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PRODUCTION OF ELECTRICITY AND HUMOTEX FROM OIL PALM SOLID WASTES THROUGH DRANCO PROCESS

(Produksi Listrik Dan Humoteks Dari Limbah Padat Kelapa Sawit Dengan Proses Dranco)

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Ringkasan

Dranco proses (Dry Anaerobic Conversion) adalah proses fermentasi anaerobic yang dapat mengubah bahan organik menjadi biogas (listrik) dan humotex (kompos anaerobik). Penelitian ini mempelajari aspek teknis dan ekonomis pemanfaatan limbah perkebunan kelapa sawit berupa tandan dan kulit buah menggunakan model perkebunan sawit seluas 2000 Ha.

Dari areal tersebut akan dihasilkan 38 ton tandan basah dan 14 ton kulit buah basah perhari atau 52 ton substrat pada 28% KK (kadar kering). Melalui proses Dranco, substrat tersebut akan diubah menjadi biogas dengan kapasitas 2700 m3 CH4 (methane) atau 7881 kwh tenaga listrik dengan netto sebesar 6881 kwh perhari. Humotex yang dihasilkan adalah 8 ton pada 90% KK.

Analisis ekonomis menunjukkan Net Present Worth Rp. 1184 juta, B/C rasio 1,83, Internal Rate of Return 41,2%. BEP untuk produksi tenaga listrik terletak pada 883 kwh dan humotex 104 ton perhari. Proyek ini secara teknis dan ekonomis beralasan untuk dikembangkan.

I. OIL PALM IN INDONESIA

Indonesia is greatly dependent on oil for its foreign currency income. This situation leads to enhancement of the production and export of non oil commodities especially agricultural products. In this respect, oil palm is an important product in the agricultural sector. It has been increasing its acreage throughout many provinces in Indonesia.

In 1983, oil palm plantations in Indonesia covered 440.766 Ha which 273.035 Ha of mature trees and 167.731 Ha of immature trees.
In the 1983—1988 period, palm estates are expected to expand at an average rate of 8% year, whereas oil palm and kernel production is expected to increase by an average of 15.7 and 15.9 % respectively. In 1989, Indonesia's oil palm plantation is 980,693 Ha, about a half of the average are in the production age. Oil palm production in 1989 is about 2 million ton.

Currently, wastes such as Empty Fruit Bunch (EFB) and Pericarp (P) are burnt in the factory and thus recycled in the form of heat and mineral fertilizers. Since EFB and P have high moisture content, they need preheating (sundrying) or mixing with another type of dried biomass to be able to be used as fuel for boilers. In order to get energy of high value from such wet materials, the possible application of biogas technology deserves to be evaluated.

In the processing of oil palm, several types of organic wastes are produced. The treatment of waste water has received a lot of attention (Petitpierre, 1982; Martin, 1981). By anaerobic digestion the COD and BOD of oil palm factory effluents can be lowered 75—95% and substantial amounts of biogas concomitantly produced. Furthermore, the digested effluents can be recycled as a non phytotoxic soil fertilizer (Lim Kim Huan, 1986).

This study focusses on the conversion of EFB and P by means of a special type of biogas fermentation, the so called Dranco Process (Dry Anaerobic Conversion).

II. *Technical Aspects*

A. *Available substrates*

This study was applied to a 2000 Ha oil palm plantation.

1. Fresh Fruit Bunch (FFB) = 20 ton green matter /Ha yr (25% DM). For 2000 ha = 40.000 ton green matter/yr or about 100 ton green matter/d.
2. Waste products
   Empty Fruit Bunch (EFB) 38% of EFB = 38 ton green EFB/d (25% DM) or 9.5 ton DM/d.
   Pericarp (P) 9% of FFB = 9 ton wet weight/d (55% DM) or 4.9 ton DM/d. After steaming

during oil palm processing, the dry matter content decrease to 35%.
Hence, one has 5.0/0.35 = 14,0 ton wet waste perday.

3. Total available substrates (EFB + P) : 38 + 14.0 = 52.0 ton/d at 28% DM (14.5/52.1) or 14.5 ton DM.

B. *Operational parameters*

1. P r o c e s s

Name of the process	:	Dranco Process
Temperature	:	55° C
Substrate dry matter	:	28%
Volumetric loading rate	:	12.5 kg DM/m^3 r.d
Retention time	:	22.5 days
Conversion to organic matter	:	40% of COD is considered to be converted to methane gas. This figure is based on laboratory tests.

Table 1. Material compositions of the fermentor
Tabel 1. Komposisi material dari fermentor

Compositions *(Komposisi)*	Thickness (m) *(Ketebalan)*	(W/m.k)
Coating (inner side) *(Lapis dalam)*	0.003	0.17
Cement plaster *(Plester semen)*	0.05	1.5
Reinforced concrete *(Beton)*	0.19	1.9
Cement plaster *(Plester semen)*	0.01	1.5
Extruded polystyrene *(Plastik polistirene)*	0.06	0.035
Cement plaster (outer side) *(Semen lapis luar)*	0.01	1.5

2. Construction and wall compositions of the fermentor.
Per day 52.1 ton substrate at 28% DM (14.5 ton DM) will be digested at loading rate of 12.5 kg DM/m^3 r.d. Hence this substrate will be fed in a fermentor of 14.500/12.5 = 1160 m^3. In practice 1400 m^3 is required. It is proposed to built a circular vessel with r = 5 m and h = 17.9 m. The wall of fermentor is composed with several different materials from the inner side to outer side which are respectively shown in table 1. These material compositions cover the whole body of the fermentor. It is however conceivable to construct the digester in a more simplified way because, as will be shown further on the heat balance of the process is not critical.

3. The inhouse power consumptions
The inhouse power consumptions of the Dranco Process are shown in table 2. These values are based on information obtained from De Wilde and Van Hile (1986).

Table 2. The inhouse power consumptions
Tabel 2. Tenaga yang dikonsumsi sendiri

I t e m s	Consumptions *(Konsumsi)*	Amount (t/d) *(Jumlah)*	Kwh/d
Chopper *(Pencacah)*	4.0 kwh/ton	55	220
Conveying and mixing *(Penghantar dan pengaduk)*	3.0 kwh/ton	200	600
Water pump *(Pompa ait)*	0.5 kwh/ton	20	10
Press machine *(Mesin pres)*	4.0 kwh/ton	32	128
Siever *(Penyaring)*	4.0 kwh/ton	10	42

C. *Production of biogas and electricity*

1. Production of biogas
The daily methane production will be : 14.5 ton DM/d x 4.4 x 1.33 x 350 m^3 CH4 = 2700 m^3 CH4, equal to 2700 m^3 x 100/60 = 4500 m^3 biogas.
2. Thermal energy needs for the Dranco process.
   * Energy needs for heating up the feed : 52100 kg/d x (35°) x 1 kcal/kg°C x 4.18 MJ/kcal x 10^{-3} = 7622 MJ/d
   * Energy needs for maintaining temperature at 55° C, are calculated based on the formula :

$$Q = \Sigma KA \nabla t, \text{ from which : } k = \frac{1}{1/\alpha i + \Sigma d/\lambda + 1/\alpha u}$$

The calculation gives : Σk = 0.53 W/m^2 °K for αi = 600 W/m^2 and αu = 25 W/m^2. Since the fermentor has a size of r = 5 m and h = 17.9 m then A = (2 π 5 x 17.9 m) + 2 (78.5) = 719.1 m^2 Maintaining the temperature will roughly require = 0.53 x 719.1 x (55 — 20) x 10^{-3}x 3.6 kj/W x 24 = 1152 MJ/d. When the wall is simplified with coating, cement plaster and reinforced concrete (d = 0.24 m), the heat required to keep the reactor on temperature is 9512 MJ/d.

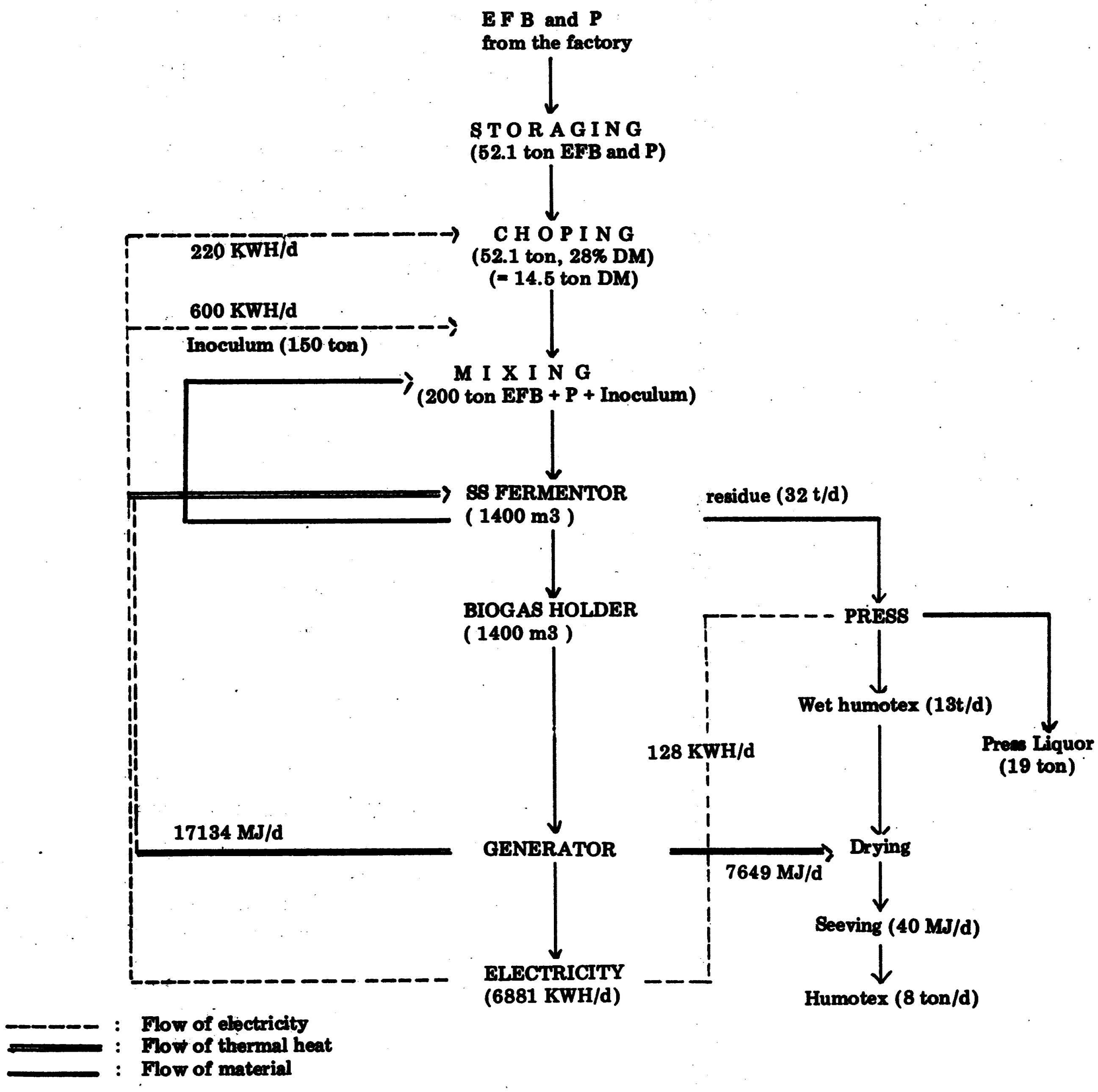

Figure 1. Process and materials lay out

Gambar 1. Diagram alir proses dan material

* Energy for drying 13 ton humotex, 70% DM to become 10 ton 90% DM = 3000 x (100 − 30) kcal/kg°C = 877.8 MJ

3000 x (100 − 30) kcal/kg°C	=	877.8 MJ
3000 x 540 x 10 x 4.18	=	6771.6 MJ
		7649.4 MJ

* Total thermal energy needs for Dranco process : 7622 + 9512 + 7649 = 24783 MJ/d.

*) 15 hours operation/day

3. Energy balance of the Dranco process.

About 50% of the biogas thermal energy can be recuperated from generator and 60% from it will be lost during heat transfer.

Total thermal energy from biogas is 2700 m^3 CH4 x 35 MJ/m^3 CH4 = 94500 MJ/d. Recuperated thermal energy is 0.5 x 94500 x 0.6 = 28350 MJ/d. Total thermal energy needs amount in the worst case is 24783 MJ/d. Thus, all the thermal energy needs for Dranco can be obtained from excess heat, produced by generator.

4. Electricity and humotex production.

* Electricity production
  Gross electricity production from the biogas is : 94500 MJ/d x 0.278 kwh/MJ x 0.3 = 7881 kwh/d. In view of the electricity required by the Dranco is self (see Table 3), the net electricity production will be : 7881 kwh/d — 1000 kwh/d = 6881 kwh/d. The generator capacity required at a load factor 0.6 is 7881 x 1/15 *) x 1/0.6 = 875 kw or 900 kwh.
* Humotex production
  After fermentation about 40% of the COD will be reduced to methane, or 14.5 ton x 1.33 = 7.7 ton. The residue after fermentation will be about 14.5 (1.33). 0.6 = 12 ton COD or ca. 9 ton DM after pressing, the dry matter content of the humotex will be 65% or the weight of humotex will be 9/0.65 = 32 ton at 28% DM. By pressing, the moisture is reduced and get 13 ton of 70% DM. The energy required for drying is 7649 MJ/d. to get 10 ton of 90% DM. After seeving, the humotex obtained is 8 ton at 90% DM.

III. ECONOMICAL ASPECT

A. *Investments*

Table 3 shows the investment of the Solid State Fermentation Project at 4500 m^3 biogas production capacity. All the biogas is converted to electricity and heat. The values between brackets indicates the cost price in million rupiah per unit. The investment needs for this project is roughly estimated at 1450 million rupiah.

Of which :

- Constructional parts (+): 748 million, life time 20 years
- Mechanical parts (—) : 622 million, life time 10 years
- Special parts (++) : 80 million, life time 5 years

B. *Depreciation*

1. Depreciation of mechanical parts
   Method : Sinking fund : d = (P—F) (A/F, i %, N)
   For i = 15%; N = 10 years; P = 622; F = 62 (10%)
   Bl (622 — 62) (0.0493) = Rp. 27.6 million
2. Depreciation of constructional parts
   For i = 15%; N = 20 years; P = 748; F = 75
   B2 = (748—75) (0.0098) = Rp. 6.6 million
3. Depreciation of special parts
   For i = 15%; N = 5 years; P = 80; F = 80
   B3 = (80 — 8) (0.1483) = Rp. 10.6 million

   Total B1 + B2 + B3 = Rp. 44.8 million/years.

Table 3. Investments of the project in 1989.
Tabel 3. Investasi proyek pada tahun 1989

	Million *(Juta)* Rp
+ Solid State Fermentor (1400 m^3 a 0.4)	560
— Conveying and mixing (200 ton a 0.5)	100
+ Gas holder (1400 m^3 a 0.05)	70
— Generator (900 kw a 0.50)	450
— Chopper (55 ton a 0.8)	45
+ Substrate storage tank (55 ton a 0.70)	38
+ Humatex strorage tank (15 ton a 0.70)	10
+ Piping and connections (200 m a 0.1)	20
— Pumping (20 ton a 0.2)	5
+ Building (250 m^2 a 0.2)	50
++ Plastic sealing machine (packaging) & sewing	10
— Press machine (15 ton a 1.5)	22
++ Control panels and computerization	20
++ Administrative accessories	20
++ Truck	30
Total	1450

C. *Production Cost*

1. Fixed Cost

Wages :

	Million Rp/y
— 1 manager Rp 500.000/month	6.0
— 1 Administrative Rp 250.000/month	3.0
— 1 Insurance 10% (of total wages)	4.0
Total C_1	13.0

2. Variable cost

	Million Rp/y
— 3 Technicians a Rp. 10.000/d	10.8
— 8 Handlabourers a Rp. 6.000/d	17.3
— 1 Truck driver a Rp.10.000/d	3.6
— 1 Chemist for quality control	5.0
— Packaging : 57600 pieces of 50 kg each, a Rp. 250	14.4
— Gasoline for truck 50 l/d	3,8
— Administrative costs	5.0
— Contingencies 1%/total production cost	1.0
Total C2	60.9

Total production cost C1 + C2 = Rp. 73.9 million

D. Annual expenses

Depreciation + annual production costs :
44.8 + 73.9 = Rp. 118.7 million

E. Annual Revenues

— Electricity :
6881 KWh/d x 360 x Rp. 100 = Rp. 247.7 mil.

— Humotex :
8000 kg (90% DM) x 360 x Rp. 100 = Rp. 288.0 mil.

Total E Rp. 535.7 mil.

F. Project evaluation

1. Present worth method (PW)

	Present worth
— Annual revenues Rp. 535.7 million (P/A, 15%, 20)	3353.1
— Salvage value (P/F, 15%,20)	
Mechanical parts	15.3
Construction parts	4.6
Special parts	3.8
	Rp. 3376.7 million

— Annual disbursement Investment	1450.0
Annual expenses (P/A, 15%, 20)	742.9
Net present worth Rp.	1183.8 million

Since the net present worth is > 0, the project is justified.

2. Benefit-cost ratio (B/C ratio)

$$\text{B/C ratio} = \frac{B - (0 + M)}{CR}, \text{ where CR} =$$

(P—F) (A/P, 1%, N) + F (1%)

CR (capital recovery) :
(1450 — (250.8 + 75 + 65.1)) 0.1598 + 390.9 (0.15) = 169.2 + 58.64 = 227.9

$$\text{B/C ratio} : \frac{535.7 - 118.7}{227.9} = \frac{417}{227.9} = 1.83$$

The project is justified since the B/c ratio > 1

3. The internal ratio of return (IRR)

$$IRR = \sum_{k=0}^{N} (R_k\ (P/F,\ i\%,\ k) - \sum_{k=0}^{N} (D_k\ (P/F,\ i\%,\ K) = 0$$

—1450 + (535.7 — 118.7) (P/A, i%, 20) + 390.9 (P/F, i%, 20) i%.

for i = 10% = -1450 + 417 (8.5136) + 390.9 (0.1486 = 2158.3)

i = 50% = -1450 + 417 (1.99) + 390.9 (0) = -620.17

$$\frac{50\% - 10\%}{2158.3 - (-620.17)} = \frac{1\% - 10\%}{2158.3}$$

$$i\,\% = 10\% + \frac{987.9}{2158.3 - (-620.17)} \times (50 - 10)$$

= 10% + (0.78 x 40) = 41.2%

G. Break even analyses

By grouping annual expenses into fixed costs and variable cost, the Break Even Point (BEP) can be calculated (at 15% interest) :

Fixed cost (FC) : 13 + 44.8 = Rp. 59.8 million

Variable costs (VC) : Rp. 73.9 million

$$BEP = \frac{FC \times Sales}{Sales - VC} \quad BEP = \frac{57.8 \times 535.7}{535.7 - 73.9} =$$

67.02

The BEP is situated at sales level of
Electricity (46%) : Rp. 30.8 million = 883 KWH/d
Humotex (54%) : Rp. 36.2 million = 1.04 ton/d

IV. DISCUSION

Conversion of Empty Fruit Bunch (EFB) and Pericarp (P) from 2000 Ha of oil palm estates by means of the Dranco process can give several advantages compared to direct burning :

— This process can produced either biogas or electricity while both are a high quality energy.

— Since the EFB and P are wet (25% DM) the direct burning system will loose lots of energy to vapourize the water, while the Dranco process can give high efficiency of conversion.

The electricity produced by the Dranco generator can be consumed either by the factory or the village people. Indeed, Martin (1981) estimated that about 400 kw of electricity is required per Ha of housing area and services.

De Baere *et al* (1987) stated that the quality of humotex produced from the organic fraction of municipal solid wastes is considerably different from that of conventional compost produced by means of an aerobic process. The humotex from Dranco process has a carbon to nitrogen ratio of 12 to 15, indicating a high degree of stability. For aerobic compost, this ratio varies from 10 to 30 depending on the marutity and the kind of material. The oxygen consumption at is leaves the reactor equivalent to that aerobic compost which has been cured during a period of minimum 4 to 6 months. Hygienic analysis of humotex indicates that fecal bacteria are almost completely absent. This high hygienic quality is also in sharp contrast with compost produced by means of conventional aerobic composting. In practice, humotex can be applied for the fertilization of the oil palm plantations, of rice fields, of horticultural crops, or for Forest Plant Estates which is projected to 6.2 million Ha in Indonesia.

Other solid organic waste materials such as the leaves of oil palm trees after prunning could also be digested. Potential biogas production from 2000 Ha plantations are estimated as follows :

2000 Ha (2.8 ton DM/Ha *) x 0.3 x 1.33 x 0.35 m^3 CH4/kg COD x 100/65 x 1/365 = 3296 m^3 /d
*) Martin, 1981.

If the biogas is converted to electricity it will produce about 5211 KWh/d.

Conversion of the leaves to biogas will shorten their humification period. Normally by the SSF process, the humification is finished in 20 — 25 days. Recent findings by Sudradjat (1990) shows that the press liquor can be used as a high quality soil conditioner as well as hydrophonic liquor. When the Dranco residue is pressed it can also be transformed to a very strong briquette whithout heat nor glue treatment is required.

V. CONCLUSIONS AND RECOMENDATION

1. This study focussed on 2000 Ha of oil palm plantation. The Empty Fruit Bunch (EFB) and Pericarp (P) are estimated to be 14.5 ton DM, equal to 52.1 ton at 28% DM content.
2. By the Dry Anaerobic Conversion (Dranco) process, the substrates can produce biogas 4500 m^3/d or 12700 m^3 CH4 equivalent to 94 500 MJ/d. The latter could yield 7662 KWh electricity per day. The net electricity production is 6881 KWh/d.
3. The total investment of the project is estimated at Rp. 1450 million (1989).
4. Economic evaluation shows the following data.

	(million Rp)
Annual expenses	118.7
Annual revenues	535.7
Present worth	1183.8
B/c ratio	1.83
I R R	41.2 %
BEP electricity	883 KWh/d
BEP humotex	1.04 ton/d

5. Other organic wastes from the plantation and factory for instance the leaves from prunning could also be used as substrate for producing biogas or electricity. For an acreage of 2000 Ha oil palm estate roughly 5211 KWh/d electricity could possibly be produced from the leaves.
6. In view of the potential benefits, both in the area of energy recovery and organic matter recycling, a more detail investigation in this field are urgently needed.

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