Protect the environment and make profit from the waste in palm oil industry

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Abstract

One of the keys for a sustainable palm oil production is the process in the oil mill itself. The by-products in a palm oil mill are empty fruit bunches (EFB), mesocarp fibre, shells, waste water or slurry (POME) and ash. On the one hand these by-products are no waste, but a valuable source of nutrients and energy which can be used in the oil mill itself or can be sold at the market. On the other hand they can pollute the environment by nutrients, the green house gas methane, and by smoke. To utilize the nutrients from the EFB and the POME or ECO-D slurry a co-composting process with windrow turning machines (EcoEFB™ process) is the most sustainable solution, which can fulfil the criteria of RSPO. The production of biogas from the POME or slurry has an additional effect to substitute mineral oil. If the oil mill sells shells and fibre as energy source to the market it has far reaching consequences for the energy production and the by-product management in the mill. Based on market prices and cost in Indonesia the economy of process alternatives is calculated. The EcoEFB™ process (co-composting of EFB and POME/ECO-D slurry) can have a short pay back time of less than 0.5 years. ECO-D slurry can reduce the investment cost and the pay back time.

Key-words: EcoEFB™, ECO-D, POME, EFB, co-composting, biogas, economy

Abbreviations: COD chemical oxygen demand, DM dry matter, EFB empty fruit bunches, FFB fresh fruit bunches, ODM organic dry matter, POME palm oil mill effluent, t metric ton

1. Introduction

The production of palm oil results in a huge amount of by-products: Empty fruit bunches, waste water, mesocarp fibre, shells and ash (figure 1). The by-products are no a waste and their utilisation is a substantial part of a sustainable palm oil production under the viewpoints of environment protection and economy. In principle 5 of RSPO (Round Table of Sustainable Palm Oil Production, Anonym 2005) (Environmental Responsibility and conservation of natural resources and biodiversity") is carried out: "Waste is reduced, recycled, and disposed of in an environmentally and socially responsible manner" (criterion 5.3), "Efficiency of energy use and use of renewable energy is maximised" (criterion 5.4), and "Plans to reduce pollution and emissions, including greenhouse gases, are developed, implemented and monitored". These guidelines show a clear way to treat and to utilise the by-products.

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The main source of environment pollution in the oil mill is the pond system for the palm oil mill effluent (POME). The anaerobic ponds emit a huge amount of the strong green house gas methane by biogas and the effluent of the ponds contains nutrients responsible for pollution of surface and ground water. Each ton of produced crude palm oil is responsible for the emission of 46 m³ (32.9 kg) of methane, corresponding 384 m³ (756 kg) CO_2-equivalent. Traditional open pond systems for the waste water will have no future anymore. New systems for oil recovery (for example the ECO-D system from Westfalia separators) and continuous sterilisation instead of batch sterilisation will change the composition and the consistency of the waste water and the process of its treatment (Tornroth, 2006; Schuchardt, 2007).

For empty fruit bunches and waste water/sludge a profitable co-composting process (EcoEFB™) is realised in several palm oil mills in Indonesia and Malaysia (Schuchardt et al. 1999, Schuchardt et al. 2002a, Schuchardt et al. 2002b, Wulfert et al. 2002; Schuchardt et al. 2006, Schuchardt et al. 2007, Guritno et al. 2007).

Because climate protection becomes more and more important and especially methane emissions are in focus, it can be expected that the conventional waste water treatment in anaerobic ponds will be banned in the future. Furthermore the palm oil industry will come under pressure, if a huge amount of CPO (crude palm oil) or bio-diesel from CPO as renewable energy source will be exported to western countries. The requirement will arise, that the CPO production has to be sustainable – less emissions, no pollution of the environment, implementation of recycling systems, utilization of energy sources, soil conservation by minimization of erosion, protection of rain forest and so on. Under these aspects the palm oil industry will be forced to implement new environmental friendly treatment technologies in their oil mills.

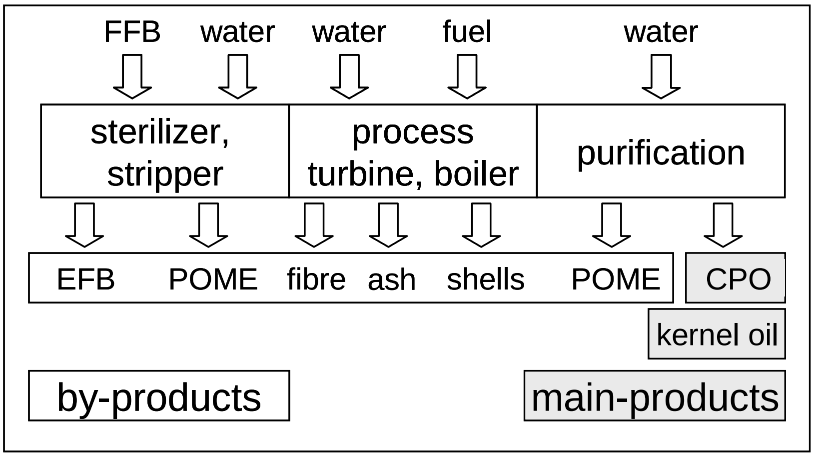

Fig. 1: Main and by-products in a palm oil mill

2. By-products in palm oil mills

2.1 Amount of composition of the by-products

Each ton of produced palm oil in an oil mill results in 5.2 to 3.3 tons of by-products. The main mass of by-products is the waste water (POME) or slurry (ECO-D from Westfalia Separator) and the empty fruit bunches (table 1).

Table 1: By-products in a 30 t palm oil mill (153,000 t FFB/year)

By-product	rel. FFB % (w/w)	Mass t/a	Mass t/t FFB	DM %	DM t/a	DM t/t FFB
EFB	23	35,190	0.230	35	12,317	0.081
Fibre	14	21,420	0.140	60	12,852	0.084
Shells	7	10,710	0.070	75	8,033	0.053
POME	65	99,450	0.650	4.1	4,077	0.027
ECO-D	25	38,250	0.250	17	6,503	0.043
EFB ash	0.51	776	0.005	100	776	0.005
Fibre ash	0.57	874	0.006	100	874	0.006
Shells ash	0.19	289	0.002	100	289	0.002

The total amount of POME/sludge can be reduced step by step by implementation of new technologies in palm oil mills like continuous sterilisation (Sivasothy et al. 2005, Sivasothy et al. 2006) and oil separation without dilution water (ECO-D) (table 2). Because the loads of suspended solids, dissolved COD etc. are nearly unaffected by the reduction of water, the dry matter content increases from 4 to 5 % in conventional POME up to 17 % of pure clarification sludge from decanter and clarifier.

In view to a combined treatment of POME/slurry and EFB the specific output of water per t EFB can be reduced from 2.68 to only 0.9 m³/t EFB. The installation of new technologies has a significant impact on

- the absolute and related amount (m³/t FFB),
- the composition (dry matter content, concentration of nutrients, liquid or slurry),
- the utilisation (type of biogas plant, size of composting plant), and
- the treatment cost

of the POME/slurry.

Table 2: Volume of POME and ECO-D slurry in palm oil mills with conventional and new technologies

Parameter		Batch sterilisation **A**	Batch sterilisation + zero dilution **B**	Continuous sterilisation + zero dilution **C**
sterilizer condensate	m³/t FFB	0.20	0.20	0
clarification sludge	m³/t FFB	0.45	0.25	0.25
sum POME+slurry	**m³/t FFB**	**0.65**	**0.45**	**0.25**
dilution water	m³/t FFB	0.20	0	0
POME+slurry	% DM	5	10	17
POME+slurry rel. EFB	m³/t EFB	2.83	1.96	1.09
POME+slurry water	m³/t EFB	2.68	1.76	0.90

A: Conventional POM with batch sterilisation and dilution water for oil separation.
B: New POM with batch sterilisation and zero dilution water for oil separation
C: New POM with continuous sterilisation and zero dilution water for oil separation

The by-products can be used as fertilizer because of the high content of plant nutrients and organic matter (table 3) or as energy source (tables 4 to 6). The main alternatives to use the by products are:

Nutrient sources:	POME/slurry
	EFB
	Fibre
	ash from fibre and shells incineration
Organic matter sources:	EFB
	Fibre
Energy sources:	Fibre
	Shells
	POME/slurry (biogas)

POME and slurry can have a double use as energy source (biogas) and as mineral nutrient source after fermentation.

Table 3: Composition of the by-products in a palm oil mill (own analyses)

			EFB	Fibre	Shells	POME	ECO-D	EFB ash	Fibre ash	Shells ash
Dry matter	DM	kg/t	350	600	750	41	170	1,000	1,000	1,000
Moisture	M	kg/t	650	400	250	959	830	-	-	-
Organ. DM	ODM	kg/t DM	937	800	964	-	-	-	-	-
Ash	-	kg/t DM	63	68	36	-	-	1,000	1,000	1,000
Carbon	C	kg/t DM	432	472	524	-	-	-	-	-
C/N ratio	C/N	-	54	21	119	-	-	-	-	-
Nitrogen	N	kg/t DM	8.00	22.20	4.40	18.29	23.53	-	-	-
Phosphorus	P	kg/t DM	0.97	1.65	0.40	4.39	1.7	15.4	26.2	6.3
Potassium	K	kg/t DM	24.0	7.6	0.8	55.4	48.5	381.0	120.3	11.9
Calcium	Ca	kg/t DM	1.80	3.78	13.60	10.73	11.5	28.6	60.0	215.9
Magnesium	Mg	kg/t DM	1.80	9.06	2.15	15.12	5.2	28.6	143.8	34.1
Plumbum	Pb	g/t DM	1.80	4.70	1.70	0.71	-	1.80	4.70	1.70
Cadmium	Cd	g/t DM	<0,3	<0,3	<0.3	<0.3	-	<0,3	<0,3	<0.3
Chrom	Cr	g/t DM	49.90	69.70	<1.0	5.40	-	49.90	69.70	<1.0
Copper	Cu	g/t DM	14.00	26.30	5.50	3.60	-	14.00	26.30	5.50
Nickel	Ni	g/t DM	30.50	34.30	<1.0	1.34	-	30.50	34.30	<1.0
Mercury	Hg	g/t DM	<0,5	<0,5	<0.5	<0.5	-	<0,5	<0,5	<0.5
Zinc	Zn	g/t DM	37.90	33.40	3.40	8.02	-	37.90	33.40	3.40

- not analysed

The content of heavy metals in the POME is from an analysis of cake from a 3-phase decanter.

The content of nutrients in the ash is calculated on the basis of the analyses of EFB, fibre and shells.

Table 4: Biogas from POME
(Wulfert et al. 2002)

Volume	m³/tFFB	0.65
COD-diss	kg/m³	25
	kg/t FFB	16.3
COD-susp	kg/m³	25
	kg/t FFB	16.3
Degrad.-rate COD		
COD-dissolved	%	90
COD-suspended	%	20
CH4-yield	m³/kg COD-degr.	0.35
CH4-concentr	%	65
Biogas (65 % CH4)	m³/t FFB	9.6
Methane	m³/m³ POME	9.6
	m³/t FFB	6.3
	kWh/t FFB	62.6
	MJ/t FFB	225

Table 5: Biogas from ECO-D slurry
(Schuchardt et al. 2007)

Volume	m³/tFFB	0.45
COD-diss	kg/t FFB	16.3
COD-susp	kg/t FFB	16.3
Degrad.-rate COD		
COD-dissolved	%	95
COD-suspended	%	90
CH4-yield	m³/kg COD-degr.	0.35
CH4-concentr	%	60
Biogas (60 % CH4)	m³/t FFB	17.5
Methane	m³/m³ POME	23.4
	m³/t FFB	10.5
	kWh/t FFB	105.2
	MJ/t FFB	378

Table 6: Heating value of the by-products in a 30 t palm oil mill (153,000 t FFB/a) and the theoretically amount of energy in one year

	Heating value		MWh/a (POME)	MWh/a (ECO-D)
Methane from POME*	MJ/m³	36.0	9,578	-
Methane from ECO-D*	MJ/m³	36.0	-	16,098
Fibre	MJ/kg	11.0	65,502	65,502
Shells	MJ/kg	13.4	39,897	39,897
EFB	MJ/kg	4.4	43,044	43,044
Sum			**158,021**	**164,542**

* based on the biogas yield in tables 4 and 5

2.2 Monetary value of the by-products

The monetary value of the by-products is calculated for the mineral nutrients and the heating value based on market prices in Indonesia in November 2007 (table 7 and 8). A calculation of the monetary value of the organic matter is difficult, because its effect depends on several factors (kind of soil, content of organic matter in the soil, kind of crop, and climate conditions).

Table 7: Market prices for mineral fertilizer in Indonesia in November 2007

Nutrient		% mineral	IDR/kg	EUR/t	IDR/kg mineral	EUR/kg mineral
N	as Urea	46	2.800	215	6.087	0,468
P	as Triple-Super-Phosphate	46	5.750	442	12.500	0,962
K	as Muriate of Potash (KCl)	60	5.700	438	9.500	0,731
Ca	as Dolomit	40	1.600	123	4.000	0,308
Mg	as Kieserit	16	1.800	138	11.250	0,865

currency rate: 1 EUR = 13.000 IDR

Table 8: Monetary value of the nutrients in the by-products in a 30 t palm oil mill (153,000 t/a) based on market prices for mineral fertilizer in Indonesia (table 7)

Nutrient			EFB	Fibre	Shells	POME	ECO-D	EFB ash	Fibre ash	Shells ash
Nitrogen	N	EUR/t DM	3.75	10.39	2.06	8.57	11.02	-	-	-
Phosphorus	P	EUR/t DM	0.93	1.59	0.38	4.22	1.64	0.96	25.18	6.11
Potassium	K	EUR/t DM	17.54	5.54	0.55	40.46	35.46	278.39	87.92	8.70
Calcium	Ca	EUR/t DM	0.55	1.16	4.18	3.30	3.53	8.79	18.46	66.42
Magnesium	Mg	EUR/t DM	1.56	7.84	1.86	13.09	4.48	24.73	124.45	29.53
	Sum	EUR/t DM	24.33	26.52	9.04	69.63	56.13	312.87	256.02	110.76
Nitrogen 50 %	N	EUR/t DM	1.88	5.21	1.03	4.29	5.52	-	-	-
	Sum	EUR/t DM	22.45	21.32	8.01	65.34	50.61	312.87	256.02	110.76

High energy prices make it more and more from interest for the palm oil mills to sell fibre and shells at the market. Although the selling price in practice is by weight only, a realistic price would consider the energy content (Fig. 2). The price for the full energy content would be 183 EUR/t for fibre and 224 EUR/t for shells. Even it is not realistic to get that price at the market, it can show the real value of the by-products shells and fibre as energy source.

The total monetary value of the by-products is given in table 9 for three scenarios.

A: Palm oil mill without biogas plant, selling of fibre and shells for 20 EUR/t.

B: Palm oil mill with biogas plant for POME, selling of fibre and shells for 20 % of the energy content; monetary value of the biogas is 20 % only of the market price for energy.

C Palm oil mill with biogas plant for POME, selling of fibre and shells for 100 % of the energy content; monetary value of the biogas is 100 % only of the market price for energy.

Fig. 2: Energy content of fibre and shells vs. market price of the products

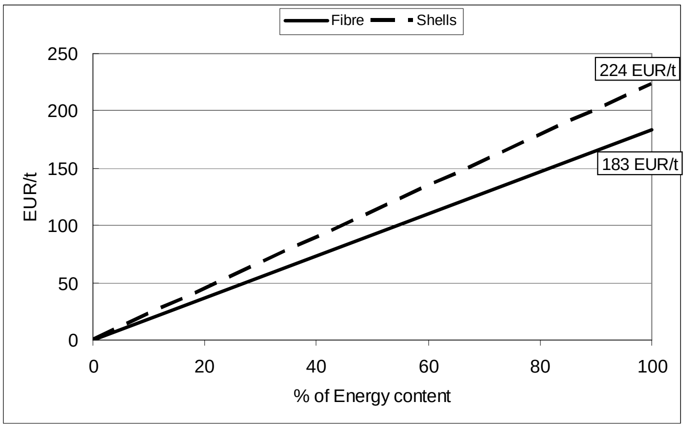

Table 9: Monetary value of the by-products in a 30 t palm oil mill (153,000 t/a) based on market prices for mineral fertilizer in Indonesia (table 7) and three different prices for the energy sources fibre and shells (A: 20 EUR/t: actual market price for shells in North Sumatra; B: 12 EUR/MWh: 20 % of the market price of Diesel fuel (0.60 EUR/L) in Indonesia (1 L Diesel = 0,01 MWh); C: 60 EUR/MWh is the full energy price of Diesel fuel.

By-product	Scenario	Nutrients EUR/a	Energy EUR/a	sum EUR/a
	A		20 EUR/t	
EFB		276,528	-	
Fibre		273,955	428,400	
Shells		59,714	214,200	
POME		266,435	-	
sum		**876,632**	**642,600**	**1,519,232**
	B		20 % of energy content (12 EUR/MWh)	
EFB		276,528	516,533	
Fibre		273,955	786,028	
Shells		59,714	478,763	
POME		266,435	114,934	
sum		**876,632**	**1,896,258**	**2,772,890**
	C		100 % of energy content (60 EUR/MWh)	
EFB		276,528	2,582,664	
Fibre		273,955	3,930,142	
Shells		59,714	2,393,814	
POME		266,435	574,668	
sum		**876,632**	**9,481,288**	**10,357,920**

2.2 Alternative utilisation of the by-products

2.2.1 Processes

The high market prices for energy make it from interest for palm oil mills to sell as much as possible of the shells and fibres and to use the EFB as a new energy source (even they have a high moisture content of about 65 % and emit smoke by the incineration). The use of EFB as energy source excludes their use for co-composting with POME/ECO-D slurry as a way of sustainable nutrient and organic mass utilisation.

What are suitable alternatives, if

- EFB are used as energy source in the palm oil mill and shells and fibre are sold as heating source externally to substitute diesel fuel or other fossil energy sources,
- EFB are used totally or partly for mulch production including evaporation of waste water,
- POME or slurry from ECO-D decanter is used to produce biogas, which is burned in the boiler to substitute solid energy sources?

For the utilisation of the by-products several alternatives are possible (table 10 and figures 3 to 10). All alternatives consider the total selling of the shells and the utilisation of the other sources (fibres, biogas from POME or ECO-D slurry, EFB) for energy production in the oil mill.

Table 10: Process alternatives for the utilisation of the by-products in a palm oil mill

Alternative		co-composting	fermentation	aerob treatment	land appl.
1	POME	■			
2		■	■		
3			■	■	
4			■		■
5	ECO-D	■			
6		■	■		
7			■		■
8		■	■		

According to the actual discussion about sustainable CPO production worldwide it is from interest, which alternative is the best one in view to

- minimization of nutrient losses,
- minimization of CO_2-emissions,
- avoiding pollution of environment (surface water and atmosphere),
- substitution of fossil fuels, and
- sustainable operation of plantation.

In the past there was no need for an oil mill to save solid waste, because there was no market for it. Therefore it was from low interest to install heating devices with higher efficiency.

Possibilities to increase the use of energy sources are:

- Biogas production from waste water to substitute solid wastes in boiler.

- Utilization of EFB as internal heating source instead of fibre and shells and selling those for external heating purposes
- Installation of new de-oiling devices to reduce water demand and amount of waste water. The consequence is a reduced energy demand for heating up of the water.

The consistency of the waste water influences the digester technology: The POME of conventional palm oil mills can be treated in an anaerobic fixed bed digester. Typical for this system is a short hydraulic retention time of <2 days, therefore only easily degradable components are processed and the biogas production is under the maximum potential. The gas yield is about 0.58 m³/kg COD dissolved with a methane content of 65 % (Wulfert et al. 2002).

In palm oil mills, equipped with new de-oiling systems (ECO-D), the effluent is no waste water anymore, it is slurry. The slurry can be digested in totally mixed digesters only, which is characterized by high degradation rate und gas yield. Results of digestion test (Schuchardt et al. 2007):

- The organic substance can be degraded almost up to 100 %.
- Within 8 days almost all of organic components can be hydrolysed and transformed to biogas.
- The specific gas yield is around 120 m³/ton biomass with a methane content of 60 %. The gas yield reaches the theoretical maximum.

Because of high cost for mineral fertilizer it should be from high interest for palm oil mill and plantation owner to utilize the nutrients from POME/slurry and waste as much as possible. Co-composting of EFB and POME (Eco-EFB™ process) or ECO-D slurry (Eco-EFB™plus process) is the optimal solution to unify all nutrients in one product. The produced mulch or compost can be used as fertilizer and soil conditioner in plantation. In practice the co-composting is done with windrow turning machines in open piles on a concrete floor. Several composting plants are running now in Indonesia and in Malaysia in full scale.

There is a conflict between the targets

- Maximization of energy production
- Optimization of nutrient recycling and
- Profit maximization.

The best solution cannot be measured by economical criteria only, because there are criteria for sustainable CPO production, which cannot be neglected:

- Pollution of surface water by discharged nutrients in waste water.
- Destroying of nutrient sources by burning.
- Improvement of soil fertility by addition of mulch.

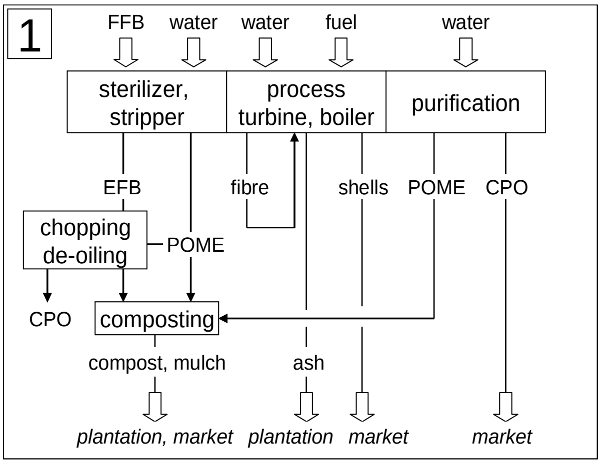

Fig 3: Flow diagram 1

- The POM is equipped with conventional de-oiling device with POME
- Fibre are used as energy source
- Co-composting of EFB and POME (EcoEFB™ process)
- Shells are sold to the market as energy source

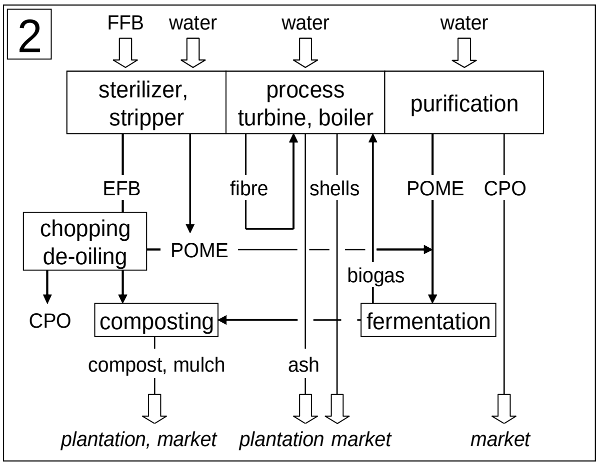

Fig 4: Flow diagram 2

- The POM is equipped with conventional de-oiling device with POME
- Fibre and biogas are used as energy source
- Co-composting of EFB and POME (EcoEFB™ process)
- Shells and surplus of fibre are sold to the market as energy source

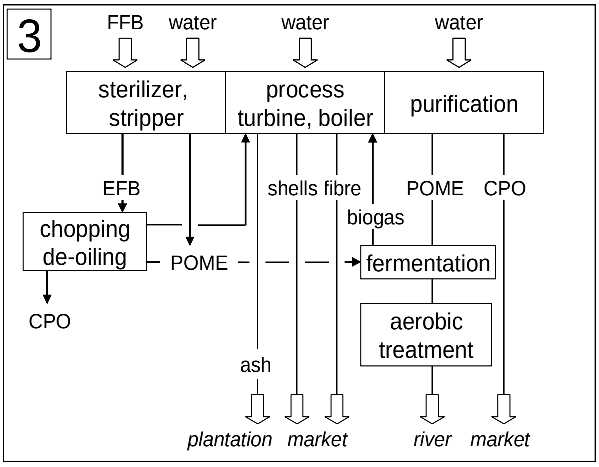

Fig 5: Flow diagram 3

- The POM is equipped with conventional de-oiling device with POME
- EFB and biogas are used as energy source
- No composting, no mulch production
- Shells and fibre are sold to the market as energy source
- POME discharged to river after aerobic post-treatment

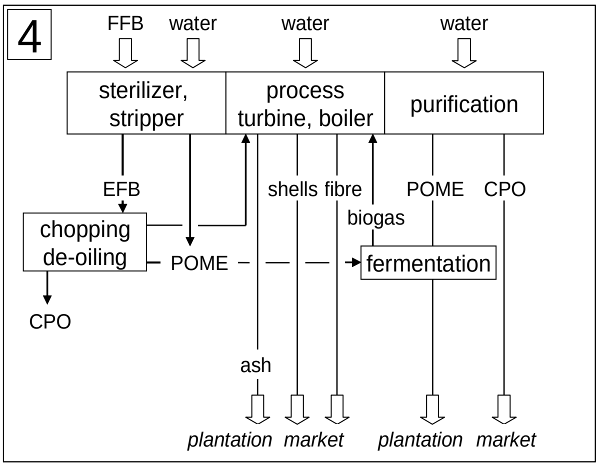

Fig 6: Flow diagram 4

- The POM is equipped with conventional de-oiling device with POME
- EFB and biogas are used as energy source
- No composting, no mulch production
- Shells and fibre are sold to the market as energy source
- POME for land-application

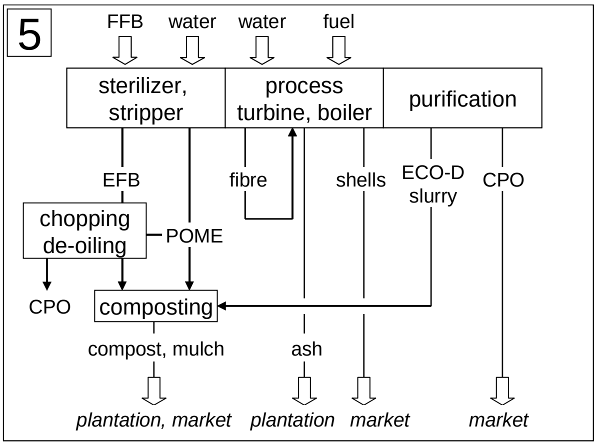

Fig 7: Flow diagram 5

- The POM is equipped with ECO-D decanter as de-oiling device
- Fibres are used as energy source
- Co-composting of EFB and slurry (EcoEFB™ plus process)
- Shells are sold to the market as energy source

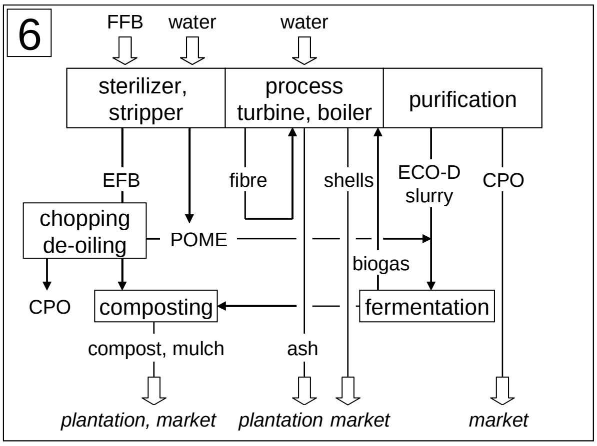

Fig 8: Flow diagram 6

- The POM is equipped with ECO-D decanter as de-oiling device
- Fibres and biogas are used as energy source
- Co-composting of EFB and slurry (EcoEFB™ plus process)
- Shells and surplus of fibre are sold to the market as energy source

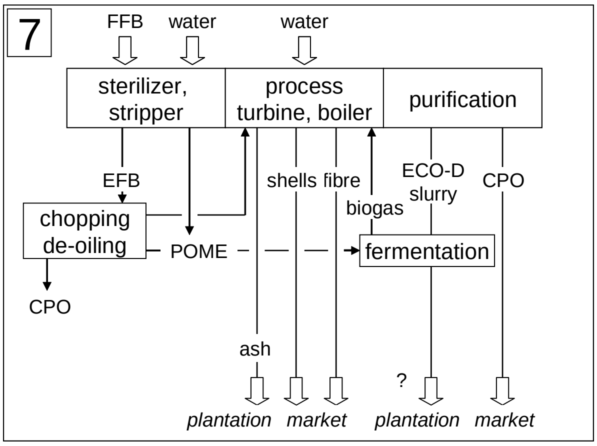

Fig 9: Flow diagram 7

- The POM is equipped with ECO-D decanter as de-oiling device
- EFB and biogas are used as energy source
- Digested slurry for land application
- Shells and fibre are sold to the market as energy source

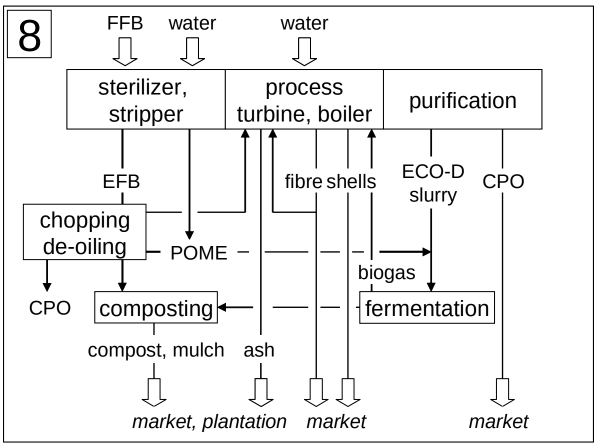

Fig 10: Flow diagram 8

- The POM is equipped with ECO-D decanter as de-oiling device
- Part of EFB, part of fibres and biogas are used as energy source
- Digested slurry for co-composting with EFB (Eco-EFB™ plus process)
- Shells and fibre are sold to the market as energy source

2.2.2 Energy balance of a palm oil mill

In a conventional 30 t palm oil mill with a steam demand of 400 kg/t FFB and a boiler efficiency of 72 % the energy demand is about 61.202 MWh/a (Fig. 3). By the fibres the energy demand of the mill can be fulfilled totally (figure 11).

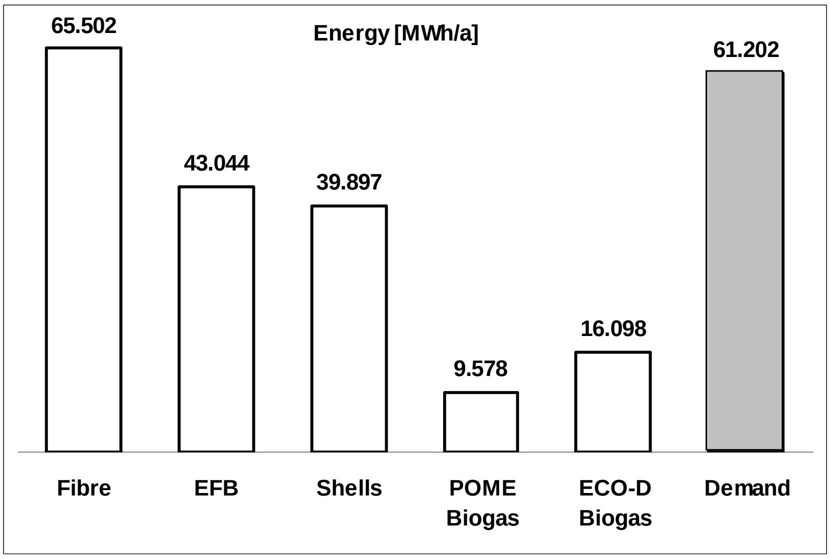

Fig. 11: Energy sources and demand in a 30 t palm oil mill (153,000 t FFB/a) current demand: 22.5 kWh/t FFB, steam demand: 400 kg/t FFB, boiler efficiency: 72 %

To cover the energy demand of a palm oil mill after selling all of the shells the demand of the other by-products is given in table 11.

Table 11: Demand on energy sources (in %) for different process alternatives in a palm oil mill after selling all of the shells

Alternative		Shells	Fibre	EFB	Biogas
1	POME	0	93	0	0
2		0	79	0	100
3		0	13	100	100
4		0	13	100	100
5	ECO-D	0	93	0	0
6		0	69	0	100
7		0	3	100	100
8		0	26	66	100

2.2.3 Economy of by-products utilisation

Based on the economical data in Indonesia a cost calculation was done for the process alternatives for mulch production (tables 12 and 13).

Table 12: Cost calculation for the mulch production (EcoEFB™ process); market prices for shells and fibre: 20 EUR/t

			POME				ECO-D slurry			
	alternative		1	2	3	4	5	6	7	8
Investment	Co-composting 1)	EUR	692.876	692.876	-	-	625.981	625.981	-	625.981
	Fermentation	EUR	-	789.215	789.215	789.215	-	806.340	806.340	806.340
	Land application 2)	EUR	-	-	-	1.453.500	-	-	1.453.500	-
	Sum	*EUR*	*692.876*	*1.482.091*	*789.215*	*2.242.715*	*625.981*	*1.432.321*	*2.259.840*	*1.432.321*
Cost	*Production cost*									
	Co-composting	EUR/a	117.555	117.555	-	-	128.196	128.196	-	128.196
	Fermentation	EUR/a	-	113.174	113.174	113.174	-	114.181	114.181	114.181
	Land application	EUR/a	-	-	-	363.375	-	-	363.375	-
	Total production cost	*EUR/a*	*117.555*	*230.730*	*113.174*	*476.549*	*128.196*	*242.377*	*477.556*	*242.377*
	Total capital cost	EUR/a	139.241	297.843	158.602	450.698	125.798	287.841	454.140	287.841
	Overall total	EUR/a	256.796	528.572	271.776	927.248	253.994	530.218	931.696	530.218
Benefit	saved POME treatment	EUR/a	85.680	85.680	85.680	85.680	85.680	85.680	85.680	85.680
	nutrients POME/ECO-D slurry 3)	EUR/a	266.435	266.435	-	266.435	266.435	266.435	266.435	266.435
	nutrients EFB	EUR/a	276.528	276.528	-	-	276.528	276.528	-	94.020
	ash nutrients fibre	EUR/a	209.054	176.338	29.306	29.087	208.083	154.065	6.712	57.055
	ash nutrients EFB	EUR/a	-	-	242.765	242.765	-	-	-	160.225
	increased FFB production (2 %)	EUR/a	351.900	351.900	-	-	351.900	351.900	-	116.127
	CO2-certificates POME (8 EUR/t)	EUR/a	177.358	177.358	177.358	177.358	177.358	177.358	177.358	177.358
	CO2-certificates EFB (8 EUR/t) 4)	EUR/a	73.440	73.440	73.440	73.440	73.440	73.440	73.440	73.440
	selling of shells/fibre (20 EUR/t)	EUR/a	242.327	304.968	586.488	586.908	244.188	347.615	629.748	533.358
	Total	*EUR/a*	*1.682.722*	*1.712.647*	*1.195.037*	*1.461.673*	*1.683.612*	*1.733.021*	*1.239.373*	*1.563.698*
Profit	**pay back period**	**years**	**0,49**	**1,17**	**0,84**	**3,05**	**0,45**	**1,12**	**4,34**	**1,28**

1) with turning machine Backhus type 17.50 as example

2) application rate: 100 m³/(ha*a)

3) Assumption: The total mass of nutrients of the ECO-D slurry incl. condensate is the same as in POME

4) 0.06 t CO2/t FFB (pers. information by J. Bintoro, 9/2007)

Table 13: Pay back time (in years) for different process alternatives and market prices for shells/fibres (a market price of 44.70 and 36.70 EUR/t resp. corresponds 20 % of the energy equivalent price in Indonesia; 0.60 EUR/L Diesel fuel)

Final	Market price [EUR/t]		POME				ECO-D slurry			
product	Shells	Fibre	1	2	3	4	5	6	7	8
mulch	20.00	20.00	0.49	1.17	0.84	3.05	0.45	1.12	4.34	1.28
mulch	44.70	36.70	0.42	0.94	0.53	1.76	0.38	0.88	2.06	0.98
compost	20.00	20.00	0.63	1.34	0.84	3.05	0.57	1.27	4.43	1.26
compost	44.70	36.70	0.52	1.07	0.53	1.76	0.48	0.99	2.06	0.88

Table 14: Impact of the mulch and compost production (EcoEFB™ process) on the environment and working places

			POME				ECO-D slurry			
	alternative		1	2	3	4	5	6	7	8
Environment	Utilisation of mineral nutrients 1)	-	all	only ash	only ash	ash+POME	all	all	only ash	only ash
	Utilisation of organic matter 1)	-	all	all	only POME	only POME	all	all	only ECO-D	ECO-D+1/3 EFB
	Pollution of surface water	-	no	no	very high	low to high	no	no	low to high	low to high
	reduced CO2 emissions									
	from POME	t/a	22.170	22.170	22.170	22.170	22.170	22.170	22.170	22.170
	from EFB	t/a	9.180	9.180	9.180	9.180	9.180	9.180	9.180	9.180
	from use of shells and fibre instead of fossil fuel	t/a	4.448	5.365	9.688	9.033	4.448	5.824	10.147	8.640
	sum	t/a	35.798	36.715	41.038	40.383	35.798	37.174	41.497	39.990
	Add. fuel consumption 2)	l/a	79.521	79.521	-	-	59.210	59.210	-	27.100
	additional CO2 emissions 3)	t/a	208	208	-	-	155	155	-	71
Social aspects	*Working places*									
	Co-composting	No.	17	17	-	-	17	17	-	17
	Fermentation	No.	-	4	4	4	-	4	4	4
	Land application	No.	-	-	-	?	-	-	-	-
	Sum	*No.*	*17*	*21*	*4*	*4*	*17*	*21*	*4*	*21*

1) from EFB and POME/ECO-D slurry
2) only for turning machine
3) 1 l Diesel --> 2,62 kg CO2

The results of the cost calculation for mulch and compost production (tables 12 and 13) from POME or slurry and the impact on the environment and working places are:

- At market prices for shells and fibre of 20 EUR/t the co-composting of EFB and POME (EcoEFB™ process) has the highest profitability of all alternatives (1 and 4).
- At market prices of 44.70 EUR/ t shells and 36.70 EUR/t fibre (20 % of the energy content) the profitability is higher than at a market price of only 20 EUR/t.
- The ECO-D process with slurry as by-product is more profitable than the conventional oil recovery process.
- The selling of shells and fibre and the utilisation of EFB as energy source in the oil mill is no profitable solution (3, 4, 7, and 8) compared to alternatives with EcoEFB™ process with total use of the EFB.
- The profitability of process alternatives with land application is much more less than all other alternatives (if the land application rate is done in a sustainable rate).
- The high profitability of most of the alternatives depends of the realisation of the benefits and can vary from place to place.
- A benefit of compost selling is not calculated in all alternatives. It can result in a higher profitability.
- In general: The calculation of the profitability can be different from place to place and depends on several local factors.
- Process alternatives with land application (4 and 7) have a risk of environment pollution.
- A process alternative with precipitation of the POME/slurry to the river (3) has a very high risk of environment pollution and is not acceptable.
- All processes with composting and land application create new working places.

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