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To cite this article: Arfiana *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **749** 012038

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IOP Conf. Series: Earth and Environmental Science **749** (2021) 012038 doi:10.1088/1755-1315/749/1/012038

# Oil palm empty fruit bunch ash as a potassium source in the synthesis of NPK fertilizer

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**Abstract.** Some studies showed that ash from Oil Palm Empty Fruit Bunch has relatively high potassium and other minerals and is commonly used directly for soil improver. In this work, we studied the production and characterization of ash from gasification of oil palm empty fruit bunch to produce NPK fertilizer. Oil Palm EFB ash produced from various gasification temperature were characterized by using Atomic Absorption Spectrometry (AAS) to identify its composition. The fertilizer formula was developed by using EFB ash for potassium source, while nitrogen and phosphates are each obtained from Urea and Diammonium Phosphate (DAP). NPK fertilizer production was conducted through some processes, including formulation, mixing, granulation, and drying. The characterization of fertilizer and EFB ash was done using Scanning Microscope Electron/Energy Dispersive X-Ray Spectroscopy (SEM-EDX) and X-Ray Diffraction (XRD). The fertilizer was also tested to the red onion plant compared to commercial NPK fertilizer through small scale field tests using polybags.

## 1. Introduction

Indonesia has many palm oil mills where biomass waste is still not fully utilized. Empty fruit bunch (EFB), fibers, and shell of oil palm are the primary solid waste which each ton of fresh fruit bunch can produce 14% fibers, 7% shells, and 23% EFBs [1]. Indonesian Palm Oil Mill industries produce about 13 million dried EFB per year [2]; this amount can provide the possibility for further utilization of EFB. Moreover, without proper handling, large quantities of EFB can cause some trouble in palm oil mills since the burning method can cause air pollution. Some studies show that EFB has a relatively high content of potassium. Based on the proximate analysis, EFB ash composition contains 55.48% potassium oxide ($K_2O$) [3–4]. The high composition of potassium in EFB ash can be utilized to synthesize NPK fertilizer since potassium is one of the main components in NPK fertilizer, which is also a macronutrient needed by red onion plants. Red onion requires an intensive supply of nitrogen (N), phosphorus (P), and potassium (K) to attain maximum yield of bulbs because the plants have shallow, sparsely branched root system [5].

Red onion (*Allium cepa L.*) is one of Indonesia's important horticultural commodities, where its needs continue to increase [6]. One of the problems in the cultivation of red onion is low productivity so that it is necessary to develop the proper fertilization. Moreover, the consumption of NPK fertilizer in Indonesia tends to increase from year to year. Utilization of EFB ash for fertilizer raw material can

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be a solution to overcome the problem of EFB solid waste in a palm oil mill and an alternative source of raw materials in the synthesis of NPK fertilizer.

In this research, EFB ash is used as the potassium source in the synthesis of NPK fertilizer. The EFB ash is combined and mixed with other raw materials to fulfill the NPK fertilizer formula, suitable for the red onion plant. The fertilizer formula is also enhanced with the addition of micronutrients to support plant growth.

## 2. Experimental

### *2.1. Materials*

The NPK fertilizer was made by using some materials including Urea fertilizer to provide the nitrogen need, Diammonium Phosphate (DAP) for supplying the phosphate requirement, EFB ash as potassium source, Potassium Chloride (KCl) as supporting source of potassium need, zeolite as a matrix, micronutrient Mg from Magnesium Sulphate fertilizer and S from ZA fertilizer, and also molasses as the binding agent.

### *2.2. Methods*

Ideally, the EFB ash was produced as waste from the gasification process of EFB. Since the existing gasification plant facility at our laboratory has a large capacity, the gasification is carried out using small scale gasifiers for this research. The composition of ash and clay and the gasifier temperature were varied, as shown in Table 1.

**Table 1.** Parameter of gasification for ash – clay mixture.

| Ash (%w) | Clay (%w) | Temperature (ºC) |
|---|---|---|
| 5 | 95 | 500 |
| 10 | 90 | 500 |
| 15 | 85 | 500 |
| 5 | 95 | 600 |
| 10 | 90 | 600 |
| 15 | 85 | 600 |
| 5 | 95 | 700 |
| 10 | 90 | 700 |
| 15 | 85 | 700 |

To study the effect of gasification on the potassium content of EFB ash, EFB ash and clay was then undergo the gasification process at the temperature of 500, 600, dan 700 ºC with the variation of ash and clay content as shown in Table 1. The clay used was crushed and screened to obtain the particle size of 60 mesh.

The gasification process was conducted using the small-scale gasifier at the Laboratory of Center for Technology Energy Resources and Chemical Industry (PTSEIK), BPPT, South Tangerang, Indonesia. The gasifier is equipped with a gas compressor, thermocouple, temperature control panel, and flow meter as showed in Figure 1.

IOP Conf. Series: Earth and Environmental Science **749** (2021) 012038 doi:10.1088/1755-1315/749/1/012038

**Figure 1**. Gasification equipment

After gasification, the mixture of ash and clay was characterized to obtain the composition of $K_2O$. The sample with the highest potassium content then used as a basis for developing a formula and calculating the need for raw materials for the synthesis of NPK fertilizer refers to procedures done by [7]. After that, the fertilizer product was tested to study its properties.

### *2.3. Characterization*

Some characterizations performed in this research including analysis of potassium ($K_2O$) content by using Atomic Absorption Spectrometry (AAS), morphology, surface structure, and element distribution through Scanning Microscope Electron/Energy Dispersive X-Ray Spectroscopy (SEM-EDX) analysis and X-Ray Diffraction (XRD) to observe the material structure. Moreover, the fertilizer performance test was also conducted to find out the effect of this fertilizer on plant growth through a field test of red onion.

## 3. Results and Discussion

### *3.1. Gasification of EFB Ash*

EFB ash in this research is used as the potassium source in the synthesis of NPK fertilizer. For producing the EFB ash, the experiment was carried out using a furnace with a temperature of 500$^o$C for 1 hour in normal condition (without inert gas) (Figure 2).

(a) (b)

**Figure 2**. EFB before (a) and after (b) furnacing process.

The ash–clay mixture samples were then characterized using Atomic Absorption Spectrometry (AAS) analysis to obtain the potassium ($K_2O$) content. This analysis is important since the formulation and calculation of raw material needed are made based on each raw material's component content. The results of the AAS test are presented in Table 2 and Figure 3.

**Table 2.** $K_2O$ content of ash – clay mixture.

| Ash (%w) | Clay (%w) | Temperature (ºC) | $K_2O$ (%) |
|---|---|---|---|
| 5 | 95 | 500 | 2.10 |
| 10 | 90 | 500 | 7.30 |
| 15 | 85 | 500 | 7.67 |
| 5 | 95 | 600 | 5.22 |
| 10 | 90 | 600 | 6.54 |
| 15 | 85 | 600 | 9.90 |
| 5 | 95 | 700 | 6.42 |
| 10 | 90 | 700 | 9.88 |
| 15 | 85 | 700 | 9.98 |
| 100 | | | 32.96 |
| Clay | | | 4.04 |

The highest potassium content was obtained for the 15% ash – 85% clay mixture with 700 ºC gasification temperature.

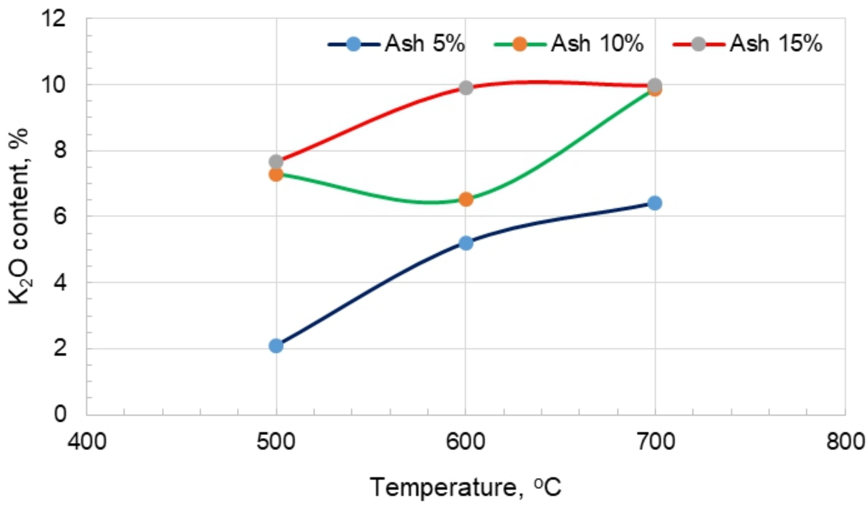



**Figure 3.** Effect of gasification temperature on the potassium content.

### *3.2. Synthesis of NPK Ash Fertilizer*

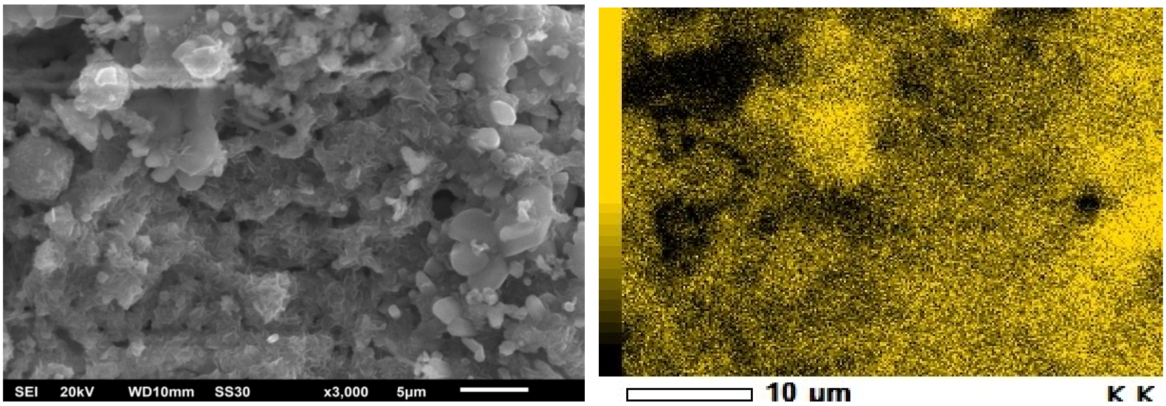
Based on the highest $K_2O$ content, then the formula of NPK ash – clay fertilizer was made. Since the content of $K_2O$ was not too high, then some amount of potassium chloride needs to be added as another source of potassium to complete the potassium content based on the fertilizer formula of NPK fertilizer, which was developed for the red onion plant. Making NPK fertilizer was carried out through several steps, including formulation, crushing, mixing, granulation, and product drying, as described in the previous paper [7].

In the synthesis of NPK fertilizer, the raw material was crushed into 60 up to 100 mesh particles to facilitate the granulation process. Some binder liquid was sprayed during the granulation process to support the material to form granules shape with a size of 3 – 5 mm. The NPK fertilizer after the drying process is shown in Figure 4 below.

**Figure 4.** NPK ash fertilizer.

### 3.3. *Morphology Analysis*

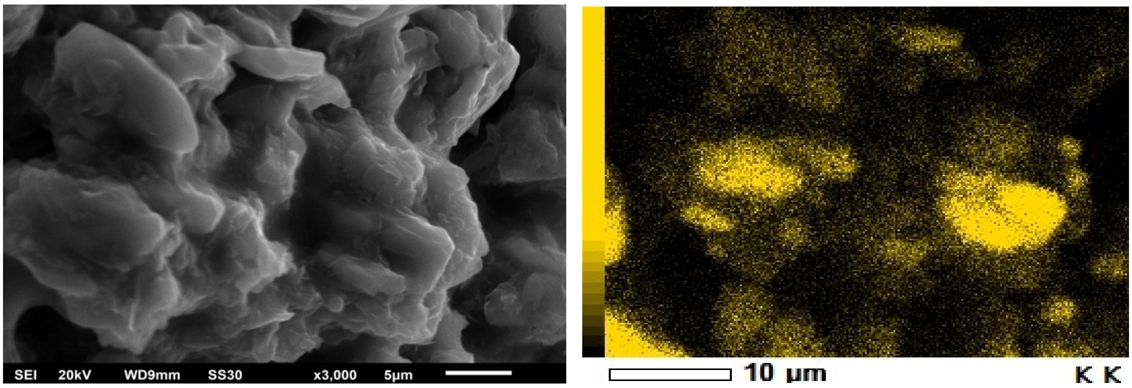
The morphology analysis for EFB ash was performed to identify the material's structure and observe potassium distribution, as shown in Figure 5 below.




(a) (b)

**Figure 5.** a). Morphology, and b). mapping of K element in EFB ash.

The morphology test result of EFB ash shows a different surface structure compared to EFB char. At EFB ash, the morphology shows a more unified structure and fewer pores than the EFB char [7–8]. This structure allows other raw materials to stick more tightly and also facilitates the NPK fertilizer granulation process. From Figure 5 b, we can observe the uniform distribution of the potassium elements in ash, which can support this element's uniform distribution in NPK fertilizer granules. Moreover, in Figure 6, we can see the morphology and mapping of NPK ash fertilizer.



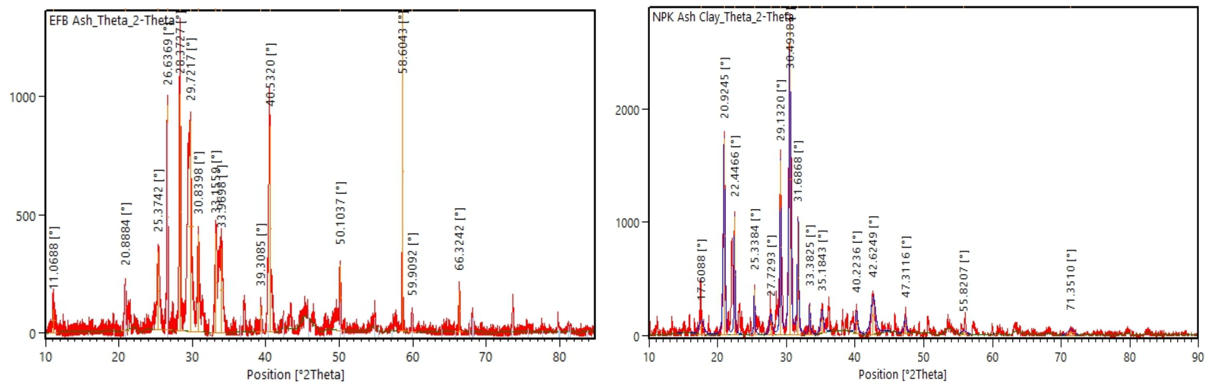

(a) (b)

**Figure 6.** a) Morphology and b). mapping of K element in NPK ash fertilizer.

The morphology of NPK ash fertilizer in Figure 6 shows the structure that tends to form aggregates between particles. The structure of fertilizer almost resembles the structure of EFB ash. In addition to ash, the presence of clay also contributes to the formation of aggregates since clay has properties that can increase the adhesion between fertilizer raw material particles. The morphology of fertilizer does not show a smooth surface, which is likely due to the attachment of nutrient material on the fertilizer's surface. Whereas in Figure 6 b, the distribution of potassium element in the NPK fertilizer is different from Figure 5 b since the EFB ash was already mixed with other raw materials and underwent some processes to produce the NPK fertilizer.

### *3.4. XRD Analysis*

X-ray Diffraction analysis was conducted for EFB ash and NPK ash fertilizer samples. This analysis aims to confirm the interaction between EFB ash and other materials and study the pattern of materials.




(a) (b)

**Figure 7.** XRD pattern of a). EFB ash and b). NPK ash fertilizer.

At EFB ash, XRD patterns at 2θ peak 22.5° represent the crystalline region of cellulose [9] that might become from cellulose content in EFB. The strongest peak shown in Figure 7 a is most likely $SiO_2$ [10] which its intensity is also found to increase after zeolite and clay were added to synthesize NPK fertilizer, as shown in Figure 7 b. The characteristic peaks of urea contain peaks at $2\theta = 23^o, 25^o, 29^o, 32^o, 36^o$, dan $37^o$ [11]. Figure 7 b shows some peaks at the range of 21 - 25° with different intensities from peaks in Figure 7 a. Those peaks are in accordance with the peak range studied by [11], which indicates that urea is strongly attached to the NPK ash fertilizer. The pattern of the two samples above also shows some differences in peak patterns, which are most likely due to interactions between ash and other fertilizer raw materials.

### *3.5. Performance Test of NPK Fertilizer*

The fertilizer's performance test was conducted by doing a small-scale field test for the red onion plant by using a polybag. This field test consists of 5 (five) treatments: without fertilizer, using commercial NPK, using NPK char fertilizer first formula (without micronutrient), NPK char fertilizer second formula (using micronutrient), and NPK ash – clay fertilizer (using micronutrient). Each treatment was tested using ten polybags.

The recommended dosage of the fertilizer for red onion was 600 kg/ha, so the dosage for each polybag was 0.47 g. The first fertilization was done after ten days of planting by giving half of the fertilizer dosage (0.236 g for each polybag), while the other half (0.236 g for each polybag) was given after 30 days of planting. The field test steps and the red onion growth are shown in Figure 8 and Figure 9.

**Figure 8**. Soil preparation.

**Figure 9**. Field test of red onion.

Soil preparation was done by adding some zeolite and compost in order to improve soil condition. The yield of red onion crop by using NPK ash fertilizer is then compared with the yield of NPK char fertilizer, commercial NPK, and without fertilizer treatments studied by [8]. The crop yield comparison is shown in Figure 10.

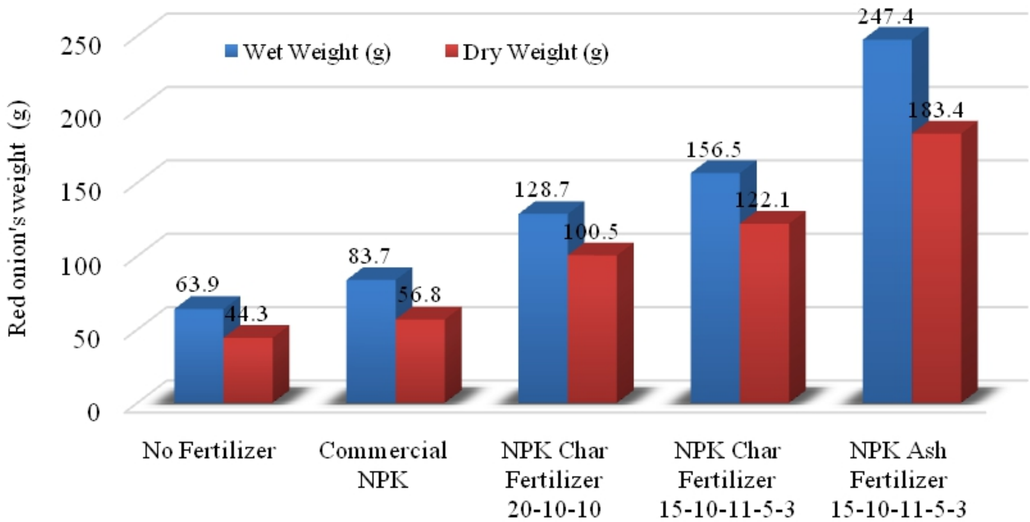



**Figure 10.** Yield comparison of red onion.

The use of NPK char fertilizer (20-10-10) succeeded in increasing the red onion product by 76.9% compared to the commercial NPK. In comparison, the addition of micronutrients of Mg and S increased the red onion product by more than 110% (NPK 15-10-11-5-3). Furthermore, the use of NPK ash fertilizer showed a more significant increase in red onion products to more than 50% compared to NPK char fertilizer. It more than doubled compared to NPK char fertilizer without Mg and S micronutrient, and more than tripled when compared to without fertilizer treatment.

Utilization of ash as a potassium source in the synthesis of NPK fertilizer can increase the yield of red onion compared to NPK char fertilizer with the same formula, most likely due to char has stronger binding properties compared to ash and clay. That condition probably affects the supply and release of nutrients to the plant and decreases bulb size [5]. While in NPK ash fertilizer, the release of nutrients occurs smoothly. EFB ash also enhances soil quality by reducing the soil acidity and improves soil chemical properties, improving plant growth [12]. Moreover, Magnesium and Sulfur as micronutrients also play an important role in the growth of onion bulbs and their quality [13].

## 4. Conclusion

EFB ash can be an alternative to be used as the potassium source in the synthesis of NPK fertilizer. The morphology of NPK ash fertilizer shows the structure that tends to form aggregates between particles caused by the interaction of clay, ash, and other materials. This interaction can have a positive impact in order to increase the adhesion between fertilizer raw material particles. From the fertilizer's performance test using a red onion plant, it was observed that the utilization of NPK ash fertilizer gives the best result compared to NPK char fertilizer, commercial NPK, and without fertilizer. EFB ash can act as a soil improver and by combination with micronutrients, positively affect and support plant growth. However, to obtain more detailed data and confirm this result, we still need to conduct the field test on a larger scale.

**Acknowledgments**
Authors wishing to thank The Agency for Assessment and Application of Technology and Japan Government through the SATREPS Project (Science and Technology Research Partnership for Sustainable Development) for financial support.

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