushing plants and the grid electricity consumption for the kernel processing. Thus, the kernel crushing plant should be integrated with a palm oil mill for the least environmental impact (Subramaniam *et. al.,* 2010).

CONCLUSION

The analysis above showed that palm kernel crushing is a profitable industry. The profit margin increases with plant capacity due to energy consumption efficiency in a large mill. Since crude palm kernel oil may be used for edible purposes, the palm kernel crushing plant setup needs to comply with *Makanan Selamat Tanggungjawab Industri* (MeSTI) requirements or adopts other food safety assurance programmes such as Hazard Analysis Critical Control Point (HACCP). The new mill premise may also need to comply with other requirements set by the authorities mentioned in the planning approval granted

Year (*t*)	Amount (RM)	Year (*t*)	Amount (RM)
1	1 090 909.10	6	677 368.72
2	991 735.50	7	615 789.74
3	901 577.76	8	559 808.86
4	819 616.15	9	508 917.14
5	745 105.59	10	462 651.95
Total Amount = RM7 373 480.51			

NPV = 7 373 480.51 – 1 500 000.00 = RM5 873 480.51

$$\text{Payback Period} = \frac{1\,500\,000}{1\,200\,000} = 1.25 \text{ yr}$$

$$\text{Return on Investment (ROI)} = \frac{587\,3480.51}{1\,500\,000 \times 10} \times 100 = 39.1565\% \text{ per annum.}$$

Life cycle impact assessment (LCA) has been performed based on the Eco-indicator 99 methodology using the Simapro software version 7.1. Six kernel crushing plants have been chosen well distributed all over Peninsular Malaysia to ensure the scenarios are representative of all kernel crushing plants in Malaysia. Five kernel crushing plants were located near the ports, while the remaining plant was located right beside a palm oil mill. The assessment results showed that the impacts directly associated with the crude palm kernel oil production

under subsection 3, Section 22, Town and Country Planning Act 1976 (Act 172) such as Department of Environment (DOE), Tenaga Nasional Berhad (TNB) *etc*.

Good Manufacturing Practice (GMP) is complex with a wide array of regulatory requirements that making a quality system set up is time-consuming. Then huge documentation effort is required to keep up with and long cycle times are often needed for quality assurance (QA) review and corrections. Initial GMP training and ongoing

standard operation procedures (SOP) compliance are costly. Although MeSTI is a free certification scheme introduced by the Ministry of Health to fulfill the minimum regulations' requirements, the GMP implementation requires higher capital expenditure (CAPEX) and operational expenditure (OPEX) compared to conventional operation, where additional costs are needed to enhance food safety controls in various aspects such as (Eresha Mendis and Niranjan Rajapakse, 2009):

- Plant environment and facilities
- Raw materials and consumables
- Storage and delivery
- Cleaning and sanitation
- Employee training and personal hygiene
- Production equipment and machinery
- Quality assurance management
- Pest control
- Recordkeeping and traceability

The CAPEX difference percentage between conventional and GMP setup may vary considerably depending on the location, available infrastructure, plant capacity, and degree of sophistication such as automation. However, the OPEX difference percentage should not exceed 30% of the gross profit margin, or else the business model viability will be affected significantly.

Conventional solvent extraction (CSE) process extracts oils from seeds based on the oil solubility in the solvent, most often hexane (C_6H_{14}). Generally, CSE involves oilseed cleaning and conditioning, oil extraction, and miscellany separation. Crude oil and meal quality depend on the solvent type, reaction temperature, and the oilseed. The oil recovery rate may achieve 90%–98% but requires high energy and high investments. The extraction method is cost-efficient and easy to use, however, the solvent is hazardous and toxic which imposes health risks with prolonged exposure. Thus, CSE is not encouraged for the edible processes but the advantages of mechanical extraction should be exploited including good quality oil production and the vast potential press cake utilisation.

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