

## **Drying of oil palm fronds using laboratory and commercial dryers** (Pengerangan pelepah kelapa sawit menggunakan pengering makmal dan pengering komersial)

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Key words: oil palm fronds, drying characteristics, drying cost, crude fibre, crude protein, animal feed

### **Abstract**

Drying at temperature of 100 °C was an effective method to remove moisture from chopped oil palm fronds (OPF). It was proven both under laboratory and commercial drying trials where the drying processes took about 2 and 3–4 h, to reduce the moisture content of layered OPF at 10–20 cm thick from 65% to 7% and 15% respectively. Relatively high quality dried OPF were obtained with the brightness (L\*), greenness (a\*) and yellowness (b\*) values of 58–63, –4 to –3, and 26–27 respectively, which were 4–9 points lower than the values measured on control sample. The crude protein and crude fibre of the dried produce were around 4.8% and 36% respectively which were 1–5% less than the protein and fibre contents in the control sample. About 412 kg dried OPF was produced using commercial size dryer with the capacity of about one tonne per batch. The drying cost to produce 1 tonne of dried product was about RM630.

### **Introduction**

Malaysia currently accounts for 51% of world's production and 62% of world's exports of palm oil and also for 8% of the world's total production and 22% of world's exports of oils and fats (Anon. 2004). Oil palm is the leading agricultural crop in Malaysia, covering about two million hectares or a third of the total cultivated area (Anon. 2004). The development of this industry is always associated with the large amount of waste and by-products such as effluent, empty fruit bunches, fibre, shell and oil palm fronds.

Oil palm fronds (OPF) are the waste or by-product that are available daily when the palms are pruned during the harvesting of fresh fruit bunches for oil production. About

30 t of OPF is produced per year from one hectare of oil palm plantation (Supranro et al. 1999). An estimate of 19.2 million tonnes (on a dry matter basis) of OPF is produced throughout the country in the year 2000 (Abu Hassan et al. 1994). The OPF are left rotting between the rows of palm trees, mainly for soil conservation, erosion control and ultimately the long-term benefit of nutrient recycling. With the large quantity of fronds produced even by the small farmers, this material has a very promising market as a source of roughage for ruminants.

Fresh OPF have been successfully used as feed for ruminants. The recommended level of OPF in the total feed mixture can be as high as 50% depending on the type of ruminant (Abu Hassan et al. 1994). The OPF

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can also be converted to silage in wet form, and cube or pellet in the dried form.

The research and development of pellet and cubes from OPF have been carried out jointly by MARDI and JICA since 1991. The process involves drying of chopped OPF, grinding, mixing, forming (pellet/cube) and cooling (Mat Daham et al. 2001). The whole processes were carried out using commercial-size machines with the production capacity of about 1.5 t/h. Drying is identified as the crucial part in the processing of OPF.

The drying requirement for OPF has not been investigated fully especially at commercial level. In this study, experiments were conducted at laboratory and commercial scales to determine the various drying aspects for OPF:

- The most effective drying temperature to dry OPF
- The drying rate at selected temperatures
- The recovery and quality of product
- Estimated cost of drying

## Materials and methods

### *Drying material preparation*

**Laboratory drying** Oil palm fronds (OPF) were chopped to about 10 mm thick and randomly collected and packed. A total of 10 plastic bags of samples each weighing about 6 kg were sealed and brought to the laboratory for the drying experiments. At the laboratory, a bag of sample was opened and dried immediately at 50 °C for 6 h then packed, sealed and labelled as control sample. The rest of the samples (9 bags) were stored in cold room (10 °C) to maintain the freshness of samples, and discharged according to the designed drying trials.

On the following days, one bag of stored OPF was discharged from cold room and spread on the plastic mat until the product temperature reached ambient condition. Small sample weighing 500 g was randomly taken and packed for moisture content analysis. Two samples of 800 g and 4 kg each were collected and used for the

drying experiment. The remaining sample (700 g) was packed and thrown away.

**Commercial drying** A total of one tonne of fresh OPF was prepared for each drying trial using artificial dryer (the trial was repeated twice). After the chopping process, the prepared material was loaded and transported to the drying area. The load was then discharged, placed in plastic containers, weighed and fed manually to dryer feeding hopper at the rate of 20 kg/min.

### *Laboratory drying experiment*

The laboratory drying experiment was carried out to determine the drying rate at selected temperatures (80, 90 and 100 °C) and the recovery and quality of the product. The experiment used small dryer (*Plate 1*) with the drying chamber measuring 50 cm long (L), 40 cm wide (W) and 50 cm high (H) (*Figure 1*). The dryer was equipped with 2 kW heating element for generating heat and was placed below the axial blower. The drying temperature was controlled by a thermostat connected to the heater and the quantity of air was regulated to blow at the rate of 15 m<sup>3</sup>/min.

Three drying temperatures (80, 90 and 100 °C) were selected for the study. The air temperature, relative humidity (RH) and product temperature inside the dryer were measured every minute using data taker model 605 (made in Australia). The thermocouple wires and RH sensor were



*Plate 1. Drying of OPF using laboratory dryer*

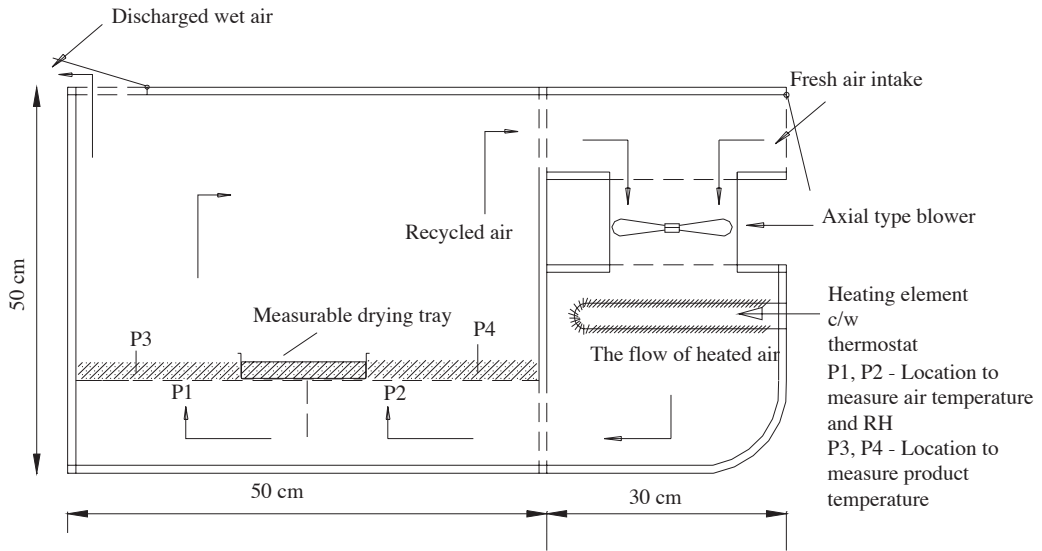


Figure 1. Schematic diagram of laboratory dryer used to dry OPF

placed at air duct below the drying bed to measure the temperature of heated air for drying. The thermocouple wires were inserted into the material layered on drying bed to measure product temperature. The drying experiment was repeated three times in order to formulate average moisture reduction, drying rate and product quality on each drying temperature.

For each drying experiment, a total of 800 g sample was placed in drying tray (20 x 28 x 10 cm – L, W, H) and 4 kg sample was spread on the drying bed to a thickness of about 10 cm. The actual weights of sample and drying tray were recorded at the beginning of drying process and repeated every 30 min. The moisture reduction and the drying rate were estimated every 30 min based on the weight differences of the samples placed in the drying tray. At the end of the drying experiment, the whole weight of dried material was determined, sealed in plastic bags and kept for quality evaluation.

### Commercial drying

The commercial drying experiment was carried out on conveyor type dryer (KAHL) that was imported from Germany (Plate 2).

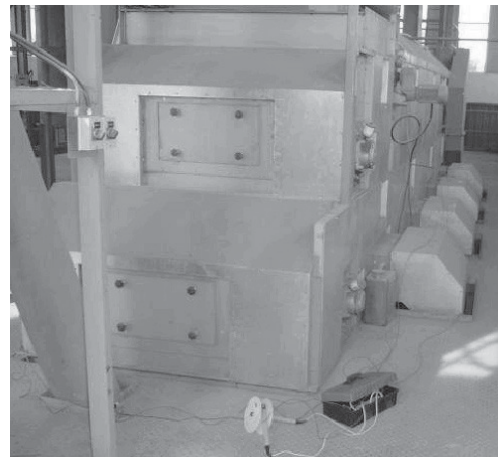


Plate 2. Drying of OPF using commercial-size dryer

The dryer measuring 9.5 x 1.65 x 2.1 m (L, W, H) was equipped with two layers of rotating bed with loading area of about 22.2 m<sup>2</sup> (Figure 2). Full loading of the dryer with about 20 cm thickness of chopped fresh OPF was about 1,000 kg. Fresh OPF was loaded at the rate of 20 kg per minute i.e. by manually pouring weighed OPF in a container (20 kg) into a dryer intake hopper. Total numbers of empty containers and time taken were recorded during the loading process. The drying was carried out

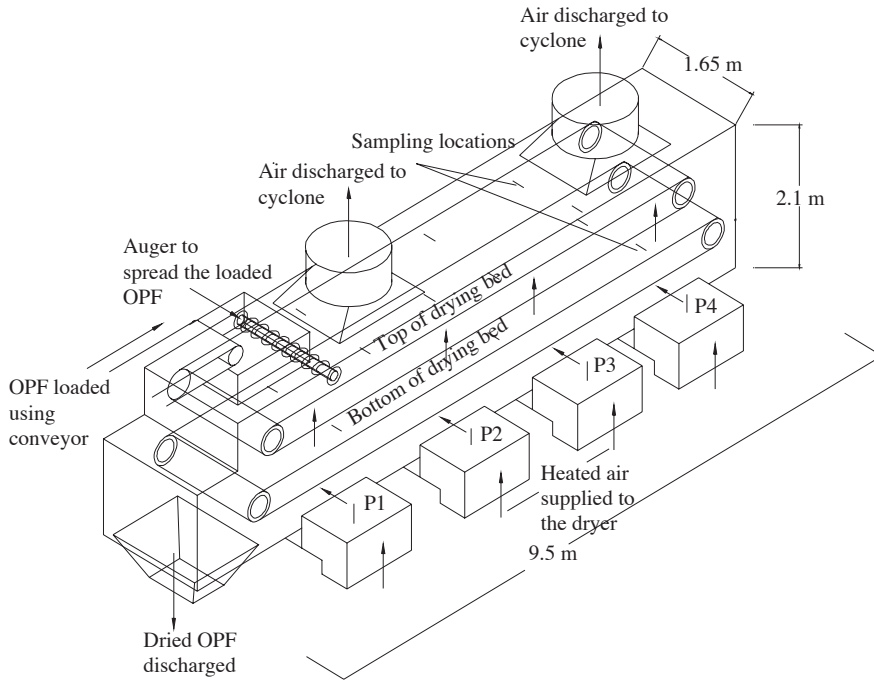


Figure 2. Schematic diagram of commercial dryer used to dry OPF

immediately after loading process was completed and was continuously heated until the produce was dried to 15% moisture content.

The drying temperature was measured at the air ducting, monitored and controlled at 100–110 °C using thermostat attached to the burner. Heated air was supplied to the dryer using blower at maximum capacity (2 m<sup>3</sup>/s) and supported by air suction provided by cyclone attached to exhaust ducting system and measured at the rate of about 5 m<sup>3</sup>/s.

Sample weight of about 2 kg was randomly taken from the OPF and loaded to the dryer. Similar amount was taken every hour during the drying process. Samples were taken at three locations from each layer and marked differently. The moisture content of the samples was determined by oven method.

After 4 h of drying, the dried OPF on the bottom layer of drying bed were discharged and the drying space were loaded with drying materials previously placed at

the top drying bed. The drying process was continued during the discharging and transferring processes, and stopped when the moisture content of OPF on the drying bed reached 15%. The quality of the dried samples was analysed at the end of the drying process. The drying experiment was repeated twice to determine the average performance and the drying cost.

#### **Quality analysis of dried OPF**

Dried samples gathered from the laboratory and commercial drying experiments were milled, packed inside 0.08 mm thick polypropylene bags and labelled. The colour of ground OPF was measured using 'Minolta chromameter CR-200'. The L\*, a\* and b\* values indicate the brightness, greenness and yellowness of the samples. About 60 g sample for colour determination was placed in three petri dishes and measured at three locations along the diameter of the dish.

About 300 g ground OPF was taken from each drying experiment, packed,

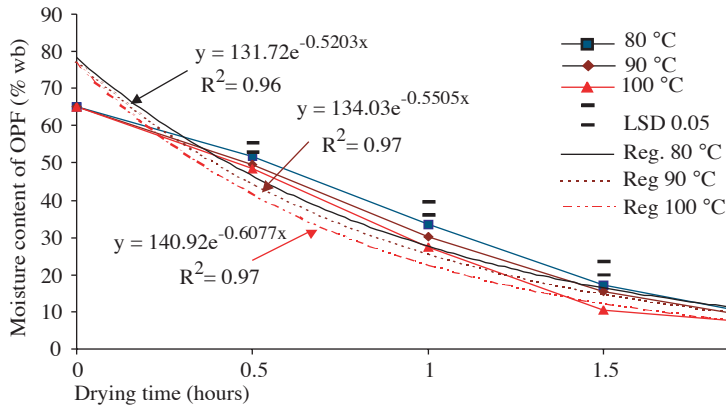


Figure 3. Moisture content of OPF dried using laboratory dryer

labelled and sent to accredited laboratory to determine the content of crude fibre and crude protein.

#### Statistical analysis

Statistical analysis was carried out to determine the effect of temperature on the quality of product. The 'Least Significant Difference (LSD)' test was applied to compare the moisture content and drying rate of OPF at three drying temperatures, while analysis of variance and Duncan test were carried out for L\*, a\* and b\* values of the samples analysed. Nine readings were taken to determine the average value of sample for each drying parameter.

### Results and discussion

#### Moisture reduction of OPF

Laboratory drying of OPF was carried out at drying temperatures of 80, 90 and 100 °C. However, several uncontrollable factors were encountered during the drying process such as temperature fluctuation inside the dryer (2–3 °C) and changes of ambient temperature and relative humidity outside the dryer. The average ambient temperature was recorded at 32–34 °C and the relative humidity varied from 58–89.5%. The average air relative humidity at 80 °C drying temperature was around 12.5%. However, the RH sensor was not able to measure the readings at 90 °C and 100 °C.

The temperature of produce at the initial stage of drying was at 27–29 °C and picked up heat while being exposed to heated air. At the end of the drying process, the temperature of produce was almost similar to the heated air used for drying.

Freshly chopped OPF contained about 65% moisture. However, it might increase to 70% when prepared under wet condition. Drying at 80, 90 and 100 °C for 2 h was able to reduce the moisture content of OPF to about 8.4, 7.4 and 6.7% respectively (Figure 3). The difference in moisture content within the drying temperatures was higher at 1.0–1.5 h of drying process. At 100 °C, the moisture content was 10.5–27.5%, which was 3–7% lower than the moisture of OPF dried at 80 °C and 90 °C.

The relationship between moisture content and drying time is represented by exponential curve, which indicated that more moisture was removed at early stage and became lesser towards the end of drying process. However, drying at 100 °C showed the best drying performance where the actual and regression curves were located at the most bottom among the drying curves plotted. The constant values of moisture content regression curve at 100 °C were 140.92 and –0.6077, which were higher than the values given by regression curves at 80 °C and 90 °C.

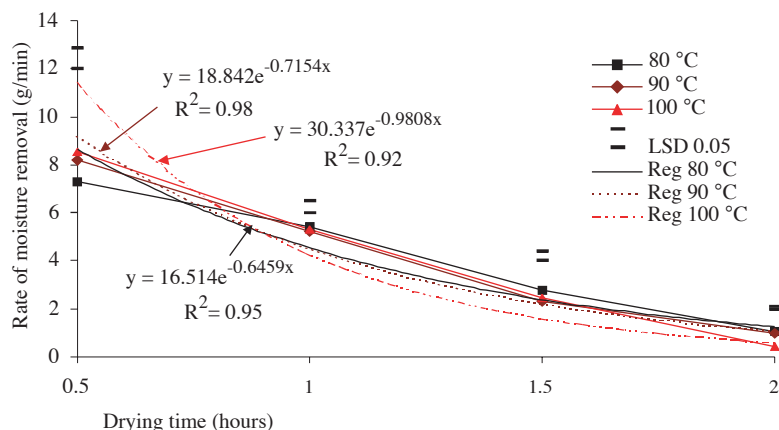


Figure 4. Rate of moisture removal from OPF during drying using laboratory dryer

### Drying rate

The optimum moisture content of dried OPF for further processing was 15%. This could be achieved by drying at 100 °C for about 1.3 h. At 80 °C and 90 °C, the estimated drying time was 1.6 h. High drying temperature was always associated with extra drying capability to evaporate water from the drying materials. It was represented by the rate of moisture removal per unit time. In case of OPF, the removal was measured every 30 min and the rate was given in gramme per minute (Figure 4). The highest rate of moisture removal was measured during drying at 100 °C. It was 8.54 g/min and measured at 0.5 h of drying period. The drying rate was very much higher and significantly different ( $p < 0.05$ ) compared with the drying rate at 80 °C and 90 °C. The drying rate was then reduced exponentially, no difference within drying temperatures after 1 hour and at the lowest rate after drying process exceeded 1.5 h and 2 h.

The drying rate of OPF at three drying temperatures was also influenced by the moisture content at various stages of drying process (Figures 3 and 4). Initially, it was high because the moisture content was above 50%, but after being reduced to 30%, the drying rate was only 4–6 g/min. At the end of the drying process where the produce

was almost dry (below 15% moisture content), the drying rate was less than 1.0 g/min.

From the study, it showed that the OPF was effectively dried at high drying temperature. The produce was not hardened, but became loose and lighter, which could accelerate the drying process. This finding suggests that the OPF can be dried using commercial dryer at a high drying temperature.

### The recovery and colour changes of dried OPF

The recovery of dried OPF was dependent on the final moisture content of the produce. At the optimum moisture content of 15%, the recovery of dried OPF was around 40%. Drying of OPF for 2 h at temperatures of 80–100 °C resulted in final moisture content (wet basis) of 6.7–8.0% and dried produce recovery at 37.5–38.5% (Table 1).

The green colour of OPF was contributed by leaves and hard skin of the petiole, whereas the internal part of petiole was white, contained 70% moisture and easily discoloured when exposed to the ambient air. The best colour of dried OPF obtained from the experiment was from the control sample that was immediately dried at 50 °C for 6 h. The ground sample gave the  $L^*$  (brightness),  $a^*$  (greenness) and  $b^*$  (yellowness) values of 67.09, -7.76 and

Table 1. The recovery and colour (L,a,b) of dried OPF

| Drying temperature (°C) | Dried OPF recovered (%) | L      | a      | b      |
|-------------------------|-------------------------|--------|--------|--------|
| 80                      | 38.5                    | 64.18a | -4.32e | 27.12h |
| 90                      | 38.0                    | 61.71b | -3.68f | 25.69i |
| 100                     | 37.5                    | 62.61b | -3.71f | 27.28h |
| 100 (c-dryer)           | 37.3                    | 57.59c | -3.31f | 27.33h |
| Control**               | 37.0                    | 67.09d | -7.76g | 23.06j |

Mean values with different letters in each column are significantly different ( $p < 0.05$ ) based on DMRT

c-dryer is commercial-size dryer

\*\*Control sample dried at 50 °C for 6 h

Table 2. The nutrient content of dried OPF

| Drying temperature (°C) | Crude protein (N x 6.25) (%) | Crude fibre (%) |
|-------------------------|------------------------------|-----------------|
| 80                      | 5.41b                        | 40.15de         |
| 90                      | 5.23ab                       | 37.74cd         |
| 100                     | 4.75a                        | 36.35c          |
| 100 (c-dryer)           | 4.72a                        | 36.53c          |
| Control**               | 5.62b                        | 41.78e          |

Mean values with different letters in each column are significantly different ( $p < 0.05$ ) based on DMRT

\*\*Control sample dried at 50 °C for 6 h

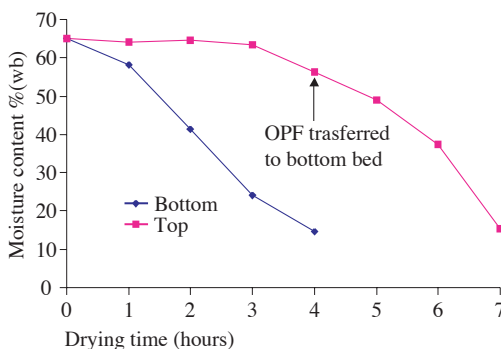


Figure 5. Moisture profile of OPF during drying using commercial-size dryer

23.06 respectively (Table 1). Other than that, the colour was slightly deteriorated due to heating effect. At drying temperature of 80 °C for instance, the colour values were changed with the L\*, a\* and b\* at 64.18,

-4.32 and 27.12 respectively and 3–4 point lower than the control sample.

The OPF dried using commercial-size dryer at 100 °C showed similar colour quality in terms of greenness (a\*) and yellowness (b\*) as the product was dried using laboratory dryer at the same temperature. However, the brightness value was less by 5 points, significantly different and could be seen visually on the samples. Browning occurred on OPF dried using commercial dryer due to slow drying process being performed on large quantity of product loaded in the dryer.

### The crude fibre and crude protein content in dried OPF

Oil palm fronds contain 38.5% crude fiber (% of dry weight) and 4.7% crude protein (Sato et al. 2004). The crude protein of OPF is 5.7% in the form of silage (Abu Hassan et. al. 1994) and 4.5% in the form of pellet or cube (Anon. 2003).

Laboratory and commercial drying experiments showed that drying at 80–100 °C could produce dried OPF with the crude protein content in the range of 4.8–5.4%. Protein content from sample dried at 100 °C was significantly less ( $p < 0.05$ ) compared with samples dried at 50 °C (control) and 80 °C (Table 2). Drying at 100 °C also affected the crude fibre content (36.4%) which was 3.5% to 4.2% less than samples dried at 50 °C (control) and 80 °C (Table 2). High drying temperature caused protein to denature and reduce the nutritional value to the product.

### Drying of OPF using commercial dryer

The total drying time to dry the whole load of OPF was 7 h (Figure 5). It took 4 h to dry OPF on bottom layer of the drying bed and another 3 h to dry OPF that was transferred from the top layer of the drying bed.

The OPF on the bottom layer of the drying bed was exposed to very high temperature and dry air. The moisture content was reduced effectively from 65% to

Table 3. Drying cost of 1,000 kg OPF using commercial-size dryer

| Item                      | Rate       | Cost (RM) |
|---------------------------|------------|-----------|
| Repair and maintenance    | 7 h        | 46.70     |
| Labourer:                 |            |           |
| a. Loading - 2 persons    | 1 h        | 10.00     |
| b. Supervision - 1 person | 1 h        | 5.00      |
| Electricity               | 60 kW h    | 18.00     |
| Diesel                    | 120 litres | 90.00     |
| Overall operating cost    |            | 169.70    |
| Fixed cost                |            | 91.60     |
| Overall drying cost       |            | 261.30    |

15% in 4 h. During that period, the moist air from the bottom layer passed through the OPF at the top layer and caused very small changes in moisture content which was about 56%, i.e. 9% less than the moisture content of fresh material. After the OPF was transferred to the bottom layer of the drying bed, the drying process progressed rapidly and the OPF was dried to 15% moisture content in another 3 h.

The dried OPF recovered after drying was estimated at about 412 kg. About 588 kg of water was removed during the drying process. Evaporation of 588 kg of water from OPF, theoretically requires 1,570 MJ energy which have to be absorbed from heated air supplied to the product (latent heat of water for OPF estimated at 2,670 kJ/kg). However, not all energy supplied could be utilized and some were lost due to air leakage, radiation and escaped through exhausted air.

Energy for the drying process was generated from diesel that was burnt to generate heat for the drying process. The total diesel used for each drying trial was recorded at 120 litres. Theoretically, the energy provided by the diesel is 4,690 MJ which will give an overall thermal efficiency around 33.5%.

The high cost of mechanical drying process was mainly due to the fuel and electricity. The dryer utilized electricity to move the conveyors and to run the blowers while fuel was used to generate heat for the

drying process. This direct cost was RM108 based on current price of fuel and electricity (*Appendix 1*), which was 41% of the overall estimated drying cost (*Table 3*). The total operating cost, which included direct labour used, repair and maintenance for the drying process, was RM169.70 per batch. The operating cost to produce one tonne of dried OPF was estimated around RM410 and the overall drying cost (including fixed cost) was RM630. The cost might be reduced slightly on the following batches as a result of faster drying time (6 h).

### Conclusion

Drying is an essential process to convert oil palm fronds (OPF) to animal feed in the form of pellets or cubes. The fresh OPF has to be dried to 15% moisture content, before grinding, mixing and forming processes could be carried out to the product. Drying can be carried out using solar energy, but a mechanical dryer with fuel burner was more effective.

Drying at 100 °C proved effective to remove moisture from fresh chopped OPF. The laboratory dryer took about 1.5 h to reduce the moisture content of 10 cm thick layered OPF from 65% to 15%. It required 3–4 h to carry out drying process at similar drying temperature on 20 cm thick OPF weighing about 0.5 t layered on the bottom bed of commercial-size dryer. An acceptable quality of dried OPF in terms of colour and nutritional value was obtained. The L\*, a\* and b\* values of the product were 57 to 63, –3.3 to –3.7 and around 27.3 respectively, with the crude protein and crude fibre contents around 4.7% and 36.0% respectively.

About 412 kg of dried product was obtained from one tonne of fresh OPF dried using commercial-size dryer. The drying cost incurred was estimated at RM261 per batch, or RM630 per tonne of dried OPF produced.



### Acknowledgement

The authors wish to thank Mr Mohd Yunus Ismail and his staffs at MARDI-JICA OPF Factory, for their assistance and effort to prepare drying materials and to carry out evaluation on commercial-size dryer located at the factory.

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### Appendix 1. Assumption to estimate the drying cost using commercial dryer (RM400,000)

1. Estimation of operating cost:-
  - a. Repair and maintenance are based on 3% of dryer cost, utilized for 180 days/year and 10 hours/day  
Cost incurred is RM1,200/year or RM20/drying trial
  - b. Labour cost rate at RM5/h/person, loading process carried out by 2 workers and the drying process is supervised at interval with total time taken about 1 hour
  - c. Electricity rate at RM0.30/kW h
  - d. Diesel cost at RM0.75/litre
2. Estimated fixed cost for the dryer:
  - a. Depreciation value of the machine operating for 15 years at the rate of 5%, cost incurred is RM25,000/year
  - b. Interest at 2.5% =  $0.5 \times \text{RM}400,000 \times 2.5\% = \text{RM}5,000/\text{year}$
  - c. Tax and insurance at 1.5% =  $0.5 \times \text{RM}400,000 \times 1.5\% = \text{RM}3,000/\text{year}$
  - d. Total estimated fixed cost/year = RM33,000
  - e. Estimated fixed cost/day/process at utilizing rate of 180 days/year and two processes/day is RM91.60

**Abstrak**

Pengeringan pada suhu 100 °C ialah kaedah yang berkesan untuk mengeringkan hirisan pelepah kelapa sawit (OPF). Kaedah ini terbukti melalui ujian pengeringan di peringkat makmal dan komersial, dengan proses pengeringan mengambil masa masing-masing 2 jam dan 3–4 jam untuk menurunkan kandungan lembapan lapisan OPF setebal 10–20 cm daripada 65% kepada 7% dan 15%. Mutu hasilan kering yang agak baik diperoleh dengan ukuran kecerahan ( $L^*$ ), kehijauan ( $a^*$ ) dan kekuningan ( $b^*$ ) masing-masing pada tahap 58–63, –4 hingga –3 dan 26–27, iaitu 4–9 unit lebih rendah daripada nilai yang diukur pada sampel kawalan. Kandungan protein dan serat mentah di dalam pelepah kelapa sawit kering masing-masing ialah 4.8% dan 36%, kurang sebanyak 1–5% berbanding dengan kandungan yang diperoleh daripada sampel kawalan. Sebanyak 412 kg hirisan pelepah kelapa sawit kering dapat dihasilkan dengan menggunakan pengering komersial dengan kapasiti satu tan setiap proses. Kos pengeringan bagi menghasilkan satu tan hasilan kering adalah sekitar RM630.