# EFFECT OF NEW PALM OIL MILL PROCESSES ON THE EFB AND POME UTILIZATION

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### **ABSTRACT**

New palm oil mill processes are characterized by advanced oil separation technologies with zero dilution water ('ECO-D' for example as a new system for oil recovery without dilution water) and continuous sterilization of the fresh fruit bunch (FFB). These processes have a deep impact on the amount and composition of waste water (POME). Compared to conventional palm oil mills the total amount of palm oil mill effluent (POME) can be reduced from 0.65 m³ t¹ FFB to 0.45 m³ t¹ (conventional sterilization and zero dilution water) and  $0.25 \, m^3 \, t^1$  (continuous sterilization and zero dilution water). These changes influence the treatment processes and its cost significantly. One process for the EFB and POME utilization which can fulfil the demand of a sustainable palm oil production is the co-composting of both of the materials. The composting process is used also for biological drying of the POME. The final product of the process is compost or mulch which unifies the nutrients of both in one product. The POME can be used also for biogas production (in fixed bed reactors for POME with low dry matter content and in totally mixed reactors for ECO-D biomass) before composting. The investment cost and profitability of the composting and fermentation process is calculated in detail based on data from practise in Indonesia. The new developments of processes in palm oil mills can reduce the cost for the waste and waste water treatment up to 35%. The benefits from biogas production and composting are the energy production, saved POME treatment cost in pond systems, total utilization of the POME nutrients, reduced cost for the EFB transport and utilization, higher empty fruit bunch (FFB) yields and from clean development mechanism (CDM).

## Keywords: POME, EFB, ECO-D, composting, biogas, economy.

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## **INTRODUCTION**

Conventional palm oil mills are considerable polluters of the environment and do not follow the principles of sustainability (Anonym, 2003; 2005). In

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the Roundtable of Sustainable Palm Oil Production (RSPO) principle 5 (environmental responsibility and conservation of natural resources and biodiversity) is written:"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 maximized" (criterion 5.4), and "plans to reduce pollution and emissions, including greenhouse gases, are developed, implemented and monitored".

The main source of environment pollution in the oil mill is the palm oil mill effluent (POME) in the open pond system. The anaerobic ponds emit a huge amount of the strong greenhouse gas methane and the effluent of the ponds contains nutrients responsible for pollution of surface and ground water. The emission rate of methane from the pond is about 6.54 kg t<sup>-1</sup> FFB (Wulfert, 2002) corresponding

137.4 kg CO<sub>2</sub> equivalent (global warming potential factor of methane: 21; IPCC/TEAP, 2005).

Because climate protection becomes more and more important and especially methane emissions are in focus, we expect 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 crude palm oil (CPO) or biodiesel 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 environment-friendly treatment technologies in their oil mills. Results from own trials in pilot plants and in practical scale could demonstrate the successful co-composting of EFB and POME and the biomethanization of POME and sludge (Schuchardt et al., 1999; 2002a, b; 2006; Wulfert et al., 2002).

The article gives some suggestions for the sustainable treatment of the waste water (POME), slurry (from an ECO-D decanter) and the EFB including a cost calculation (based on data in Indonesia in 2007). The results and conclusions can be different from country to country and from mill to mill, depending on the local conditions.

## ALTERNATIVES OF POME, SLUDGE AND EFB TREATMENT AND UTILIZATION

If the POME is not treated in an anaerobic-aerobic pond system, several alternatives are possible:

- a. aerobic treatment in aerated ponds to avoid methane emissions is not suitable, because of:
  - enormous demand of current for aerators;
  - problems with de-sludging of ponds and handling of sludge; and
  - biological problems (chemical oxygen demand, COD, with 50 000 mg litre<sup>-1</sup> is too high for direct aerobic treatment).
- anaerobic pre-treatment in a biogas plant and aerobic post-treatment in aerobic ponds is possible, but the aerobic post-treatment is not recommended, because:
  - the aerobic post-treatment still has the problem of sludge sedimentation in the ponds (50% of COD is suspended organic material, which are not degraded in a fixed bed digester with a hydraulic retention time of < four days) (Wulfert, 2002);
  - difficult sludge handling;
  - methane formation in sludge sediment can not be avoided; and

- losses of all nutrients from POME and pollution of rivers and lakes.
- c. drying of POME in a dryer is not suitable, because of high invest and running costs, and high energy demand.
- d. land application of the POME is not recommended, because of the high cost, if the application rate is in balance with nutrient uptake by the oil palm tree (Schuchardt *et al.*, 2005). Furthermore, the POME has to be pre-treated anaerobically to fulfil the application regulations (in Indonesia: BOD <5000 mg O<sub>2</sub> litre<sup>-1</sup>). One result of the anaerobic treatment is emission of methane.
- e. utilization of POME for moistening in combination with EFB composting. This system is recommended, because:
  - the liquid of POME will be naturally evaporated without any additional energy input (except fuel demand of the turning machine);
  - all nutrients of POME are saved in the compost;
  - there is no waste water anymore, except leakage and rain water from the composting plant area; and
  - pollution of surface water, ground water and atmosphere can be avoided.

Since incineration of EFB is forbidden because of environment pollution by smoke, land application is the common accepted method of its sustainable utilization. In praxis, the oil mills use different procedures for handling, pre-treatment and distribution:

- f. untreated EFB are distributed in plantation, negative aspects are:
  - EFB are still wet with high weight per bunch;
  - distribution happens only manually;
  - danger of *Ganoderma boninense* outbreak and *Oryctes rhinoceros* (Rhinoceros beetle) in oil palm plantation if EFB are dumped in heaps (Patterson, 2007); and
  - slow mineralization of the nutrients, the fertilizer effect is difficult to calculate.
- g. distribution of chopped fresh EFB, positive aspects are:
  - easier to handle;
  - distribution can be done mechanized by spreader or blower;
  - material has the function of mulch and soil conditioner; and
  - mineralization is faster.
- h. compost production from chopped EFB and distribution of compost, positive aspects are:
  - operating dispenses for transport and distribution can be reduced by the reduction of the volume and mass tonnage in the composting process; and

• high content of mineralized nutrients, fertilizer effect can be quantified.

Dumping of the EFB is not only a pollution of the environment (methane emissions. leakage water with nutrients) but also a loss of money by the its nutrients. In some cases palm oil mills burn EFB in open heaps (with heavy smoke pollution) to get the ash as mineral fertilizer.

### Palm Oil Mills with New Technologies

The discussion about POME treatment is based on an 'end of pipe strategy'. An alternative is to modernize the production process itself. In palm oil mills, new technologies (so called 'new palm oil mills') had been developed and are in progress (Sivasothy *et al.*, 2005; Sivasothy and Hwa, 2006; Chungsiriporn and Prasertsan, 2006; Westfalia Separator Industry, 2006; Tornroth, 2006). These technologies are particularly:

- new sterilization processes without condensate instead of conventional autoclave sterilization. The conventional sterilization creates a condensate flow of 0.20 m³ t⁻¹ FFB. By modification to a new sterilization processes polluted condensate can be avoided almost totally; and
- zero dilution water for oil separation. The conventional oil recovery process as a combination of vertical clarifier and separators needs dilution water for good function. The process creates waste water: 0.45 m³ t¹ FFB. By using new oil recovery technology (for example 'ECO-D' system by Westfalia Company) an addition of dilution water is not necessary anymore and the amount of effluent can be reduced up to 0.25 m³ t¹ FFB. The slurry of the separator has an consistency like a cream.

The total amount of POME can be reduced step by step by implementation of new technologies (Table 1). Because the loads of suspended solids,  $COD_{diss.}$  etc. are nearly unaffected by the reduction of water, the dry matter content will increase from about 4% to 5% in conventional POME up to about 17% in the slurry discharged from the ECO-D decanter system (Table 1).

As shown in *Table 2*, new technologies in palm oil mills, continuous sterilization and oil recovery without dilution water, has a significant impact on:

- amount of POME and water in POME (m³ t<sup>-1</sup> FFB);
- the composition (dry matter content, concentration of nutrients, liquid or sludge);

TABLE 1. COMPOSITION OF POME (two phase decanter, including condensate; Pom Pagar Mabau, Indonesia) AND ECO-D SLUDGE (Pom Tasma Puja, Pekanbaru, Indonesia); OWN ANALYSES

		POME	ECO-D
CODtot.	kg m <sup>-3</sup>	50	nd
CODdiss.	kg m <sup>-3</sup>	25	nd
BOD	kg m <sup>-3</sup>	25	nd
DM	kg m <sup>-3</sup>	41	170
SS	kg m <sup>-3</sup>	18	nd
TVS	kg m <sup>-3</sup>	34	147
N-Kj.	kg m <sup>-3</sup>	0.75	4.00
N-diss (NH4-N)	kg m <sup>-3</sup>	0.04	nd
P-tot.	kg m <sup>-3</sup>	0.18	0.29
K	kg m <sup>-3</sup>	2.27	8.25
Ca	kg m <sup>-3</sup>	0.44	1.95
Mg	kg m <sup>-3</sup>	0.62	0.88

Note: nd - not determined.

TABLE 2. POME AND SLUDGE FROM CONVENTIONAL AND 'NEW' PALM OIL MILLS

Parameter	POM	Conventional	'New	POM'
		batch sterilization A	Batch sterilization + zero dilution B	Continuous sterilization + zero dilution C
Sterilizer condensate	m³ t-1 FFB	0.20	0.20	0
Clarification sludge	m³ t-1 FFB	0.45	0.25	0.25
Sum POME+slurry	m <sup>3</sup> t <sup>-1</sup> FFB	0.65	0.45	0.25
Dilution water	m³ t-1 FFB	0.20	0	0
POME+slurry	% DM	5	10	17
POME+slurry rel. EFB	m³ t-1 EFB	2.83	1.96	1.09
POME+slurry water	m³ t-1 EFB	2.68	1.76	0.90

Notes: Cooling water is not taken into account because it is reused in the mill. Cleaning water is not taken into account because the amount is negligible low.

- the utilization (type of biogas plant, size of composting plant); and
- the treatment cost of the POME.

#### **RESULTS**

## **Concept and Further Strategy**

The proposed concept of a sustainable POME and EFB treatment can fulfil the following aspects:

- alternative to common procedures as pond system and dumping of EFB;
- elimination of pollution of surface water, ground water and atmosphere (realization of zero-waste-concept);
- minimization of nutrient losses and concentration of all nutrients from POME and EFB in one product;
- possibility of biogas production by demand;
- generating certified emission reduction (CER);
- flexible application for conventional and palm oil mills with new technologies.

The basic lines of the concept are shown in *Figure 1*. The key-process in the concept is the composting of EFB. The chopped EFB are transported to a composting plant and set up to windrows. The heaps can evaporate 70 kg water/(t EFB\*day) because of the high self-heating temperature as result of the intensive rotting process (Schuchardt *et al.*, 1998;

2002) and would fall dry, if the heaps are not irrigated regularly. POME is used to keep the moisture in the rotting material. The rotting material is mixed and turned by windrow turning machines to optimize the biological process and to maximize water evaporation. The size and costs of a composting plant depends on the amount of water, which have to be evaporated. Under this aspect, it is important how much POME accumulate in the oil mill. Therefore three alternatives will be considered:

- A: conventional POM with 0.65 m<sup>3</sup> POME t<sup>-1</sup> FFB.
- B: new POM with new oil recovery process with 0.45 m<sup>3</sup> POME t<sup>-1</sup> FFB and
- C: new POM with new technology for sterilization and new oil recovery processes with 0.25 m<sup>3</sup> POME t<sup>-1</sup> FFB.

If the POM has a demand or a market for biogas / energy, the POME can be treated in a biogas plant. The produced biogas is used as energy source. Different types of biogas plants are suggested, depending on the kind of effluent. For POME with low dry matter content, fixed bed digesters are favoured, because of a very good process stability in view to shock loads, variation of feeding rate and COD concentration (Wulfert et al., 2002). For POME / ECO-D slurry with high dry matter content (>10%) totally mixed digesters are necessary to handle such kind of sludge. After anaerobic pre-treatment, the effluent of a biogas plant is used for moistening of the compost heaps.

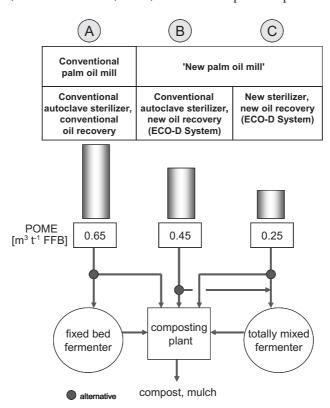


Figure 1. Alternative use of POME and ECO-D biomass from conventional and from new palm oil mills.

# **Process Design of Anaerobic POME Treatment**

After POME passed the de-oiling (de-oiling pond, oil skimmer) the hot POME is cooled down (*Figure 2*). As cooling medium cold process water and/or air is used. The water is pumped via pipe to the waste water treatment plant, where it passes a screen, which separates all solid with a size >0.75 mm (minimization of risk of plugging the fixed bed). The effluent of the screen flows directly into the prestorage to enable a continuously feeding of the digester 24 hr a day at seven days a week.

For anaerobic treatment, a fixed bed digester is chosen with feeding at the bottom of the digester and up flow mode. A part of the effluent is used as circulation water and is mixed with the fresh waste water coming from pre-storage tank. The circulation flow is necessary to dilute the high polluted feeding waste water, to raise the low pH, and to decrease the acid concentration. The anaerobic bacteria degrade the dissolved organic components of POME during passing the fixed bed and transform them to biogas. The biogas is collected and used as energy source.

The effluent of the digester flows by gravity into a post-storage, where a part of the suspended solids settles down, which is partly used to dilute the digester inflow. The other part will be used in the composting plant. The post-storage is constructed as closed tank to collect the biogas, which is produced there still.

The loading rate (kg degradable organic matter per m³ digester volume and day) is the most important parameter for dimensioning of a fixed bed digester. The loading rate ranges between 6 and 10 kg/(m³\*d).

# Results of Digestion Tests with Biomass from ECO-D System

To determine the degradability and biogas yield and composition of ECO-D slurry, a standard

digestion test was done in lab-scale digesters with semi-continuous mixing (net volume: 7 litres; feeding: once a day; loading rate: 2 to 4 g degradable organic matter per litre fermenter volume and day; mixing: 1 min mixing, 1 min break; digestion temp. 38°C; gas counting: precision gas counter by Ritter Apparatebau GmbH). The composition of the slurry is given in *Table 1*.

Results of the digestion test:

- the organic substance can be degraded almost up to 100%.
- within eight days almost all of organic components can be hydrolysed and transformed to biogas.
- the specific gas yield is up to120 m³ t¹ biomass with a methane content of 60%.
   The gas yield reaches the theoretical maximum; and
- as consequence of the protein content it might happen that the ammonia/ammoniac concentration reaches a level, which caused an inhibition of anaerobic bacteria. This problem can be solved by addition of dilution water (c-NHx-max = 5200 mg litre<sup>-1</sup>).

The digestion tests showed the very good biomethanization of Eco-D slurry. The characteristic of digestion is comparable with other substrates from food industries which are digested successfully in full scale plants already.

### **Process Design of Anaerobic Sludge Treatment**

The totally mixed digester is the most common type to treat sludge in biogas plants worldwide. The construction of the digester is a cylindrical closed steel or concrete tank, equipped with a mixing device, to ensure a well mixing of the content, a good distribution of fed substrate, and to avoid the formation of sediment and swimming scum.

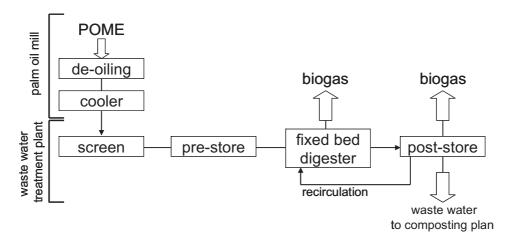


Figure 2. Process design of anaerobic treatment of POME with low dry matter content.

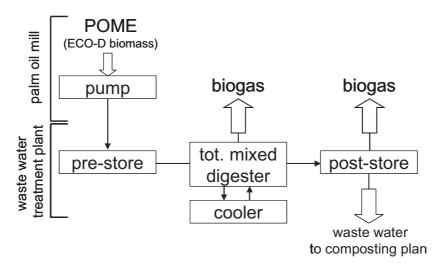


Figure 3.

For dimensioning of the biogas plant only few parameters are relevant:

- the hydraulic retention time has to be more than 15 days to ensure that the bacteria grows is higher than the bacteria losses by effluent;
- the loading rate (kg degradable organic matter per m³ digester volume and day) ranges between 2 and 4 kg/(m³\*d) otherwise the risk of overloading increase; and
- the digestion temperature for mesophilic process ranges between 28°C and 40°C. The chosen temperature should be kept at constant level +/- 0.5°C.

The biomass from the ECO-D System or the mixture of biomass and condensate is pumped to the biogas plant, where the suspension is stored in a tank (*Figure 3*). The pre-store tank is equipped with mixing device to ensure a homogeneous composition. Via a pump the digester is fed continuously. The mixing device in the digester ensures a good distribution of the substrate. The digestion temperature is controlled by an internal or external cooling device. The adjusted temperature level can range between 28°C and 40°C. In view of the high ammonia concentration, a temperature of 30°C to 35°C is proposed. At higher temperature the dissociation of the ammonia can inhibit the process.

The effluent flows out via overflow by gravity into the closed post-storage, from where it is pumped to composting plant.

## **Process Design of Composting Plant**

After chopping the EFB, heaps are formed for composting (Figure 4). The size of the heaps depends on the size of the turning machine. The self-heating process of the EFB, initiated by the microorganims in the substrate, starts within few hours and water is evaporated to the atmosphere (Schuchardt et al., 1998). POME (with or without anaerobic pretreatment) will be added step by step to the rotting EFB, depending on the rate of water evaporation. The composting process can go on until the substrate is totally stabilized as 'compost' (C/N ratio <15) or it can be stopped at a stabilization level of 'mulch' (C/N ratio >15); it depends on the further use of the substrate. If compost should be produced as a market product screening before packaging is suggested to have a product with a homogenous structure. The mixture of leakage water and rain water from the composting area is collected in a pond and will be used for irrigation of the heaps (or in plantation area). The floor of the composting area is made by concrete or asphalt, to protect the environment by uncontrolled run off of the leakage water (with

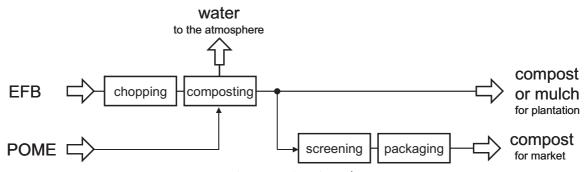


Figure 4. Process design combined EFB/POME composting.

nutrients) and to ensure a controlled turning of the heaps and high compost quality. A protection of the heaps with a geo-textile is not necessary.

# CONCLUSIONS AND CONSEQUENCES FOR THE CO-COMPOSTING OF EFB AND POME

The composting process can be divided into two process stages:

- a. Stage 1:
  - addition of POME;
  - evaporation of the water;
  - biological drying; and
  - final product: mulch.
- b. Stage 2:
  - stabilization of the compost;
  - drying period (for screening as market product); and
  - final product: compost.

At the end of the stage 1 (after 12, 24 and 37 day respectively, *Table 3*) the EFB are like mulch and not stabilized as a mature compost. The mulch can be used in plantation area for palm oil trees (or other

*Figures 5* to 9 show the flow sheets and the equipment for the biological drying/composting of EFB and POME.

#### **Cost Calculation**

To compare the anaerobic treatment alternatives for POME, the cost calculation based on a biogas production rate of 1000 m³ methane per day (1000 litres Diesel fuel equivalent or 10 000 kWhr¹). The composting plant is calculated for a 30 t mill with 153 000 t FFB yr¹ and the full rate of POME/sludge. All prices based on market prices in Indonesia in the years 2006/2007. The data for the cost calculation are given in *Tables 4* to 8.

#### CONCLUSION

New palm oil mills (Type B with conventional autoclave sterilizer and new oil recovery process and type C with new sterilizer process and new oil recovery process) produce a sludge with high dry matter and COD content ('ECO-D slurry'). The sludge can be used for biogas production in a totally

TABLE 3. TIME FOR BIOLOGICAL DRYING AND STABILIZATION OF EFB AND POME COMPOSTING

	Type of palm oil mill	No.	Biol. drying (d)	Stabilization (d)	Total time (d)	Product
A	POM with conventional sterilization, with dilution water; for composting fresh POME or after fermentation	1 2	37 37	0 30	37 67	mulch compost
В	POM with conventional sterilization, new oil recovery, fresh POME for composting	3 4	24 24	0 30	24 54	mulch compost
	POM with conventional sterilization, new oil recovery, POME after fermentation for composting	5 6	24 24	0 30	24 54	mulch compost
C	POM with new sterilization, new oil recovery, fresh POME for composting	7 8	12 12	0 30	12 42	mulch compost
	POM with new sterilization, new oil recovery, POME after fermentation for composting	9 10	12 12	0 30	12 42	mulch compost

plants) but not in a nursery. The biological degradation of the EFB/POME mixture will go on under the natural soil and climate conditions. If mature compost should be produced (C/N>15), the rotting time should be prolonged for about 30 days more. An addition of water could be necessary during that time to afford the biological activity. To produce dry compost for screening and packaging the retention/drying time depends on the climate conditions. The retention time of the EFB in the composting plant is relevant for the cost of the composting process.

A reduction of the specific POME amount will reduce the time necessary to evaporate the water.

TABLE 4. BASIC DATA FOR COST CALCULATION FOR ANAEROBIC TREATMENT AND COMPOSTING

Maintenance	% of investment	2 to 5
Depreciation	years	10
Currency	1 EUR	11 000 IDR
Capital cost		
Credit	%	70
Equity	%	30
Interest	%	16
Pay back time	yr	5
Energy		
Diesel fuel	EUR/1	0.60

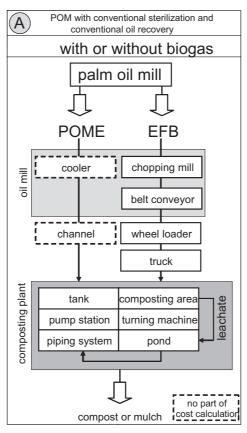


Figure 5. Equipment of a composting plant for EFB with addition of POME (POM type A).

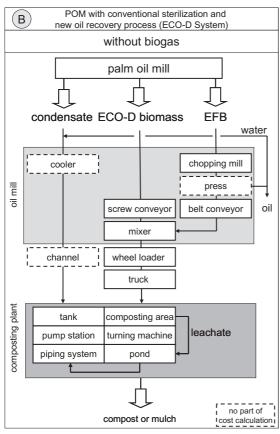


Figure 6. Equipment of a composting plant for EFB with addition of POME without biogas production (POM type B).

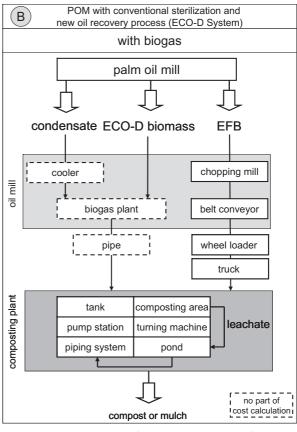


Figure 7. Equipment of a composting plant for EFB with addition of POME with biogas production (POM type B).

TABLE 5. COST CALCULATION FOR BIOGAS PLANT WITH FIXED BED DIGESTER (1000 litres diesel fuel equivalent); POM TYPE A

=		
Investment cost (1)	EUR	486 560
Capital costs	EUR yr <sup>-1</sup>	148 599
Production cost (2)	EUR yr <sup>-1</sup>	72 784
Total annual costs	EUR yr <sup>-1</sup>	221 383
Benefit (3)	EUR yr <sup>-1</sup>	219 000
Profit calculation		
Pay back period, year (annuity-method)	yr	2.96
Actuarial return with reference to total investment	%	39.5
Actuarial return with reference to equity	2 %	66.4

Notes: (1) Components: preparation work, cooling, pre-storage, digester including support material, security device, post-storage, gasholder, de-sulphurization, biogas flare + blower, process measurement and control, switch board room, pipes for water, gas pipes,cable/power supply, traffic area, planning cost.

TABLE 6. COST CALCULATION FOR BIOGAS PLANT WITH TOTALLY MIXED DIGESTER (1000 litres diesel fuel equivalent) POM TYPE B/C

1	, -	
Investment cost (1)	EUR	424 200
Capital costs	EUR yr <sup>-1</sup>	129 555
Production cost (2)	EUR yr <sup>-1</sup>	63 298
Total annual costs	EUR yr <sup>-1</sup>	192 853
Benefit (3)	EUR yr <sup>-1</sup>	219 000
Profit calculation Pay back period, year (annuity-method) Actuarial return with	yr %	2.50
reference to total investment Actuarial return with	/o %	40.1
reference to equity	,,,	75.7

Notes: (1) Components: preparation work, cooling, pre-storage, digester, mixer, security device, post-storage, gasholder, de-sulphurization, biogas flare + blower, process measurement and control, switch board room, pipes for water, gas pipes, cable/power supply, traffic area, planning cost.

TABLE 7. OVERVIEW ABOUT COST CALCULATION FOR THE MULCH AND COMPOST PRODUCTION FROM EFB AND POME WITHOUT ANAEROBIC PRE-TREATMENT OF THE POME

		Inves	tment	Difference	Pay back	Actuarial	return [%]
POM	No.	EUR	%	EUR	yr	Total investm.	Ref. to equity
		Only mulch	n productio	n (biological dr	ying)		
A	1	749 705	100	-	1.48	67	144
В	3	680 924	91	- 68 781	1.34	75	170
C	7	592 492	79	- 157 213	1.28	87	210
		Compost p	roduction				
A	2	1 158 185	100	-	2.42	40	66
В	4	871 404	75	- 286 781	1.74	56	113
C	8	782 972	68	- 375 213	1.55	64	136

TABLE 9. OVERVIEW ABOUT COST CALCULATION FOR THE MULCH AND COMPOST PRODUCTION FROM EFB AND POME WITH ANAEROBIC PRE-TREATMENT OF THE POME

		Inves	tment	Difference	Pay back	Actuarial	return [%]
POM	No.	EUR	%	EUR	yr	Total investm.	Ref. to equity
		Mulch prod	luction (bio	logical drying)	and biogas p	roduction	
A	1	749 705	100	-	1.48	67	144
В	5	654 924	87	- 94 781	1.28	78	180
C	9	566 492	79	- 183 213	1.10	91	223
		Compost p	roduction a	nd biogas prod	uction		
A	2	1 158 185	100	-	2.42	40	66
В	6	845 404	73	- 312 781	1.68	58	119
C	10	756 972	65	- 401 213	1.49	67	144

<sup>(2)</sup> Includes maintenance, labour cost, depreciation and general cost; energy demand is fulfilled by the oil mill, the cost are not calculated separately.

<sup>(3)</sup> Energy-production (diesel fuel equivalent).

<sup>(2)</sup> Includes maintenance, labour cost, depreciation, and general cost; energy demand is fulfilled by the oil mill, the cost are not calculated separately.

<sup>(3)</sup> Energy-production (diesel fuel equivalent).

TABLE 8. COST CALCULATION FOR ALTERNATIVE COMPOSTING PLANTS IN A 30 t OIL MILL (153 000 t yr¹) FOR POM TYPE A, B AND C WITH MULCH PRODUCTION AND COMPOST PRODUCTION (see Table 3)

			COMEOSI	rnopociii	COMITOSI FINODOCITOIN (See tubite 3)	9)					
Type of oil mill (1)		A	A	В	В	В	В	C	C	C	C
Alternative		1	7	က	4	ъ	9	7	<b>∞</b>	6	10
Product		mulch	compost	mulch	compost	mulch	compost	mulch	compost	mulch	compost
Investment cost (2)	EUR	749 705	1 158 185	680 924	871 404	654 924	845 404	592 492	782 972	566 492	756 972
Capital costs	${ m EUR~yr^{-1}}$	228 967	353 751	207 961	266 135	200 020	258 194	180 953	239 127	173 012	231 186
Production cost (3)	${ m EUR~yr^{1}}$	189 877	272 052	171 557	216 131	167 267	211 841	151 439	194 508	147 149	190 218
Total annual costs	${ m EUR~yr^{-1}}$	418 844	625 772	379 518	482 266	367 287	470 035	332 392	433 635	320 161	421 404
Benefit (4)	${ m EUR~yr^{-1}}$	607 412	613 313	604 234	611 497	604 234	611 497	600 602	608 774	600 602	608 774
Profit calculation											
Pay back period, year	yr	1.48	2.42	1,34	1.74	1.28	1.68	1.16	1.55	1.10	1.49
(annuity-method)											
Actuarial return with reference to	%	9.99	39.5	74.6	56.3	77.8	58.2	87.1	64.1	91.3	6.5
total investment											
Actuarial return with reference	%	144.2	9:29	169.5	112.6	179.7	118.5	209.5	136.4	223.3	144.0
to equity											

Notes: (1) A: Conventional palm oil mill with conventional autoclave sterilizer and oil recovery.

B: 'New palm oil mil' with conventional autoclave sterilizer and new oil recovery process (ECO-D System).

C: 'New palm oil mill' with new sterilizer process and new oil recovery process (ECO-D System).

Components: POME/sludge tank, chopping mill, belt conveyor, screw conveyor, mixer, turning machine, concrete floor 15 cm, dump truck, wheel loader, pond for leakage water, piping system, pump stations, mechanical work, electrical work, planning cost. (5)

Fuel, electricity, labour, maintenance, depreciation, general cost.

Cost saved for POME treatment in ponds, value of the nutrients in POME, reduced cost for compost transport + distribution, increased FFB production of 2%, CER only for POME (8 EUR t-1).  $\mathfrak{S}$   $\mathfrak{A}$ 

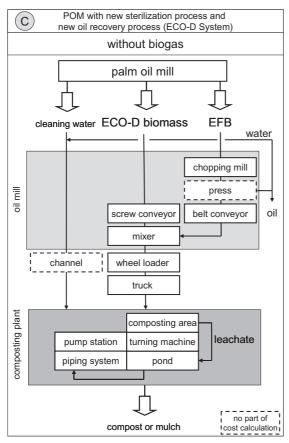


Figure 8. Equipment of a composting plant for EFB with addition of POME without biogas production (POM type C).

mixed reactor. Compared to conventional palm oil mills (type A) which should use a fixed bed fermenter for the POME treatment, the investment cost can reduced up to 13% and the pay back time can reduced from 2.96 to 2.5 years. The biogas production from POME or ECO-D biomass is profitable (calculated on the diesel fuel energy equivalent and a price of 0.60 EUR litre<sup>-1</sup>) when the gas can be used.

The mulch or compost production from EFB with addition of POME/Eco-D biomass is profitable with pay back times between 1.1 and 2.4 years. Compared to conventional palm oil mills (type A) the investment cost can be reduced up to 35%.

With the process of mulch or compost production from EFB in combination with POME or ECO-D slurry (with or without anaerobic fermentation with biogas production before) it is possible to realize a sustainable process in palm oil mills with 'zero waste'.

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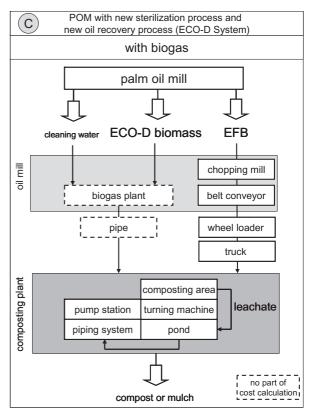


Figure 9. Equipment of a composting plant for EFB with addition of POME with biogas production (POM type C).

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