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ASSESSMENT OF OIL PALM WASTE TREATMENT TECHNOLOGY

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Abstract

Oil palm tree is the primary producer of the world cooking oil. The total crude palm oil (CPO) production contributes around 26.5 per cent (25 Million Tons per year) of the total world market. It is predicted that palm oil will share about 27.6 per cent of total world cooking oil consumption between 2008 and 2012. In addition to oil as a main product, a palm oil plant also produces the wastes, both solid and liquid wastes. These are empty palm fruit bunches, shells, fibers, sludge, and solid wastes from the kernel processes. The composition of the palm fruit empty bunch (EB), shell, fiber and sludge decanter is about 4, 11, 6 and 1 per cent dry weight of the total fresh fruit, respectively. These wastes will pollute the environment if their treatment technologies are not suitably applied and chosen. The common current treatment technology for the solid waste of the palm oil industry in Indonesia is incineration and field disposal. These treatment technologies could danger the environment if they are not designed, constructed, and operated properly based on the principle of cleaner technology. Research and development on several treatment technologies of palm oil wastes have been done. This paper will introduce the variety of technologies that could be used to treat different types of wastes of the palm oil industry at environmentally safe, technically acceptable and economically feasible.

Keywords: *Palm oil industry, crude palm oil (CPO), solid waste, empty bunch (EB), shell, fiber, sludge decanter, treatment technology.*

1. INTRODUCTION

1.1 Background

Oil palm tree is the world cooking oil producer, in addition to soybean, sun flower, and rape reed. The amount of produced crude palm oil (CPO) contributes to about 26.5 per cent of world market vegetable oil or about 25 Million Ton per year between 2003–2007. Before 1998–2002, palm oil tree give a contribution to the world market vegetable oil of about 24.8 per cent. In the years 2008 – 2012 it is predicted to reach 27.6 per cent contribution[1,2)].

In the last two decades, the world palm oil production has increased significantly. It is indicated by the data that between 1980 and 1990 its production increased from 4.55 Million Tons to 10.95 Million Tons. Then in 1997 it increased to 17.46 Million Tons, and in 2000 it reached 21.258 Million Tons.

Beside CPO as a main product, palm oil plant also results waste consisting of liquid, solid and gaseous wastes[1, 3)]. Liquid waste of palm oil plant comes from

sterilization unit, clarification unit and hydro-cyclone. The solid waste is in the form of empty fruit bunches, shell or endocarp, fiber, sludge and oil cake. Gaseous waste and dust come from the combustion of shells and fibers as fuels for boiler and sterilization process (in the form of water vapor). Gaseous waste can be from empty fruit bunches combustion in the kiln.[4)]

The environmental problem associated with palm oil plant is important topic to be discussed because of its abundant liquid and solid wastes produced that are not optimally treated.[2)] The liquid waste contains high organic matter. Even though this pollutant is not toxic its high BOD concentration will degrade the environment if it is disposed directly into the river without proper pretreatment.[1)]

Other problems with an existing palm oil plant is disposal and burning empty fruit bunches[5)]. Uncontrollable disposal of empty fruit bunches into the land of palm oil tree estate results in over-helming empty fruit bunches biomass on that area. Because empty fruit bunches is mostly organic matter the stacking empty fruit bunches will go decomposition process anaerobically. Huge decomposition process of empty fruit bunches generates several gases such as CH_4, H_2S, NH_3, and NO_x[1, 4)] that pollute the atmospheric air. Some of those gases have green house effects and in turn, will contribute to the global warming. Locally, some gases will danger people health due to their tocixity and bad odor. In addition to gaseous pollutants, decomposition of empty fruit bunches will also produce leachate that causes the pollution to the surface and ground water. Due to the potential pollution of the empty fruit bunches waste, it must be treated wisely.

1.2 Condition of Palm Oil Estate in Indonesia

Palm oil estate operation in Indonesia is coordinated by Agriculture Ministry. Plant oil estate has strategic and important role in national development, especially in improving prosperity and people welfare, gaining foreign exchange revenue, opening work forces, adding value gain and competition, increasing domestic consumption needs, providing industrial raw material and also optimizing sustainable resources for other industries.

To prevent disturbances and to avoid environmental damage, each palm oil estate has an obligation to conduct and implement a study of the environmental impact analysis (EIA) as well as an environmental management risk (EMR) assessment.[1,3)] . An environmentally-friendly palm oil estate practices can be met if it is supported by knowledge and appropriate technologies, as well as good skill employees.

Nowadays, the availability of palm oil estate in Indonesia is very important to national capacity building of agricultural sector, in terms of its contribution to the foreign exchange revenue, work force absorption and growth domestic product.[6,7)] Foreign exchange revenue gained from agricultural sector was 5,364 million dollar US in 2002, and from palm oil estate sector was 88.76 %. Data of employment absorption in 2002 indicated that of 38.2 million people who worked on agricultural field, about 42 % of them worked on palm oil estate sector. Contribution of palm oil estate to national Growth Domestic Product was 2.53 % and to agriculture sector was 16.65 %. In 2004, total foreign exchange revenue from agricultural sector other than palm oil estate was only US$ 4,859 million whereas the palm oil estate sector amounted US$ 7,784 million (160.19%)[7)].

In 2003 palm oil estate area was 5,238,557 ha and yielded 10,440,834 tons crude palm oil (CPO). Farmers who involved in palm oil plantation were 1.02 million families. In 2005, oil palm area grew up to 5,597,158 ha with production of 12,451,981 tons CPO that distributed in 20 provinces of Indonesia[6)].

In 2005, Indonesia is the second biggest palm oil exporter in the world after

Malaysia, and right now there were 320 units of palm oil plants with total capacities of 13,520 tons fresh fruit bunch (FFB) and 6 seed producers with capacities of 124 million seeds per year.[6)]

In the future, palm oil estate growth will predictably be good prospects. By 2012, according to world production and consumption balance, vegetable oil production will grow to 108,512,000 tons in which about 30, 8 % of them comes from palm oil [7)]. Government policy for supporting palm oil estate development is (1) to increase the productivity of palm oil in terms of quantity and quality, (2) to increase its added value, (3) to develop integrated palm oil industries and (4) to facilitate support fund availability.

The potential data of area and production of palm oil estate is given in Table 1.[8)] Figure 1 shows the graphical trend of area and production, whereas palm oil waste from 2000 to 2005 is given in Figure 2.

Table 1. Area and production of palm oil plantation in Indonesia

Year: Area & Production	Region or Island					INDONESIA
	Sumatera	Java	Kalimantan	Sulawesi	Papua & Maluku	
2000						
Area (ha)	2,479,796	21,306	752,498	107,966	31,855	**3,393,421**
Production (Ton)	5,520,538	30,439	554,000	109,217	56,677	**6,270,871**
2001						
Area (ha)	3,675,774	20,331	880,912	131,625	50,137	**4,758,779**
Production (Ton)	7,143,750	32,426	903,714	232,996	65,586	**8,378,472**
2002						
Area (ha)	3,890,422	23,234	957,186	143,399	52,817	**5,067,058**
Production (Ton)	8,190,271	33,523	1,064,823	261,315	72,412	**9,622,344**
2003						
Area (ha)	4,031,855	23,456	969,635	145,735	68,490	**5,239,171**
Production (Ton)	8,674,691	48,991	1,380,625	246,397	17,482	**10,368,186**
2004						
Area (ha)	4,190,850	25,790	1,049,553	128,498	52,872	**5,447,563**
Production (Ton)	9,891,023	50,462	1,509,410	262,526	93,128	**11,806,549**
2005						
Area (ha)	4,280,093	26,045	1,108,287	129,355	53,375	**5,597,155**
Production (Ton)	10,384,304	52,726	1,648,632	270,353	95,922	**12,451,937**

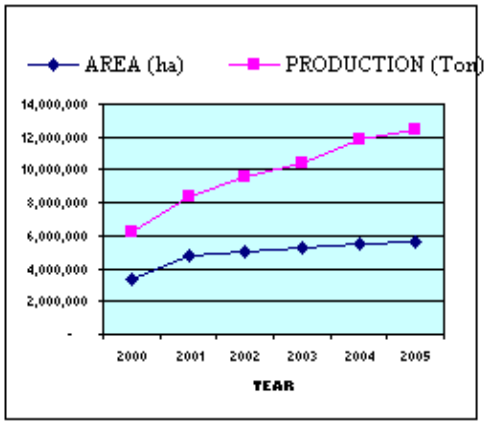

Figure 1. Palm oil area and production in Indonesia

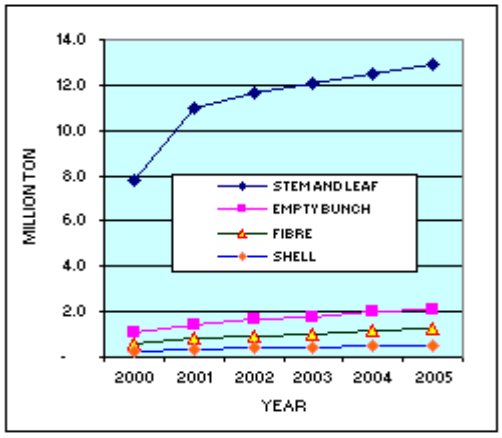

Figure 2. Palm oil waste production in

2. SOLID WASTE OF PALM OIL

Solid waste produced from palm oil plant consists of empty fruit bunch (EFB), endocarp, fiber, oil cake of palm nut and sludge. The composition of solid waste of palm oil plant is given in Table 1.[8)]

Table 2. Solid waste composition of palm oil plant.

Types of Waste	Percentage to Total Weight of Fresh Fruit (%)	
	Wet	Dry
EFB	21 – 23*	10 – 12
Fiber	8 – 12**	5 - 8
Endocarp	5 - 8	4
Sludge decanter	2	1

Note: EFB: Empty Fruit Bunch

- * At 60 – 65% water content
- ** At 40% water content

Source: Naibaho, 1998; Davendra, 1997; Schuchardt, 2001

2.1 Empty Bunch (EB)

Empty bunches (EB) is fruit bunch that is taken out from its fruit meat. Its form is oval consisting of spires with strong fiber in it. Its size is between 40 to 50 cm. The density before and after chopping is almost the same, that is 0.4 and 0.35 Ton per m^3, respectively. Calorific value of EB is relatively high that is about 3,700 kcal per kg. Fiber content of EB is between 62 – 72,6 per cent. EB contains cellulose and hemicellulose of about 35,81 and 27,01 kg per ton dry weight, respectively. Its chemical content is dominated by carbohydrate, glucan, xylan, K_2O and SiO_2.[2,5,9)]

2.2 Endocarp

Endocarp is also called shell. Endocarp is part of palm oil fruit that its structure is hard black color with diameter of 1 (one) centimeter. Endocarp has a function to cover the kernel. It is commonly utilized as a fuel for boiler in palm oil plant.[1,3,10)] .

2.3 Fiber

Fiber comes from mesocarp of palm fruit that has been hydraulically pressed in the screw press. Palm fiber is relatively short in size depending upon the size of mesocarp of the fruit that is pressed. Compare with calorific value of EB (3,700 kcal/kg), calorific value of the fiber is higher (4,586 kcal/kg) because of drier and higher efficiency. Chemical composition of the fiber is dominated by glucane (219 kg/ton), xylan (153 kg/ton), lignin (234 kg/ton), SiO_2 (632 kg/ton), K_2O (90 kg/ton), and CaO (72 kg/ton).[2)]

2.4 Oil Cake of Palm Nut

Oil Cake (OC) of palm nut is a solid waste due to separation of nut oil from kernel by hydraulic press. Oil cake is a solid waste that is rich with nutrients, such as protein. The content of protein, fat, extract material without nitrogen, and rough fiber are 15.59, 1.64, 48.26 and 1.64 per cent.[1)]

2.5 Sludge

Sludge comes from two sources: (1) oil clarification which usually uses decanter, and (2) from liquid waste treatment plant. Sludge from decanter is as oil residue mixing with other residues whereas sludge from liquid waste treatment plant is in the form of solid sediment mixed with micro-organisms living in it.

Dry weight of sludge from decanter is relatively high (175 kg/m^3) with ash content of about 240 kg/ton dry basis. Its chemical composition is dominated by N (27,03 kg/ton), P (2,54 kg/ton), K (15,5 kg/ton), Ca (14,20 kg/ton) and Mg (7,36 kg/ton) of dry basis.. The dry weight of sludge from liquid waste treatment plant is between *24,2 - 68 kg/m^3 with organic content of about 6,3 kg/m^3. The C/N ratio value is only 5.*[5)]

3. RESEARCH ON THE SOLID WASTE

Based on its physical characteristics and chemical composition, solid waste of palm oil plant has a potency to be treated to become useful products, such as energy, organic fertilizer, and fibrous products. Therefore, several researches and development of solid waste treatment both laboratory and pilot scales have been conducted by several research workers.

Schematic diagram of the palm oil plant processes is given in Figure 3.[3)]

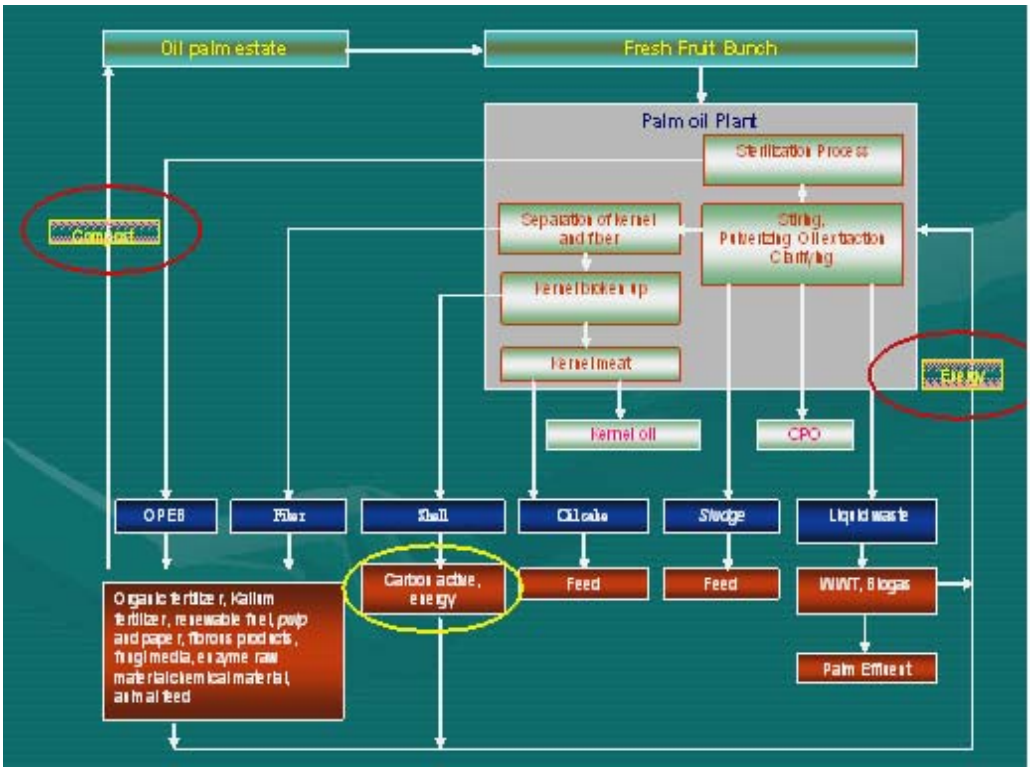

Figure 3. Schematic diagram of the palm oil plant processes

3.1 Empty Bunch Treatment

Empty bunch (EB) can be utilized as raw material for carbon active and energy source.

Carbon Active

Research on carbon active making from EB was done by Mulop, *et. al.*[11)]. The treatment was conducted in a fixed bed reactor (batch) at atmospheric pressure. It was a two stage reactor of the carbonization followed by activation stage with water vapor gasification. Optimal activation time was found to be 45 minutes and resulted specific surface area of 710 m^2/g and product efficiency of about 21 %. Specific surface area increased with water humidity (nisbah gram air) that was fed per gram of EB. Activated carbon from EB of palm oil resulted higher specific surface area than that from other materials.

Alternatif Energy

Palm oil plant is able to provide its own energy resources.[4)] Electrical energy utilized is supplied from turbine powered by high pressure steam of boiler with EB and fiber

wastes. Diesel generator set (genset) is usually operated first for starting up a plant operation before high pressure steam is generated by the boiler. Steam requirement is between 500 - 600 kg per ton of total fresh fruit. Electricity demand for this activity is between 17 – 21 kWh per ton of total fresh fruit. That energy can be supplied by boiler that generates steam at 20-21 kg/cm^2 pressure.

3.2 Research on Slude Treatment

Sludge as a byproduct of palm oil making process can be made to become animal feed and compost enrichment.

Animal Feed

Sludge from palm oil decanter can be converted to become animal feed such as poultry and ruminant. Palm oil sludge is usually wet material (high humidity) so that it needs to be dry up before it is made as animal feed. Dry sludge is then ground. The ground material is then mixed with bran until the proportion of one to one or two to one is met.

Beside using bran addition method, sludge can be utilized as a feed after it is fermented using fungi of *Aspergillus niger*. The fermented sludge is then directly or mixed first with bran as animal feed. Lubis *et.al.* found that fermented sludge contained about 30-40% of protein that is good for poultry, buffalo and cow feed.[1]

Compost Enrichment Material

Sludge contains high nutrient and humid or wet and therefore it is very good to be used for enriching compost especially compost made from oil palm empty bunch (EB). Its wet characteristic can keep the humidity of material to be composted so that the composting process will run optimally.[5)] Besides, its nutrient content will increase the produced compost quality.

3.3 Treatment on palm oil cake

Palm oil cake contains lower protein than that of other cakes. However, it is still enough to be used for protein source. It also contains high enough of calcium and phospor.[1)] Its use for cow and buffalo as mixing feed up to 30% is very good.

3.4 Treatment on Palm Fiber and Empty Bunch

Fiber has similar physical and chemical characteristic to EB so that their utilization is also similar. Research on treatment technologies associated with the fiber varies depending upon product types required. The utilization of the fiber is for example as organic fertilizer, kalium fertilizer, alternative fuel, pulp and paper, building materials, fungi media, enzime raw material, and chemicals.[3,5,8)]

Mulch

Experiment on application of EB as a mulch without choping has been done some workers.[5,12)] EB dose of 20, 40, dan 60 ton/ ha/year each with and without addition of urea fertilizer and rock phosphate respectively, has been applied as fertilizer for oil palm tree. Observation indicated that addition of urea to increase the rapidness of EB decomposition did not significantly increase the production of fresh fruit bunch (FFB). However, weight of the bunch and the fresh fruit production per tree increase sigificantly with treatment dose of 40 and 60 ton EB/ ha/year both without and with extra fertilizer whereas with a dose of 20 ton EB/ha/year increased the bunch weight and fesh fruit production significantly when extra fertilizer was given.

The highest average production was reached at 40 ton EB/ha/year tretament with extra fertilizer of about 60% of control dose, that was 174,8 kg FFB/tree/year or 34% higher that control product.

Composting

Currently many researches have been conducted by several workers to apply EB as compost raw material. Dr. Didi Hadjar Gunadi, Ir. Firman L Sahwan, M.Si, Sri Wahyono, M.Sc, dan Dr. F. Schuchardt are examples of some workers who conducted this experiment. The first experiment was to compost EB using *Caspary* system through *OrgaDec* bioreactor. Secondly, it was used *windrow* system without bioaktivator.[8,10)]

Basically, the process of composting EB is quiet similar to that of other organic solid material, such as animal dung and municipal solid waste (city waste). The little different is only at pre-composting treatment and duration time of composting process. Pretreatment required for EB is a choping process to reduce the size to about 5 cm.

In the windrow system, minced EB and oil palm mud is mixed, then layed out with the width of 2.5 meters and height of 1.5 meters, with length depending on the condition (Firman, L.S, 2000). In the compost process, layers of EB has a controlled temperature and aeration by reversal and spraying mechanism. Reversal is done at a minimum of once a week. Spraying 1 ton of EB can absorb about 3.2 – 5.4m3 of liquid waste.[5)]

Composting temperatures reach 75 ^{o}C in the third day. In the first three weeks, the temperature of composting reach 60 ^{o}C. The high temperature will also evaporate liquid waste of about 3.4 liquid waste/ton EB.[5)] After 6 to 7 weeks the temperature is gradually lowered. Soft and easily screened compost takes about 10 to 12 weeks to achieve. The composition of empty bunch is shown in Tabel 2.

EB compost consist of organic materials, high in nitrogen and calium, and low in phosporus. The high level of Nitrogen and Calium is caused by the addition of liquid waste during compost processing.

Table 2. Empty bunch composition

Parameter	Value
Dry weight or DW (kg/ton)	8,36
Organic material (kg/ton DW)	673
C (kg/ton DW)	351
C/N	15
N_H (kg/ton DW)	23,4
P (kg/ton DW)	3,1
K (kg/ton DW)	55,3
Ca (kg/ton DW)	14,6
Mg (kg/ton DW)	9,6
pH	7,5
Density (ton/m^3)	0,45
Cr (mg/kg)	29,7
Ni (mg/kg)	19,1
Cu (mg/kg)	38,0
Zn (mg/kg)	154,0
As (mg/kg)	2,5
Cd (mg/kg)	< 0,3
Hg (mg/kg)	< 0,5
Pb (mg/kg)	69,6

Source: Schuchardt, F., et al. 2001.[5)]

Calium Compost

EB combustion inside an incinerator produce ashes with Calium (C_20) composition of 30%. The ash produced is 0.5% of the EB.[12)] Bunch of ashes is alcalic and can be reduced by adding phosphate acid..

Alternative Energy

Technological innovation research on the use of serabut and EB as an alternative energy has been conducted in both the laboratorium and pilot scale. Research on the use of serabut and EB as a source of energy is done by normal combustion, gasification, and coal brickets.

In operating serabut oil palm factories (including the shell) is publicly used for boiler fuel. Combustion process is done normally with enough oxygen.

Hot steam from the boiler is used as mechanical and heat energy. As a mechanical energy, hot steam is used to run a generator which in turn produces electricity that are used for cyclone, pressing, sludge separator, nut polishing,

etc. Meanwhile, the heat is used for other processes such as sterilizing, digester, etc.

ITB researchers Susanto, H. And Budhy, Y.W.[4] has done a laboratorium and piloting scale gasification research. The results of the laboratorium research shows that EB gasification can produce gas producer with 15-18% of carbon and 14-17% of hydrogen gas, with combustion heat between 3500 – 4500 kJ/Nm3 and fire temperature of the gas reaching 1200 ^{o}C.

In the pilot scale research of gasification with capacity of 100 kg/hour, shows that gas producer combustion is relatively unstable and fluctuates at a temperature of 800 – 900 ^{o}C. The instability is caused by the inconsistency of EB particle flow in the gasifier which must be aided with shaking. Even with those obstacles, EP gasification still has high chance of being used as boiler fuel.[4]

Briquet

As a lignocellulocit, EB can be easily turned into briquet. But because of its low density, EB needs to be processed again to become good briquet with high density, similar shape, and easily used as fuel.[12]

Pulp and Paper

Pulp and paper from EB has been done by many parties including the Oil Palm Research Center, Medan. They have researched in pilot scale on making pulp, printing paper, kraft paper, and map paper.

The following is quoted research conducted by Guritno, P. et.al.[13]) about making whitened pulp and printing paper, as well as un-whitened semi-chemical pulp and map paper from EB. Before used as pulp raw material, EB is chopped into 3-5 cm size an then hydraulically pressed to have oil, water and other liquid wastes that could be released. This chopped and hydraulically pressed EB is then cooked in the digester using addition of antracinone soda and surfactant. After cooking the chopped EB is washed with the hot water to loosen its fibers. The fiber is then screened using centrifugal screener with 2 mm screen diameter. The screened pulp is then coagulated using cylindrical thickener equipped with vacuum pump, and then diluted and cleaned with a two stage centrifugal cleaner. After that, it is rolled followed by hydraulic pressing until its water content reduces to 70 %.

Average value of physical properties of EB pulp is as follows. The torn, crack and drag indexes are 6.30 Nm^2/kg, 3,39 MN/kg and 26,76 Nm/kg, respectively. These phisical properties will increase when the paper is whitened. Those are 7,09 Nm^2/kg, 4,54 MN/kg and 38,60 Nm/kg for the respective torn, crack and drag indexes. The degree of whiteness is about 75.5 % in average.

EB pulp is then made to become EB paper. The resulted printing paper has a weight of 83.5 grams per m^2 and a thickness of 0.1315 mm. Torn, crack, drag indexes and cutted length are 8,80 Nm^2/kg, 2,87 MN/kg, 35,136 Nm/kg and 3582 m, respectively. The printed whiteness degree is about 76.5% with opacity of about 91.08%. That printing paper is classified into printing paper class A according to Indonesian National Standard.

Fibrous Product

As a source of fiber, EB has been assessed its utilization as a biodegradable palstic materials, particle board, etc.[10] The research reported that macroscopically EB fiber has similar length (10.5 – 16.3 cm) to that of coconut shell 911.4-16.4 cm). The fiber content of EB is also very high (67.88%).

It was also reported that oil and water content of EB fiber is still high enough. The content of oil and other liquid wastes from loosening process of EB fiber reached 8.24%. The oil content in EB will influence in rubber fiber making-process so that EB fiber needs to be first hydraulically pressed in order to reduce it.

Oil palm fiber can also be used for plant pot (polipot) to replace plastic polybag. Based on research done by Oil Palm Research Center of Medan, North Sumatera,

EB can also be used as a material for making bio-degradable plastic. Those made from degradable plastic were plate (dish) and plastic pipe with drag force of 2.30 kfg/mm2.

Fungi Media

Basically EB is a substrate that similar to rice straw, wood waste and other biomass wastes and therefore it is essential material to be used as a media for fungi to grow. Bioconversion of lignocelluse containing solid waste such as EB can be a good prospect as a food fungi.[10)]

Enzyme Raw Material

Fiber and EB can be used as a media to grow microbes that produces enzyme. The microbe might be in a class of thermophilic bacteria of *Trichoderma reesai*.

Fiber and EB can be converted biologically to chemical materials that is useful products for human, such as xylitol, glutamate acid, and single cell protein. Study on that bioconversion has been conducted by several workers from Division of Food Technology, Malaysia Sains University. The information of the processes of making xylitol, glutamate acid, and single cell protein was reported by Sa'id, E. G. [12)]

Ruminant Animal Feed

Fiber and EB can be made to become animal feed through amoniase and wastelage fermentation processes. The research in making animal feed from the fiber was done by Lubis, A. D. et. al.[1]

The aerobically making process of animal feed through amoniase was done in the closed hole under the ground. The good product of amoniase process is indicated by the soft texture, the same color as original material, ammonia containing odor, pH of 7.5 – 8, decrease in rough fiber and increase in protein content.

4. SOME CONSTRAINTS

Several researches, assessment and development of oil palm solid waste treatment technologies have been carried out by some workers However, their application so far has not been done commercially by industries. The constraints in the implementation of these technologies might be explained as follows.

- There has been no a full scale treatment of oil palm solid waste implemented in Indonesia. The current application is only limited in the combustion of the solid biomass in the small kiln and disposal to estate land for mulching purpose or just disposal for the sake of cleaning the waste from plant area. The pilot scale experimental results have not yet convinced palm oil industry society to carry out a full scale treatment of their waste.
- Other treatments than combustion (burning) in the kiln and disposal into the land of the waste require high investment, operational and maintenance costs. Due to the huge waste produced the cost of palm oil waste treatment will be high.
- Waste treatment in full scale particularly using technology that does not directly relate to the palm oil cycle processes is assumed to be beyond the authority of the palm oil plant. If it is done under the same management as that of palm oil plant it is estimated to lessen the focus of CPO production activity.

5. SUMMARY

5.1. One technology of oil palm waste treatment that has high degree of prospective is composting. The benefit of EB composting is as follows.

- Composting process is environmentally friendly treatment because the process does not produce the waste that is discharged into water, soil, and air.
- EB can be biologically converted to become organic fertilizer that can then be utilized for land or soil conditioning of oil palm tree so that organic material cycle can occur.

- Compost of EB contains high organic material, nitrogen and kalium, and low phosphorus.
- EB compost application for oil palm estate could reduce the use of chemical fertilizer by 40%.
- Liquid waste produced from palm oil plant is reduced significantly because it could be used in EB composting process.

5.2. Cost calculation of EB composting activity was done that is around US$ 0.55 cent per kg EB. Even though the cost of EB burning and disposal are cheaper, only cost respectively around US$0.11 cent and US$ 0.12 cent per kg EB, compost can be sold with a market price of around US$ 3.3 cent per kg compost. Therefore, economically composting is still very prospective treatment for EB. Large scale composting plant is currently applied in palm oil plant of Aek Pancur, Medan, North Sumatera.

5.3. In addition to the compost, other useful products made from palm oil waste are activated carbon from the shell and briquette fuel from the shell or electricity from directly using empty bunch, shell, stem in combustion or gasification processes.

5.4. Liquid waste is also very useful for biogas and its byproduct of the solid one is a good fertilizer that could be utilized in the plantation area.

5.5. Finally, stem and leaf is produced in high quantity as byproducts and therefore they are also very prospective to be converted into useful products as well. They could be used as fuel for gasification or combustion, as furniture or children toys, pulp and paper.

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