Leaching of Potassium from Oil Palm Empty Fruit Bunch (OPEFB) Using Tapioca Wastewater

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ABSTRACT
Empty fruit bunch (EFB) of palm oil is an abundant by-product that is resulted from the crude palm oil (CPO) extraction process and has great potential for bioenergy application. However, EFB has a high content of mineral such potassium (K) and silica (Si) that result in a negative impact on boiler like ash deposit, corrosive, slagging and fouling during combustion. One of the wise solutions to improve fuel quality of EFB is leaching treatment using tapioca wastewater to reduce its mineral content. It is expected that in addition to fuel quality improvement of EFB, the wastewater is also improved in terms of fertilizer that increase its quality as irrigation water. This study aims to obtain the best combination of soaking time and types of tapioca wastewater in reducing the mineral content of EFB. Wastewater from tapioca mill and effluent from biogas digester were used to wash EFB at a ratio of 1: 40 (w/v). EFB analysis was performed at different soaking durations, namely 0 (control), 5 min, 30 min, 60 min, 90 min, 120 min, 12 hours, and 24 hours. Results showed that wastewater from tapioca mill was more effective to wash metal content in the EFB as compared to biogas digester effluent. Using tapioca wastewater, potassium (K) rapidly decreased from 67.04% to 20.72% in 30 min. Result also indicated that soaking EFB in tapioca wastewater is effective to reduce ash content from 5.97% to 1.13% in 30 min.

Keywords: *Oil Palm Empty Fruit Bunch, Tapioca Waste Water, Leaching, Potassium*

1. INTRODUCTION

Empty fruit bunch (EFB) of palm oil is an abundant byproduct generated from the crude palm oil (CPO) extraction process.It has great potential for bioenergy application. The average capacity of palm oil mill is 60 tons of fresh fruit bunch (FFB) per hour and produces 12,6 tons of empty fruit bunch (EFB) which is equivalent to 21% of processed FFB [1]. The utilization of EFB, however, is far below its potential. Approximately 95.47 Mt/year of EFB produced are not utilized properly and stacked on landfill which causing foul odor that forms 7.35 kt/year methane gas (CH4) [2]. Hence, EFB must be managed properly to take advantage of its potential and to reduce emissions. One of the wise solutionfor EFB is processing it into biopellet as bioenergy product to replace coal and fossil fuels. Several factors must be considered in processing EFB into biopellet, because EFB contain high mineral such as potassium (K) and silica (Si) that have a negative impact on the boiler during combustion. Chloride (Cl) and potassium harm boiler in way such as ash deposit, corrosive, slagging and fouling during combustion process. Generally, most of the biomass contain high amount of potassium (K) and potassium content in EFB is the highestas compared to that of other plant materials [3,4]. Besides, the high ash content of EFB has also an effect on the boiler during processing which lower heat energy produced [5]. One of the solutions to improve the fuel quality of EFB is applying leaching treatment to reduce potassium content.

Characteristic of potassium element is highly soluble in water, therefore the leaching treatment by water is the best way to reduce potassium content of EFB up to 90% and increase pyrolysis oil yield from 40% to 60% [6]. Leaching treatment using tap water is very effective in reducing the ash content of EFB around 24.9% to 70.3%and reducing potassium by 71% andsodium by

96%[7]. Combination process hydrothermal in 180 °C and leaching treatment with 1:10 ratio (biomass/water) can effectively reduce ash content up to 82%, 71.6% chlorine and 82% potassium content [8]. According to previous studies, there are various methods to reduce the mineral content of EFB, such as a combination between pyrolysis process and hydrothermal with washing water in significant temperature, leaching treatment using tap water and distilled water. In this study tapioca wastewater effluent mill and tapioca wastewater effluent biogas were used as solvents for the leaching method of the mineral content of EFB, as an economical and environmentally friendly alternative.

Approximately 2400 million m3tapioca wastewater is produced annually in Indonesia from processing cassava into tapioca flour. Generally, tapioca wastewater has not been utilized optimally and disposed directly into the river without any treatments. The discharged tapioca wastewater has a negative impact on the river and the community around the factory. In addition, nutrient content in tapioca wastewater can be used as organic fertilizer and biogas, it is because tapioca wastewater rich with nutrient content called, N 260.27 mg/l, P 88.56 mg/l, K 508,17 mg/l and pH 4.81 [9]. Tapioca wastewater also has additive like HCN (hydrogen cyanide), that have the ability to neutralize and prevent all the problem related to ash content during biomass combustion [10]. Tapioca wastewater effluent mill contains high organic acid that can bind the K element of EFB into the waterbecause the chelating ability is greater than acid compatibility [11]. Using tapioca wastewater as a solvent to remove the mineral content in EFB is a solution to prevent pollution to the environment and maximize the potential of tapioca wastewater. Therefore, the purpose of this study is to achieve the best combination of type of tapioca wastewater and soaking time in reducing potassium content in EFB optimally.

2. MATERIAL AND METHOD

2.1. Place and Time

Research activities and analysis were conducted in March toMay 2019 at the Agro-industrialWaste Management Lab, Agro-Industrial Technology Department, Agriculture Faculty, theUniversity of Lampung.Mineral composition of ash was analyzed using XRF (X-ray Fluorescence)atthe Chemistry Laboratory, State University of Padang.

2.2. Materials

The EFB using in this experiment was taken from the palm oil mill PTPN VII,Bekri, Central Lampung, Lampung Province.The EFB was analyzed for mineral content, ash content, and water content.Tapioca wastewater and digester effluent were taken from a small-scale tapioca mill in NegeriKaton, Regency of Pesawaran, Lampung province.

2.3. Methodology

This experiment was carried out in a dose of 1: 40 (biomass/water) using 5 g of EFB and 200 ml of wastewater with repetitions 3 times for each treatment. Two factors are investigated in this experiment. The first factor is soaking time: 0 (control), 5, 30, 60, 90, 120, 720, and 1440 minutes. Second factor is the type of wastewater, namely wastewater from tapioca mill (LCTS) and effluent from biogas digester (LCTB). After soaking, the EFB sample was drained and then dried in the oven for 24 hours, then burnt in the furnace for 2 hours in 6000C. Then resulted ash analyzed using X-RF (X-ray Fluorescence) to reveal the mineral content of EFB. The tapioca wastewater from soaking treatments was analyzed to determine pH value and K element content.

3. RESULT AND DISCUSSION

3.1. Material and Characteristic

The initial analysis in EFB and tapioca wastewater before treatment areshown in Table 1. Table 1 showed that potassium (K) content in EFB approximately 67,04 % which is the highest number than other elements like Si 8,87 %, Mg 3,01 %, Cl 8,53 %, Ca 6,63 % and P 2,01%, with water content 8.2% and ash content 5.97%.

Table 1. Characteristic of EFB and wastewater used in the experiment

Characteristic	EFB	Digester effluent	Mill effluent
pH	-	7.92	4.72
K	67,04%	218 mg/L	221.87 mg/L
Si	8,87%	-	-
Mg	3,01%	-	0.82** mg/L
Cl	8,53%	-	-
Ca	6,63%	-	1.48** mg/L
P	2,01%	226* mg/L	120* mg/L
Water content (% wb)	8.2		
Ash content (% TS)	5.97		
BOD		119*	633*

COD		1070*	4270*
TS		3230*	4850*

Note: *[12], **[13]

Furthermore, Table 2show that the pH value and mineral content of two types of tapioca wastewater are different. The pH value of tapioca wastewater effluent mill is 4.72 and 7.92 for effluent biogas. However, the potassium (K) content in two types of tapioca wastewater is not much different, namely 221.87 mg/l for tapioca wastewater effluent mill and 218 mg/l tapioca wastewater effluent biogas.

3.2. The pH Value

The pH value of tapioca wastewater after leaching treatment is shown in Fig. 1. Figure 1 shows that the tendency of two types of wastewater is not greatly different for each soaking treatment, that is 0 (control), 5, 30, 60, 90, 120, 720, and 1440 minutes. After 5 minutes of soaking the pH value of tapioca wastewater effluent biogas has no significant difference from the pH control of 7.95 to 8.49. The pH value for all soaking treatments in tapioca wastewater effluent biogas (LCTB) was 8.36 for 60 minutes soaked, 8.47 for 90 minutes soaking, 8.23 for 120 minutes, 7.83 for 12 hours and 7.98 for 24 hours. This mean pH value of tapioca wastewater effluent biogas is not significantly different after soaking treatment.

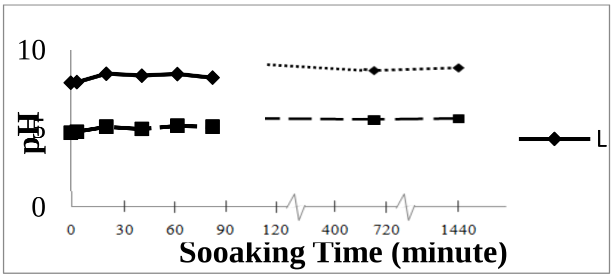

Figure 1 The pH value of tapioca wastewater after soaking treatment

Similarly, the pH value of tapioca wastewater effluent mill (LCTS) for all soaking treatments also the same as the pH value of wastewater effluent biogas that is not significantly different. The pH value of tapioca wastewater mill effluent after 5 minutes soaking is still same as pH control that is 4.72 to 4.79.Moreover pH value for 30 minutes soaking is 5.11, 60 minutes soaking 4.97, 90 minutes soaking 5.17, 120 minutes soaking 5.11, 12 hours soaking 5.05 and 24 hours soaking 5.12. Based on Fig. 1, all the solvent from washed and unwashed material have frequency of pH values not far between 7 and 8 for tapioca wastewater effluent biogas (LCTB) and between 4 to 5 for tapioca wastewater effluent mill (LCTS). It was reported that treatment of washing EFB raw materials with water does not increase the pH value of the solvent [3].

3.3. Ash Content of EFB After Leaching Treatment

Ash content of EFB before and after leaching treatment is shown in Fig.2. Ash content decreased drastically about 70% after soaked for 5 minutes in tapioca wastewater effluent mill, from 5.97% to 1.80%, while soaked for 5 minutes in tapioca wastewater effluent biogas decreased around 61% from 5.97% to 2.3%.

Based on Fig.2, approximately 81% of the ash content of EFB after soaked in tapioca wastewater (LCTS) for 30 minutes is 1.13%, which is the lowest ash content of all of the soaking treatments. After soaking for 60 minutes till 1440 minutes (24 hours) the ash content increased for two types of tapioca wastewater with the value range are not much different.

However, the tendency of graphics in Fig.2.for two types of tapioca wastewater is the same but the ash content of tapioca wastewater effluent biogas is higher than ash content of tapioca wastewater effluent mill. 30 minutes soaking in tapioca wastewater effluent mill is efficient to reduce ash content in EFB, same as previous study [7] said that leaching treatment using tap water is efficient to reduce ash content in EFB from 24.9% to 70.3%. The main reason of reducing ash content is because the negative effect to boiler such as ash deposit on the surface of the heat transfer equipment, slagging in the furnace or other surfaces effected by heat radiation and corrosion which put damage to the intrinsic nature of a material due to the reaction [14]. Reducing ash content in EFB after leaching treatment will affect mineral content too such as potassium (K).

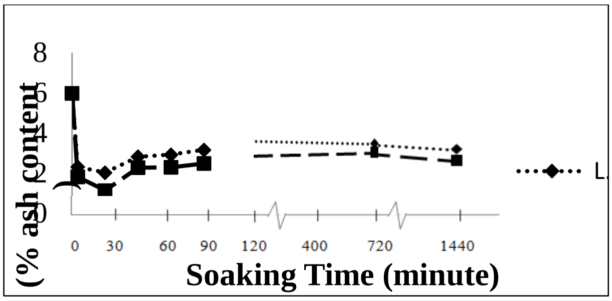

Figure 2 Ash content of EFB after soaking in tapioca wastewater

3.4. Potassium (K) content in EFB

Potassium (K) is an important element for plant growth, therefore in solid biomass fuels, potassium content can be higher than fossil fuels, but the high content of element K can vary for each type of biomass [15].Leaching treatment using tapioca wastewater affects the mineral content of EFB especially potassium (K). Potassium is the main elements basically can be mutually reactive and affected some bad things in the boiler during combustion under low temperature also produce low heat energy for biopellet product. The result of leaching treatment to potassium in EFB after leaching treatment shown in Fig. 3.

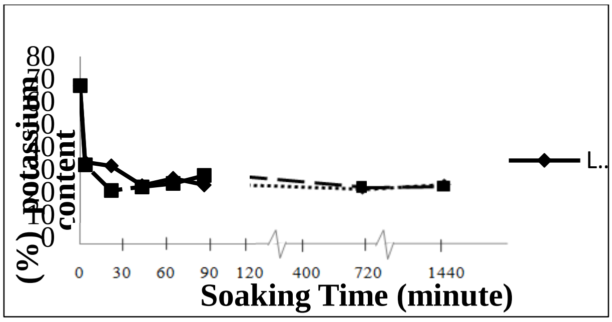

Figure 3 Potassium (K) content in EFB after leaching treatment (relative value)

Figure 3 shows the potassium content of EFB has decreased around 69% from 67,04% to 20,72% after leaching treatment using tapioca wastewater effluent mill in 30 minutes soaked,Meanwhile, potassium levels in EFB after washing using tapioca effluent biogas (LCTB) wastewater in the same soaking time are still high namely 31,63%. Based on Fig. 3.shows that the value of element K after leaching treatment from leaching treatment with 2 types of tapioca wastewater is not much different, especially at the time of soaking 60 minutes to 1440 minutes (24 hours). The value of K content of EFB substances after soaked in 2 types of tapioca wastewater for 60 minutes and 90 minutes is on the trend and the range of values is not much different, namely 22.92% and 26.13%, while the value of K content immersed in tapioca effluent wastewater treatment plants with the same immersion time is 22.39%, and 23.82%. Soaked for 60 minutes is the maximum time or saturation point for washing element K at OPEFB so that the K element value with immersion at 90 minutes to 24 hours (1440 minutes) is unstable (up and down) and tends to be the same.

From the Fig. 3 it can be confirmed that leaching treatment by soaking EFB in tapioca wastewater effluent mill (LCTS) for 30 minutes is quite effective and fast in reducing element K to 69% from 67.04% to 20.72%. Potassium is the highest ash constituent in EFB, to know in more detail the effectiveness of the leaching process in this study, the calculation of the balance of potassium content in EFB as a whole absolute values are presented in Figure 4. this absolute value graph aims to see the value of the remaining potassium content in the EFB sample as a whole from the washing treatment process using 2 types of tapioca wastewater.

Based on Fig.3. That leaching treatment with EFB soaked in tapioca wastewater for 30 minutes is effective and the fastest way in reducing K element content around 69% from 67,04% to 20,72%. Soaking time for 30 minutes is effective to decrease elemental alkali content in ash, around 90% potassium element washed after soaked in tap water for 30 minutes [7]. The K element dissolved in tapioca wastewater after leaching treatment is shown in Fig.13. to reveal the balancing of K content in EFB and wastewater. The initial K element content of tapioca wastewater before soaking treatment is 218 mg/l for tapioca wastewater effluent biogas and 221,87 mg/l for tapioca wastewater effluent mill. After soaking treatment with EFB the K element content increase dramatically more than 50%, after soaked for 5 minutes the K content is increased from 218 mg/l to 629,06 mg/l for tapioca wastewater effluent biogas and 221,87 mg/l to 686,41 mg/l for tapioca wastewater effluent mill. The optimum soaking time to dissolve the K element of EFB is 60 minutes, it is because the K element content in cassava wastewater after soaking for 60 minutes is the highest than K element content for other soaking time treatments.

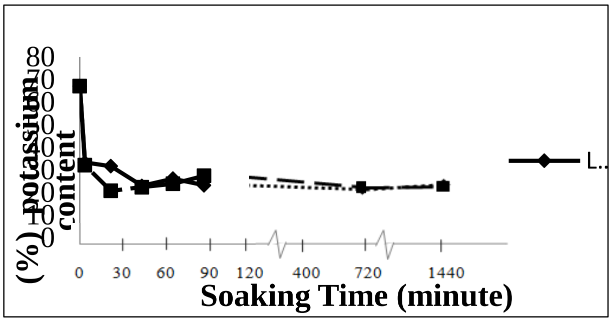

Figure 4 Absolute value of potassium in EFB after leaching treatment

The absolute value of potassium in Figure 4.shows that after soaking EFB in both tapioca wastewater has decreased in all soaking treatment times, especially in tapioca wastewater effluent mill (LCTS) with a faster rate of decline than soaking in tapioca wastewater effluent biogas (LCTB). The immersion time of 30 minutes in tapioca effluent mill (LCTS) is quite optimal in reducing the content of potassium in EFB around 56%. This proves that the graphic elements K in Figure 3. and Figure 4 showed the same thing namely soaking treatment for 30 minutes in tapioca wastewater effluent mill is the optimum immersion time in reducing the value of the element K content from the initial condition ie 0,6 g down to 0,09 g. While the value of K content in EFB as a whole from the results of soaking in tapioca wastewater effluent biogas is higher than the soaking results in tapioca wastewater effluent mill, so the use of tapioca wastewater effluent mill for leaching treatment is more effective and faster.

The balance analysis of the results of the leaching treatment process is not only in biomass samples but also an analysis of the tapioca wastewater soaking results, this analysis to obtain how much K element dissolved into the wastewater.The mass equilibrium analysis is performed to find out the outcome measured has the same amount as the initial input. The results of the analysis of dissolved K elements from EFB and contained in both tapioca wastewater (effluent biogas and effluent mill) are presented in Figure 5.

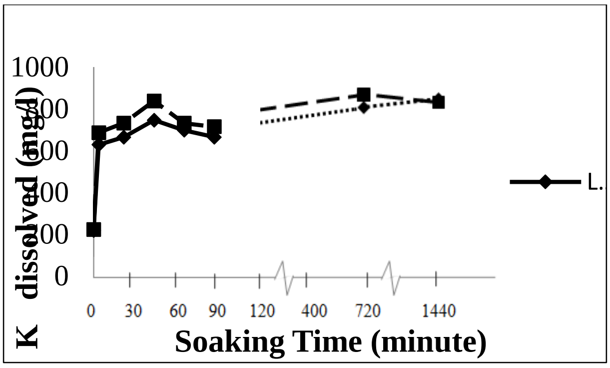

Figure 5 Dissolved K in wastewater as a function of soaking time

Before being given tapioca wastewater treatment already has the element K content of 218 mg/l in tapioca wastewater effluent biogas and 221, 87 mg/l in tapioca wastewater effluent mills, then rises dramatically after soaking treatment with EFB. After EFB soaked for 5 minutes the value of potassium content doubled from the initial value of 218 mg/l to 629.06 mg/l in tapioca effluent biogas and from 221,87 mg/l to 686,41 mg/l on tapioca effluent wastewater mill.Then the value of the element K content rises gradually until immersion for 60 minutes and decreases fluctuatively until 24 hours immersion. The highest dissolved K content value in both types of wastewater was in the soaking treatment for 60 minutes, namely 746,2 mg/l in tapioca wastewater effluent biogas and 838,27 mg/l tapioca wastewater effluent mill. This proves that the optimum washing activity (leaching) of element K is at the time of immersion 60 minutes so that immersion with a long time is not effective to dissolve element K from EFB into wastewater. Based on Figure 3, Figure 4. and Figure 5. From the results of the treatment in this study, it can be stated that the use of tapioca liquid waste is quite effective in reducing the K element in EFB.

Based on Fig. 5. The graphic trend in two types of wastewater is the same but the value of K element content in tapioca wastewater effluent mill higher than cassava wastewater effluent biogas. It is because acid content in tapioca wastewater effluent mill has chelate ability stronger than the effect of acidity [11]. The previous study [16]said that using dilute acid for the first step effectively reduce hemicellulose content around 90% and 32% lignin, furthermore in the second step NaOH (sodium hydroxide) was then applied, which extracted lignin effectively with a 70% delignification yield, partially disrupting the ordered fibrils of the EFB and thus enhancing the enzyme digestibility of the cellulose.On the other hand, potassium is very easily reactive with other elements forming a bond and dissolve into the water or acid solution, hence leaching treatment by tapioca wastewater is effective to remove it. The efficiency factors to decrease of K and Cl content in ash treatment there are 3 main factors: a) ash concentration in slurry (ash: water ratio), b) solubility for each element in the slurry, c) the degree of solid-liquid separation of the slurry [5].

The result analysis of FTIR in tapioca extracted and ionic tapioca there are 3 groups, Hydoxile (-OH), carboxyl (-COOH) and Amida (-CONH2), thus make tapioca wastewater have positive and negative charged (amphoteric) biocoagulants[17]. But need other factors to improve the solubility efficiency of mineral content in EFB into the water especially Ca, Mg and Si elements, such as temperature treatments, shaking treatments, ratio (biomass:water), and addition more additive (acid or base solvent) to improve solubility of alkali and alkali elements. Furthermore, Based on Fig. 5. the content of K in tapioca wastewater after leaching treatment can be used as liquid organic fertilizer to improve nutrients in soils and plants[12]. Soils that are watered by tapioca wastewater increasing EC, accumulation of organic matter, and N- total element content and P availability higher than soils that are not watered by tapioca wastewater. The result of this this study, it is assumed that nothing is wasted into the environment from the leaching treatments because all samples both EFB and tapioca wastewater have good nutrition content and do not have a negative effect on the environment. So this research can be stated based on sustainable, zero waste and zero emissions

4. CONCLUSIONS AND RECOMMENDATION

The leaching treatment with soaking EFB in cassava wastewater effluent mill (LCTS) for 30 minutes is effective and fast to reduce around 81% ash content, 69% K element, consist of 1.1.3% ash content and 20.72% K element content. However, the soaking treatments using two types of tapioca wastewater is not significant on pH values in both types of wastewater.

For further study to improve efficiency solubility of leaching treatment alkali and earth elements in EFB using cassava wastewater it needs several additional factors such as high-temperature usage, ratio treatment (w/v), acid and base treatment (pH value of solvent), and soaking time treatment.

ACKNOWLEDGMENT

This research was supported financially by BadanPengelola Dana Perkebunan Kelapa Sawit (BPDPKS) with contract number : PRJ-85/DPKS/2018

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