

Production of Granular Potassium Fertilizer from Oil Palm Empty Fruit Bunch (EFB) Incineration Ash

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Abstract

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The transformation of oil palm empty fruit bunch (EFB) incineration ash into granular potassium fertilizer offers a promising approach to recycling agro-industrial waste while producing value-added products. This study focuses on the formulation of EFB ash-based granules using tapioca starch as a natural binder, and examines the effects of binder weight and drying time on granule yield, pH, K_2O content, and moisture content. Tapioca starch was incorporated at five different weight (5, 10, 15, 20, and 25 g) to evaluate its influence on granulation performance. The results showed that increasing tapioca starch content significantly improved the granule yield, achieving a maximum of 67.91% at 15 g. However, there are no granular formed. The granular formed at weight of binder 25 g that resulted 67.22% yield and 36.72% Potasium. The pH of the granules slightly decreased with increasing binder dosage. Moisture content was influenced by both the binder weight and drying time; higher starch content retained more water. This study demonstrates that tapioca starch is a viable biodegradable binder for producing eco-friendly granular fertilizers from EFB ash, supporting sustainable waste valorization and agricultural practices.

1. Introduction

The palm oil industry, particularly in Southeast Asia, generates large volumes of biomass waste, most notably Empty Fruit Bunches (EFB), which comprise up to 23–25% of total Fresh Fruit Bunches (FFB) processed at palm oil mills. EFBs are typically disposed of through incineration, resulting in ash that is rich in potassium (K) and other alkaline minerals. While this EFB incineration ash holds promise as a potassium-rich soil amendment, its fine and dusty texture poses challenges in handling, transportation, and application, leading to potential nutrient loss and inefficiency in field use [1, 2].

A promising strategy to improve the usability of EFB ash is to transform it into granular form, using suitable binders that help agglomerate fine particles into stable granules. Granulation not only facilitates ease of application but also enhances nutrient retention and release. However, the formulation of granular fertilizers from ash materials is highly influenced by the type and amount of binder used, as well as the processing conditions such as mixing and drying time. The binder weight significantly affects key parameters such as *granule yield*, pH, and potassium content (K_2O). For instance, increasing the binder content may improve granule cohesion and yield, but can also

dilute the nutrient content, particularly K_2O , due to the inert or organic nature of the binder [3-5]. Similarly, binder weight and drying time influence the final *moisture content* of the granules, which is critical for shelf life and storage stability. Higher binder content tends to retain more moisture, while longer drying times can reduce water content but may also risk structural degradation of the granules [6, 7].

Previous research has explored the use of various agricultural and industrial ashes in fertilizer formulations. Some researchers examined the recovery of potassium from EFB ash and highlighted its potential as a fast-releasing potassium source [8]. Ash-based granular fertilizers developed using disc granulation and reported that binder type and concentration critically impacted granule strength and nutrient leaching [9]. In other studies, starches and clays were used as natural binders, with results indicating that binder concentration must be optimized to balance physical strength and nutrient availability [10-12]. However, these studies often lacked a detailed analysis of how binder weight and granulation time collectively influence yield efficiency, moisture stability, pH buffering capacity, and nutrient composition in the final product.

The novelty of this study lies in its detailed examination of the interaction between binder weight and processing time on the physicochemical properties of potassium fertilizer granules made from EFB ash. Unlike prior works that generally focus on either granule strength or nutrient leaching, this research investigates how variations in binder dosage affect multiple critical parameters—such as granule yield, pH, moisture content, and potassium (K_2O) concentration—within a controlled formulation process. The study employs bentonite and tapioca starch as eco-friendly binders, emphasizing the potential for low-cost, biodegradable fertilizer production in the context of sustainable palm oil waste management.

The objective of this study is to develop potassium-rich granular fertilizer from EFB incineration ash using a disc granulation technique and to evaluate the effect of binder weight and drying time on key performance indicators. Specifically, this research aims to: (1) assess how different binder-to-ash ratios influence yield, pH, and potassium (K_2O) content; (2) analyze the combined effect of binder weight and drying time on moisture content; and (3) identify optimal formulation conditions to produce physically robust and nutrient-efficient granules suitable for agricultural application.

2. Methods

2.1 Materials and Equipment

The primary raw material used in this study was ash obtained from the incineration of Oil Palm Empty Fruit Bunches (EFB), sourced from a local palm oil mill located in West Aceh, Indonesia. Prior to use, the EFB ash was stored in sealed containers to prevent moisture absorption and contamination. The binder used is tapioca starch (a biodegradable organic binder derived from cassava) which is a natural binder selected to facilitate granulation and distilled water was used as a granulating fluid to activate binder adhesion and initiate agglomeration.

The major equipment used included a laboratory-scale pan granulator (diameter: 40 cm, adjustable rotation speed), a sieve shaker (ASTM standard sieves: 1 mm to 5 mm), a drying oven (capable of maintaining a constant 60 °C), and a universal testing machine (for crushing strength analysis). Additional laboratory

apparatus such as digital pH meters, moisture analyzers, and atomic absorption spectrophotometers (AAS) were used for chemical characterization.

2.2 Granulation Procedure

If the oil palm empty fruit bunch (EFB) incineration ash is still coarse or contains large particles, it should be sieved first to obtain a finer texture, facilitating its processing into granules. The ash is then mixed with a tapioca starch binder to form a moldable dough. The typical mixing ratio is approximately 150 grams of ash to 25 grams of tapioca starch. Gradually, a small amount of water is added to the ash-binder mixture while stirring continuously until the dough reaches a moist consistency that can be compacted but is not overly wet. The amount of water added is approximately 40% of the total material weight. This moisture level helps bind the ash and starch particles effectively.

The dough is then granulated by taking small portions and forming them into small balls or granules by agitating the material on a flat pan or tray. Once the granules are formed, they are dried in an oven at 40 °C until completely dry. Proper drying is essential to prevent microbial spoilage or mold growth. After drying, the granules are sieved to remove broken or undersized particles, ensuring that only intact granules are retained for use as fertilizer. The final granular fertilizer product is stored in a sealed container to maintain its quality and prevent degradation prior to application.

2.3 Characterization and Testing

2.3.1 Moisture Content Analysis

Moisture content was determined based on the difference in sample weight before and after drying. The procedure involved weighing 10 grams of the sample into a porcelain crucible, which was then placed in an oven at 105 °C for 1 hour. After drying, the sample was weighed again and reheated until a constant weight was achieved. Moisture content was calculated using the following equation:

$$\text{Moisture Content (\%)} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times 100\%$$

2.3.2 pH Measurement

The pH of the granular fertilizer was measured by weighing 10 grams of the sample and dissolving it in distilled water at a 1:10 (w/v) ratio. The mixture was stirred for 10–15 minutes

to ensure homogeneity. The pH of the resulting solution was then measured using a calibrated pH meter.

2.3.3 Potassium Content Analysis

The potassium (K) content in the granular fertilizer was determined using the Atomic Absorption Spectrophotometry (AAS) method. Prior to analysis, the sample was oven-dried at 105 °C for 3 hours to remove moisture, ensuring a constant weight to prevent humidity interference in the analysis. The dried sample was then ground using a grinder to obtain a uniform particle size, followed by sieving through a 100-mesh sieve to achieve a homogeneous powder.

Subsequently, 1 gram of the fine sample was digested in 50 mL of concentrated nitric acid (HNO₃), or a mixture of nitric acid and perchloric acid (HClO₄) at a specific ratio. The digestion was carried out cautiously on a hot plate until complete dissolution of the sample. The digested solution was filtered using filter paper to remove insoluble residues, and the filtrate was diluted to 100 mL with distilled water. This final solution was then used for potassium analysis using the AAS instrument.

3. Results and Discussion

3.1 Effect of Binder Weight on Granule Yield, pH, and K₂O Content

The effect of binder weight on granule yield, pH, and K₂O content presented in Table 1. The effect of binder weight on the physical and chemical properties of potassium-based granular fertilizer derived from oil palm empty fruit bunch (EFB) incineration ash was investigated. As shown in the data, binder weights of 5, 10, and 15 grams did not result in successful granule formation, despite yielding relatively high production values of 66.41%, 60.25%, and 67.91%, respectively. These results indicate that while the binder addition supported agglomeration to some extent, the quantity was insufficient to promote cohesive granular formation. The pH values for these treatments remained consistently high, around 11.45–11.52, suggesting the alkaline nature of the EFB ash regardless of the binder presence.

Table 1. Analysis results of granular fertilizer products

Binder weight (g)	Yields (%)	pH	Kalium (%)	Remarks
5	66,41	11,52	-	No granular formation
10	60,25	11,52	-	No granular formation
15	67,91	11,45	-	No granular formation
20	59,57	11,23	38,25	granular formation
25	67,22	11,26	36,72	granular formation

Granular formation was only achieved when the binder weight reached 20 g and above. At 20 g, the yield slightly dropped to 59.57%, but granules were successfully formed, with a measured potassium (K₂O) content of 38.25%. Increasing the binder weight to 25 g improved the yield to 67.22%, although the potassium content slightly decreased to 36.72%. This indicates a trade-off between binder quantity and nutrient concentration, possibly due to the dilution effect of the organic binder material. Nevertheless, both formulations maintained a strongly alkaline pH of approximately 11.23–11.26, which is beneficial for neutralizing acidic soils.

The findings suggest that a minimum binder weight of 20 g is essential to achieve acceptable granule formation. However, optimization is required to balance between mechanical integrity (yield), nutrient content, and process efficiency. The strong alkalinity and high potassium content make the resulting product suitable for application as a soil amendment in potassium-deficient and acidic agricultural lands.

3.2 Effect of Binder Weight and Drying Time on Moisture Content

The effect of binder weight and drying time on moisture content is presented in Table 2. Table 2 presents the moisture content (%) of potassium-based granular fertilizer derived from EFB incineration ash, evaluated across different binder weights (5–25 g) and drying durations ranging from 12 to 60 hours. Overall, the moisture content followed a typical pattern observed in agglomerated materials, where values initially increased from 12 to 36 hours and subsequently declined at 48 and 60 hours. This behavior is consistent with prior studies,

where moisture redistribution and reabsorption occur in the early stages of drying due to the hygroscopic nature of biomass-based materials, followed by moisture evaporation as drying progresses[13].

Table 2. Percentage of moisture content analysis

Binder weight (g)	Drying time (hour)				
	12	24	36	48	60
5	23,45	28,49	29,58	27,51	27,22
10	24,12	30,57	33,00	31,65	31,35
15	22,67	29,76	32,56	30,78	30,28
20	22,22	26,16	28,61	26,68	26,33
25	23.12	27,45	29,74	27,98	27,46

At a binder weight of 5 g, the moisture content increased from 23.45% at 12 hours to 29.58% at 36 hours, before slightly decreasing to 27.22% at 60 hours. No granule formation was observed at this level, suggesting that the surface area remained high and unbound, which may have facilitated moisture uptake and slowed the drying rate. Similarly, treatments with 10 g and 15 g binders resulted in the highest moisture contents, peaking at 33.00% and 32.56% at 36 hours, respectively. The absence of stable granulation under these conditions may have contributed to the formation of loosely aggregated structures with high porosity and water retention capacity, as has been reported in prior fertilizer granulation studies using organic binders [14, 15].

In contrast, binder weights of 20 g and 25 g, which successfully produced granules, demonstrated lower and more stable moisture profiles throughout the drying period. The 20 g binder treatment showed a moderate increase in moisture content from 22.22% at 12 hours to 28.61% at 36 hours, then declined to 26.33% at 60 hours. These results suggest that a compact granule structure was formed, limiting capillary water absorption and enhancing drying efficiency. The 25 g binder treatment followed a similar trend, though with slightly higher moisture values (e.g., 27.46% at 60 hours), likely due to the increased binder-to-ash ratio, which slowed water migration and evaporation[16].

When compared at the longest drying time (60 hours), the final moisture content was lowest for the 20 g binder (26.33%), followed by 5 g (27.22%) and 25 g (27.46%), while significantly higher values were recorded for 10 g (31.35%) and 15 g (30.28%). This outcome confirms that a binder weight of 20 g represents an optimal formulation for producing physically

stable granules with minimal residual moisture, thereby improving shelf-life and reducing microbial degradation risks. These findings align with previous work indicating that optimal binder concentration is essential to balance mechanical integrity, nutrient retention, and drying efficiency in bio-based fertilizer production[17].

Moisture content is a critical parameter influencing the stability, shelf life, and flowability of granular fertilizers. The results indicated that both binder weight and drying time significantly affected the residual moisture in the granules. At a fixed drying time of 12 hours, granules with 5 g binder retained around 23.45% moisture, while those with 10 g binder showed a higher moisture content (~2.8%). This trend suggests that higher binder concentrations increase water retention capacity, especially in the case of starch, which has hydrophilic properties and can trap water within its matrix structure.

4. Conclusion

The production of granular potassium fertilizer from oil palm empty fruit bunch (EFB) incineration ash demonstrates the potential of valorizing agricultural waste into valuable agro-industrial products.

The results revealed that the weight of the binder (tapioca starch) significantly affected the physical and chemical properties of the granules. An increase in binder weight improved the granule yield and cohesiveness, leading to more uniform and compact granules.

However, excessive binder resulted in a slight reduction in pH, possibly due to partial acidification during binding. Furthermore, the potassium content (K₂O) of the granules remained relatively stable across varying binder weights, indicating minimal dilution effect from the starch addition.

In terms of moisture content, both binder weight and drying time played critical roles. Higher binder concentrations tended to retain more moisture, requiring extended drying periods. Conversely, longer drying times effectively reduced the moisture content to a stable level, ensuring the physical stability and shelf-life of the fertilizer product. These findings suggest that an optimal formulation—balancing binder proportion and drying duration—is essential to produce high-quality, stable, and nutrient-rich granular potassium fertilizer suitable for agricultural applications.

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