The Potential of Biogas Slurry and Palm Oil Mill Effluent Slurry as Slow-Release Fertilizer Pellet Through Densification

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ABSTRACT

Organic fertilizer can yield higher production compared to regular fertilizer if properly applied. Thus, it can be a solution to improve nutrient content of soil. The biggest source of bio slurry in plantation is from Palm Oil Mill Effluent (POME) and cow dung biogas. This research aimed to analyze the residue's potential from the result of biogas processing and bio slurry from POME as slow-release fertilizer pellet. Bio slurry was processed into pellet through densification process using pellet mill. The research was arranged in a Randomized Block Design method with five slurry compositions as treatments, including 70:30, 60:40, 50:50, 40:60, and 30:70 (ratio of biogas slurry and POME slurry), each consisted of three replications. According to the data obtained, fertilizer pellets had characteristics of 25 – 29 mm of length, 5.23 – 5.85 mm of diameter, 0.44 – 0.53 g/cm^3 of density, 54.78% - 81.96% of durability, and 7.81% - 8.57% of moisture content. Based on density and durability aspects, 30:70 composition was the higher. Macronutrient content of the five compositions were 1.88% - 2.72%, in which on day 22, N, P, and K release was 0.36 – 1.01%, 73.51 – 97.48%, and 3.19 – 7.85%, respectively. Meanwhile, on day 17, the nutrition solution conductivity of all compositions had already reached 0.80 – 1 mS/cm.

Keywords: Biogas, Densification, Fertilizer Pellet, Palm Oil Mill Effluent, Slurry

ABSTRAK

Pupuk organik dapat menghasilkan hasil panen lebih tinggi dibandingkan pupuk biasa jika diaplikasikan dengan tepat, sehingga dapat menjadi solusi yang baik untuk memperbaiki kandungan nutrisi tanah. Sumber *slurry* terbesar di perkebunan adalah *slurry* limbah cair kelapa sawit dan biogas. Penelitian ini bertujuan untuk mengkaji potensi residu hasil proses biogas dan *slurry* dari limbah cair kelapa sawit sebagai pelet pupuk *slow release*. *Slurry* nantinya diolah dalam bentuk pelet yakni dengan proses densifikasi menggunakan *pellet mill*. Percobaan dilakukan menggunakan metode rancangan acak kelompok, terdiri dari lima perlakuan: 70:30, 60:40, 50:50, 40:60, dan 30:70 perbandingan komposisi antara *slurry* biogas dan *slurry* limbah cair kelapa sawit dan pengulangan tiga kali. Berdasarkan data pengujian sifat fisik pelet pupuk memiliki panjang dan diameter seragam: panjang 25-29 mm, diameter 5,23 – 5,85 mm, densitas 0,44 – 0,53 g/m³, durabilitas 54,78 % - 81,96, dan kadar air 7,81 % - 8,57 %. Berdasarkan densitas dan durabilitas, komposisi 30:70 adalah yang tertinggi. Kandungan unsur hara makro di kelima komposisi berkisar 1,88 % - 2,72 %, pada hari ke- 22 pelepasan N 0,36-1,01%, P 73,51-97,48% dan K 3,19-7,85%. Pada hari ke-17 daya hantar listrik larutan nutrisi dari semua komposisi telah mencapai rentang 0,80-1 mS/cm.

Kata kunci: Biogas, Densifikasi, Limbah Cair Kelapa Sawit, Pelet Pupuk, *Slurry*

INTRODUCTION

Land degradation is one of factors causing the decreasing of agricultural production in Indonesia. It decreases soil fertility and leads to suboptimal land, by decreasing nutrients, organic contents, and soil pH (Martínez-Alcántara et al., 2016). Lack of knowledge about the advantages and functions of organic fertilizer makes most of Indonesian farmers apply chemical fertilizer to increase production. The use of chemical fertilizer in a long term can make soil nutrients and many important minerals scraped away, thus soil will become less fertile, thereby decreasing the production (Wang et al., 2019).

The solution to the soil fertility problem is fertilization. Fertilization improves soil fertility, providing sufficient nutrients for plants in terms of both quality and quantity (Möller, 2015). Organic fertilizer is advantageous for soil and plants, as it contains important substances to improve the physical, chemical, and biological properties of the soil. The organic fertilizer used in a long term has improved land productivity and prevented land from degradation, thereby being able to optimize land conservation (Ciesielczuk et al., 2017) especially those intended for human consumption, poses new requirements for gardening. It is recommended to use organic slow-action fertilizers, which provide doses of nutrients essential for plants for a long time. Particularly valuable fertilizers are those that arise within the household, due to their high quality and the absence of costs associated with their purchase and transport. Organic matter contained in the food industry waste or arising in households, in the absence of contamination by other types of waste, can be used for self-production of organic fertilizer. The paper presents the results of testing organic fertilizers, which you can make yourself, destined for the cereal plants. The experimental fertilizers were made from coffee spent grounds (CSG.

Slurry from biogas and POME has big potential to be processed become organic fertilizer. If a group of farmers has 5 cows, assuming that a cow produces 15 kg dung/day on average, cow dung produced can reach 525 kg/day (Widyowanti et al., 2021). Meanwhile, palm oil mill with 60 ton/h capacity produces 42 m^3 effluent (Dharmawati et al., 2017).

The research about organic fertilizer is well-developed, as some researchers are known developing pellet organic fertilizer from many sources of biomass. One of them is research from Ciesielczuk et al. (2017)especially those intended for human consumption, poses new requirements for gardening. It is recommended to use organic slow-action fertilizers, which provide doses of nutrients essential for plants for a long time. Particularly valuable fertilizers are those that arise within the household, due to their high quality and the absence of costs associated with their purchase and transport. Organic matter contained in the food industry waste or arising in households, in the absence of contamination by other types of waste, can be used for self-production of organic fertilizer. The paper presents the results of testing organic fertilizers, which you can make yourself, destined for the cereal plants. The experimental fertilizers were made from coffee spent grounds (CSG, where they investigated pellet fertilizer from coffee waste and combustion ash. Lawong et al. (2011) also investigated pellet organic fertilizer from cow dung and chicken manure. Mixing organic fertilizer with urea is known to increase harvest index and protein content of wheat, better than when only urea is used (Reza et al., 2011). Organic fertilizer pellet made from POME slurry, solid decanter, and palm oil boiler ash has also already investigated by Widyowanti et al. (2019) in six compositions, produced with NPK 5.93% - 8.08%.

Based on the previous researches, the novelty of this research is on the materials used to produce fertilizer pellet with densifiation process, which are biogas slurry and POME slurry. This research is essential as it optimizes slurry's potential to be environment-friendly organic fertilizer, which can be said that it applies ecoefficiency aspect. Ecoefficiency is a principle to minimize materials wasted from a production process by utilizing them become more useful and productive materials.

This research aimed to analyze the residue's potential from the result of biogas processing and bio slurry from POME. The slurry was processed into pellet through densification process using pellet mill (pellet mold machine) in order to produce similar shape that is not bulky, making them suitable as slow release fertilizer and easy to transport (Wigena et al., 2006). The research was arranged in a Randomized Block Design with five treatments of biogas slurry and POME slurry compositions, consisting of 70:30, 60:40, 50:50, 40:60, and 30:70, and each treatment contained three replications (Puspadewi et al., 2016). The physical properties and nutrient contents of the pellet organic fertilizer were then investigated.

MATERIALS AND METHOD

The research was conducted from April to August 2020 in the soil laboratory of the Faculty of Agriculture and pilot plant of the Faculty of Agricultural Technology, Stiper Agricultural University (INSTIPER) Yogyakarta.

The tools used in pellet production included pelletizer, disk mill *FFC 23*, and sieve shaker TA-517 Tatonas, while those used for analysis were oven Memmert UN55, analytical scale AND FX-300, Kjedahl Pyrex, UV Vis Spectrophotometer 1240 Shimadzu, Atomic Absorption Spectrophotometer Perkin Elmer 3110, tumbler, EC-meter Lutron CD 4303, and pH-meter Ohaus Starter 600. The materials used consisted of biogas residue from cattle group in Kalasan, Sleman, POME slurry from palm oil mill in Blitar, and tapioca as adhesive. Tapioca was used as an adhesive since it is easy to get at a low cost in Yogyakarta.

The process is illustrated in Figure 1. Firstly, biogas slurry and POME slurry as raw materials were sun-dried for 8 hours to reduce the moisture content. Their final moisture content was managed at 8 – 20% (in wet basis). The dried materials then were converted to powder using disk mill and sifted using sieve shaker (mesh 20) to obtain similar particle size. The next step was mixing, which is the important step that can affect the success of the whole making. Starch flour as much as 5% from total weight of slurry biogas and POME was used as adhesive. After all materials were well-mixed, it was molded using pellet mill. The last step was drying, in which the pellets were sun-dried with natural air.

Sampling was done using quartering method (Widyowanti et al., 2019). The physical properties were analyzed after that. The research was arranged in Randomized Block Design method with five treatments of biogas slurry and POME slurry compositions, including 70:30, 60:40, 50:50, 40:60, and 30:70, and each treatment consisted of three replications (Puspadewi et al., 2016).

The physical properties observed were diameter, length, density, durability, and moisture content. The length and diameter of organic fertilizer pellet were measured using caliper. Density was calculated from the weight per volume of pellet (Kim et al., 2014). Durability of pellet was investigated as Pellet Durability Index (PDI) using p-fost tumbling method or rotational movement (Stelte et al., 2012).

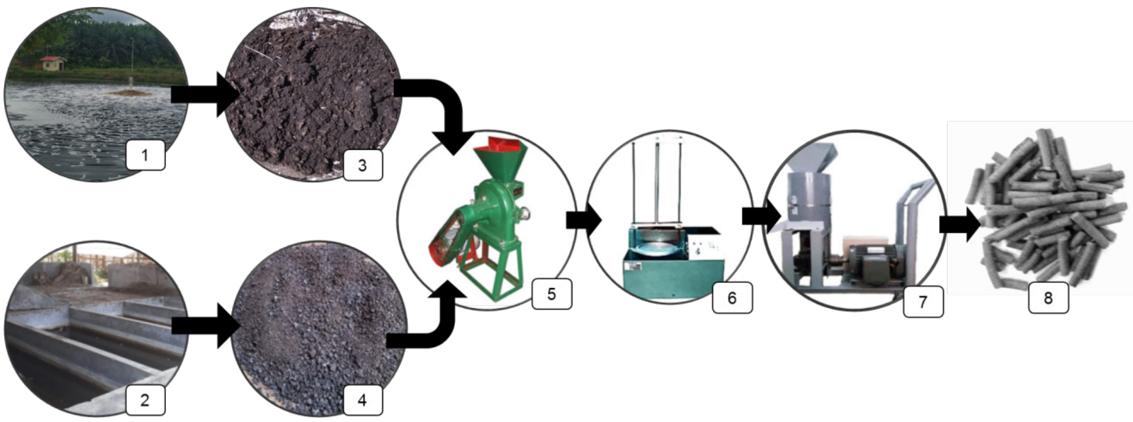

Figure 1. Production process of organic fertilizer pellet made from the slurry of biogas and POME (1. Palm Oil Mill Effluent Pond; 2. Biogas slurry pond; 3. Dried POME slurry; 4. Dried biogas slurry; 5. Disk mill; 6. Sieve shaker; 7. Pellet mill; 8. Fertilizer pellet)

The observation was made on the nutrients contained in pellet, including NPK content, organic C, pH, and silica. The content of N and P was investigated using Kjedahl method and UV-Vis Spectrophotometer, respectively. Meanwhile, K and Si content was observed using Atomic Absorption Spectrophotometer (AAS). The organic C and moisture content were measured using ash and gravimetry method, consecutively (Mahal et al., 2019). The quality of fertilizer pellet was analyzed according to quality requirements of solid organic fertilizer in granule/pellet form stated in Decree of Agriculture Minister of Republic of Indonesia No. 70/2011.

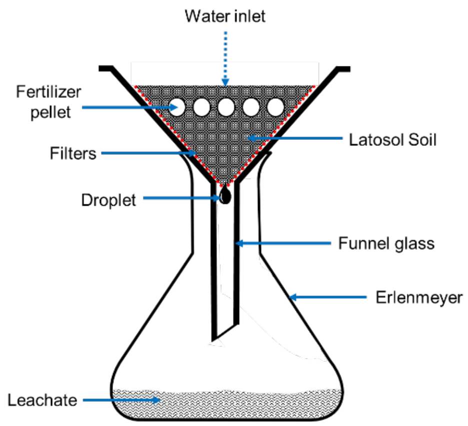

Figure 2. Tool and process of nutrient leaching test

The analysis of NPK release was performed using nutrient leaching test (Wahyu et al., 2018) using less than 2 mm of dry latosol soil. Based on the latosol soil test, it has 0.0972% of N, 0.36% of P, and 0.1289% of K. The tools used in this method are shown in Figure 2. Firstly, 1 g of pellet was mixed with 10 g of soil (Danarto et al., 2017). The mixture was poured into glass funnel with 5 cm diameter. Sieve paper was placed on the top of the glass funnel, while the glass funnel was placed in an Erlenmeyer glass. 20 ml of water with pH 7 was dripped everyday into the glass funnel and collected in Erlenmeyer glass below. The analysis of NPK content, electrical conductivity, and pH was carried out to the collected solution in day 2, 7, 12, 17, and 22. The electrical conductivity and pH of the solution were consecutively measured using EC-meter and pH-meter.

RESULTS AND DISCUSSION

The fertilizer pellet produced is shown in Figure 3. One of the advantages of organic fertilizer in pellet form is that it has cylinder shape with similar length and diameter. Fertilizer pellet is produced from densification process using pellet mill with 10 kg/h of capacity (Renjani et al., 2016). Main component of pellet mill called dies, consisting of 251 holes with 6.5 mm of diameter (Renjani & Wulandani, 2019). Biogas residue and POME slurry as the materials were pressed using two rotated rollers on the top of dies. The pressure allows densification process of the materials, and it makes them formed by the dies and coming out from dies holes. Pellet's length can be adjusted using cutter blade, in which the length of 25 – 30 mm was desired. Physical property is one of success indicators in the making of fertilizer pellet. Physical properties of fertilizer pellet are necessarily observed as basic calculation of storage, packaging, handling, and transportation. The physical properties observed

Figure 3. Fertilizer pellet product from biogas slurry and POME slurry mixture

Table 1. Physical properties of fertilizer pellet

Variables	Composition of Fertilizer Pellet				
	30:70	40:60	50:50	60:40	70:30
Length (mm)	27.74 ± 0.49	29.25 ± 0.89	26.29 ± 0.77	25.67 ± 0.70	28.57 ± 0.61
Diameter (mm)	5.72 ± 0.40	5.65 ± 0.35	5.85 ± 0.33	5.49 ± 0.31	5.23 ± 0.44
Density (g/cm3)	0.53 ± 0.13	0.51 ± 0.81	0.48 ± 0.17	0.45 ± 0.10	0.44 ± 0.09
Durability (%)	81.96 ± 0.24	78.47 ± 0.37	77.36 ±0.42	65.73 ±0.51	54.78 ± 0.11
Moisture content (%)	7.81 ± 0.64	8.00 ± 0.51	8.57 ± 0.24	8.32 ± 0.17	8.06 ± 0.21

Table 2. Nutrient content of fertilizer pellet

Parameters	Quality Standard*	Fertilizer pellet compositions				
		30:70	40:60	50:50	60:40	70:30
NO_3^- (%)	-	2.24	1.42	1.37	1.27	1.27
P_2O_5 (%)	-	0.84	0.85	0.87	0.89	1.00
K_2O (%)	-	0.23	0.25	0.23	0.36	0.26
$N+P_2O_5+K_2$ (%)	Min 4	2.72	1.93	1.88	1.94	1.94
pH of pellet	Min 15	29.04	26.19	28.30	28.30	18.66
pH of solution	4-9	7	7	7	7	7
Si (%)	-	7.15	7.18	7.19	7.17	7.16
C-organic (%)	-	17.52	21.59	19.05	20.68	17.61

Remarks: *Decree of Agriculture Minister of Republic of Indonesia No.70/2011

Table 3. Percentage of NPK release (%)

Sample	Day 3			Day 7			Day 12			Day 17			Day 22		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
30:70	0.17	4.54	0.68	0.17	7.26	0.80	0.02	16.34	0.88	0.00	19.97	0.55	0.00	25.41	0.28
40:60	0.23	5.40	2.16	0.20	8.09	0.64	0.03	14.39	0.65	0.10	18,89	0.39	0.13	29.68	3.65
50:50	0.25	10.60	1.35	0.30	12.37	0.44	0.00	17.67	1.14	0.33	22.97	0.55	0.13	33.57	3.80
60:40	0.20	8.68	0.68	0.29	13.02	0.30	0.05	16.50	0.15	0.00	19.97	0.20	0.18	28.65	4.43
70:30	0.38	11.89	0.88	0.27	14.27	0.61	0.11	19.81	0.67	0.00	22.98	0.40	0.00	28.53	5.29

in this research were length and diameter of the pellet. The physical properties of the pellet in 5 compositions are presented in Table 1. The results showed that length and diameter of the pellets were already homogenous, with 25 – 29 mm of length and 5.23 – 5.85 mm of diameter, which were insignificantly different from standard deviation (<1).

The density of fertilizer pellet was calculated from its mass (g) compared to cylinder's volume (cm^3). Higher density means the more solid of pellet, indicating the more difficult of water to penetrate the pellet. Another advantage of organic fertilizer pellet is that it is not bulky so that the large space for storage is not necessary. The density of pellet is affected by texture and structure of its composer materials.

Pellet Durability Index (PDI) is an endurance parameter of pellet due to mechanical impacts from handling and transportation process, dispersion process of fertilizer onto soil by applying fertilizer spreader, or fertilizer diffusion into soil after dissemination. Appropriate densification process of fertilizer pellet can be determined based on hardness and mechanical durability. Through analysis of physical and mechanical properties, the quality of pellet can be identified (Pocius et al.,

Table 4. Accumulative percentage of NPK release in media (%)

Sample	Day 3			Day 7			Day 12			Day 17			Day 22		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
30:70	0.17	4.54	0.68	0.34	11.80	1.48	0.36	28.14	2.36	0.36	48.10	2.91	0.36	73.51	3.19
40:60	0.23	5.40	2.16	0.43	13.49	2.80	0.46	27.88	3.45	0.56	46.77	3.84	0.69	76.45	7.49
50:50	0.25	10.60	1.35	0.55	22.97	1.78	0.55	40.64	2.92	0.88	63.61	3.48	1.01	97.19	7.28
60:40	0.20	8.68	0.68	0.49	21.70	0.98	0.54	38.20	1.13	0.54	58.17	1.33	0.73	86.82	5.76
70:30	0.38	1.89	0.88	0.65	26.15	1.49	0.76	45.97	2.16	0.76	68.95	2.56	0.76	97.48	7.85

Table 5. Solution conductivity of NPK release

Sample	Accumulation of conductivity (mS/cm^2) until day i				
	3	7	12	17	22
30:70	0.38	0.62	0.81	0.92	0.96
40:60	0.50	0.71	0.87	0.99	1.06
50:50	0.35	0.58	0.74	0.85	0.91
60:40	0.45	0.66	0.80	0.91	0.98
70:30	0.60	0.81	0.97	1.07	1.14

2016). Based on PDI analysis, optimum durability (81.96%) was produced by 30:70 of slurry composition. Table 1 shows that durability is in line with density. The higher POME slurry content in the pellet composition, the higher the density and durability score.

Bulk density of dried POME was 0.80 g/cm^3, while bulk density of biogas residue was 0.46 g/cm^3. Compared to dried POME, biogas residue has very coarse and crumble of texture and structure, that it has lower bulk density than dried POME. Table 1 shows that the density of fertilizer pellet decreased as the increasing amount of biogas slurry added to the composition. Due to its coarse and crumble structure, granules of biogas residue are not tacked to each other, causing cavity between the granules, thus the density of mixed pellet decreased. The highest density of pellet was produced from 30:70 composition, as much as 0.53 g/cm^3.

Moisture content of fertilizer pellet is an aspect to determine the stable storage of fertilizer pellet. Moisture content required by Decree of Agriculture Minister of Republic of Indonesia No. 70/2011 is 8 – 20%. The composition of 30:70 gave low moisture content (7.8%), while the moisture content of other compositions has met the standard requirement. Moisture content change in fertilizer pellet might happen during densification process, where it involves pressure and heat in pellet mill dies (Widyowanti et al., 2019). According to Arifin et al., (2019), moisture content has important role in nitrogen release control, and high moisture content decreases nitrate (NO_3) as much as 28 – 50% from total availability, so it is suggested to apply N fertilizer with low moisture content.

The NPK content, organic C content, pH, and silica content of the pellet were compared to the quality requirements of solid organic fertilizer in granule or pellet form required by Decree of Agriculture Minister of Republic of Indonesia No. 70/2011. The content of NPK in five compositions is shown in Table 2. According to Kumar et al. (2015), biogas slurry contains total N as much as 1.4-1.8%, P_2O_5 1.1-2%, K_2O 0.89-1.2%, with total NPK of 2.37%. Meanwhile, POME slurry contains total N of 0.61%, P_2O_5 of 0.30%, (Loh et al., 2013), and K_2O of 0.89% (Wu et al., 2009).

Based on the analysis of NPK content, POME slurry addition increased N content of fertilizer pellet. According to Wahyu et al. (2018), longer drying and densification process affect the probability of the lost NPK. Organic fertilizer pellet in five compositions had 1.88% - 2.72% of total N+P_2O_5+K_2O. The highest NPK content was produced from 30:70 composition, as much as 2.72%, indicating that it belongs to soil ameliorant category. Soil ameliorant is synthetic or natural, organic or mineral, solid or liquid materials that can improve physical, chemical, and biological properties of soil. Soil ameliorant has ability to improve soil structure, modify soil capacity in water holding and streaming, and improve soil ability in nutrient holding to prevent nutrient lost.

Organic matter is supporting element of soil fertility. Organic matter affects plants growth in complex reaction and influences plants growth by modifying soil condition, such as soil aggregation, water holding capacity, aeration, and permeability. The more organic matter, the more fertile the soil. Organic C is carbon (C) content in organic matter (Afu et al., 2016). Minimum standard required by Decree of Agriculture Minister of Republic of Indonesia No.70/2011 is 15%. Meanwhile, organic carbon content produced from fertilizer pellet was 18.66% - 29.04%. The highest carbon content was given by 30:70 composition (29.04%), and the lowest was given by 70:30 composition (18.66%). According to Zakaria et al. (2016), carbon content of POME slurry is 25.53%. This research showed that high addition of POME slurry increased organic matter content.

Table 2 presents the result of pH test, which was done in two stages, in which the first stage was for fertilizer pellet, and the second one was for the solution produced from nutrient leaching test. Soil pH has an important role in nutrient availability in soil. The appropriate pH for the plant is 6 – 7. If the pH is too high or too low, it is difficult for plant to absorb the macronutrient, followed by a high amount of micronutrient, which is toxic for the plant. In the Decree of Agriculture Minister of Republic of Indonesia No.70/2011, it is mentioned that the recommended pH for fertilizer is 4 – 9. Pellets from this research have reached the standard, where all pellets have pH 7 or neutral. Meanwhile, the solution pH from the nutrient leaching test is an important indicator to know the nutrition absorption of the plant in ion form. Plant nutrition requires water in the fertilizer smelting process, and fertilizer is dissolved into the soil easier in the neutral condition. This research proved that the pellet fertilizer dissolution process into soil caused changes in pH. Latosol soil had a pH of 4.5-6.5, indicating that it is not suitable for plant growth, but the addition of pellets turned the soil to soil ameliorant with neutral pH. Solution pH from nutrient leaching test was 7.15 – 7.19.

Silica is the second largest element in soil after oxygen. A total of 50 – 70% of soil mass is silica dioxide. Thus, roots in soil contain Si in their tissues. Silica (Si) has important role to maintain plants health under stress (Sahebi et al., 2015; Santi et al., 2018), improve NPK content absorption, and act as pH buffer. Silicon has role as physic-mechanic barrier, which takes part of epidermis cell wall and vessel tissue in stem, pods, leaf, and tree bark (Siddiqui & Al-whaibi, 2014). Silica elements could be applied in soil as an easy way to improve plants endurance of drought and help reduce water needed in irrigation (Santi et al., 2018). According to the testing data, fertilizer pellet contained 17.52 – 21.59% of silica. The highest content of silica was produced by 40:60 and 60:40 composition. Generally, minimum mineral content required for fertilizer containing Si is 10% (Marafon & Endres, 2013).

NPK release process from organic fertilizer pellet is a dissolving process of nutrients from solid form. This process is important as nutrients can only be absorbed by plants in solution form (Pertiwiningrum et al., 2017). Fast release fertilizer, such as urea and ZA, is easily absorbed by plants because it is easy to dissolve. Otherwise, slow-release fertilizer will be slowly absorbed by plants due to its low solubility. Some of slow-release fertilizers, such as phosphate boulder, compost, and sulfur-coated urea. Fertilizer solubility is determined by its rate and easiness to dissolve in water and to be absorbed by root plants. This solubility characteristic is necessary to determine fertilizer, fertilizing method, fertilizing application time, and plant type.

The percentage of NPK release in day 3, 7, 12, 17, and 22 is presented on Table 3. The percentage of release on day 3 is the ratio of the solution contained on day 1, 2, and 3 to the initial NPK content. The percentage of release on day 7 is the ratio of the solution contained on day 4, 5, 6, and 7 to the initial NPK content, and so on, until the percentage of release on day 22. Table 4 presents the percentage of accumulative NPK release on day 3, 7, 12, 17, and 22.

Based on Table 4, on the day 22, the released N, P, and K was 0.36 – 1.01%, 73.51 – 97.48%, and 3.19 – 7.85%, respectively. The pellet composition of 50:50 resulted in the highest percentage of N release of 1.01%. According to Salman et al. (2015), the percentage of urea fertilizer release with bio-blend polystyrene coating was 18.3 – 28% in day 10, while granule urea fertilizer released was 90.1%. Meanwhile, P and K release given by 70:30 pellet composition were relatively high, which were 97.48% and 7.85%, consecutively.

Fertilizer with nutrient ions easily controlled by plants root is a good fertilizer. Nutrient ions of fertilizer are expected to have low solubility in water, but high solubility in organic acid such as citric acid and oxalate to ensure their availability for plants. This type of fertilizer is known as Slow Release Fertilizer (SLR), which involves slower nutrient release compared to regular fertilizer (Kaplan et al., 2013). Solid organic fertilizer, such as compost, is a slow release fertilizer (Fernández-Escobar et al., 2004; Kim et al., 2014). Densification occurring in pellet molding process allows materials to be more solid, thereby slowing down the releasing process of nutrients in the soil.

N nutrients are absorbed by plants in nitrate (NO_3^-) and ammonium (NH_4^+) form. P nutrients are absorbed by plants in the form of phosphate or oxidized compound, either $H_2PO_4^-$ or HPO_4^{2-}, depending on the medium pH. K nutrients are absorbed by plants in the form of K^+, because all those nutrients contain ions. The electrical conductivity of nutrition solutions can be measured using EC-meter. The recommended electrical conductivity of the nutrition solution for most plants is 0.79 – 1.70 mS/cm (Nasir et al., 2012). Furthermore, nutrition solution should have a pH of 5.5 – 7.0, so that plants can easily absorb the ions (Lykas et al., 2006). pH is measured using pH-meter. Based on Table 5, the electrical conductivity of the nutrition solution in the composition of 70:30 pellets reached the recommended score on day 7 (0.81 mS/cm^2). On day 7, the nutrition solution of that pellet composition was ready to be absorbed by plants. That was also supported by the measured pH, which was 7.15–7.19. On day 12 to day 22, the electrical conductivity in all pellet compositions reached 0.81 – 1.14 mS/cm^2. Conductivity analysis was done to the nutrition solution collected during NPK release in latosol soil media.

CONCLUSION

Densification that occurred in the pelleting process of biogas slurry and palm oil mill effluent slurry allowed materials to become denser as slow-release fertilizer pellet, thereby slowing down the releasing process of nutrients in the soil. The recommended composition of fertilizer pellets made from biogas slurry and palm oil mill effluent slurry is 30:70, because on the seventh day, the nutrient ions had been absorbed by plants as a slow-release fertilizer.

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REFERENCES

Afu, S. M., Asadu, C. L. A., Ofem, K., & Olim, D. (2016). Contribution of organic matter fractions to cation exchange capacity of organic matter under four land uses in Southeastern Nigeria. *African Journal of Agricultural Science and Technology*, *4*(12), 871–876.

Arifin, M. R., Ahmed, O. H., Isa, I. M., & Khairuddin, M. N. (2019). Effects of Moisture Level on Nitrogen Availability in Tropical Peat Soil Cultivated with. *AGRIVITA Journal of Agricultural Science*, *41*(1), 166–174. https://doi.org/10.17503/agrivita.v41i1.2007

Ciesielczuk, T., Poluszy□ska, J., & Rosik-Dulewska, C. (2017). Homemade slow-action fertilizers, as an economic solution for organic food production. *Journal of Ecological Engineering*, *18*(2), 78–85. https://doi.org/10.12911/22998993/68139

Danarto, Y. C., Nugrahey, A., & Noviani, S. M. (2017). Kinetika Slow Release Pupuk Urea Berlapis Chitosan Termodifikasi. *Equilibrium*, *16*(36).

Dharmawati, N. D., Farida, G. Y., Wahyono, & Renjani, R. A. (2017). Process Analysis of Raw Palm Oil Mill Effluent using Single Feeding System. *Proceeding of ISAE International Seminar*, 497–504.

Fernández-Escobar, R., Benlloch, M., Herrera, E., & Garc, J. M. (2004). Effect of traditional and slow-release N fertilizers on growth of olive nursery plants and N losses by leaching. *Scientia Horticulture*, *101*(2004), 39–49. https://doi.org/10.1016/j.scienta.2003.09.008

Kaplan, L., Tlustoš, P., Száková, J., & Najmanová, J. (2013). The influence of slow-release fertilizers on potted chrysanthemum growth and nutrient consumption. *Plant, Soil and Environment*, *59*(9), 385–391.

Kim, P., Hensley, D., & Labbé, N. (2014). Geoderma Nutrient release from switchgrass-derived biochar pellets embedded with fertilizers. *Geoderma*, *232–234*, 341–351. https://doi.org/10.1016/j.geoderma.2014.05.017

Kumar, S., Malav, L. C., Malav, M. K., & Khan, S. A. (2015). Biogas Slurry: Source of Nutrients for Eco-friendly Agriculture. *International Journal of Extensive Research*, *2*(2015), 42–46.

Lawong, W., Hwangdee, P., & Thumma, S. (2011). Development of Two Pellet Die Organic Fertilizer Compression Machine. *Engineering Procedia*, *8*, 266–269. https://doi.org/10.1016/j.proeng.2011.03.049

Loh, S. K., Lai, M. E., Ngatiman, M., Lim, W. S., Choo, Y. M., Zhang, Z., & Salimon, J. (2013). Zero discharge treatment technology of palm oil mill effluent. *Journal of Oil Palm Research*, *25*(3), 273–281.

Lykas, C., Katsoulas, N., Giaglaras, P., & Kittas, C. (2006). Electrical Conductivity and pH Prediction in a Recirculated Nutrient Solution of a Greenhouse Soilless Rose Crop. *Journal of Plant Nutrition*, *29*(2006), 1585–1599. https://doi.org/10.1080/01904160600848904

Mahal, N. K., Osterholz, W. R., Miguez, F. E., Poffenbarger, H. J., Sawyer, J. E., Olk, D. C., Archontoulis, S. V., & 1, M. J. C. (2019). Nitrogen Fertilizer Suppresses Mineralization of Soil Organic Matter in Maize Agroecosystems. *Frontires in Ecology and Evolution*, *7*, 1–12. https://doi.org/10.3389/fevo.2019.00059

Marafon, A. C., & Endres, L. (2013). Silicon : fertilization and nutrition in higher plants. *Amazonian Journal of Agricultural and Environmental Sciences*, *56*(4), 380–388. https://doi.org/10.4322/rca.2013.057 Anderson

Martínez-Alcántara, B., Martínez-Cuenca, M. R., Bermejo, A., Legaz, F., & Quiñones, A. (2016). Liquid organic fertilizers for sustainable agriculture: Nutrient uptake of organic versus mineral fertilizers in citrus trees. *PLoS ONE*, *11*(10), 1–20. https://doi.org/10.1371/journal.pone.0161619

Möller, K. (2015). Effects of anaerobic digestion on soil carbon and nitrogen turnover, N emissions, and soil biological activity. A review. *Agronomy for Sustainable Development*, *35*(3), 1021–1041. https://doi.org/10.1007/s13593-015-0284-3

Nasir, A., Khalid, M. U., Anwar, S., Arslan, C., Akhtar, M. J., & Sultan, M. (2012). Evaluation of bio-fertilizer application to ameliorate the environment and crop production. *Pakistan Journal of Agricultural Sciences*, *49*(4), 527–531.

Pertiwiningrum, A., Budyanto, E. C., Hidayat, M., Rochijan, Soeherman, Y., & Habibi, M. F. (2017). Making organic fertilizer using sludge from biogas production as carrier agent of Trichoderma harzianum. *Journal of Biological Sciences*, *17*(1), 21–27. https://doi.org/10.3923/jbs.2017.21.27

Pocius, A., Jotautiene, E., Pekarskas, J., & Palsauskas, M. (2016). Investigation of Physical-Mechanical Properties of Experimental Organic Granular Fertilizers. *Engineering for Rural Development*, 1115–1120.

Puspadewi, S., Sutari, W., & Kusumiyati. (2016). The effect of organic liquid fertilizer concentration and N, P, K fertilizer dosage on growth and yield of sweet corn (Zeamays L. var. Rugosa bonaf) cultivar Talenta (An Indonesia Language). *Jurnal Kultivasi*, *15*(3), 208–216.

Renjani, R. A., & Wulandani, D. (2019). Pellet Mill Fixed Dies Type for Production of Solid Fuel Pellets from Acacia mangium Bark. *IOP Conference Series: Materials Science and Engineering*, *557*(1). https://doi.org/10.1088/1757-899X/557/1/012057

Renjani, R. A., Wulandani, D., Saulia, L., & Hermawan, W. (2016). Design Improvement of Pelletization Machine for Production Solid Fuel from Acacia mangium Bark. In L. O. Nelwan, U. Ahmad, R. Hasbullah, & I. W. Astika (Eds.), *International Conference on the Role of Agricultural Engineering for Sustainable Agriculture Production* (Issue 1, pp. 197–202). Department of Mechanical and Biosystem Engineering IPB.

Reza, B., Ali-Akbari, G., Hossein-Kianmehr, M., Sarvastani, Z. a T., & Hamzekhanlu, M. Y. (2011). The effect of pellet fertilizer application on corn yield and its components. *African Journal of Agricultural Research*, *6*(10), 2364–2371. https://doi.org/10.5897/AJAR11.011

Sahebi, M., Hanafi, M. M., Siti, A., Akmar, N., Rafii, M. Y., Azizi, P., Tengoua, F. F., Nurul, J., Azwa, M., & Shabanimofrad, M. (2015). Importance of Silicon and Mechanisms of Biosilica Formation in Plants. *BioMed Research International*, *2015*.

Salman, Febriyenti, & Akmal, D. (2015). Pengaruh Penggunaan Penyalut Bioblend PS/PCL Terhadap pelepasan Zat Aktif Urea Granul. *Jurnal Riset Kimia*, *8*(2), 158–164.

Santi, L. P., Nurhaimi-Haris, & Mulyanto, D. (2018). Effect of bio-silica on drought tolerance in plants Effect of bio-silica on drought tolerance in plants. *International Biotechnology Conference on Estate Crops*.

Siddiqui, M. H., & Al-whaibi, M. H. (2014). Role of nano-SiO 2 in germination of tomato (Lycopersicum esculentum seeds Mill .). *Saudi Journal of Biological Sciences*, *21*(1), 13–17. https://doi.org/10.1016/j.sjbs.2013.04.005

Stelte, W., Sanadi, A., Shang, L., Holm, J. K., Ahrenfeldt, J., & Henriksen, U. B. (2012). Recent Developments in Biomass Pelletization - A Review. *Bioresources*, *7*(3), 4451–4490.

Wahyu, C., Respito, A., & Pramuni, E. (2018). Environmental Technology & Innovation Slow release fertilizer preparation from sugar cane industrial waste. *Environmental Technology & Innovation*, *10*(2018), 275–280. https://doi.org/10.1016/j.eti.2018.02.010

Wang, H., Xu, J., Liu, X., Zhang, D., Li, L., Li, W., & Sheng, L. (2019). Effects of long-term application of organic fertilizer on improving organic matter content and retarding acidity in red soil from China. *Soil & Tillage Research*, *195*(2019), 104382. https://doi.org/10.1016/j.still.2019.104382

Widyowanti, R. A., Dharmawati, N. D., Hertini, E. S., & Renjani, R. A. (2019). Characterization of Organic Fertilizer Pellet from Slurry of Palm Oil Mill Effluent As Slow Release Fertilizer (an Indonesian Language). *Jurnal Teknik Pertanian Lampung*, *8*(3), 187–197. https://doi.org/10.23960/jtep-l.v8.i3.187-197

Widyowanti, R. A., Sunardi, Setyorini, T., & Renjani, R. A. (2021). Pendampingan Pembuatan dan Aplikasi Pelet Pupuk Limbah Biogas untuk Tanaman Perkebunan. *Wikrama Parahita: Jurnal Pengabdian Masyarakat*, *5*(1), 15–21. https://doi.org/10.30656/jpmwp.v5i1.2632

Wigena, I. G. ., Purnomo, J., Tuherkih, E., & Saleh, A. (2006). Effect of Compacted Compound Slow Release Fertilizer to Immature Oil Palm Growth and Yield on Xanthic Hapludox, in Merangin, Jambi (An Indonesia Language). *Jurnal Tanah Dan Iklim*, *24*, 10–20.

Wu, T. Y., Mohammad, A. W., Jahim, J., & Anuar, N. (2009). A holistic approach to managing palm oil mill effluent (POME): Biotechnological advances in the sustainable reuse of POME. *Biotechnology Advances*, *27*(1), 40–52. https://doi.org/10.1016/j.biotechadv.2008.08.005

Zakaria, A. J., Jol, H., Sultan, U., Abidin, Z., Tembila, C., Tun, B., Razak, A., Tun, B., Razak, A., Ventures, F. G., Tun, B., & Razak, A. (2016). The Potential of Treated Palm Oil Mill Effluent (POME) Sludge As an Organic Fertilizer. *AGRIVITA Journal of Agricultural Science*, *38*(2), 142–154. https://doi.org/10.17503/agrivita.v38i2.753