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LAPORAN AKHIR
PEMBUATAN DAN PENGUJIAN PELLET PUPUK KOMPOS BERBAHAN CAMPURAN TKKS BEKAS MEDIA JAMUR MERANG

Skema Penelitian Terapan Dengan Nomor Kontrak:
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RINGKASAN

Tanaman membutuhkan nutrisi di sepanjang siklus hidupnya. Pupuk diberikan dalam rangka untuk memenuhi kebutuhan tanaman tersebut. Secara umum pupuk diberikan atau diaplikasikan di awal saat pengolahan lahan, kemudian sekitar 15-10 hari setelah tanam, dan saat menjelang berbungan atau sekitar umur 35-40 hari. Pengaplikasian pupuk tiga kali ini cukup merepotkan petani karena selain menambah tenaga juga menambah biaya. Selain itu, masalah rendahnya kadar hara NPK pada pupuk kompos membuat petani malas menggunakannya. Volume pupuk kompos yang besar juga membatasi penggunaannya. Di sisi lain, penambahan bahan-bahan organik ke lahan sangat diperlukan untuk mempertahankan keberlanjutan dalam jangka Panjang.

Tujuan jangka panjang penelitian adalah untuk menghasilkan pupuk kompos pellet dengan pengkayaan unsur NPK dan tiga karakteristik rapuh, sedang, dan keras. Ketiga jenis pupuk kompos pellet tersebut hanya perlu diaplikasian sekali di awal tanam. Pupuk pellet yang rapuh akan langsung hancur, yang sedang akan hancur sekitar 20 hari, dan yang keras akan hancur sekitar 35 hari setelah aplikasi. Dengan demikian petani lebih mudah mengaplikasikannya dan hanya perlu mengaplikasikan pupuk kompos pellet sekali saja di awal tanam dalam satu siklus tanam. Sehingga biaya dan tenaga dalam proses produksi tanaman dapat dihemat, yang akhir harga komoditas bisa lebih kompetitif. Keuntungan lain adalah berupa penurunan volume curah sehingga memudahkan dalam pengepakan, penyimpanan, dan transportasi.

Pupuk kompos dibuat dari campuran bahan-bahan seperti tandan kosong kelapa sawit bekas media jamur, kotoran sapi, kotoran ayam, serbuk sabut kelapa, arang sekam, lumpur limbah MSG yang tersedia di Daerah provinsi Lampung. Dengan metoda mengadonan dan pengepresan, campuran bahan-bahan kompos di pelletkan. Variasi penambahan air dan penambahan pupuk NPK pada waktu pengadonan dapat menghasilkan pupuk kompos pellet dengan tiga karakteristik tersebut di atas.

Pada Tahun I (2021), penelitian digunakan untuk mengkaji pengaruh kadar air atau penambahan air dan konsentrasi NPK pada waktu pengadonan terhadap karakteristik pupuk kompos pellet. Hasil Penelitian I menunjukkan bahwa kadar air dan pengayaan NPK berpengaruh nyata terhadap beberapa sifat fisik kompos pelet,

yaitu: berat jenis curah (517,65 – 587,60 kg.m^{-3}), berat jenis pelet (1059,55 – 1329,91 kg.m^{-3}), kuat tekan (2,08 - 7,78 MN.m^{-2}), soliditas (42,66 - 91,91%), PDI (62,11 - 97,68 %), waktu hancur (74,44 - 147,56 jam), dan pH (6,29-6,96). Semua pelet yang dihasilkan bersifat higroskopis. Ketahanan pelet sangat dipengaruhi oleh kadar air sedangkan pH dipengaruhi oleh kadar pengayaan NPK. Kandungan fosfor dan kalium dapat dipertahankan dengan menggunakan mesin pelletizer tipe auger, sementara nitrogen mengalami penurunan. Akhirnya, percobaan menunjukkan bahwa perlakuan kadar air 10-15% dan kadar NPK 3% (W1N2) menghasilkan pelet kompos dengan kelarutan terendah, sedangkan perlakuan kadar air 20-25% dan kadar NPK 0% (W2N1) dan perlakuan kadar air 30-35% dan kadar NPK 0% (W3N1) menghasilkan pelet kompos dengan kelarutan tertinggi.

Pada Tahun II (2022), penelitian digunakan untuk menguji pupuk kompos pellet dengan tanaman di pot. Pupuk kompos pellet diuji pada tanaman sayuran, padi, jagung, kedele. Rancangan pupuk pellet adalah pellet yang rapuh diperkaya dengan pupuk NPK, pellet yang sedang diperkaya dengan urea, dan pupuk pellet yang keras diperkaya dengan urea dan KCl. Pengujian dilakukan dengan cara membandingkan antara aplikasi pupuk pellet rancangan dengan aplikasi pupuk konvensional dengan dosis rekomendasi umumnya. Tingkat dan laju kehancuran pupuk kompos pelet di media tanam diamati. Selain itu parameter agronomis tanaman seperti pertumbuhan dan hasil panen juga didata.

Pada Tahun **III (2023)**, penelitian digunakan untuk menguji plot pupuk kompos pellet di lahan petani dan promosi. Pupuk kompos pellet hasil rancangan pada penelitian Tahun II diperkenalkan kepada petani mitra dan diuji di lahan. Kegiatan terdiri dari promosi dan sosialisasi produk pupuk kompos pellet kepada petani tanaman pangan, industri, dan hortikultura. Dari aspek usaha, produk pupuk kompos pelet dan kemasan dengan beberapa ukuran termasuk desainnya akan dikembangkan. Pupuk pellet juga dikembangkan ke arah spesifik jenis tanaman terutama untuk tanaman bunga. Masalah administrasi dan perjanjian usaha diselesaikan pada penelitian tahap Tahun III.

Kata Kunci: kompos, organik, pellet, pupuk sawit,

DAFTAR ISI

LATAR BELAKANG

Pemanfaatan tandan kosong kelapa sawit (TKKS) untuk media tumbuh budidaya jamur merang dapat menambah keuntungan, dibandingkan dengan pemanfaatan langsung lainnya semisal dikomposkan langsung [1, 2, 3, 4], sebagai sumber energi [5, 6], maupun sebagai mulsa [7]. Satu ton TKKS kering bisa menghasilkan jamur merang minimal seberat 70 kg [8]. Jika harga jamur merang segar Rp 40.000,- per kg, maka panenan jamur merang tersebut setara dengan pendapatan Rp 2.800.000,- dalam satu silkus. TKKS bekas media jamur selanjutnya juga sangat bagus untuk dimanfaatkan sebagai pupuk kompos [9, 10, 11], dan bisa menghasilkan pendapatan yang tidak sedikit. Hasil penelitian menunjukkan bahwa 1 kg pupuk kompos (bahan TKKS bekas media jamur merang dicampur dengan limbah pertanian yang lain) menghasilkan sayuran selada merah organik sebanyak 207 g [12]. Jika harga sayuran selada merah organik berharga Rp 60.000,- per kg, maka pemanfaatan 1 ton pupuk kompos tersebut setara dengan pendapatan sebesar Rp 12,4 juta lebih dalam satu siklus.

Namun demikin, seperti limbah pertanian umumnya, permasalahan pemanfaatan pupuk organik dari limbah TKKS secara langsung maupun TKKS bekas media jamur juga terletak pada volumenya yang bersifat *bulky* [13]. Pembuatan pellet pupuk organik bertujuan untuk menurunkan volume, sehingga memudahkan dalam pengemasan, transportasi, penyimpanan, dan aplikasinya. Selain itu, berdasarkan data penelitian-penelitian sebelumnya, pupuk organik yang dihasilkan mengandung hara yang cukup rendah [14, 15, 16], sehingga aplikasinya masih perlu dikombinasikan dengan pupuk anorganik. Pemberian pupuk kompos dan pupuk anorganik dalam waktu yang tidak bersamaan menambah waktu dan menambah tenaga kerja.

Dalam penelitian ini, akan dicoba juga membuat formula pupuk pellet campuran kompos TKKS bekas jamur, limbah pertani yang lain, dan pupuk anorganik yang bisa diaplikasikan sekali saja di awal tananam. Tingkat densitas pellet dibuat bertingkat: rendah, sedang, dan tinggi. Pellet dengan densitas rendah akan mudah hancur ketika terkena air, yang densitas sedang tidak langsung hacur, dan yang densitas tinggi paling akhir hancur ketika terkena air. Pembedaan densitas pellet bertujuan untuk memfasilitasi pengguna yang membutuhkan aplikasi pupuk tidak hanya sekali dalam

satu siklus tanam. Ketika pellet dengan ketiga jenis densitas tersebut diberikan di awal tanam, maka pellet yang densitas rendah akan langsung hancur saat tanam, yang densitas sedang akan hancur pada saat tanaman berbunga, dan yang densitas tinggi akan hancur pada saat berbuah. Jadi substansi dari pembedaan densitas pellet adalah *rapid*, *moderate*, dan *slow release*. Dengan pembedaan densitas tersebut, maka nutrisi dapat diberikan secara efektif (tepat waktu dan dosis), dan efisien dalam penggunaan tenaga karena hanya sekali aplikasi. Penelitian pembuatan kompos pellet sudah banyak dilakukan, tetapi pupuk pellet dengan densitas yang berbeda-beda belum diteliti.

Penelitian dilakukan dalam tiga tahun. Tahun I digunakan untuk membuat pupuk pellet campuran TKKS bekas media jamur, limbah pertanian yang lain, dan mempelajari pengaruh kadar air dan penambahan NPK terhadap karakteristik pupuk kompos pelet. Tahun II, hasil pellet terbaik pada Tahun I diuji agronomis pada pot (*pot experiment*). Tahun III, penelitian untuk menguji plot pupuk pellet pada tanaman hortikultura dan tanaman pangan bersama petani mitra.

TINJAUAN PUSTAKA

Sejak Tahun 2011, Tim Unila mengembangkan pupuk organik berbasis sumberdaya lokal, yang dinamakan ”Organonitrofos” [14]. Pupuk Organonitrofos granul dibuat dari bahan campuran kotoran sapi segar (disediakann oleh PT Juang Jaya, Gambar 1a) dan batuan fosfat (dari tambang rakyat Selagai Lingga) yang tersedia secara lokal dan diperkaya dengan penambahan mikroba N-*fixer* dan P-*solubilizer* [17]. Pupuk organik tersebut yang mengandung C-organik = 13,91%, N-organik=2,30%, P-larut=1,64%, diproduksi oleh CV Organik Super Agro (CV OSA, Gambar 1b), Tanjung Bintang Lampung Selatan. Pupuk organik granul tersebut banyak digunakan untuk tanaman pangan dan perkebunan. Untuk tanaman berbuah, pupuk organik granul tersebut masih perlu dikombinasi kan dengan pupuk anorganik.

a b

Gambar 1. a. Bahan baku kotoran sapi segar di PT Juang Jaya, b. Proses produksi pupuk Organonitrofos granul di CV Organik Super Agro

Pada Tahun 2013, pupuk Organonitrofos remah dikembangkan untuk diproduksi (Gambar 2a) dan digunakan oleh kelompok tani. Bahan baku dikembangkan lagi dengan menggunakan bahan-bahan limbah yang tersedia secara lokal, yaitu: kotoran sapi segar (PT Juang Jaya), limbah indusri MSG (dari PT Kirin Indonesia, Lampung Timur), serbuk sabut kelapa (dari PT Chrezz, Lampung Selatan), limbah kotoran ayam (dari peternak ayam di sekitar), dan arang sekam (dari perusahaan tahu tempe rumahan). Pupuk organik remah tersebut banyak digunakan oleh petani hortikultura dan tanaman pangan (Gambar 2b). Untuk tanaman berbuah, pupuk organik remah ini juga masih perlu dikombinasikan dengan pupuk anorganik. Komposisi NPK-Org = 45-36-120-1,000 kg ha^{-1} telah diketahui menjadi komposisi terbaik [15]. Pada tahun 2015, Organonitrofos diperkaya dengan penambahan *biochar* dan diberi nama

”Organonitrofos Plus” [18]. Data menunjukkan bahwa dengan penambahan *biochar* 5000 kg ha^{-1}, aktivitas mikroba tanah pada tanaman jagung manis meningkat.

a b

Gambar 2. a. Produksi pupuk Organonitrofos remah dikelompok tani, b. Deplot tanaman cabai

Tandan kosong kelapa sawit (TKKS) bekas media jamur merang berpotensi untuk bahan campuran pupuk Organonitrofos. Hasil penelitian menunjukkan bahwa pupuk Organonitrofos dari bahan campuran TKKS bekas media jamur merang 50% dan kotoran sapi, kotoran ayam, serbuk sabut kelapa, limbah industri MSG, dan arang sekam (50%) mengandung C organik = 16,11%, N = 1,26%, P = 3,04%, K= 0,42% [16]. Untuk tanaman sayuran daun, pupuk Organonitrofos ini berkinerja cukup bagus [12]. Namun untuk tanaman pangan, pupuk Organonitrofos ini juga masih perlu dikombinasikan dengan pupuk anorganik.

Penggunaan pupuk organik Organonitrofos dan kemudian menambahkan pupuk anorganik untuk tanaman pangan dan tanaman hortikultura yang berbuah, dianggap cukup merepotkan petani, karena harus menambah tenaga dan biaya. Jika pupuk organik dan pupuk anorganik bisa digabungkan dan diaplikasikan dalam waktu yang bersama-sama di awal atau sebelum tanam, maka hal ini bisa menghemat waktu dan tenaga yang tidak sedikit. Fortifikasi atau penambahan nutrisi pupuk kompos dengan pupuk anorganik pernah diteliti oleh [19].

Penelitian mesin pupuk pellet dengan bahan organik sebagai bahan baku sudah banyak dilakukan. Pelletisasi bertujuan untuk meningkatkan densitas sehingga memudahkan penanganan, penyimpanan, transportasi, dan aplikasi. Sedikit berbeda dengan pellet pakan [20], pellet pupuk lebih mirip dengan pellet/briket bahan bakar [21], yang membutuhkan kemampatan atau densitas yang tinggi. Lawong et al. [22] membuat pellet kompos dengan densitas 745.40 kg m^{-3}, dan Imatong and Bagtang [19] juga melaporkan densitas pellet kompos yang tidak jauh berbeda yaitu 889.92

kg.m^{-3}. Demikian juga, Mieldazys et al. [23] mendapatkan densitas pellet kompos diameter 6 mm sebesar 789kg.m^{-3}. Namun Zafari and Kianmehr [24] berhasil membuat pellet kompos dengan densitas lebih besar dari 1000 kg m^{-3}, dengan kadar air bahan baku 40%, kecepatan piston 2 mm/s, tebal die 12 mm, dan diameter die 0,9 mm.

Untuk mendapatkan konsistensi pellet, Ofori-Amanfo et al. [25] menggunakan tapioka dan tanah liat sebagai perekat pellet kompos. Nikiema et al [26]. juga melaporkan pembuatan pellet excreta dengan bahan perekat dari tapioka. Sementara, Hettiarachchi [27] menyatakan bahwa dengan tekanan dan kadar air bahan yang tepat, pellet kompos dapat diproduksi tanpa perekat. Daniyan et al [28] melaporkan bahwa pellet kompos tanpa bahan perekat tidak hancur dalam uji rendam air selama satu bulan. Dalam uji yang lain, dengan penambahan tepung beras 3%, pellet kompos hancur dalam 3 hari.

Kekerasan atau kemampatan pupuk pellet ditentukan pada waktu diproduksi. Zafari and Kianmehr [29] mendapatkan pellet kompos dengan densitas tertinggi ketika menggunakan kadar air bahan baku 40%. Pocius et al [30] menyatakan kekuatan pupuk pellet tergantung dari parameter rheologi dan geometri. Pupuk pellet dengan densitas rendah akan mudah hancur ketika terkena air, dan mudah melarutkan nutrisi anorganik yang dicampurkan di dalam pupuk pellet tersebut. Karakteristik pupuk seperti ini tentu sangat cocok untuk diaplikasikan di awal atau sebelum tanam. Biasanya, beberapa tanaman pangan membutuhkan pemupukan lebih dari sekali, minimal dua kali (saat tanam dan saat berbunga). Beberapa tanaman hortikultura seperti cabai bahkan memerlukan pemupukan berkali-kali. Kebutuhan ini bisa difasilitasi oleh aplikasi pupuk pellet dengan beberapa tingkat densitas. Pupuk pellet dengan kemampatan tinggi akan sulit hancur ketika terkena air sehingga lebih lambat melarutkan nutrisi anorganik yang dicampurkan di dalamnya. Jika pupuk pellet dengan densitas rendah - tinggi (seusai proporsi) diberikan sekali saja di awal tanam, maka kebutuhan tanaman akan nutrisi akan terpenuhi sesuai tahapan pertumbuhannya, karena pupuk pellet akan hancur dan nutrisi larut secara berurutan sesuai tingkat densitasnya. Dengan teknik seperti ini, tenaga dan biaya aplikasi pupuk bisa lebih efisien dan nutrisi lebih efektif karena tersedia tepat waktu dan tepat dosis. Hettiarachchi [27] menyatakan bahwa pemilihan bahan perekat yang tepat dapat mengontrol waktu kehancuran pellet sehingga pupuk pellet dapat didesain untuk melepaskan nutrisi dengan waktu dan dosis susauai dengan kebutuhan tanaman.

Berdasarkan hasil-hasil penelitian yang ada dan uraian tersebut di atas, peta jalan penelitian pembuatan pupuk pellet campuran TKKS bekas media jamur dengan bahan-bahan kompos yang lain, dan juga dengan penambahan pupuk anorganik, disusun seperti pada Gambar 3. Proses pembuatan pupuk pellet berbeda dengan pupuk granul yang membutuhkan bahan tepung yang halus bebas serabut. Mesin pupuk pellet bisa menerima bahan-bahan serbuk kasar dan berserabut. Bahan TKKS tidak akan menjadi tepung halus ketika dihancurkan, tetapi akan banyak mengandung serat-serat kecil tidak hancur. Pemilihan bentuk pellet salah satunya didasarkan pada kenyataan tersebut. Tahun I mempelajari sifat-sifat fisik dan kimia pellet. Tahun II menguji agronomis pupuk pellet di pot dengan beberapa tanaman di greenhouse. Tahun III menguji dan sosialisasi pupuk pellet di petani mitra dengan beberapa tanaman sayuran dan tanaman pangan.

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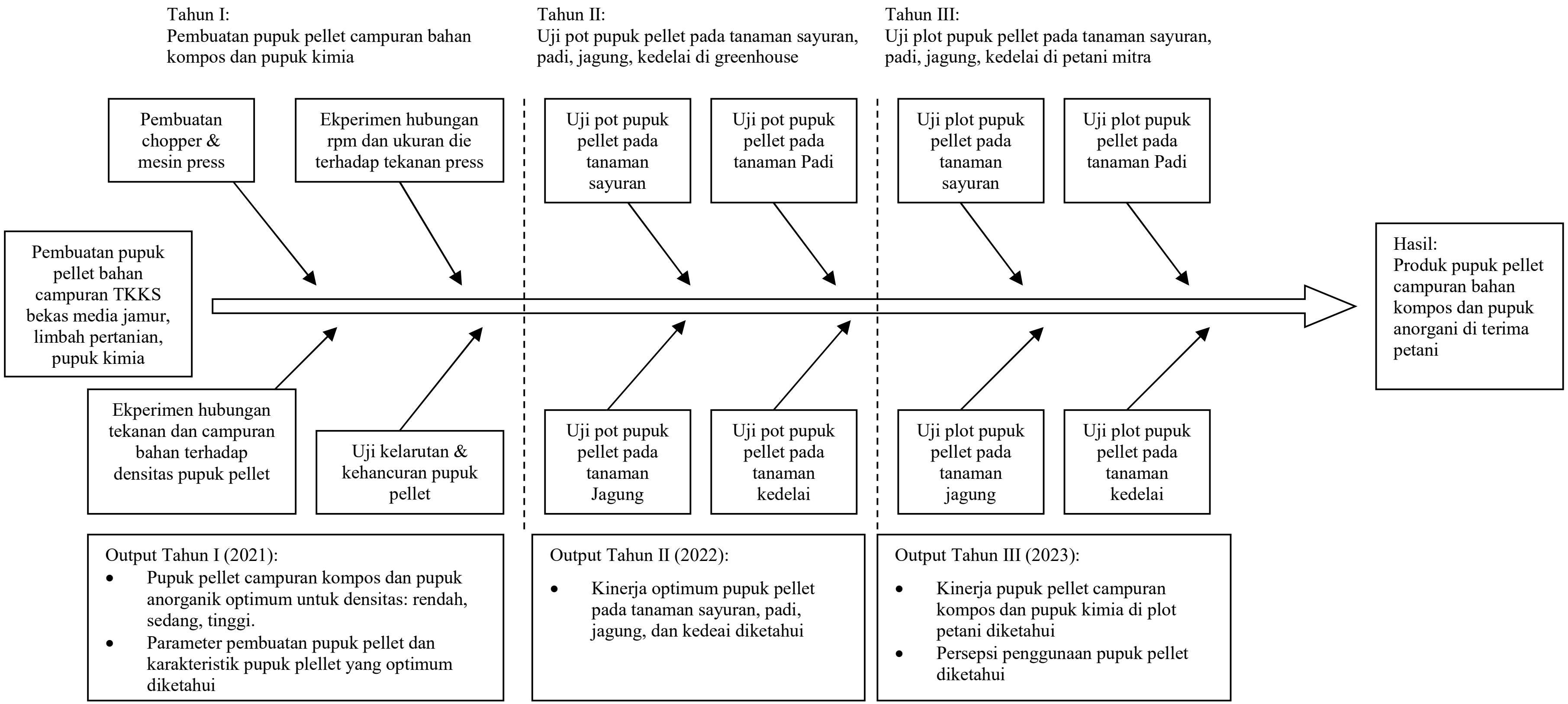


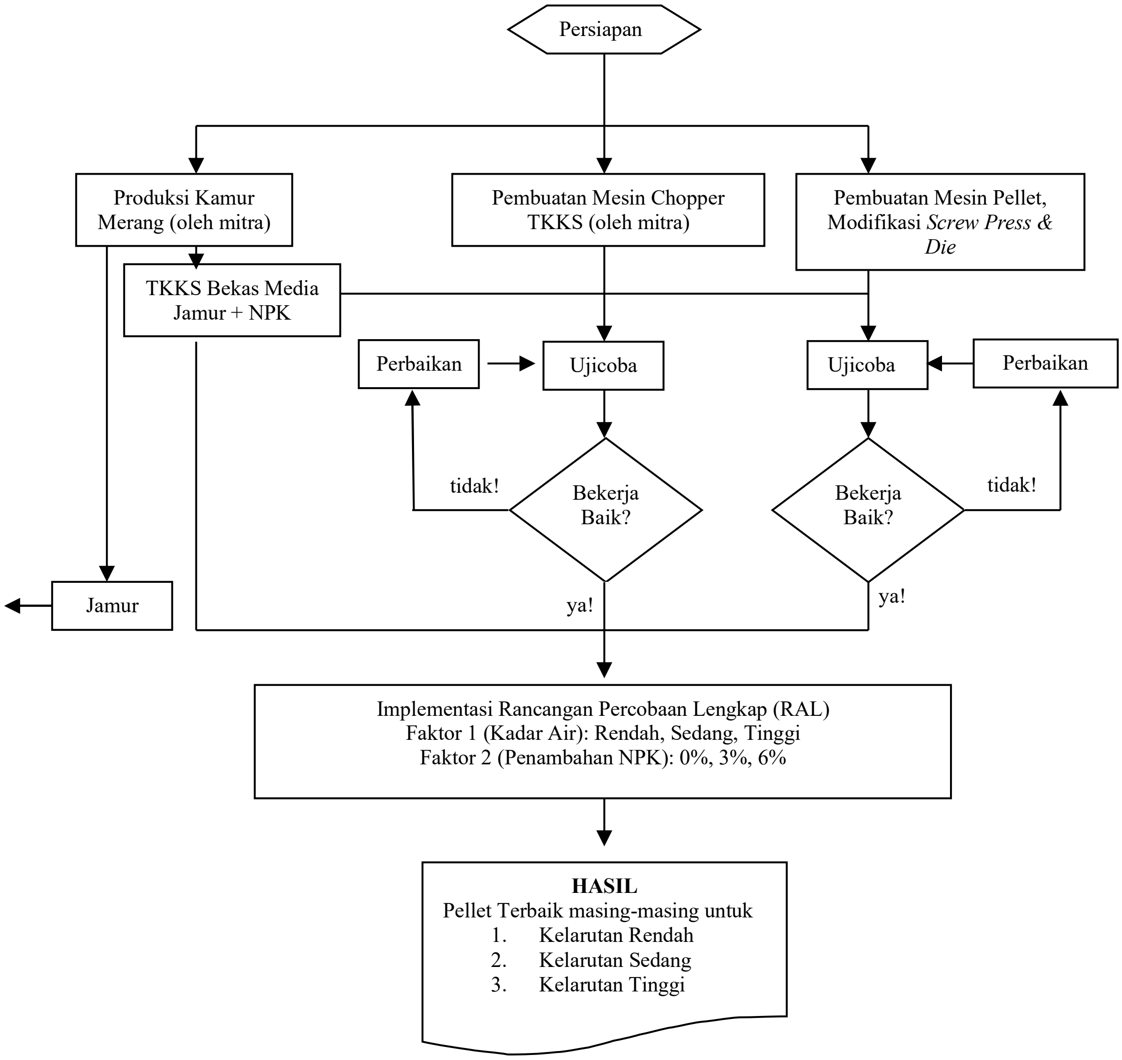
Gambar 3. Peta jalan penelitian pembuatan pupuk pellet

METODE

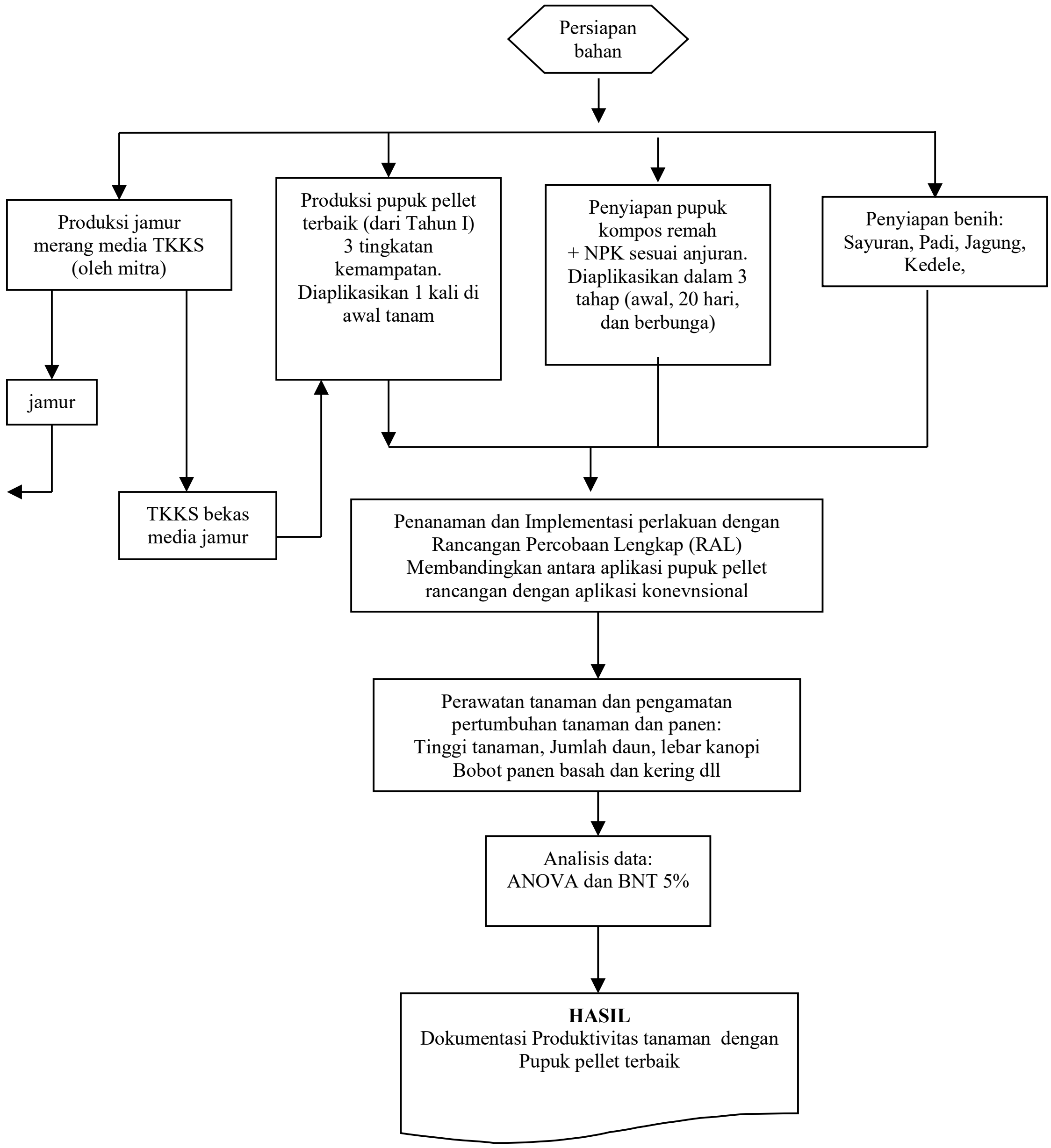
Penelitian dilakukan dalam tiga tahun. Penelitian Tahun I dimulai dengan menyiapkan TKKS bekas jamur (dari mitra produsen jamur), membuat mesin chopper TKKS (oleh bengkel mitra), mesin *screw press* pupuk pellet (oleh bengkel mitra), mesin pelumat/pengadon, dan memproduksi dan menguji pupuk pellet (oleh Tim Unila). Bengkel mitra sudah sangat berpengalaman dalam produksi alsintan, namun peneliti perlu melakukan modifikasi power motor, bentuk *screw press* dan ukuran *die.* Kajian digunakan untuk mempelajari pengaruh kadar air and penambahan NPK terhadap karakteristik pellet yang dihasilkan. Pada tahap ini, eksperimen menggunakan rancangan acak lengkap (RAL) dengan 2 faktor yang disusun secara faktorial. Fator 1 (kadar air) terdiri dari 3 taraf; kadar air rendah 10-15% (K1), kadar air sedang 20-25% (K2), dan kadar air tinggi 30-35% (K3). Faktor 2 (konsentrai penambahan NPK) terdiri dari 3 taraf: kadar NPK 0% (N1), kdar NPK 3% (N2), kadar NPK 6% (N3). Selanjutnya data karekteristik pupuk pellet diuji dengan ANOVA dan dilanjutkan dengan BNT 0,05%. Parameter yang diamati mencakup: densitas curah pellet, densitas pellet, kekuatan tekan, soliditas, pellet durability index (PDI), hygroskopisitas, pH, dan kandungan NPK. Diagram alir penelitian Tahun I disajikan pada Gambar 4.

Penelitian Tahun II digunakan untuk melakukan uji pot pupuk pellet yang diaplikasikan ke tanaman. Kinerja pupuk pellet dibandingkan dengan kinerja metoda pemupukan secara konvensional pada tanaman. Uji pot di dalam *greenhouse* dengan menggunakan 4 tanaman yaitu sayuran, jagung, kedele, padi. Faktor 1 adalah tipe pupuk: pellet (P) dan remah (R). Tahapan pelaksanaan penelitian Tahun II disajikan pada Gambar 5.

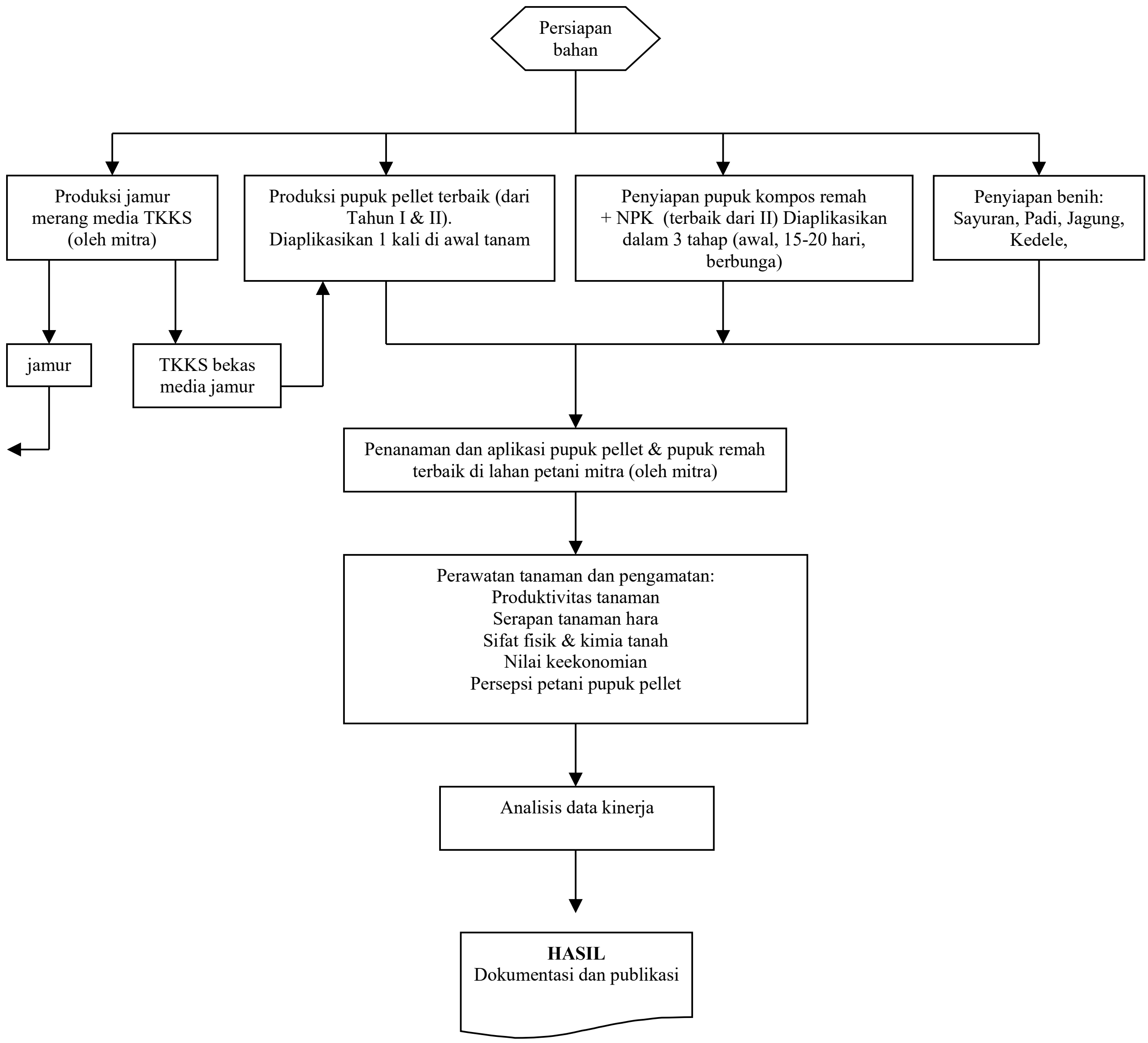
Penelitian Tahun III digunakan untuk sosialisasi pupuk kompos pellet pada petani mitra dengan tanaman sayuran, jagung, kedele, padi. Persepsi petani mitra dan nilai keekonomian penggunaan pupuk pellet akan di kaji. Tahapan penelitian pada Tahun 3 disajikan pada Gambar 6.



Gambar 4. Bagan alir pelaksanaan penelitian Tahun I: produksi jamur merang, pembuatan mesin chopper, pembuatan mesin pres dan modifikasi *screw press* dan *die*, eksperimen pengaruh kadar air dan penambahan NPK terhadap fisik dan kualitas pupuk pllet



Gambar 5. Bagan alir pelaksanaan penelitian Tahun II: Ujian pot pupuk pellet di greenhouse



Gambar 6. Bagan alir pelaksanaan penelitian Tahun III: Uji plot pupuk pellet di petani mitra

HASIL DAN PEMBAHASAN

Hasil Seminar

1. Link seminar: http://environment.triacon.org/gcal.html
2. Link bukti korespondensi dan bahan seminar: https://drive.google.com/drive/folders/1gfnwVIWSnLQ0U9qPBIJg34N78-TcTi9C

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EFFECT OF WATER CONTENT AND NPK ENRICHMENT ON SOME PROPERTIES OF A PELLETIZED COMPOST FERTILIZER

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ABSTRACT

Practical methods of fertilizer applications to enhance farm productivity with sustainability concern and least environmental risk have been getting a lot of attention. This research study aimed to evaluate the effect of mill water content and NPK enrichment on some properties of pelletized compost fertilizer. Three equal piles of compost were sprayed with different levels of liquid NPK, namely: 0% (N0), 3% (N1), and 6% (N2) on the basis of compost dry weight. Each of the three different NPK level piles was divided into other three piles, each of which was subjected to be sprayed with additional water in order to meet three different levels of water contents, namely: 10-15% (W1), 20-25% (W2), and 30-35% (W3) which were required in the experiment. Total piles of nine treatment combinations between water content and NPK enriched compost levels were pelletized and dried under the sun. After the sun drying, each of the nine pellet piles was sampled with three replicates and tested for physical and chemical properties namely: bulk and pellet densities, hygroscopicity, compressive strength, solidity, pellet durability index (PDI), disintegration time, pH, and chemical content. By doing these steps, the requirement of completely randomized design with factorial arrangement was considerably fulfilled. The data sets were analyzed by using analysis of variance and followed by LSD multiple comparation. The results showed that water content and NPK enrichment significantly affected some physical properties of compost pellets, namely: the bulk density (517.65 to 587.60 $kg.m^{-3}$), pellet density (1059.55 to 1329.91 $kg.m^{-3}$), compressive strength (2.08 to 7.78 $MN.m^{-2}$), solidity (42.66 to 91.91%), PDI (62.11 to 97.68 %), disintegration time (74.44 to 147.56 hours), and acidity (6.29-6.96). All produced pellets were hygroscopic. Pellets durability was much affected by water content levels whilst pH was affected by NPK enrichment levels. Phosphorus and potassium contents were manageable by using auger-type pelletizer, whilst nitrogen loss from the pelletizing process was noticeable. At last, the experiment revealed that W1N2 treatment produced the lowest dissoluble compost pellet, while the W2N1 and W3N1 produced the highest dissoluble compost pellets.

Keywords: compost, enrichment, fortification, pellet, slow release.

INTRODUCTION

The continuous use of chemical fertilizers in modern agriculture has exposed many negative effects on the environment. Soil becomes increasingly poor due to leaching process (Hartemink, 2007; Rahmaliza, 2014). The population of soil microorganisms is also suppressed because of a lack of organic matter (Miransari, 2013). The lack of organic matter also causes the soil to become hard and sticky that its water holding capacity diminishes (FAO, 2005), and plant roots become difficult to develop (Juarsah et al., 2008). In addition to being easily eroded, fertilizer and pesticide residues are easily carried away by runoff, causing pollution downstream (Las et al., 2006).

The direct loss experienced by farmers is the use of higher doses of chemical fertilizers while productivity does not get improved.

The supply of organic matter on farm land can be done by giving compost fertilizer. In general, compost fertilizers are made from agricultural residues or wastes. One advantage of compost fertilizer is its capability to improve physical properties of soil, promoting the growth of plant roots, and stimulating the growth of microorganisms population of which becomes more dynamic (Pertiwi and Lululangi, 2019). The mineralization process becomes faster and nutrient enrichment of the soil is enhanced. According to Dreval et al. (2020) organic matter can significantly improve soil nitrogen nutrient if compared to the application of nitrogen fertilizers. However, organic or compost fertilizers have a number of challenges. One disadvantage of compost fertilizers is that the volume is huge, that transportation becomes the primary hindrance (Simanungkalit, 2006). Slower plant response to absorb the nutrients is also another problem (Hasbianto, 2013). Low nutrient content of compost fertilizer is other reason why farmers are reluctant to use compost fertilizers.

Application of compost fertilizer coupled with chemical fertilizers is common practices among farmers to enhance production. Belay et al. (2001) stated that the response of plants to the application of inorganic fertilizers is strongly influenced by the presence of organic matter in the soil. However, the application of chemical fertilizers and organic fertilizers at the same time raises other problems such as the increasing energy and application costs. Other effort that has been made is the application of fortification technology (Marwanto et al., 2019). Fortification is known as a nutrient enrichment of compost fertilizers, usually with the addition of NPK mineral fertilizers (Ndung'u et al., 2009; Mieldazys et.al., 2017). Pelletizing compost fertilizer is another method to make it easier in application of the compost fertilizer. Compost pellets is supposed to be more convenient in handling, packaging, storage, and transportation (Lubis et al., 2016). Compost pellets can reduce volume up to 50-80% in addition to reducing dust in handling (Hara, 2001). Therefore, pelletizing coupled with NPK enrichment of compost fertilizer may potentially become the problem solution of compost application.

The manufacture of compost fertilizer pellets is done by applying high pressure so that the compost fertilizer material becomes denser and the volume becomes smaller (Mieldazys et al., 2017). The characteristics of the fortified compost pellet produced are absolutely influenced by some factors such as pressure levels (Tumuluru, 2018), particle size of the material, moisture content of the material, and the level of added NPK mineral fertilizer. Mieldazys et al. (2017) makes compost pellets from cattle manure with moisture content of 28%, and results in bulk density of 584±16.8 kg.m^{-3} and pellet density of 789±40.4 kg.m^{-3}. The density of pellets depends on the pressure applied during pelletizing process. This study aims to determine the effect of mill water content and NPK enrichment on some properties of compost pellets from formulated powder compost.

MATERIALS AND METHODS

Raw material preparation.

The formulated compost used in this research was made from raw materials such as: spent mushroom substrate (used empty fruit bunch or EFB), fresh cattle manure, chicken litter, coconut peat, rice husk ash, and MSG industry sludge. The used EFB was collected from research facility of the University of Lampung, Indonesia (Triyono et al. 2019) whilst the other materials were gathered from other available local resources. Some chemical properties of the formulated powder compost were C=16.11±0.59%, N=1.26±0.59%, P=3.04±0.19%, and K=0.42±0.04%.

The formulated compost was ground by using a 20 hp machine, and screened by using a 0,3 cm screen size. The main purpose of the grinding and screening were to homogenize the aggregate sizes and remove rough impurities. The formulated compost was split into 3 piles (about 36 kg each) and sprayed with three different levels of liquid NPK fertilizer, namely: 0% (N0), 3% (N1), and 6% (N2) based on the compost dry weight. Further, each of the three different NPK level piles was again split into three piles, and each of which was sprayed with water in order to get three different levels of water contents, namely: 10-15% (W1), 20-25% (W2), and 30-35% (W3). So, there were 9 treatment combinations between three levels of NPK enrichment and three levels of water content. The nine treatment combinations of compost were kept in air tight plastic bags and ready to be pelletized.

Pellet production

Each of the 9 groups of moisturized compost was separately milled to form a dough, then pelletized using a 20 hp screw pelletizer. The outcoming pellets from 1 cm diameter dies were casted on a flat tray on which the pellets were cut into 2 cm long. On the trays, the pellets were dried under the sun for two or three days to get storable moisture contents. Afterall, each of the 9 groups of dried pellets was stored in a air tight plastic bag, and labeled.

Experiment design and data analysis

Three replicates were randomly sampled from each of the 9 air tight plastic bags of the pellets with the 9 treatment combinations. By doing these procedures, requirement of completely randomized design (CRD) with factorial arrangement was considerably fulfilled. So, the experiment included two factors: three NPK enrichment levels (N0, N1, N2) and three water contents (W1, W2, W3) with three replicates, making a total of 27 experimental units. This experimental design was implemented to every testing and measurement. Some physical and chemical properties of the pellets included in the testing and measurement were bulk and pellets densities, hygroscopicity, compressive strength, solidity, Pellet Durability Index (PDI), disintegration time, pH, and chemical contents. The data sets were analyzed by using analysis of variance and followed by LSD multiple comparation, using Statistical Analysis System (SAS) software.

Bulk density of pellets was measured by weighing of 500 ml pellet bulk. Pellet density was measured by measuring the diameter and length of individual pellets. Hygroscopicity was determined by placing samples in a room at controlled temperature and humidity of 26-28^{o}C and ±80%, respectively. Compressive strength was determined by placing (vertical axis position) an individual pellet on a digital scale and compressed from the top with a hydraulic press till broken. The axial load reading (kg) on the display was recorded by using video camera and the maximum load could be easily read from the video, then the load was converted to compressive strength (MPa). The solidity of pellets was tested by dropping a 200-g metal weight from 40 cm height (equivalent to 800 Joule energy) to a standing pellet, then largest surviving pellet mass was weighted and read as pellet solidity in percentages. Pellet Durability Index (PDI) was measured by using a modified method because of absence of standard apparatus. An individual pellet was inserted into a transparent plastic jar, and shaked by a rotating 5.5-cm displacement elbow at $\pm 20Hz$ for 10 minutes. The largest surviving pellet mass was weighted and read as pellet durability index in percentages. Complete disintegration time of individual pellet was determined by emerging a pellet in a jar of water, and the time till complete disintegration was recorded. Acidity (pH) and chemical contents were determined by using laboratory standard methods.

RESULTS AND DISCUSSIONS

Bulk density of compost pellets

Bulk densities of produced biofertilizer pellets were tested and the Analysis of Variance showed that the interaction effect of water contents and NPK enrichment on both of the bulk and pellet densities were significant at the level of α=0.05. The results of LSD comparison were shown on Figure 1.

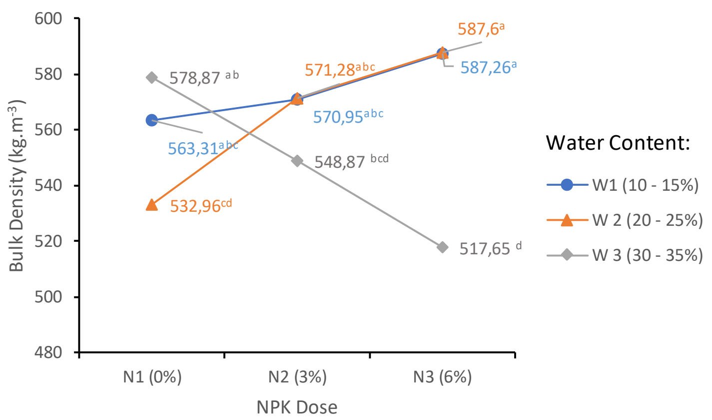

Figure 1. The interaction effect of water contents and NPK Doses on the bulk densities of compost pellet

The bulk density of compost pellets ranged between 517,65-587.60 $kg.m^{-3}$, but tendency to change with water contents and NPK doses were noticeable. With the increasing NPK levels, the bulk density of compost pellet remained constant at low water content W1(10 – 15%), tended to increase at moderate water content W2((20 – 25%), and tended to decrease at high water content W3(30 – 35%). Conversely, with the increasing water content, at no NPK enrichment N1(0%) the bulk density was the lowest at moderate water content W1(20 – 25%), remained constant at moderate NPK enrichment N1(3%), and tended to decrease at high NPK dose N3(6%). So, this finding suggested that water content of pellet mill may not more than ± 25% otherwise the bulk density of the pellet will be even lower. Most of the treatment combinations, however, showed that W1N1, W3N1, W1N2, W2N2, W3N2, W1N3, and W2N3, statistically produced highest bulk densities with average of 575,64 $kg.m^{-3}$.

The average of the highest bulk densities in this research was within the range of 312 to 701 $kg.m^{-3}$ which was reported by Romano et.al. (2014). Mieldazys et al. (2017) also reported their finding of pellet bulk density of 584±16.8 $kg.m^{-3}$. From powder manure raw material bulk density of 556.4± 5.81 $kg{\cdot}m^{-3}$ Mieldazys et al. (2017) gained little increase of the bulk density of pellets. Hettiarachchi et.al. (2019) also reported that the increasing

bulk densities from 300-400 kg/m^{-3} of powder compost to 825-870 kg.m^{-3} of compos pellets. In our research, the bulk density of powder compost (before pelletized) was noted about 338 kg.m^{-3}, so the bulk density (after pelletized) increased about 70,33%. In spite of water content variations, other factors especially interstitial spaces (among the individual pellets in a pile) affected the bulk density of pellets. The interstitial space was affected by the size of the pellets as bigger diameters and longer the pellets the larger the interstitial space among the individual pellets. That was indicated in the data reported by Romano et.al. (2014). In our research study, the diameter and length of the pellets were 10 mm and 20 mm respectively. Whereas, Romano et.al. (2014) and Mieldazys et al. (2017) used diameter of about 5 mm and length of about 13 mm.

One important objective of the pelletized compost fertilizer is to get higher bulk density so that this make it more convenient in handling, storage, and transportation. This research study and others succeed to reveal the improved bulk density of pelletized compost. Other advantages in making use of compos pellets may be achieved in practical and easier applications, both manual or mechanized. The use of compost pellets was also environmentally friendly since its application does not generate dust. When dried and stored properly, the compost pellets would not moldy and could be stored in a long period of time.

Pellet density of compost pellets

Pellet density of compost pellets referred to the compactness of a single individual compost pellets. Analysis of Variance showed that interaction effect between water content of mill and NPK enrichment levels was significant at $\alpha = 0.05$. LDS multiple comparison analysis is shown on Figure 2. Just like the bulk density figure, the pellet density increased at low and moderate compost water content (W1 and W2), and tended to decrease at high water content (W3). Statistically the best treatment combinations (resulting highest particle densities) were found on W2N1, W3N1, W1N2, W2N2, W3N2, W1N3, W2N3, and the average of the highest pellet density was 1225.3 kg.m^{-3}. The importance of pellet density of compost pellets corresponds to the dissolubility of the pellet fertilizers and the rates of nutrient releases. The dissolubility of the pellets was supposed to increase with decreasing pellet density. Low pellet density of the compost pellets may be required for fast release fertilizers, while high pellet density of the compost pellets may be more appropriate for the purpose of slow release fertilizers.

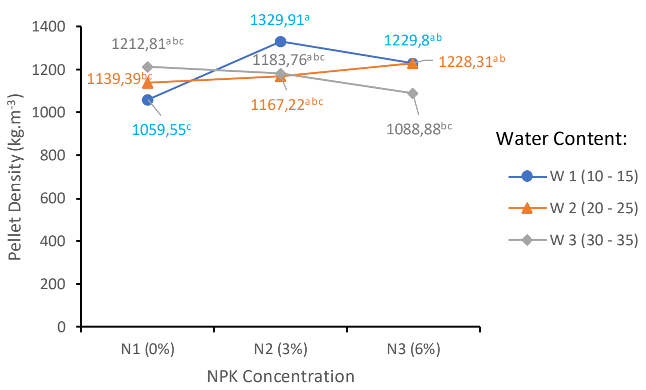

Figure 2. The interaction effect of water contents and NPK Doses on the pellet densities of compost pellets

The average of highest pellet densities found in this research study was quite high as compared to results of other researches. Mieldazys et al., (2017) reported and found that compost pellet density was 789±40.4 kg.m^{-3} which was much lower than found in this research. The particle density in this research was corroborated by what Zafaria et al. (2014) reported. Zafaria et al. (2014) found the particle density of compost pellets was about 1200 kg/m^{-3}. Mani et al, (2006) states that particle density is affected by compression, particle sizes of raw material, water contents, and chemical content especially for protein since protein melts easily at high temperature during pelletizing. In this research, effect of mill water content and NPK enrichment levels was visible, as at low and moderate water content (10-25%) the particle density tended to increase and high particle density could be achieved. In contrast, at high mill water content (30-35%) and high level of NPK enrichment, the particle density tended to be lower. But overall, the particle densities found in this research were considerably high (ranging from 1059.55 to 1329.91 kg.m^{-3}).

If pellets with low particle densities is desired (which is likely to break more easily when fertilizer is applied to the field), a lot of water during pellet mill preparation was necessarily to be added. On the other hand, if high particle density pellets are desired (not easily disintegrated when applied to the field), the amount of water added for pellet mill preparation should be limited.

Full disintegration Time

Disintegration test was carried out in order to determine the duration of compost pellets withstanding when immersed in water till fully disintegrated. The disintegration test with presence of water was in fact to simulate disintegration time of pellets in farm soil. Even the disintegration rates in water does not the same as the actual rates in farm soil, at least the relationship between water content of compost mill and NPK enrichment with the disintegration rates of pellets can be described.

Analysis of variance showed that interaction effect between water content and NPK enrichment levels on full disintegration time of compost pellets was not significant, but the individual effects of water content and NPK enrichment levels on full disintegration time of compost pellets was significant at $\alpha = 0{,}05$. The LSD multiple comparisons of the two factors were placed on Figure 3 and 4.

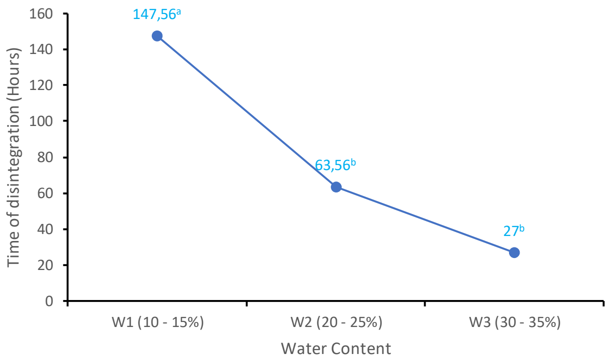

Figure 3. Effect of water content on disintegration time of compos pellets

As we can see on Figure 3, full disintegration time of compost pellet decreased with the increasing water content of compost mill. At low water content (W1) of compost mill, full disintegration time of compost pellets was 147,56 hours, at W2 full disintegration time of pellets significantly decreased to 63.56 hours, and at W3 full disintegration time of pellets decreased to 27 hours even not significantly different from that at W2. Nikiema et al. (2013) mentions that disintegration of compost pellets is a complex phenomenon which is usually accelerated by many factors such as~~;~~ swelling of molecules, modification of surface tension, pH, temperature, chemical content, water content of compos mill, and binding agent additions. The longest of full disintegration time (147,56 hours) found in this research was in fact still longer than that reported by Nikiema et al. (2013). The longest time of disintegration reported by Nikiema et al. (2013) was 120 hours when they worked on fecal sludge processing for fertilizer pellets.

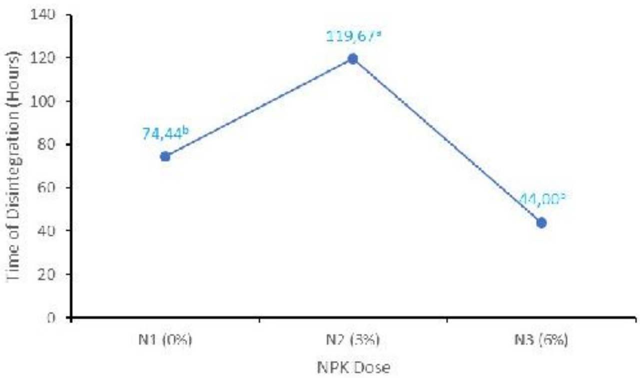

Figure 4. Effect of NPK enrichment on disintegration time of compos pellets

Figure 4 shows the effect of NPK enrichment levels on the disintegration time of compos pellets in water. Inorganic fertilizers were known as hygroscopic compounds, as shown on the Figure 4, that the disintegration was accelerated by NPK enrichment. However, the pattern of the disintegration time that low for N1 (plain compost pellets with 0% NPK enrichment), increased for N2, and decreased for N3 needed to be explained carefully. The disintegration time of 74.44 hours for N2 was in fact relatively high because Nikiema et al. (2013) reported that disintegration time of plain compost pellets (without enrichment nor binder agent) was 57 hours. For enriched pellets of N2 (3% NPK enrichment) in this research, the disintegration time was 119,67 hours, practically the same as Nikiema et al. (2013) finding of 120-hour disintegration when they used about 6% ammonium sulphate ~~(~~($(NH_4)_2SO_4$) to enrich dewatered fecal sludge pellets. But for N3 (6% NPK enrichment) the disintegration time decreased significantly to 44.00 hours. The possible explanation of such behaviour might be found in the

physicochemical properties of the NPK fertilizer. The NKP fertilizer might have promoted gelatinization process of powder compost material when it was applied at 3%. But when it was applied at 6%, the NPK fertilizer enrichment was too much that tended to absorb much water resulting in faster disintegration of pellets.

Pellet Hygroscopicity

Hygroscopicity test was required to determine the stability of water content when compost pellets were stored in a room at temperature and relative humidity of 26-28 ºC and ±80% respectively. Analysis of Variance showed that effects of water content and NPK enrichment on the second day of storage were not significant, and their interaction was not significant either. Figure 5 shows the average of pellet water content along the 12 day storage after taken from oven (0%). The water content changed very quickly from 0% to 8.47% just in 2 days, and was stable at about 9.38% after 6 days of the storage, which just returned to initial water content of pellets (ranging from 8.32 to 9.65%).

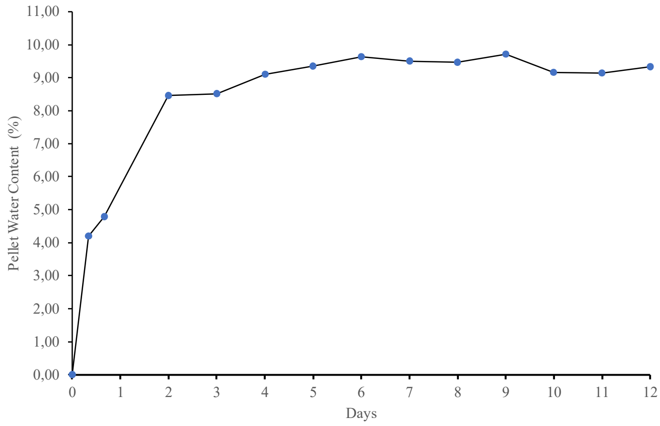

Figure 5. Average of pellet water content along 12 day storage

Compressive Strength

Compressive strength (MPa) of pellet refers to how high vertically axial load (N) can be gradually applied to an individual pellet till broken. Analysis of variance showed that interaction effect of mill water content and NPK enrichment on compressive strength of pellets was significant. Effect of water content was significant too but effect of NPK enrichment was not. Graphical representation of LSD multiple comparison was shown on Figure 6. If read vertically, it was very visible that there was no different compressive strength at N1, decreasing with increasing water content at N2 and N3. But the highest compressive strength was 7.78 MPa found at the treatment of W1N2 (10-15% water content and 3% NPK enrichment).

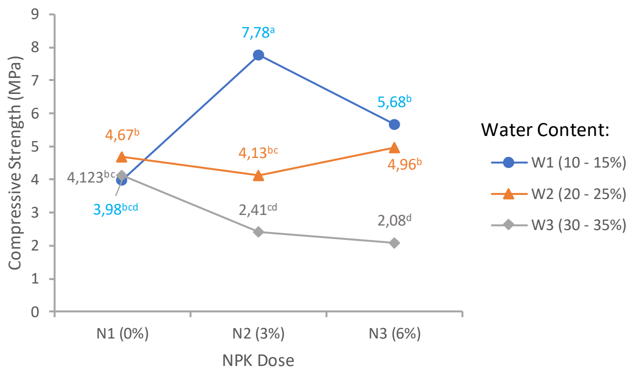

Figure 6. Effect of water content and NPK enrichment on compressive strength of compos pellets

The highest compressive strength of 7.78 MPa was higher than what Zafaria and Kianmehr (2014) reported. Zafaria and M.H. Kianmehr (2014) found the highest compressive strength of municipal solid waste pellets to be 113.2 N which was equivalent to 4 MPa with 6 mm die diameter. They used pelletizing method with 60-70 MPa piston type hydraulic press. Other research was done by Hettiarachchi et al (2019) who worked with municipal solid waste, used piston type hydraulic press with 30 HP motor, and found 2 MPa of highest compressive strength of pellets (64.3 N load with 6 mm diameter die). In our research, gelatinization process or dough making of

powder compost was incorporated before pellet was produced using an auger type press machine which was powered by a 20 HP diesel engine. This method of pelletizing proved to be able to produce high strength pellets with relatively low power. Drawback of this pelletizing method was the produced pellets need longer drying time.

Pellet Solidity Against Impact Load

The pellet solidity refers to how an individual pellet can be resistant when it is dropped by a metal weight from a particular height. Mass of the largest surviving part of the pellet was weighted and its percentage was compared. Analysis of variance showed that interaction effect between mill water content and NPK enrichment on the impact strength was significant. Effect of NPK enrichment was significant too but effect of water content alone was not. Graphical presentation of LSD comparison was shown on Figure 7.

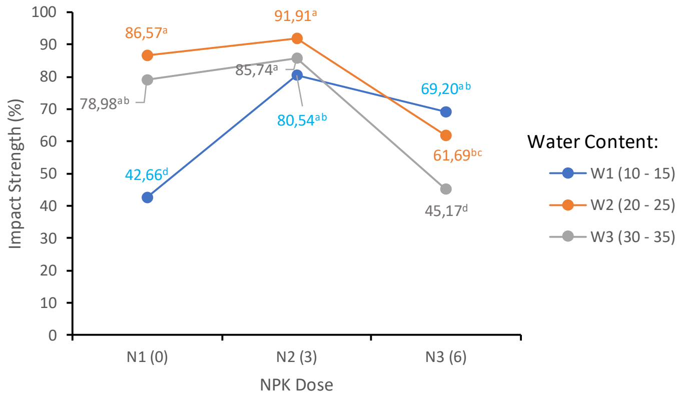

Figure 1. Effect of water content and NPK enrichment on impact strength of compos pellets

From Figure 7, we can see that at low water contents (W1) the impact strength of pellets tended to increase while at high water content (W1, W3) the impact strength of pellets tended to decrease. Statistically; however, the best impact strengths ranged from 66.20-91.91% with average of 82,16%.

Pellet Durability Index (PDI)

Pellet durability indicates the ability of the pellet to resist attrition during a shaking or vibrating test. In this research durability of an individual pellet was tested by using a shaking motion. This test is to simulate any impacts of abrasive actions on pellets during storage and transportation. The pellet was being abraded during the vibration and the largest surviving mass of the pellet was weighted, then its percentage, so called as pellet durability index (PDI) was compared. Analysis of variance showed that interaction effect between mill water content and NPK enrichment on the pellet vibration durability was not significant. The effect of NPK enrichment alone on the pellet vibration durability was not significant either but the effect of mill water content was significant. The LSD comparison of the effect of mill water content on the vibration durability is shown on Figure 8.

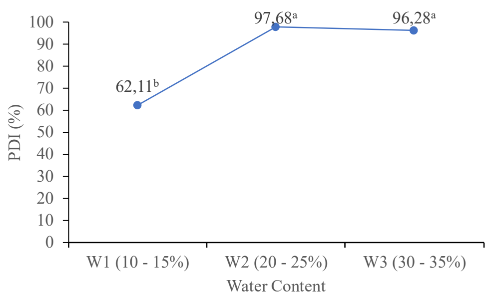

Figure 8. Effect of water content and NPK enrichment on durability of compos pellets

On Figure 8, we can see that durability increased with the increasing mill water content from 62.11% at W1 to 97,68% at W2, and stable to W3. This phenomenon indicated that compost water content could stimulate gelatinization when dough making process, and strengthen particle bounds of pellets resulting in higher PDI. Similar trend was observed in previous research of pelletizing fecal sludge for fertilizer (Nikiema et al. 2013).

Acidity (pH)

By definition, pH is negative logarithmic of the hydrogen-ion concentration, simply meaning more H^+ (hydrogen) ions, the more acidic. Interaction of the mill water content and the NPK enrichment significantly affected pellet acidity (pH) but all of the values were close and not more than neutral pH of 7. The pellet pH values decreased with increasing NPK doses ranging from 6.29 to 6.96. The highest pellet pH belonged to the treatment combination of W2N1 whilst the lowest belonged to W1N3. The effect of the inorganic fertilizer enrichment on the pellet pH was stronger at high mill water content (W3) being low pH at W3N3 and high at W1N3.

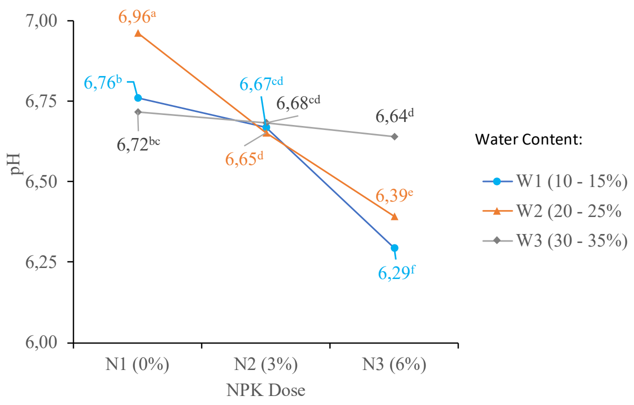

Figure 9. Effect of water content and NPK enrichment on pH of compos pellets

The varying pH values were definitely because of the presence of NPK fertilizer addition. Ammonium based component of the NPK fertilizer was the primary reason of the decreasing pH values through nitrification process. Nitrifying microbes breakdown ammoniacal nitrogen (ammonium) and release H^+ ion (Sparks, 2016). This reaction was promoted by the presence of tremendous numbers of microbes in the compost materials, and even more active in higher water content environment. Other mechanism was that the existence of ammonium sulfate in NPK fertilizer can be hydrolyzed and release H^+ ion (Kaya, 2014). Fortunately the decreasing pellet pH was not much, and still in the tolerable ranges of plant requirement.

Nutrient Contents

Figure 10 shows nutrient status of the raw compost (powder) and NPK enriched compost pellets. Among the three nutrient statuses (NPK), nitrogen content was the only nutrient that decreased from raw compost to compost pellet. Nitrogen content of raw compost was about 1.26±0.59%, decreasing to 0.55±0.04% in plain compost pellet, to 0.53±0.15% in 3% NPK enriched compost pellet, to 0.59±0.08% in 6% NPK enrich compost pellet. The decreasing nitrogen content could be because that nitrogen is bound in ammonium fertilizer which easily shifts to free ammonia and escape as nitrogen gas, and this mechanism was promoted by high temperature when compost was compressed to become pellets. As mentioned before the fact that pH was around neutral could be a significant role too in the volatilization process of nitrogen as observed by Mani et al, (2006). This result suggested that more appropriate methods of producing compost pellets may need to be investigated in order to maintain nitrogen content conservation.

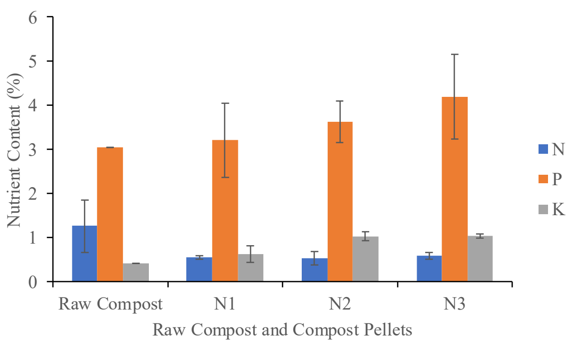

Figure 10. Effects of NPK enrichment on nutrient content of the compost pellets

Phosphorus content looked more conservative, as seen on Figure 10, than other two nutrients (N dan K). The P content was increasing with the increasing NPK enrichment levels, ranging from 3,62±0.47% at 3% NPK enrichment level to 4.19±0.97% at 6% NPK enrichment level, whilst P content for raw compost was 3.04±0.19% and 3.20±0.85% for plain compost pellet. Potassium content showed little conservation, as K increased to maximum of 1.03±0.06% at 6% NPK enrichment level, whilst K contents was 0.42±0.04% for raw compost and 0.63±0.19% for plain compost pellet.

Conclusions

Interaction between water contents and NPK enrichment levels was significant on some physical properties of compost pellet parameters such as bulk density, pellet density, compressive strength, pellet solidity, acidity. High performances of bulk density, pellet density, compressive strength, and disintegration time could be found at the treatment combination of 10-15% water content and 3% NPK enrichment (W1N2), but high solidity was found in all treatments of water content levels. Pellet durability against vibration was much affected by water content than by NPK enrichment levels, but pH was much affected by NPK enrichment rather by water content, and decreased with increasing NPK enrichment levels. All resulted pellets were hygroscopic that approaching to initial water content in just 2 days of storage. Phosphorus and potassium enrichments of pellet were manageable by using auger-type pelletizer but nitrogen might need other method of pelletizing.

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Draf Paten Sederhana

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PROSES PEMBUATAN PUPUK KOMPOS PELET DENGAN PENGKAYAAN FOSFAT

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DESKRIPSI

PROSES PEMBUATAN PUPUK FOSFAT PELLET DARI KOMPOST YANG DIPERKAYA

Bidang Teknik Invensi

Invensi ini berhubungan dengan suatu proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat dan bahan-bahan: tandan kosong kelapa sawit (TKKS) bekas media jamur merang, kotoran sapi, kotoran ayam, serbuk sabut kelapa, arang sekam, limbah lumpur industri MSG. Secara spesifik pembuatan pupuk kompos pellet dengan pengkayaan fosfat dilakukan melalui dua tahap yaitu proses fermentasi bahan kompos dan proses extrusi adonan kompos. Kompos dibuat dari bahan-bahan limbah organik yang salah satunya kaya akan kandungan fosfor, yaitu lumpur limbah industri MSG, dilanjutkan dengan pembuatan pellet dengan menggunakan mesin extruder tipe ulir (auger).

Latar Belakang Invensi

Penggunaan pupuk kimia secara terus-menerus dalam pertanian modern banyak menimbulkan efek negatif terhadap lingkungan. Tanah menjadi semakin miskin akibat proses pelindian. Populasi mikroorganisme tanah juga tertekan karena kekurangan bahan organik. Kekurangan bahan organik juga menyebabkan tanah menjadi keras dan lengket sehingga daya ikat air berkurang, serta akar tanaman sulit berkembang. Nutrisi mudah terbawa aliran permukaan sehingga menimbulkan pencemaran di hilir. Kerugian langsung yang dialami petani adalah penggunaan pupuk kimia dosis tinggi sementara produktivitas tetap tidak membaik.

Penyediaan bahan organik pada lahan pertanian dapat dilakukan dengan pemberian pupuk kompos. Pada umumnya pupuk kompos dibuat dari sisa atau limbah pertanian. Salah satu keunggulan pupuk kompos adalah kemampuannya untuk memperbaiki sifat fisik tanah, mendorong pertumbuhan akar tanaman, dan merangsang dinamika populasi mikroorganisme. Namun, pemanfaatan pupuk organik atau kompos memiliki sejumlah tantangan. Salah satu kelemahan pupuk kompos adalah volumenya yang besar sehingga menjadi kendala utama dalam penyimpanan, pengemasan, transportasi, dan aplikasi. Kandungan hara pupuk kompos yang rendah

(terutama NPK) juga menjadi alasan lain mengapa petani enggan menggunakan pupuk kompos.

Peletisasi dan pengkayaan (fortifikasi) pupuk kompos berpotensi bisa menjadi solusi alternatif dari permasalahan tersebut. Dengan rekayasa peletisasi, volume pupuk menjadi lebih kecil sehingga lebih memudahkan dalam pengemasan, transportasi, penyimpanan, dan aplikasi. Fortifikasi dikenal sebagai teknik meningkatkan kualitas nutrisi kompos dengan cara menambahkan pupuk mineral ke pupuk kompos. Dengan teknik fortifikasi, pupuk kompos menjadi lebih menarik bagi petani untuk menggunakannya.

Pembuatan pellet untuk beberapa tujuan telah banyak dilakukan, misalnya pellet arang untuk energi, pellet pakan ternak, pellet pakan ikan. Pellet rerumputan untuk pakan ternak telah banyak dibuat. Pellet kompos dari bahan tinja, kotoran sapi, sampah domestik, juga sudah banyak dilakukan. Namun proses pembuatan pupuk kompos dengan bahan-bahan limbah organik yang diformulasikan dan pembuatan pelletnya dengan pengkayaan fosfat belum pernah dilakukan.

Uraian Singkat Invensi

Invensi yang diusulkan ini pada dasarnya adalah suatu proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat dengan menggunakan mesin extruder tipe auger, dari bahan-bahan limbah organik yang diformulasikan. Bahan-bahan limbah organik terdiri dari TKKS sawit bekas media jamur merang, kotoran sapi, kotoran ayam, serbuk sabut kelapa, dan limbah lumpur industri MSG, serta penambahan pupuk mineral fosfat. Konsep invensi proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat dari campuran bahan-bahan kompos yang diformulasikan dan kemudian difermentasikan. Setelah selesai, kompos remah digiling dan diayak agar halus dan homogen. Setelah halus, kompos remah di lumat dengan menggunakan mesin mixer sampai menjadi adonan. Pada waktu pembuatan adonan, air dan pupuk fosfat ditambahkan. Banyaknya air dan konsentrasi pupuk fosfat yang ditambahkan berpengaruh terhadap tingkat kekerasan pellet yang dihasilkan. Setelah dimixer, adonan pupuk kompos di cetak dengan mesin extruder menjadi pellet ukuran diameter 5-10 cm memanjang kemudian dipotong-potong dengan panjang tertentu, dan dijemur di bawah terik matahari. Setelah kering, pupuk kompos pellet dapat dikemas dalam kantung plastic kedap udara dan disimpan.

Uraian Lengkap Invensi

Pembuatan pupuk kompos pellet dengan pengkayaan fosfat dimulai dengan mengumpulkan bahan-bahan yaitu: TKKS sawit bekas media jamur merang, kotoran sapi, kotoran ayam, serbuk sabut kelapa, dan lumpur limbah industri MSG. di antara bahan-bahan tersebut yang mengandung fosfor tinggi adalah limbah lumpur industri MGS (21,74%). Kemudian bahan-bahan dicampur dengan perbandingan; TKKS : kotoran sapi : kotoran ayam : serbuk sabut kelapa : arang sekam : lumpur limbah industri MSG = 50 : 30 : 5 : 5 : 5 : 5. Campuran bahan kompos ditumpuk membentuk unggun sambil disiram air secara bertahap. Tumpukan bahan kompos kemudian ditutup terpal, kemudian difermentasikan selama 3 bulan. Bahan kompos diaduk-aduk, dibalik, dan disiram air secara rutin setiap 1-2 minggu. Alas bagian bawah tumpukan kompos harus berdrainase baik agar tidak ada air yang menggenang di kompos. Setelah 3 bulan, sudah cukup matang, kompos dibongkar, digiling, dan diayak dengan saringan berukuran 5 mm. Kompos remah yang dihasilkan kemudian dikemas dalam karung untuk disimpan sementara.

Selanjutnya pembuatan pupuk kompos pellet dengan pengkayaan fosfat dari bahan kompos remah dimulai. Kompos remah dimasukkan ke dalam mesin mixer berkekuatan 8 HP, ditambahkan air 30-35% dan pupuk mineral fosfat sebanyak 6%. Bahan kemudian dilumat dengan mesin mixer selama kurang lebih 15 menit, dan setelah kenyal/kalis, adonan diangkat. Adonan ini menghasilkan pellet dengan tingkat kekerasan yang redah sehingga cepat hancur dan larut ketika diaplikasikan di awal tanam, atau bersama dengan pengolahan tanah. Adonan untuk mendapatkan pellet yang keras dan padat sehingga waktu hancurnya lebih lama bisa lakukan pada tahapan ini.

Setelah menjadi cukup kenyal dan kalis, adonan kompos dimasukkan ke dalam mesin extruder 20 HP, dicetak menjadi pellet. Penggunaan daya mesin extruder ini sangat rendah jika dibandingkan dengan mesin extruder pencetak pellet untuk energi yang mencapai 200 HP. Mesin pellet untuk pakan ternak menggunakan daya rendah karena memang untuk menghasilkan pellet yang tidak begitu padat sehingga nyaman untuk dimakan oleh ternak. Sedangkan dalam proses pencetakan pellet untuk pupuk kompos ini, selain kekerasan, daya larut nutrisi pupuk juga sangat penting untuk diperhitungkan.

Pellet yang keluar dari mesin extruder berdiameter sesuai dengan lubang cetakan (die) dan memanjang. Kemudian pellet dipotong-potong sehingga

panjangnya seragam. Setelah ditampung pada nampan, pellet di jemur di bawah terik matahari 1-2 hari hingga kering simpan pada kadar air antara 8-10%. Setelah kering, pupuk kompos pellet dikemas dalam karung plastik yang kedap udara dan disimpan. Kemasan harus kedap udara agar kadar air tidak benyak berubah yang berakibat bisa jamuran. Karakteristik pupuk kompos pellet dengan pengkayaan fosfat disajikan pada Tabel 1.

Tabel 1. Karakteristik pupuk kompos pellet dengan pengkayaan fosfor

No	Parameter	Nilai	Satuan
1	Masa jenis curah pellet	517,65	kg. m^{-3}
2	Masa jenis pellet	1008,88	kg. m^{-3}
3	Lama waktu hancur total	35,30	jam
4	Higroskopisitas	0,35	%/jam
5	Kekuatan kompresi	2,08	MPa
6	Soliditas	45,17	%
7	Durabilitas Indeks	96,28	%
8	pH	6,64	-
9	Kadar P	4,19	%

Klaim

Suatu proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat dengan langkah-langkah sebagai berikut;

a. Mengumpulkan bahan-bahan kompos yaitu TKKS bekas media jamur merang, kotoran sapi segar, kotoran ayam, serbuk sabut kelapa, arang sekam dikumpul.
b. Mencampur hahan-bahan dengan perbandingan volume masing-masing; 50:30:5:5:5 secara berurutan seperti pada butir a, dengan menggunakan cangkul atau garpu.
c. Membuat unggun atau tumpukan secara vertical setinggi 1-15 m. Dimensi horizontal ditentukan oleh banyaknya bahan kompos yang diolah.
d. Menyiram dengan air sampai basah merata pada tumpukan bahan setiap kira-kira 10-20 cm tinggi. Alas bawah dibuat porus agar aliran drainase cukup baik sehingga tidak ada air yang menggenang di dalam tumpukan bahan kompos.
e. Menutup tumpukan bahan kompos dengan terpal agar terlindung dari terik matahari dan air hujan.

f. Membuka tutup terpal, mengaduk bahan kompos dengan cangkul atau garpu, dan menyiram air dengan gembor sampai basah merata setiap minggu kemudian ditutup dengan terpal kembali. Setelah pengompos berusia 1 bulan, frekuensi pembalikan dan penyiraman bisa diturunkan menjadi 2-3 minggu sekali. Dan setelah berusia 2 bulan, kompos tidak perlu lagi dibalik dan disiram.
g. Membongkar dan memanen kompos setelah fermentasi berjalan 3 bulan. Kemudian kompos dihampar diatas terpal dan dijemur agar kadar air menurun sampai sekitar 15-20%.
h. Menggiling kompos dengan mesin chopper dan mengayaknya dengan ukuran saringan 5 mm. Penggilingan dan pengayakan kompos untuk memperkecil bongkahan kompos agar lebih lembut untuk dan membersihkan kompos dari kotoran kasar. Setelah itu, kompos halus dikemas dalam karung agar tertata rapih.
i. Mengukur kadar air kompos remah secara gravimetri.
j. Memasukkan pupuk kompos remah ke dalam mesin mixer 8 HP. Kemudian menambahkan air hingga kadar air kompos mencapai 30-35%. Pada saat yang bersamaan, pupuk mineral fosfat ditambahkan sebanyak 6% ke dalam kompos.
k. Melumat pupuk kompos remah menjadi adonan dengan kecepatan mixer sekitar 90 rpm selama kurang lebih 15 menit hingga adonan menjadi kenyal dan kalis.
l. Memasukkan adonan kompos ke dalam mesin extruder extruder (20 HP) untuk dicetak menjadi pellet dengan ukuran diameter 1 cm.
m. Pellet yang keluar dari cetakan ditampung dengan nampan. Dengan pemasangan pisau pemotong di depan lubang cetakan, maka panjang potongan pellet menjadi seragam 2-2,5 cm.
n. Penjemuran pellet pupuk kompos di bawah terik matahari selama 1-2 haris.
o. Pengukuran karakteristik pupuk kompos pellet dengan pengkayan fosfat.

Abstrak

PROSES PEMBUATAN PUPUK KOMPOS PELET DENGAN PENGKAYAAN FOSFAT

Invensi Proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat meliputi tahapan: penyiapan bahan-bahan TKKS bekas media jamur merang, kotoran sapi, kotoran ayam, serbuk sabut kelapa, arang sekam, dan limbah lumpur industry MSG dengan perbandingan 50:30:5:5:5:5. Bahan-bahan difermentasi sampai menjadi kompos matang kemudian dilumatkan dengan penambahan air 30-35% dan pupuk fosfat (16%) sebanyak 6%, sampai menjadi adonan yang kenyal. Adonan dicetak dengan menggunakan mesin extruder 20HP, dengan diameter 1 cm dan dipotong menjadi panjang 2cm. Pellet dikeringkan dengan cara dijemur di bawah terik matahari selama 1-2 hari. Pupuk kompos pellet kemudian disimpan di dalam karung plastik dan diukur karakteristiknya. Karakteristik pupuk kompos pellet yang dihasilkan yaitu: masa jenis curah 517,65 kg.m^{-3}, masa jenis pellet individual 1008,88 kg.m^{-3}, lama waktu direndam air sampai hancur 35,30 jam, higroskopisitas 0,35 % jam^{-1}, kekuatan kompresi 2,08 MPa, soliditas (daya tahan getaran) 45,17%, Durabilitas indeks 96.28%, pH 6,64, kadar P 4,19 %.

KESIMPULAN

Penelitian pembuatan pupuk kompos pellet telah menghasilkan luaran berupa:

1. Publikasi seminar internasional (sudah dilaksanakan
2. Publikasi jurnal internasional bereputasi, Q2 (dalam proses revisi)
3. Draf paten sederhana (proses usulan)

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Lampiran 1

Tabel 1. Luaran penelitian

No	Jenis luaran		Indikator Capaian		
			2021	2022	2023
1	Artikel ilmiah	Internasional	1		2
2	Seminar (Prosiding)	Nasional	1	2	2
3	Kekayaan Intelektual (KI)	Hak Cipta	1		
4	Teknologi Tepat Guna: pupuk pellet		1		
5	Buku ISSN				1

Tingkat Kesiapan Teknologi (TKT) 4 bidang pertanian yaitu: Komponen teknologi telah divalidasi dalam lingkungan laboratorium. Dengan indikator sebagai berikut:

1. Produsi pupuk kompos pellet telah dilakukan.
2. Karakteristik pupuk kompos pellet telah diukur
3. Uji pot pupuk kompos pellet pada beberapa tanaman telah dilakukan.
4. Uji plot dan sosialisasi pupuk kompos pellet di mitra petani sudah dilakukan
5. Analisis usaha pupuk kompos pellet sudah dibuat
6. Rancangan kemasan pupuk kompos pellet sudah ada
7. Perjanjian kerja sama dengan mitra usaha sudah dibuat
8. Pemasaran produk pupuk kompos pellet dilakukan

Bidang Fokus Riset: Pangan dan Pertanian
Tema: Teknologi ketahanan dan Kemandirian pangan

LAPORAN AKHIR (DRAF)
PEMBUATAN DAN PENGUJIAN PELLET PUPUK KOMPOS BERBAHAN CAMPURAN TKKS BEKAS MEDIA JAMUR MERANG

Skema Penelitian Terapan Dengan Nomor Kontrak:
3973/ UN26.21/PN/2021 Tanggal 14 Juli 2021

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UNIVERSITAS LAMPUNG
AGUSTUS 2021

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RINGKASAN

Tanaman membutuhkan nutrisi di sepanjang siklus hidupnya. Pupuk diberikan dalam rangka untuk memenuhi kebutuhan tanaman tersebut. Secara umum pupuk diberikan atau diaplikasikan di awal saat pengolahan lahan, kemudian sekitar 15-10 hari setelah tanam, dan saat menjelang berbungan atau sekitar umur 35-40 hari. Pengaplikasian pupuk tiga kali ini cukup merepotkan petani karena selain menambah tenaga juga menambah biaya. Selain itu, masalah rendahnya kadar hara NPK pada pupuk kompos membuat petani malas menggunakannya. Volume pupuk kompos yang besar juga membatasi penggunaannya. Di sisi lain, penambahan bahan-bahan organik ke lahan sangat diperlukan untuk mempertahankan keberlanjutan dalam jangka Panjang.

Tujuan jangka panjang penelitian adalah untuk menghasilkan pupuk kompos pellet dengan pengkayaan unsur NPK dan tiga karakteristik rapuh, sedang, dan keras. Ketiga jenis pupuk kompos pellet tersebut hanya perlu diaplikasian sekali di awal tanam. Pupuk pellet yang rapuh akan langsung hancur, yang sedang akan hancur sekitar 20 hari, dan yang keras akan hancur sekitar 35 hari setelah aplikasi. Dengan demikian petani lebih mudah mengaplikasikannya dan hanya perlu mengaplikasikan pupuk kompos pellet sekali saja di awal tanam dalam satu siklus tanam. Sehingga biaya dan tenaga dalam proses produksi tanaman dapat dihemat, yang akhir harga komoditas bisa lebih kompetitif. Keuntungan lain adalah berupa penurunan volume curah sehingga memudahkan dalam pengepakan, penyimpanan, dan transportasi.

Pupuk kompos dibuat dari campuran bahan-bahan seperti tandan kosong kelapa sawit bekas media jamur, kotoran sapi, kotoran ayam, serbuk sabut kelapa, arang sekam, lumpur limbah MSG yang tersedia di Daerah provinsi Lampung. Dengan metoda mengadonan dan pengepresan, campuran bahan-bahan kompos di pelletkan. Variasi penambahan air dan penambahan pupuk NPK pada waktu pengadonan dapat menghasilkan pupuk kompos pellet dengan tiga karakteristik tersebut di atas.

Pada Tahun I (2021), penelitian digunakan untuk mengkaji pengaruh kadar air atau penambahan air dan konsentrasi NPK pada waktu pengadonan terhadap karakteristik pupuk kompos pellet. Hasil Penelitian I menunjukkan bahwa kadar air dan pengayaan NPK berpengaruh nyata terhadap beberapa sifat fisik kompos pelet,

yaitu: berat jenis curah (517,65 – 587,60 $kg.m^{-3}$), berat jenis pelet (1059,55 – 1329,91 $kg.m^{-3}$), kuat tekan (2,08 - 7,78 $MN.m^{-2}$), soliditas (42,66 - 91,91%), PDI (62,11 - 97,68 %), waktu hancur (74,44 - 147,56 jam), dan pH (6,29-6,96). Semua pelet yang dihasilkan bersifat higroskopis. Ketahanan pelet sangat dipengaruhi oleh kadar air sedangkan pH dipengaruhi oleh kadar pengayaan NPK. Kandungan fosfor dan kalium dapat dipertahankan dengan menggunakan mesin pelletizer tipe auger, sementara nitrogen mengalami penurunan. Akhirnya, percobaan menunjukkan bahwa perlakuan kadar air 10-15% dan kadar NPK 3% (W1N2) menghasilkan pelet kompos dengan kelarutan terendah, sedangkan perlakuan kadar air 20-25% dan kadar NPK 0% (W2N1) dan perlakuan kadar air 30-35% dan kadar NPK 0% (W3N1) menghasilkan pelet kompos dengan kelarutan tertinggi.

Pada Tahun II (2022), penelitian digunakan untuk menguji pupuk kompos pellet dengan tanaman di pot. Pupuk kompos pellet diuji pada tanaman sayuran, padi, jagung, kedele. Rancangan pupuk pellet adalah pellet yang rapuh diperkaya dengan pupuk NPK, pellet yang sedang diperkaya dengan urea, dan pupuk pellet yang keras diperkaya dengan urea dan KCl. Pengujian dilakukan dengan cara membandingkan antara aplikasi pupuk pellet rancangan dengan aplikasi pupuk konvensional dengan dosis rekomendasi umumnya. Tingkat dan laju kehancuran pupuk kompos pelet di media tanam diamati. Selain itu parameter agronomis tanaman seperti pertumbuhan dan hasil panen juga didata.

Pada Tahun **III (2023)**, penelitian digunakan untuk menguji plot pupuk kompos pellet di lahan petani dan promosi. Pupuk kompos pellet hasil rancangan pada penelitian Tahun II diperkenalkan kepada petani mitra dan diuji di lahan. Kegiatan terdiri dari promosi dan sosialisasi produk pupuk kompos pellet kepada petani tanaman pangan, industri, dan hortikultura. Dari aspek usaha, produk pupuk kompos pelet dan kemasan dengan beberapa ukuran termasuk desainnya akan dikembangkan. Pupuk pellet juga dikembangkan ke arah spesifik jenis tanaman terutama untuk tanaman bunga. Masalah administrasi dan perjanjian usaha diselesaikan pada penelitian tahap Tahun III.

Kata Kunci: kompos, organik, pellet, pupuk sawit,

DAFTAR ISI

LATAR BELAKANG

Pemanfaatan tandan kosong kelapa sawit (TKKS) untuk media tumbuh budidaya jamur merang dapat menambah keuntungan, dibandingkan dengan pemanfaatan langsung lainnya semisal dikomposkan langsung [1, 2, 3, 4], sebagai sumber energi [5, 6], maupun sebagai mulsa [7]. Satu ton TKKS kering bisa menghasilkan jamur merang minimal seberat 70 kg [8]. Jika harga jamur merang segar Rp 40.000,- per kg, maka panenan jamur merang tersebut setara dengan pendapatan Rp 2.800.000,- dalam satu silkus. TKKS bekas media jamur selanjutnya juga sangat bagus untuk dimanfaatkan sebagai pupuk kompos [9, 10, 11], dan bisa menghasilkan pendapatan yang tidak sedikit. Hasil penelitian menunjukkan bahwa 1 kg pupuk kompos (bahan TKKS bekas media jamur merang dicampur dengan limbah pertanian yang lain) menghasilkan sayuran selada merah organik sebanyak 207 g [12]. Jika harga sayuran selada merah organik berharga Rp 60.000,- per kg, maka pemanfaatan 1 ton pupuk kompos tersebut setara dengan pendapatan sebesar Rp 12,4 juta lebih dalam satu siklus.

Namun demikin, seperti limbah pertanian umumnya, permasalahan pemanfaatan pupuk organik dari limbah TKKS secara langsung maupun TKKS bekas media jamur juga terletak pada volumenya yang bersifat *bulky* [13]. Pembuatan pellet pupuk organik bertujuan untuk menurunkan volume, sehingga memudahkan dalam pengemasan, transportasi, penyimpanan, dan aplikasinya. Selain itu, berdasarkan data penelitian-penelitian sebelumnya, pupuk organik yang dihasilkan mengandung hara yang cukup rendah [14, 15, 16], sehingga aplikasinya masih perlu dikombinasikan dengan pupuk anorganik. Pemberian pupuk kompos dan pupuk anorganik dalam waktu yang tidak bersamaan menambah waktu dan menambah tenaga kerja.

Dalam penelitian ini, akan dicoba juga membuat formula pupuk pellet campuran kompos TKKS bekas jamur, limbah pertani yang lain, dan pupuk anorganik yang bisa diaplikasikan sekali saja di awal tananam. Tingkat densitas pellet dibuat bertingkat: rendah, sedang, dan tinggi. Pellet dengan densitas rendah akan mudah hancur ketika terkena air, yang densitas sedang tidak langsung hacur, dan yang densitas tinggi paling akhir hancur ketika terkena air. Pembedaan densitas pellet bertujuan untuk memfasilitasi pengguna yang membutuhkan aplikasi pupuk tidak hanya sekali dalam

satu siklus tanam. Ketika pellet dengan ketiga jenis densitas tersebut diberikan di awal tanam, maka pellet yang densitas rendah akan langsung hancur saat tanam, yang densitas sedang akan hancur pada saat tanaman berbunga, dan yang densitas tinggi akan hancur pada saat berbuah. Jadi substansi dari pembedaan densitas pellet adalah *rapid*, *moderate*, dan *slow release*. Dengan pembedaan densitas tersebut, maka nutrisi dapat diberikan secara efektif (tepat waktu dan dosis), dan efisien dalam penggunaan tenaga karena hanya sekali aplikasi. Penelitian pembuatan kompos pellet sudah banyak dilakukan, tetapi pupuk pellet dengan densitas yang berbeda-beda belum diteliti.

Penelitian dilakukan dalam tiga tahun. Tahun I digunakan untuk membuat pupuk pellet campuran TKKS bekas media jamur, limbah pertanian yang lain, dan mempelajari pengaruh kadar air dan penambahan NPK terhadap karakteristik pupuk kompos pelet. Tahun II, hasil pellet terbaik pada Tahun I diuji agronomis pada pot (*pot experiment*). Tahun III, penelitian untuk menguji plot pupuk pellet pada tanaman hortikultura dan tanaman pangan bersama petani mitra.

TINJAUAN PUSTAKA

Sejak Tahun 2011, Tim Unila mengembangkan pupuk organik berbasis sumberdaya lokal, yang dinamakan ”Organonitrofos” [14]. Pupuk Organonitrofos granul dibuat dari bahan campuran kotoran sapi segar (disediakann oleh PT Juang Jaya, Gambar 1a) dan batuan fosfat (dari tambang rakyat Selagai Lingga) yang tersedia secara lokal dan diperkaya dengan penambahan mikroba N-*fixer* dan P-*solubilizer* [17]. Pupuk organik tersebut yang mengandung C-organik = 13,91%, N-organik=2,30%, P-larut=1,64%, diproduksi oleh CV Organik Super Agro (CV OSA, Gambar 1b), Tanjung Bintang Lampung Selatan. Pupuk organik granul tersebut banyak digunakan untuk tanaman pangan dan perkebunan. Untuk tanaman berbuah, pupuk organik granul tersebut masih perlu dikombinasi kan dengan pupuk anorganik.

a b

Gambar 1. a. Bahan baku kotoran sapi segar di PT Juang Jaya, b. Proses produksi pupuk Organonitrofos granul di CV Organik Super Agro

Pada Tahun 2013, pupuk Organonitrofos remah dikembangkan untuk diproduksi (Gambar 2a) dan digunakan oleh kelompok tani. Bahan baku dikembangkan lagi dengan menggunakan bahan-bahan limbah yang tersedia secara lokal, yaitu: kotoran sapi segar (PT Juang Jaya), limbah indusri MSG (dari PT Kirin Indonesia, Lampung Timur), serbuk sabut kelapa (dari PT Chrezz, Lampung Selatan), limbah kotoran ayam (dari peternak ayam di sekitar), dan arang sekam (dari perusahaan tahu tempe rumahan). Pupuk organik remah tersebut banyak digunakan oleh petani hortikultura dan tanaman pangan (Gambar 2b). Untuk tanaman berbuah, pupuk organik remah ini juga masih perlu dikombinasikan dengan pupuk anorganik. Komposisi NPK-Org = 45-36-120-1,000 kg ha^{-1} telah diketahui menjadi komposisi terbaik [15]. Pada tahun 2015, Organonitrofos diperkaya dengan penambahan *biochar* dan diberi nama

”Organonitrofos Plus” [18]. Data menunjukkan bahwa dengan penambahan *biochar* 5000 kg ha^{-1}, aktivitas mikroba tanah pada tanaman jagung manis meningkat.

a b

Gambar 2. a. Produksi pupuk Organonitrofos remah dikelompok tani, b. Deplot tanaman cabai

Tandan kosong kelapa sawit (TKKS) bekas media jamur merang berpotensi untuk bahan campuran pupuk Organonitrofos. Hasil penelitian menunjukkan bahwa pupuk Organonitrofos dari bahan campuran TKKS bekas media jamur merang 50% dan kotoran sapi, kotoran ayam, serbuk sabut kelapa, limbah industri MSG, dan arang sekam (50%) mengandung C organik = 16,11%, N = 1,26%, P = 3,04%, K= 0,42% [16]. Untuk tanaman sayuran daun, pupuk Organonitrofos ini berkinerja cukup bagus [12]. Namun untuk tanaman pangan, pupuk Organonitrofos ini juga masih perlu dikombinasikan dengan pupuk anorganik.

Penggunaan pupuk organik Organonitrofos dan kemudian menambahkan pupuk anorganik untuk tanaman pangan dan tanaman hortikultura yang berbuah, dianggap cukup merepotkan petani, karena harus menambah tenaga dan biaya. Jika pupuk organik dan pupuk anorganik bisa digabungkan dan diaplikasikan dalam waktu yang bersama-sama di awal atau sebelum tanam, maka hal ini bisa menghemat waktu dan tenaga yang tidak sedikit. Fortifikasi atau penambahan nutrisi pupuk kompos dengan pupuk anorganik pernah diteliti oleh [19].

Penelitian mesin pupuk pellet dengan bahan organik sebagai bahan baku sudah banyak dilakukan. Pelletisasi bertujuan untuk meningkatkan densitas sehingga memudahkan penanganan, penyimpanan, transportasi, dan aplikasi. Sedikit berbeda dengan pellet pakan [20], pellet pupuk lebih mirip dengan pellet/briket bahan bakar [21], yang membutuhkan kemampatan atau densitas yang tinggi. Lawong et al. [22] membuat pellet kompos dengan densitas 745.40 kg m^{-3}, dan Imatong and Bagtang [19] juga melaporkan densitas pellet kompos yang tidak jauh berbeda yaitu 889.92

kg.m^{-3}. Demikian juga, Mieldazys et al. [23] mendapatkan densitas pellet kompos diameter 6 mm sebesar 789kg.m^{-3}. Namun Zafari and Kianmehr [24] berhasil membuat pellet kompos dengan densitas lebih besar dari 1000 kg m^{-3}, dengan kadar air bahan baku 40%, kecepatan piston 2 mm/s, tebal die 12 mm, dan diameter die 0,9 mm.

Untuk mendapatkan konsistensi pellet, Ofori-Amanfo et al. [25] menggunakan tapioka dan tanah liat sebagai perekat pellet kompos. Nikiema et al [26]. juga melaporkan pembuatan pellet excreta dengan bahan perekat dari tapioka. Sementara, Hettiarachchi [27] menyatakan bahwa dengan tekanan dan kadar air bahan yang tepat, pellet kompos dapat diproduksi tanpa perekat. Daniyan et al [28] melaporkan bahwa pellet kompos tanpa bahan perekat tidak hancur dalam uji rendam air selama satu bulan. Dalam uji yang lain, dengan penambahan tepung beras 3%, pellet kompos hancur dalam 3 hari.

Kekerasan atau kemampatan pupuk pellet ditentukan pada waktu diproduksi. Zafari and Kianmehr [29] mendapatkan pellet kompos dengan densitas tertinggi ketika menggunakan kadar air bahan baku 40%. Pocius et al [30] menyatakan kekuatan pupuk pellet tergantung dari parameter rheologi dan geometri. Pupuk pellet dengan densitas rendah akan mudah hancur ketika terkena air, dan mudah melarutkan nutrisi anorganik yang dicampurkan di dalam pupuk pellet tersebut. Karakteristik pupuk seperti ini tentu sangat cocok untuk diaplikasikan di awal atau sebelum tanam. Biasanya, beberapa tanaman pangan membutuhkan pemupukan lebih dari sekali, minimal dua kali (saat tanam dan saat berbunga). Beberapa tanaman hortikultura seperti cabai bahkan memerlukan pemupukan berkali-kali. Kebutuhan ini bisa difasilitasi oleh aplikasi pupuk pellet dengan beberapa tingkat densitas. Pupuk pellet dengan kemampatan tinggi akan sulit hancur ketika terkena air sehingga lebih lambat melarutkan nutrisi anorganik yang dicampurkan di dalamnya. Jika pupuk pellet dengan densitas rendah - tinggi (seusai proporsi) diberikan sekali saja di awal tanam, maka kebutuhan tanaman akan nutrisi akan terpenuhi sesuai tahapan pertumbuhannya, karena pupuk pellet akan hancur dan nutrisi larut secara berurutan sesuai tingkat densitasnya. Dengan teknik seperti ini, tenaga dan biaya aplikasi pupuk bisa lebih efisien dan nutrisi lebih efektif karena tersedia tepat waktu dan tepat dosis. Hettiarachchi [27] menyatakan bahwa pemilihan bahan perekat yang tepat dapat mengontrol waktu kehancuran pellet sehingga pupuk pellet dapat didesain untuk melepaskan nutrisi dengan waktu dan dosis susauai dengan kebutuhan tanaman.

Berdasarkan hasil-hasil penelitian yang ada dan uraian tersebut di atas, peta jalan penelitian pembuatan pupuk pellet campuran TKKS bekas media jamur dengan bahan-bahan kompos yang lain, dan juga dengan penambahan pupuk anorganik, disusun seperti pada Gambar 3. Proses pembuatan pupuk pellet berbeda dengan pupuk granul yang membutuhkan bahan tepung yang halus bebas serabut. Mesin pupuk pellet bisa menerima bahan-bahan serbuk kasar dan berserabut. Bahan TKKS tidak akan menjadi tepung halus ketika dihancurkan, tetapi akan banyak mengandung serat-serat kecil tidak hancur. Pemilihan bentuk pellet salah satunya didasarkan pada kenyataan tersebut. Tahun I mempelajari sifat-sifat fisik dan kimia pellet. Tahun II menguji agronomis pupuk pellet di pot dengan beberapa tanaman di greenhouse. Tahun III menguji dan sosialisasi pupuk pellet di petani mitra dengan beberapa tanaman sayuran dan tanaman pangan.

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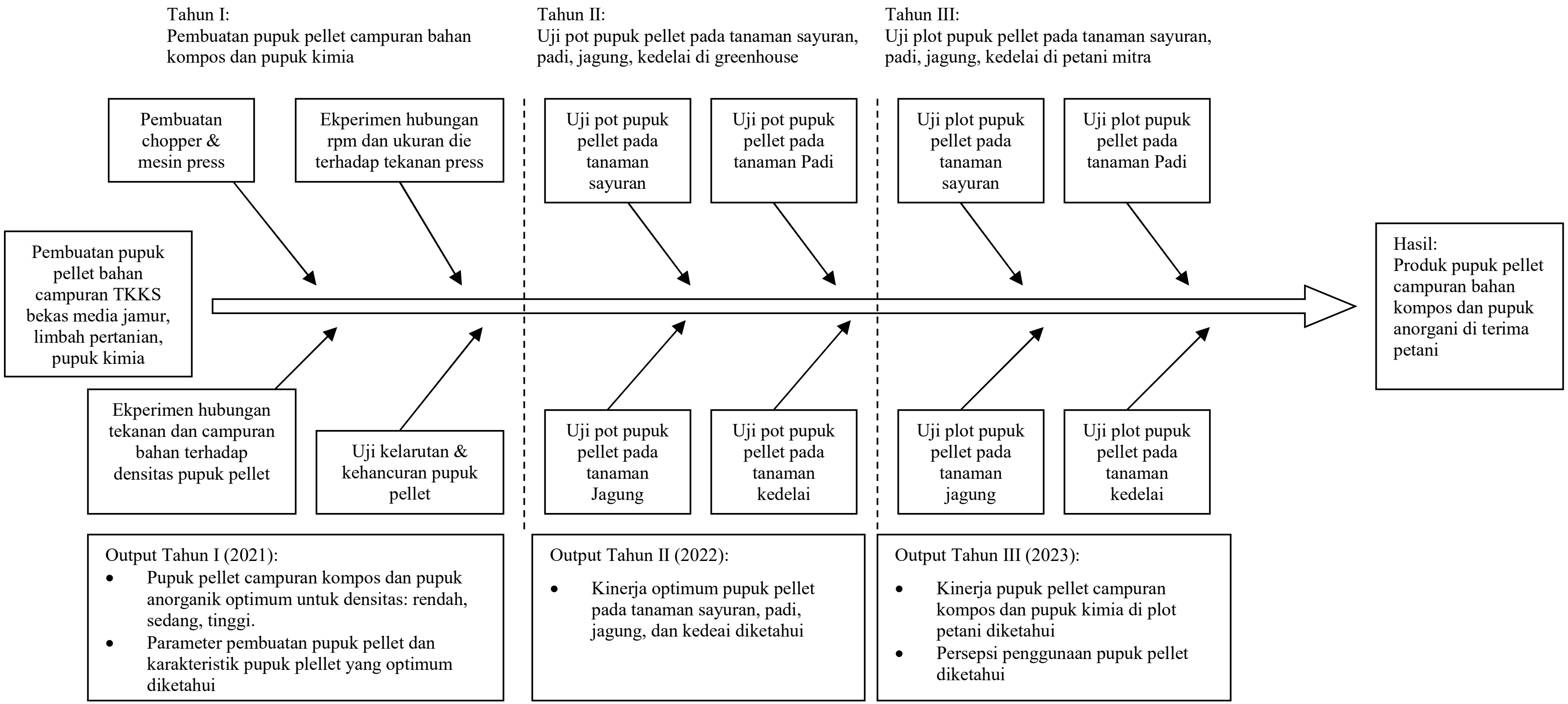


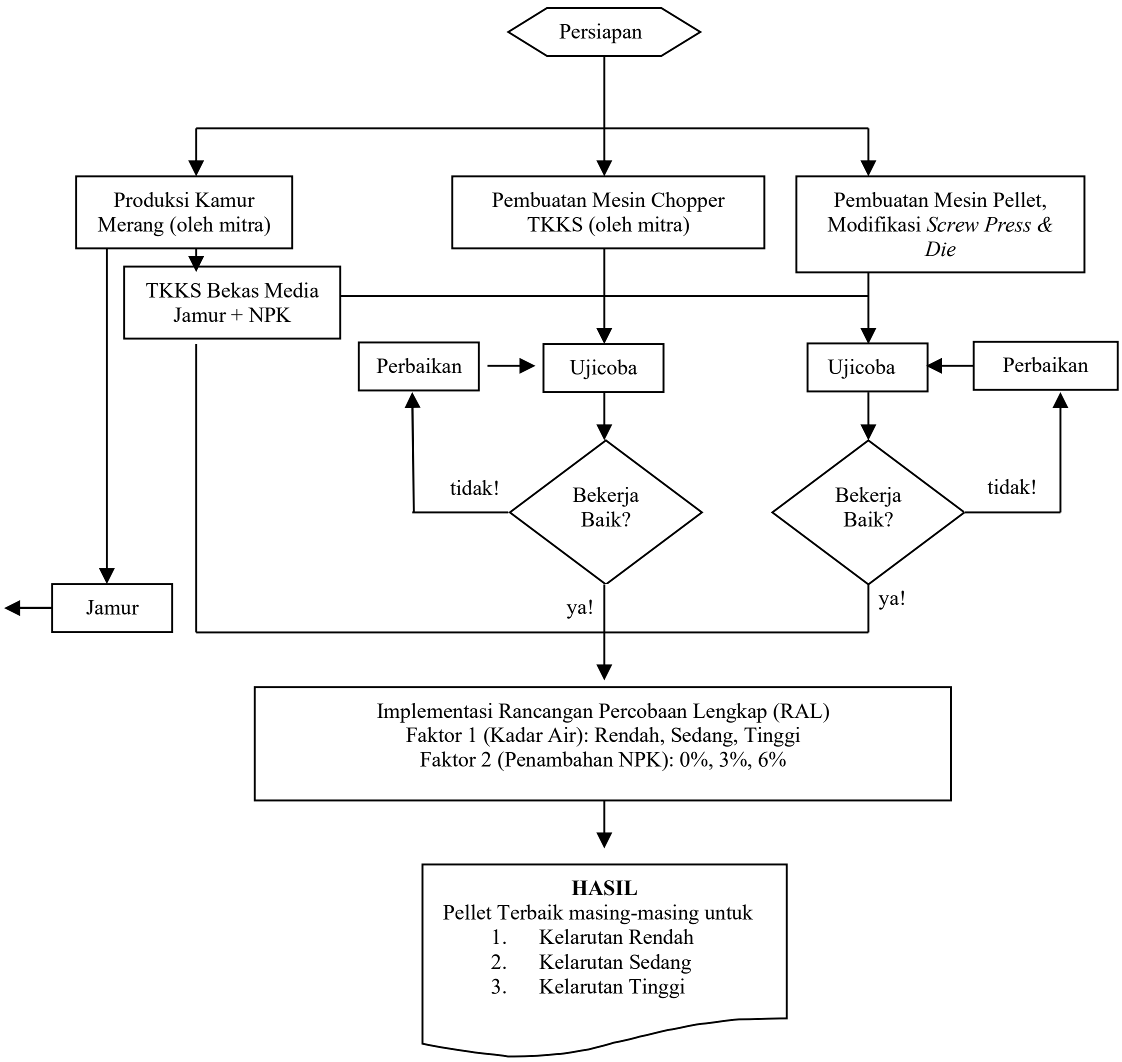
Gambar 3. Peta jalan penelitian pembuatan pupuk pellet

METODE

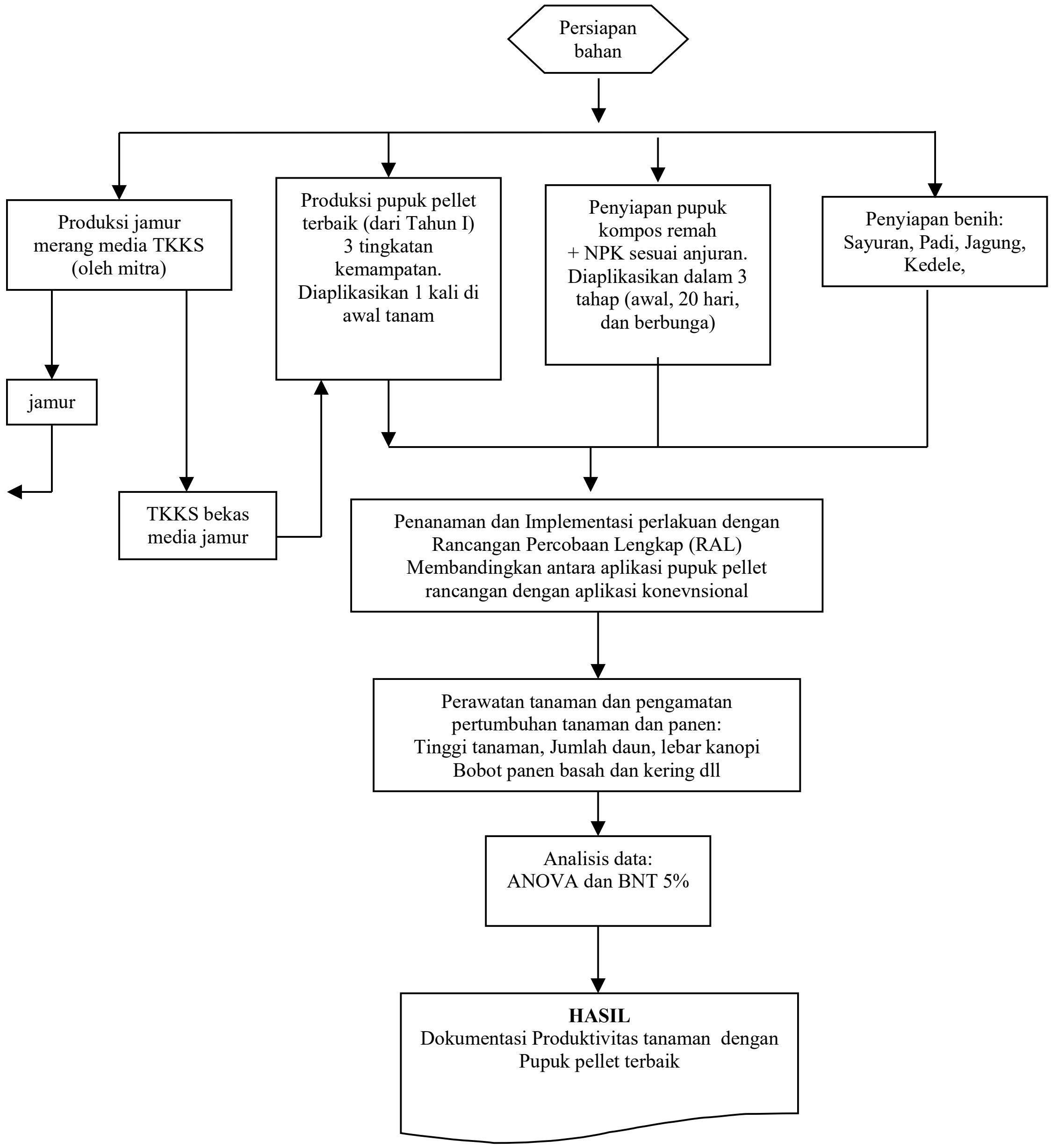
Penelitian dilakukan dalam tiga tahun. Penelitian Tahun I dimulai dengan menyiapkan TKKS bekas jamur (dari mitra produsen jamur), membuat mesin chopper TKKS (oleh bengkel mitra), mesin *screw press* pupuk pellet (oleh bengkel mitra), mesin pelumat/pengadon, dan memproduksi dan menguji pupuk pellet (oleh Tim Unila). Bengkel mitra sudah sangat berpengalaman dalam produksi alsintan, namun peneliti perlu melakukan modifikasi power motor, bentuk *screw press* dan ukuran *die.* Kajian digunakan untuk mempelajari pengaruh kadar air and penambahan NPK terhadap karakteristik pellet yang dihasilkan. Pada tahap ini, eksperimen menggunakan rancangan acak lengkap (RAL) dengan 2 faktor yang disusun secara faktorial. Fator 1 (kadar air) terdiri dari 3 taraf; kadar air rendah 10-15% (K1), kadar air sedang 20-25% (K2), dan kadar air tinggi 30-35% (K3). Faktor 2 (konsentrai penambahan NPK) terdiri dari 3 taraf: kadar NPK 0% (N1), kdar NPK 3% (N2), kadar NPK 6% (N3). Selanjutnya data karekteristik pupuk pellet diuji dengan ANOVA dan dilanjutkan dengan BNT 0,05%. Parameter yang diamati mencakup: densitas curah pellet, densitas pellet, kekuatan tekan, soliditas, pellet durability index (PDI), hygroskopisitas, pH, dan kandungan NPK. Diagram alir penelitian Tahun I disajikan pada Gambar 4.

Penelitian Tahun II digunakan untuk melakukan uji pot pupuk pellet yang diaplikasikan ke tanaman. Kinerja pupuk pellet dibandingkan dengan kinerja metoda pemupukan secara konvensional pada tanaman. Uji pot di dalam *greenhouse* dengan menggunakan 4 tanaman yaitu sayuran, jagung, kedele, padi. Faktor 1 adalah tipe pupuk: pellet (P) dan remah (R). Tahapan pelaksanaan penelitian Tahun II disajikan pada Gambar 5.

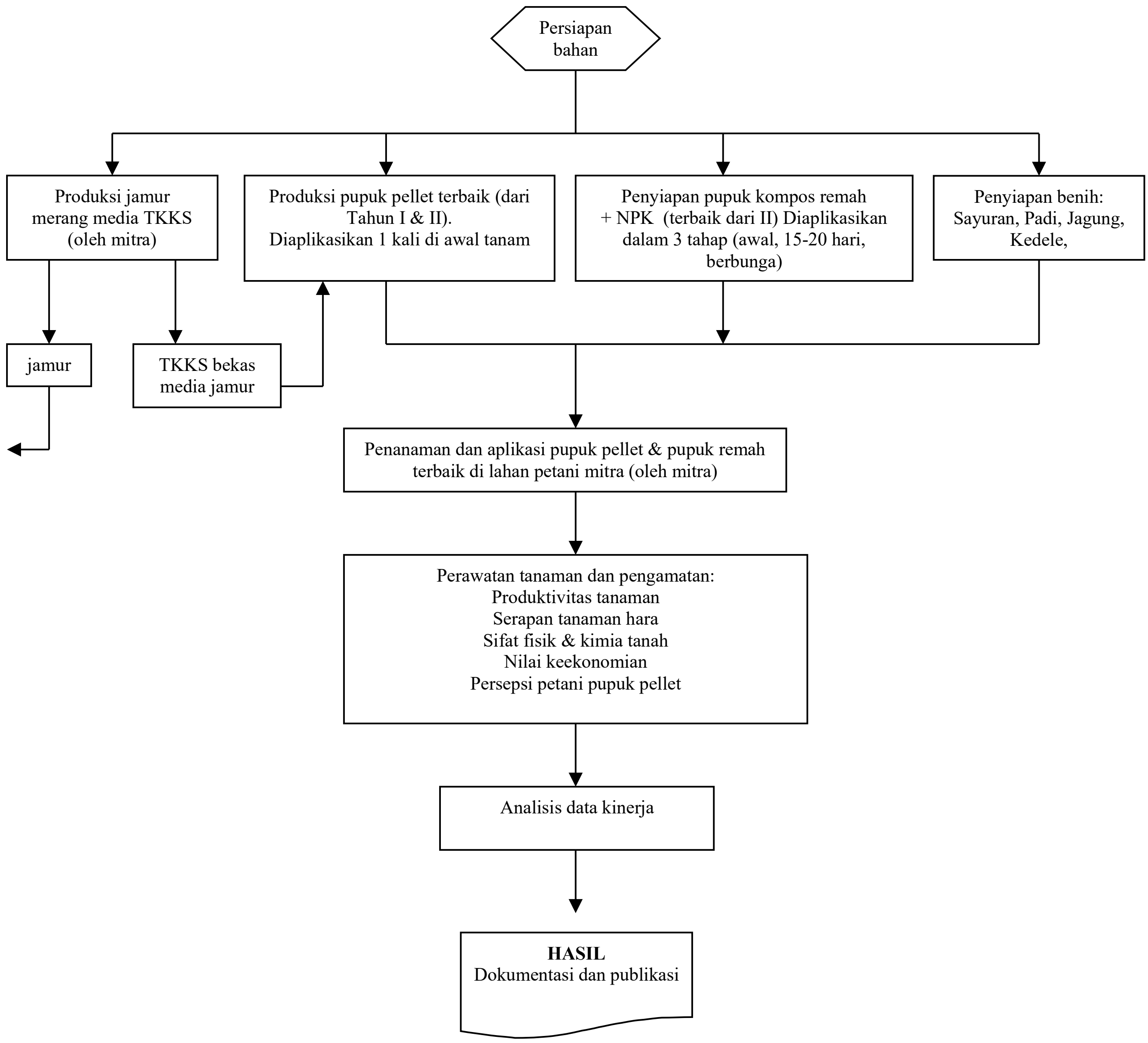
Penelitian Tahun III digunakan untuk sosialisasi pupuk kompos pellet pada petani mitra dengan tanaman sayuran, jagung, kedele, padi. Persepsi petani mitra dan nilai keekonomian penggunaan pupuk pellet akan di kaji. Tahapan penelitian pada Tahun 3 disajikan pada Gambar 6.



Gambar 4. Bagan alir pelaksanaan penelitian Tahun I: produksi jamur merang, pembuatan mesin chopper, pembuatan mesin pres dan modifikasi *screw press* dan *die*, eksperimen pengaruh kadar air dan penambahan NPK terhadap fisik dan kualitas pupuk pllet



Gambar 5. Bagan alir pelaksanaan penelitian Tahun II: Ujian pot pupuk pellet di greenhouse



Gambar 6. Bagan alir pelaksanaan penelitian Tahun III: Uji plot pupuk pellet di petani mitra

HASIL DAN PEMBAHASAN

Hasil Seminar

1. Link seminar: http://environment.triacon.org/gcal.html
2. Link bukti korespondensi dan bahan seminar: https://drive.google.com/drive/folders/1gfnwVIWSnLQ0U9qPBIJg34N78-TcTi9C

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EFFECT OF WATER CONTENT AND NPK ENRICHMENT ON SOME PROPERTIES OF A PELLETIZED COMPOST FERTILIZER

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ABSTRACT

Practical methods of fertilizer applications to enhance farm productivity with sustainability concern and least environmental risk have been getting a lot of attention. This research study aimed to evaluate the effect of mill water content and NPK enrichment on some properties of pelletized compost fertilizer. Three equal piles of compost were sprayed with different levels of liquid NPK, namely: 0% (N0), 3% (N1), and 6% (N2) on the basis of compost dry weight. Each of the three different NPK level piles was divided into other three piles, each of which was subjected to be sprayed with additional water in order to meet three different levels of water contents, namely: 10-15% (W1), 20-25% (W2), and 30-35% (W3) which were required in the experiment. Total piles of nine treatment combinations between water content and NPK enriched compost levels were pelletized and dried under the sun. After the sun drying, each of the nine pellet piles was sampled with three replicates and tested for physical and chemical properties namely: bulk and pellet densities, hygroscopicity, compressive strength, solidity, pellet durability index (PDI), disintegration time, pH, and chemical content. By doing these steps, the requirement of completely randomized design with factorial arrangement was considerably fulfilled. The data sets were analyzed by using analysis of variance and followed by LSD multiple comparation. The results showed that water content and NPK enrichment significantly affected some physical properties of compost pellets, namely: the bulk density (517.65 to 587.60 $kg.m^{-3}$), pellet density (1059.55 to 1329.91 $kg.m^{-3}$), compressive strength (2.08 to 7.78 $MN.m^{-2}$), solidity (42.66 to 91.91%), PDI (62.11 to 97.68 %), disintegration time (74.44 to 147.56 hours), and acidity (6.29-6.96). All produced pellets were hygroscopic. Pellets durability was much affected by water content levels whilst pH was affected by NPK enrichment levels. Phosphorus and potassium contents were manageable by using auger-type pelletizer, whilst nitrogen loss from the pelletizing process was noticeable. At last, the experiment revealed that W1N2 treatment produced the lowest dissoluble compost pellet, while the W2N1 and W3N1 produced the highest dissoluble compost pellets.

Keywords: compost, enrichment, fortification, pellet, slow release.

INTRODUCTION

The continuous use of chemical fertilizers in modern agriculture has exposed many negative effects on the environment. Soil becomes increasingly poor due to leaching process (Hartemink, 2007; Rahmaliza, 2014). The population of soil microorganisms is also suppressed because of a lack of organic matter (Miransari, 2013). The lack of organic matter also causes the soil to become hard and sticky that its water holding capacity diminishes (FAO, 2005), and plant roots become difficult to develop (Juarsah et al., 2008). In addition to being easily eroded, fertilizer and pesticide residues are easily carried away by runoff, causing pollution downstream (Las et al., 2006).

The direct loss experienced by farmers is the use of higher doses of chemical fertilizers while productivity does not get improved.

The supply of organic matter on farm land can be done by giving compost fertilizer. In general, compost fertilizers are made from agricultural residues or wastes. One advantage of compost fertilizer is its capability to improve physical properties of soil, promoting the growth of plant roots, and stimulating the growth of microorganisms population of which becomes more dynamic (Pertiwi and Lululangi, 2019). The mineralization process becomes faster and nutrient enrichment of the soil is enhanced. According to Dreval et al. (2020) organic matter can significantly improve soil nitrogen nutrient if compared to the application of nitrogen fertilizers. However, organic or compost fertilizers have a number of challenges. One disadvantage of compost fertilizers is that the volume is huge, that transportation becomes the primary hindrance (Simanungkalit, 2006). Slower plant response to absorb the nutrients is also another problem (Hasbianto, 2013). Low nutrient content of compost fertilizer is other reason why farmers are reluctant to use compost fertilizers.

Application of compost fertilizer coupled with chemical fertilizers is common practices among farmers to enhance production. Belay et al. (2001) stated that the response of plants to the application of inorganic fertilizers is strongly influenced by the presence of organic matter in the soil. However, the application of chemical fertilizers and organic fertilizers at the same time raises other problems such as the increasing energy and application costs. Other effort that has been made is the application of fortification technology (Marwanto et al., 2019). Fortification is known as a nutrient enrichment of compost fertilizers, usually with the addition of NPK mineral fertilizers (Ndung'u et al., 2009; Mieldazys et.al., 2017). Pelletizing compost fertilizer is another method to make it easier in application of the compost fertilizer. Compost pellets is supposed to be more convenient in handling, packaging, storage, and transportation (Lubis et al., 2016). Compost pellets can reduce volume up to 50-80% in addition to reducing dust in handling (Hara, 2001). Therefore, pelletizing coupled with NPK enrichment of compost fertilizer may potentially become the problem solution of compost application.

The manufacture of compost fertilizer pellets is done by applying high pressure so that the compost fertilizer material becomes denser and the volume becomes smaller (Mieldazys et al., 2017). The characteristics of the fortified compost pellet produced are absolutely influenced by some factors such as pressure levels (Tumuluru, 2018), particle size of the material, moisture content of the material, and the level of added NPK mineral fertilizer. Mieldazys et al. (2017) makes compost pellets from cattle manure with moisture content of 28%, and results in bulk density of 584±16.8 kg.m^{-3} and pellet density of 789±40.4 kg.m^{-3}. The density of pellets depends on the pressure applied during pelletizing process. This study aims to determine the effect of mill water content and NPK enrichment on some properties of compost pellets from formulated powder compost.

MATERIALS AND METHODS

Raw material preparation.

The formulated compost used in this research was made from raw materials such as: spent mushroom substrate (used empty fruit bunch or EFB), fresh cattle manure, chicken litter, coconut peat, rice husk ash, and MSG industry sludge. The used EFB was collected from research facility of the University of Lampung, Indonesia (Triyono et al. 2019) whilst the other materials were gathered from other available local resources. Some chemical properties of the formulated powder compost were C=16.11±0.59%, N=1.26±0.59%, P=3.04±0.19%, and K=0.42±0.04%.

The formulated compost was ground by using a 20 hp machine, and screened by using a 0,3 cm screen size. The main purpose of the grinding and screening were to homogenize the aggregate sizes and remove rough impurities. The formulated compost was split into 3 piles (about 36 kg each) and sprayed with three different levels of liquid NPK fertilizer, namely: 0% (N0), 3% (N1), and 6% (N2) based on the compost dry weight. Further, each of the three different NPK level piles was again split into three piles, and each of which was sprayed with water in order to get three different levels of water contents, namely: 10-15% (W1), 20-25% (W2), and 30-35% (W3). So, there were 9 treatment combinations between three levels of NPK enrichment and three levels of water content. The nine treatment combinations of compost were kept in air tight plastic bags and ready to be pelletized.

Pellet production

Each of the 9 groups of moisturized compost was separately milled to form a dough, then pelletized using a 20 hp screw pelletizer. The outcoming pellets from 1 cm diameter dies were casted on a flat tray on which the pellets were cut into 2 cm long. On the trays, the pellets were dried under the sun for two or three days to get storable moisture contents. Afterall, each of the 9 groups of dried pellets was stored in a air tight plastic bag, and labeled.

Experiment design and data analysis

Three replicates were randomly sampled from each of the 9 air tight plastic bags of the pellets with the 9 treatment combinations. By doing these procedures, requirement of completely randomized design (CRD) with factorial arrangement was considerably fulfilled. So, the experiment included two factors: three NPK enrichment levels (N0, N1, N2) and three water contents (W1, W2, W3) with three replicates, making a total of 27 experimental units. This experimental design was implemented to every testing and measurement. Some physical and chemical properties of the pellets included in the testing and measurement were bulk and pellets densities, hygroscopicity, compressive strength, solidity, Pellet Durability Index (PDI), disintegration time, pH, and chemical contents. The data sets were analyzed by using analysis of variance and followed by LSD multiple comparation, using Statistical Analysis System (SAS) software.

Bulk density of pellets was measured by weighing of 500 ml pellet bulk. Pellet density was measured by measuring the diameter and length of individual pellets. Hygroscopicity was determined by placing samples in a room at controlled temperature and humidity of 26-28^{o}C and ±80%, respectively. Compressive strength was determined by placing (vertical axis position) an individual pellet on a digital scale and compressed from the top with a hydraulic press till broken. The axial load reading (kg) on the display was recorded by using video camera and the maximum load could be easily read from the video, then the load was converted to compressive strength (MPa). The solidity of pellets was tested by dropping a 200-g metal weight from 40 cm height (equivalent to 800 Joule energy) to a standing pellet, then largest surviving pellet mass was weighted and read as pellet solidity in percentages. Pellet Durability Index (PDI) was measured by using a modified method because of absence of standard apparatus. An individual pellet was inserted into a transparent plastic jar, and shaked by a rotating 5.5-cm displacement elbow at $\pm 20Hz$ for 10 minutes. The largest surviving pellet mass was weighted and read as pellet durability index in percentages. Complete disintegration time of individual pellet was determined by emerging a pellet in a jar of water, and the time till complete disintegration was recorded. Acidity (pH) and chemical contents were determined by using laboratory standard methods.

RESULTS AND DISCUSSIONS

Bulk density of compost pellets

Bulk densities of produced biofertilizer pellets were tested and the Analysis of Variance showed that the interaction effect of water contents and NPK enrichment on both of the bulk and pellet densities were significant at the level of α=0.05. The results of LSD comparison were shown on Figure 1.

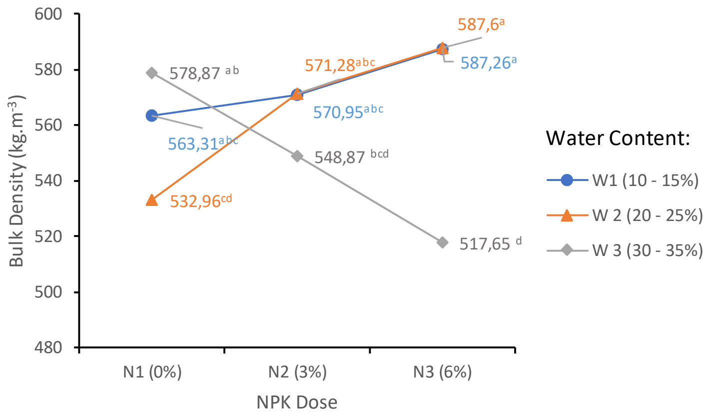

Figure 1. The interaction effect of water contents and NPK Doses on the bulk densities of compost pellet

The bulk density of compost pellets ranged between 517,65-587.60 $kg.m^{-3}$, but tendency to change with water contents and NPK doses were noticeable. With the increasing NPK levels, the bulk density of compost pellet remained constant at low water content W1(10 – 15%), tended to increase at moderate water content W2((20 – 25%), and tended to decrease at high water content W3(30 – 35%). Conversely, with the increasing water content, at no NPK enrichment N1(0%) the bulk density was the lowest at moderate water content W1(20 – 25%), remained constant at moderate NPK enrichment N1(3%), and tended to decrease at high NPK dose N3(6%). So, this finding suggested that water content of pellet mill may not more than ŧ 25% otherwise the bulk density of the pellet will be even lower. Most of the treatment combinations, however, showed that W1N1, W3N1, W1N2, W2N2, W3N2, W1N3, and W2N3, statistically produced highest bulk densities with average of 575,64 $kg.m^{-3}$.

The average of the highest bulk densities in this research was within the range of 312 to 701 $kg.m^{-3}$ which was reported by Romano et.al. (2014). Mieldazys et al. (2017) also reported their finding of pellet bulk density of 584±16.8 $kg.m^{-3}$. From powder manure raw material bulk density of 556.4± 5.81 $kg\cdot m^{-3}$ Mieldazys et al. (2017) gained little increase of the bulk density of pellets. Hettiarachchi et.al. (2019) also reported that the increasing

bulk densities from 300-400 kg/m^{-3} of powder compost to 825-870 kg.m^{-3} of compos pellets. In our research, the bulk density of powder compost (before pelletized) was noted about 338 kg.m^{-3}, so the bulk density (after pelletized) increased about 70,33%. In spite of water content variations, other factors especially interstitial spaces (among the individual pellets in a pile) affected the bulk density of pellets. The interstitial space was affected by the size of the pellets as bigger diameters and longer the pellets the larger the interstitial space among the individual pellets. That was indicated in the data reported by Romano et.al. (2014). In our research study, the diameter and length of the pellets were 10 mm and 20 mm respectively. Whereas, Romano et.al. (2014) and Mieldazys et al. (2017) used diameter of about 5 mm and length of about 13 mm.

One important objective of the pelletized compost fertilizer is to get higher bulk density so that this make it more convenient in handling, storage, and transportation. This research study and others succeed to reveal the improved bulk density of pelletized compost. Other advantages in making use of compos pellets may be achieved in practical and easier applications, both manual or mechanized. The use of compost pellets was also environmentally friendly since its application does not generate dust. When dried and stored properly, the compost pellets would not moldy and could be stored in a long period of time.

Pellet density of compost pellets

Pellet density of compost pellets referred to the compactness of a single individual compost pellets. Analysis of Variance showed that interaction effect between water content of mill and NPK enrichment levels was significant at $\alpha = 0.05$. LDS multiple comparison analysis is shown on Figure 2. Just like the bulk density figure, the pellet density increased at low and moderate compost water content (W1 and W2), and tended to decrease at high water content (W3). Statistically the best treatment combinations (resulting highest particle densities) were found on W2N1, W3N1, W1N2, W2N2, W3N2, W1N3, W2N3, and the average of the highest pellet density was 1225.3 kg.m^{-3}. The importance of pellet density of compost pellets corresponds to the dissolubility of the pellet fertilizers and the rates of nutrient releases. The dissolubility of the pellets was supposed to increase with decreasing pellet density. Low pellet density of the compost pellets may be required for fast release fertilizers, while high pellet density of the compost pellets may be more appropriate for the purpose of slow release fertilizers.

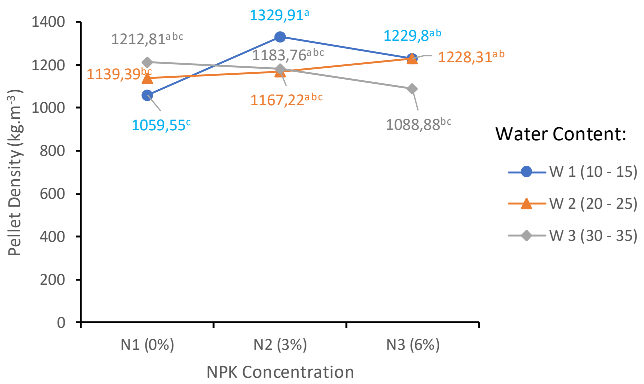

Figure 2. The interaction effect of water contents and NPK Doses on the pellet densities of compost pellets

The average of highest pellet densities found in this research study was quite high as compared to results of other researches. Mieldazys et al., (2017) reported and found that compost pellet density was 789±40.4 kg.m^{-3} which was much lower than found in this research. The particle density in this research was corroborated by what Zafaria et al. (2014) reported. Zafaria et al. (2014) found the particle density of compost pellets was about 1200 kg/m^{-3}. Mani et al, (2006) states that particle density is affected by compression, particle sizes of raw material, water contents, and chemical content especially for protein since protein melts easily at high temperature during pelletizing. In this research, effect of mill water content and NPK enrichment levels was visible, as at low and moderate water content (10-25%) the particle density tended to increase and high particle density could be achieved. In contrast, at high mill water content (30-35%) and high level of NPK enrichment, the particle density tended to be lower. But overall, the particle densities found in this research were considerably high (ranging from 1059.55 to 1329.91 kg.m^{-3}).

If pellets with low particle densities is desired (which is likely to break more easily when fertilizer is applied to the field), a lot of water during pellet mill preparation was necessarily to be added. On the other hand, if high particle density pellets are desired (not easily disintegrated when applied to the field), the amount of water added for pellet mill preparation should be limited.

Full disintegration Time

Disintegration test was carried out in order to determine the duration of compost pellets withstanding when immersed in water till fully disintegrated. The disintegration test with presence of water was in fact to simulate disintegration time of pellets in farm soil. Even the disintegration rates in water does not the same as the actual rates in farm soil, at least the relationship between water content of compost mill and NPK enrichment with the disintegration rates of pellets can be described.

Analysis of variance showed that interaction effect between water content and NPK enrichment levels on full disintegration time of compost pellets was not significant, but the individual effects of water content and NPK enrichment levels on full disintegration time of compost pellets was significant at $\alpha = 0{,}05$. The LSD multiple comparisons of the two factors were placed on Figure 3 and 4.

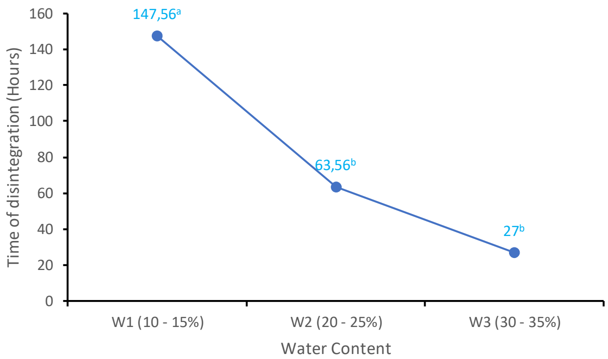

Figure 3. Effect of water content on disintegration time of compos pellets

As we can see on Figure 3, full disintegration time of compost pellet decreased with the increasing water content of compost mill. At low water content (W1) of compost mill, full disintegration time of compost pellets was 147,56 hours, at W2 full disintegration time of pellets significantly decreased to 63.56 hours, and at W3 full disintegration time of pellets decreased to 27 hours even not significantly different from that at W2. Nikiema et al. (2013) mentions that disintegration of compost pellets is a complex phenomenon which is usually accelerated by many factors such as; swelling of molecules, modification of surface tension, pH, temperature, chemical content, water content of compos mill, and binding agent additions. The longest of full disintegration time (147,56 hours) found in this research was in fact still longer than that reported by Nikiema et al. (2013). The longest time of disintegration reported by Nikiema et al. (2013) was 120 hours when they worked on fecal sludge processing for fertilizer pellets.

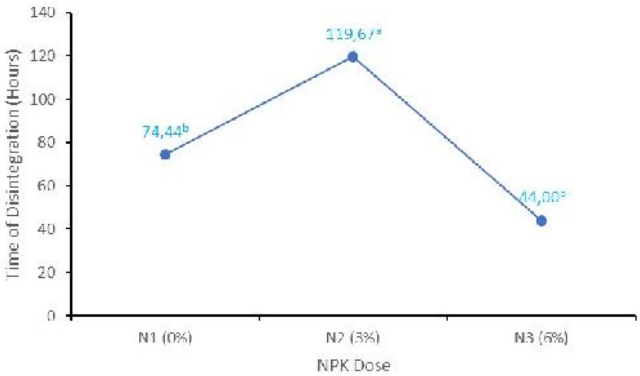

Figure 4. Effect of NPK enrichment on disintegration time of compos pellets

Figure 4 shows the effect of NPK enrichment levels on the disintegration time of compos pellets in water. Inorganic fertilizers were known as hygroscopic compounds, as shown on the Figure 4, that the disintegration was accelerated by NPK enrichment. However, the pattern of the disintegration time that low for N1 (plain compost pellets with 0% NPK enrichment), increased for N2, and decreased for N3 needed to be explained carefully. The disintegration time of 74.44 hours for N2 was in fact relatively high because Nikiema et al. (2013) reported that disintegration time of plain compost pellets (without enrichment nor binder agent) was 57 hours. For enriched pellets of N2 (3% NPK enrichment) in this research, the disintegration time was 119,67 hours, practically the same as Nikiema et al. (2013) finding of 120-hour disintegration when they used about 6% ammonium sulphate (($NH_4)_2SO_4$) to enrich dewatered fecal sludge pellets. But for N3 (6% NPK enrichment) the disintegration time decreased significantly to 44.00 hours. The possible explanation of such behaviour might be found in the

physicochemical properties of the NPK fertilizer. The NKP fertilizer might have promoted gelatinization process of powder compost material when it was applied at 3%. But when it was applied at 6%, the NPK fertilizer enrichment was too much that tended to absorb much water resulting in faster disintegration of pellets.

Pellet Hygroscopicity

Hygroscopicity test was required to determine the stability of water content when compost pellets were stored in a room at temperature and relative humidity of 26-28 ºC and ±80% respectively. Analysis of Variance showed that effects of water content and NPK enrichment on the second day of storage were not significant, and their interaction was not significant either. Figure 5 shows the average of pellet water content along the 12 day storage after taken from oven (0%). The water content changed very quickly from 0% to 8.47% just in 2 days, and was stable at about 9.38% after 6 days of the storage, which just returned to initial water content of pellets (ranging from 8.32 to 9.65%).

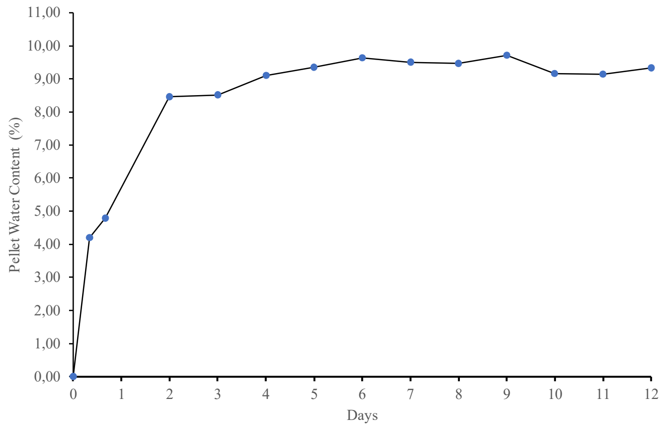

Figure 5. Average of pellet water content along 12 day storage

Compressive Strength

Compressive strength (MPa) of pellet refers to how high vertically axial load (N) can be gradually applied to an individual pellet till broken. Analysis of variance showed that interaction effect of mill water content and NPK enrichment on compressive strength of pellets was significant. Effect of water content was significant too but effect of NPK enrichment was not. Graphical representation of LSD multiple comparison was shown on Figure 6. If read vertically, it was very visible that there was no different compressive strength at N1, decreasing with increasing water content at N2 and N3. But the highest compressive strength was 7.78 MPa found at the treatment of W1N2 (10-15% water content and 3% NPK enrichment).

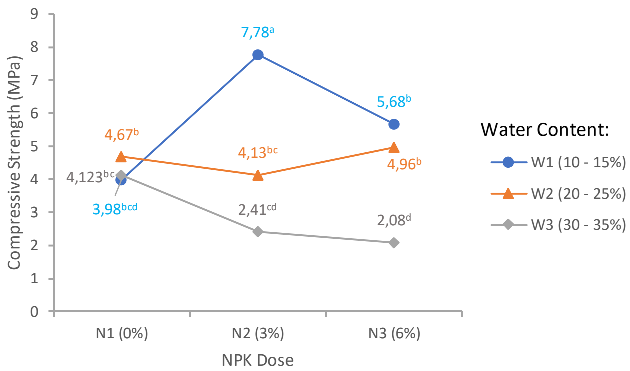

Figure 6. Effect of water content and NPK enrichment on compressive strength of compos pellets

The highest compressive strength of 7.78 MPa was higher than what Zafaria and Kianmehr (2014) reported. Zafaria and M.H. Kianmehr (2014) found the highest compressive strength of municipal solid waste pellets to be 113.2 N which was equivalent to 4 MPa with 6 mm die diameter. They used pelletizing method with 60-70 MPa piston type hydraulic press. Other research was done by Hettiarachchi et al (2019) who worked with municipal solid waste, used piston type hydraulic press with 30 HP motor, and found 2 MPa of highest compressive strength of pellets (64.3 N load with 6 mm diameter die). In our research, gelatinization process or dough making of

powder compost was incorporated before pellet was produced using an auger type press machine which was powered by a 20 HP diesel engine. This method of pelletizing proved to be able to produce high strength pellets with relatively low power. Drawback of this pelletizing method was the produced pellets need longer drying time.

Pellet Solidity Against Impact Load

The pellet solidity refers to how an individual pellet can be resistant when it is dropped by a metal weight from a particular height. Mass of the largest surviving part of the pellet was weighted and its percentage was compared. Analysis of variance showed that interaction effect between mill water content and NPK enrichment on the impact strength was significant. Effect of NPK enrichment was significant too but effect of water content alone was not. Graphical presentation of LSD comparison was shown on Figure 7.

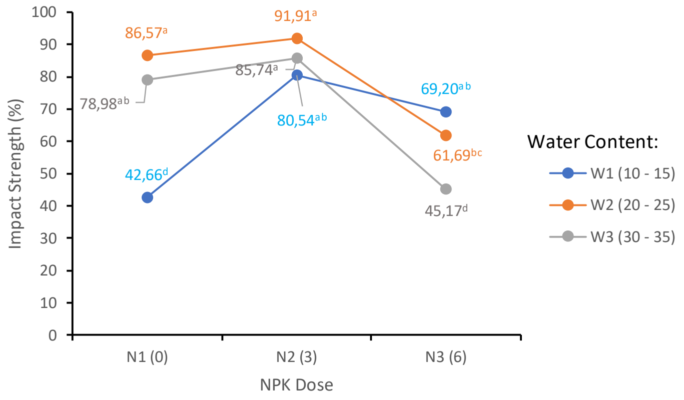

Figure 1. Effect of water content and NPK enrichment on impact strength of compos pellets

From Figure 7, we can see that at low water contents (W1) the impact strength of pellets tended to increase while at high water content (W1, W3) the impact strength of pellets tended to decrease. Statistically; however, the best impact strengths ranged from 66.20-91.91% with average of 82,16%.

Pellet Durability Index (PDI)

Pellet durability indicates the ability of the pellet to resist attrition during a shaking or vibrating test. In this research durability of an individual pellet was tested by using a shaking motion. This test is to simulate any impacts of abrasive actions on pellets during storage and transportation. The pellet was being abraded during the vibration and the largest surviving mass of the pellet was weighted, then its percentage, so called as pellet durability index (PDI) was compared. Analysis of variance showed that interaction effect between mill water content and NPK enrichment on the pellet vibration durability was not significant. The effect of NPK enrichment alone on the pellet vibration durability was not significant either but the effect of mill water content was significant. The LSD comparison of the effect of mill water content on the vibration durability is shown on Figure 8.

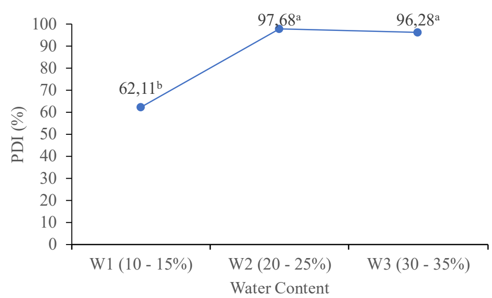

Figure 8. Effect of water content and NPK enrichment on durability of compos pellets

On Figure 8, we can see that durability increased with the increasing mill water content from 62.11% at W1 to 97,68% at W2, and stable to W3. This phenomenon indicated that compost water content could stimulate gelatinization when dough making process, and strengthen particle bounds of pellets resulting in higher PDI. Similar trend was observed in previous research of pelletizing fecal sludge for fertilizer (Nikiema et al. 2013).

Acidity (pH)

By definition, pH is negative logarithmic of the hydrogen-ion concentration, simply meaning more H^+ (hydrogen) ions, the more acidic. Interaction of the mill water content and the NPK enrichment significantly affected pellet acidity (pH) but all of the values were close and not more than neutral pH of 7. The pellet pH values decreased with increasing NPK doses ranging from 6.29 to 6.96. The highest pellet pH belonged to the treatment combination of W2N1 whilst the lowest belonged to W1N3. The effect of the inorganic fertilizer enrichment on the pellet pH was stronger at high mill water content (W3) being low pH at W3N3 and high at W1N3.

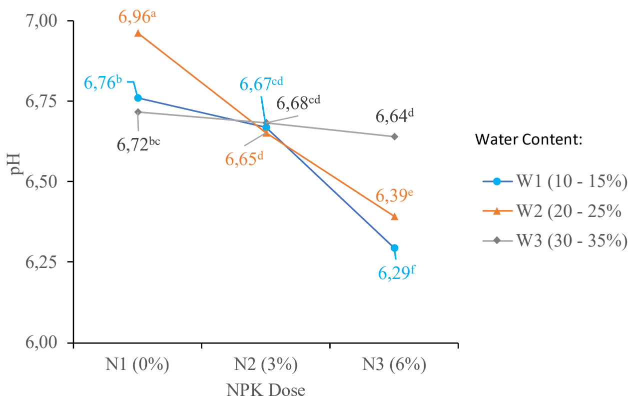

Figure 9. Effect of water content and NPK enrichment on pH of compos pellets

The varying pH values were definitely because of the presence of NPK fertilizer addition. Ammonium based component of the NPK fertilizer was the primary reason of the decreasing pH values through nitrification process. Nitrifying microbes breakdown ammoniacal nitrogen (ammonium) and release H^+ ion (Sparks, 2016). This reaction was promoted by the presence of tremendous numbers of microbes in the compost materials, and even more active in higher water content environment. Other mechanism was that the existence of ammonium sulfate in NPK fertilizer can be hydrolyzed and release H^+ ion (Kaya, 2014). Fortunately the decreasing pellet pH was not much, and still in the tolerable ranges of plant requirement.

Nutrient Contents

Figure 10 shows nutrient status of the raw compost (powder) and NPK enriched compost pellets. Among the three nutrient statuses (NPK), nitrogen content was the only nutrient that decreased from raw compost to compost pellet. Nitrogen content of raw compost was about 1.26±0.59%, decreasing to 0.55±0.04% in plain compost pellet, to 0.53±0.15% in 3% NPK enriched compost pellet, to 0.59±0.08% in 6% NPK enrich compost pellet. The decreasing nitrogen content could be because that nitrogen is bound in ammonium fertilizer which easily shifts to free ammonia and escape as nitrogen gas, and this mechanism was promoted by high temperature when compost was compressed to become pellets. As mentioned before the fact that pH was around neutral could be a significant role too in the volatilization process of nitrogen as observed by Mani et al, (2006). This result suggested that more appropriate methods of producing compost pellets may need to be investigated in order to maintain nitrogen content conservation.

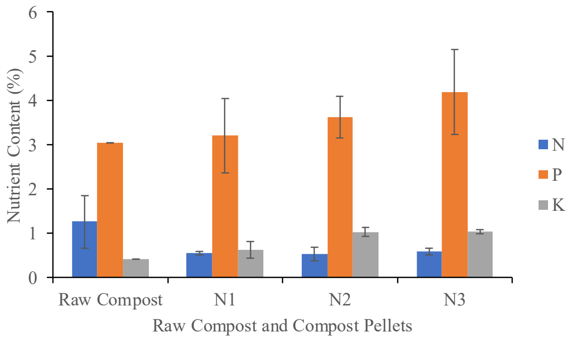

Figure 10. Effects of NPK enrichment on nutrient content of the compost pellets

Phosphorus content looked more conservative, as seen on Figure 10, than other two nutrients (N dan K). The P content was increasing with the increasing NPK enrichment levels, ranging from 3,62±0.47% at 3% NPK enrichment level to 4.19±0.97% at 6% NPK enrichment level, whilst P content for raw compost was 3.04±0.19% and 3.20±0.85% for plain compost pellet. Potassium content showed little conservation, as K increased to maximum of 1.03±0.06% at 6% NPK enrichment level, whilst K contents was 0.42±0.04% for raw compost and 0.63±0.19% for plain compost pellet.

Conclusions

Interaction between water contents and NPK enrichment levels was significant on some physical properties of compost pellet parameters such as bulk density, pellet density, compressive strength, pellet solidity, acidity. High performances of bulk density, pellet density, compressive strength, and disintegration time could be found at the treatment combination of 10-15% water content and 3% NPK enrichment (W1N2), but high solidity was found in all treatments of water content levels. Pellet durability against vibration was much affected by water content than by NPK enrichment levels, but pH was much affected by NPK enrichment rather by water content, and decreased with increasing NPK enrichment levels. All resulted pellets were hygroscopic that approaching to initial water content in just 2 days of storage. Phosphorus and potassium enrichments of pellet were manageable by using auger-type pelletizer but nitrogen might need other method of pelletizing.

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Draf Paten Sederhana

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PROSES PEMBUATAN PUPUK KOMPOS PELET DENGAN PENGKAYAAN FOSFAT

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DESKRIPSI

PROSES PEMBUATAN PUPUK FOSFAT PELLET DARI KOMPOST YANG DIPERKAYA

Bidang Teknik Invensi

Invensi ini berhubungan dengan suatu proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat dan bahan-bahan: tandan kosong kelapa sawit (TKKS) bekas media jamur merang, kotoran sapi, kotoran ayam, serbuk sabut kelapa, arang sekam, limbah lumpur industri MSG. Secara spesifik pembuatan pupuk kompos pellet dengan pengkayaan fosfat dilakukan melalui dua tahap yaitu proses fermentasi bahan kompos dan proses extrusi adonan kompos. Kompos dibuat dari bahan-bahan limbah organik yang salah satunya kaya akan kandungan fosfor, yaitu lumpur limbah industri MSG, dilanjutkan dengan pembuatan pellet dengan menggunakan mesin extruder tipe ulir (auger).

Latar Belakang Invensi

Penggunaan pupuk kimia secara terus-menerus dalam pertanian modern banyak menimbulkan efek negatif terhadap lingkungan. Tanah menjadi semakin miskin akibat proses pelindian. Populasi mikroorganisme tanah juga tertekan karena kekurangan bahan organik. Kekurangan bahan organik juga menyebabkan tanah menjadi keras dan lengket sehingga daya ikat air berkurang, serta akar tanaman sulit berkembang. Nutrisi mudah terbawa aliran permukaan sehingga menimbulkan pencemaran di hilir. Kerugian langsung yang dialami petani adalah penggunaan pupuk kimia dosis tinggi sementara produktivitas tetap tidak membaik.

Penyediaan bahan organik pada lahan pertanian dapat dilakukan dengan pemberian pupuk kompos. Pada umumnya pupuk kompos dibuat dari sisa atau limbah pertanian. Salah satu keunggulan pupuk kompos adalah kemampuannya untuk memperbaiki sifat fisik tanah, mendorong pertumbuhan akar tanaman, dan merangsang dinamika populasi mikroorganisme. Namun, pemanfaatan pupuk organik atau kompos memiliki sejumlah tantangan. Salah satu kelemahan pupuk kompos adalah volumenya yang besar sehingga menjadi kendala utama dalam penyimpanan, pengemasan, transportasi, dan aplikasi. Kandungan hara pupuk kompos yang rendah

(terutama NPK) juga menjadi alasan lain mengapa petani enggan menggunakan pupuk kompos.

Peletisasi dan pengkayaan (fortifikasi) pupuk kompos berpotensi bisa menjadi solusi alternatif dari permasalahan tersebut. Dengan rekayasa peletisasi, volume pupuk menjadi lebih kecil sehingga lebih memudahkan dalam pengemasan, transportasi, penyimpanan, dan aplikasi. Fortifikasi dikenal sebagai teknik meningkatkan kualitas nutrisi kompos dengan cara menambahkan pupuk mineral ke pupuk kompos. Dengan teknik fortifikasi, pupuk kompos menjadi lebih menarik bagi petani untuk menggunakannya.

Pembuatan pellet untuk beberapa tujuan telah banyak dilakukan, misalnya pellet arang untuk energi, pellet pakan ternak, pellet pakan ikan. Pellet rerumputan untuk pakan ternak telah banyak dibuat. Pellet kompos dari bahan tinja, kotoran sapi, sampah domestik, juga sudah banyak dilakukan. Namun proses pembuatan pupuk kompos dengan bahan-bahan limbah organik yang diformulasikan dan pembuatan pelletnya dengan pengkayaan fosfat belum pernah dilakukan.

Uraian Singkat Invensi

Invensi yang diusulkan ini pada dasarnya adalah suatu proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat dengan menggunakan mesin extruder tipe auger, dari bahan-bahan limbah organik yang diformulasikan. Bahan-bahan limbah organik terdiri dari TKKS sawit bekas media jamur merang, kotoran sapi, kotoran ayam, serbuk sabut kelapa, dan limbah lumpur industri MSG, serta penambahan pupuk mineral fosfat. Konsep invensi proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat dari campuran bahan-bahan kompos yang diformulasikan dan kemudian difermentasikan. Setelah selesai, kompos remah digiling dan diayak agar halus dan homogen. Setelah halus, kompos remah di lumat dengan menggunakan mesin mixer sampai menjadi adonan. Pada waktu pembuatan adonan, air dan pupuk fosfat ditambahkan. Banyaknya air dan konsentrasi pupuk fosfat yang ditambahkan berpengaruh terhadap tingkat kekerasan pellet yang dihasilkan. Setelah dimixer, adonan pupuk kompos di cetak dengan mesin extruder menjadi pellet ukuran diameter 5-10 cm memanjang kemudian dipotong-potong dengan panjang tertentu, dan dijemur di bawah terik matahari. Setelah kering, pupuk kompos pellet dapat dikemas dalam kantung plastic kedap udara dan disimpan.

Uraian Lengkap Invensi

Pembuatan pupuk kompos pellet dengan pengkayaan fosfat dimulai dengan mengumpulkan bahan-bahan yaitu: TKKS sawit bekas media jamur merang, kotoran sapi, kotoran ayam, serbuk sabut kelapa, dan lumpur limbah industri MSG. di antara bahan-bahan tersebut yang mengandung fosfor tinggi adalah limbah lumpur industri MGS (21,74%). Kemudian bahan-bahan dicampur dengan perbandingan; TKKS : kotoran sapi : kotoran ayam : serbuk sabut kelapa : arang sekam : lumpur limbah industri MSG = 50 : 30 : 5 : 5 : 5 : 5. Campuran bahan kompos ditumpuk membentuk unggun sambil disiram air secara bertahap. Tumpukan bahan kompos kemudian ditutup terpal, kemudian difermentasikan selama 3 bulan. Bahan kompos diaduk-aduk, dibalik, dan disiram air secara rutin setiap 1-2 minggu. Alas bagian bawah tumpukan kompos harus berdrainase baik agar tidak ada air yang menggenang di kompos. Setelah 3 bulan, sudah cukup matang, kompos dibongkar, digiling, dan diayak dengan saringan berukuran 5 mm. Kompos remah yang dihasilkan kemudian dikemas dalam karung untuk disimpan sementara.

Selanjutnya pembuatan pupuk kompos pellet dengan pengkayaan fosfat dari bahan kompos remah dimulai. Kompos remah dimasukkan ke dalam mesin mixer berkekuatan 8 HP, ditambahkan air 30-35% dan pupuk mineral fosfat sebanyak 6%. Bahan kemudian dilumat dengan mesin mixer selama kurang lebih 15 menit, dan setelah kenyal/kalis, adonan diangkat. Adonan ini menghasilkan pellet dengan tingkat kekerasan yang redah sehingga cepat hancur dan larut ketika diaplikasikan di awal tanam, atau bersama dengan pengolahan tanah. Adonan untuk mendapatkan pellet yang keras dan padat sehingga waktu hancurnya lebih lama bisa lakukan pada tahapan ini.

Setelah menjadi cukup kenyal dan kalis, adonan kompos dimasukkan ke dalam mesin extruder 20 HP, dicetak menjadi pellet. Penggunaan daya mesin extruder ini sangat rendah jika dibandingkan dengan mesin extruder pencetak pellet untuk energi yang mencapai 200 HP. Mesin pellet untuk pakan ternak menggunakan daya rendah karena memang untuk menghasilkan pellet yang tidak begitu padat sehingga nyaman untuk dimakan oleh ternak. Sedangkan dalam proses pencetakan pellet untuk pupuk kompos ini, selain kekerasan, daya larut nutrisi pupuk juga sangat penting untuk diperhitungkan.

Pellet yang keluar dari mesin extruder berdiameter sesuai dengan lubang cetakan (die) dan memanjang. Kemudian pellet dipotong-potong sehingga

panjangnya seragam. Setelah ditampung pada nampan, pellet di jemur di bawah terik matahari 1-2 hari hingga kering simpan pada kadar air antara 8-10%. Setelah kering, pupuk kompos pellet dikemas dalam karung plastik yang kedap udara dan disimpan. Kemasan harus kedap udara agar kadar air tidak benyak berubah yang berakibat bisa jamuran. Karakteristik pupuk kompos pellet dengan pengkayaan fosfat disajikan pada Tabel 1.

Tabel 1. Karakteristik pupuk kompos pellet dengan pengkayaan fosfor

No	Parameter	Nilai	Satuan
1	Masa jenis curah pellet	517,65	kg. m^{-3}
2	Masa jenis pellet	1008,88	kg. m^{-3}
3	Lama waktu hancur total	35,30	jam
4	Higroskopisitas	0,35	%/jam
5	Kekuatan kompresi	2,08	MPa
6	Soliditas	45,17	%
7	Durabilitas Indeks	96,28	%
8	pH	6,64	-
9	Kadar P	4,19	%

Klaim

Suatu proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat dengan langkah-langkah sebagai berikut;

a. Mengumpulkan bahan-bahan kompos yaitu TKKS bekas media jamur merang, kotoran sapi segar, kotoran ayam, serbuk sabut kelapa, arang sekam dikumpul.
b. Mencampur hahan-bahan dengan perbandingan volume masing-masing; 50:30:5:5:5 secara berurutan seperti pada butir a, dengan menggunakan cangkul atau garpu.
c. Membuat unggun atau tumpukan secara vertical setinggi 1-15 m. Dimensi horizontal ditentukan oleh banyaknya bahan kompos yang diolah.
d. Menyiram dengan air sampai basah merata pada tumpukan bahan setiap kira-kira 10-20 cm tinggi. Alas bawah dibuat porus agar aliran drainase cukup baik sehingga tidak ada air yang menggenang di dalam tumpukan bahan kompos.
e. Menutup tumpukan bahan kompos dengan terpal agar terlindung dari terik matahari dan air hujan.

f. Membuka tutup terpal, mengaduk bahan kompos dengan cangkul atau garpu, dan menyiram air dengan gembor sampai basah merata setiap minggu kemudian ditutup dengan terpal kembali. Setelah pengompos berusia 1 bulan, frekuensi pembalikan dan penyiraman bisa diturunkan menjadi 2-3 minggu sekali. Dan setelah berusia 2 bulan, kompos tidak perlu lagi dibalik dan disiram.
g. Membongkar dan memanen kompos setelah fermentasi berjalan 3 bulan. Kemudian kompos dihampar diatas terpal dan dijemur agar kadar air menurun sampai sekitar 15-20%.
h. Menggiling kompos dengan mesin chopper dan mengayaknya dengan ukuran saringan 5 mm. Penggilingan dan pengayakan kompos untuk memperkecil bongkahan kompos agar lebih lembut untuk dan membersihkan kompos dari kotoran kasar. Setelah itu, kompos halus dikemas dalam karung agar tertata rapih.
i. Mengukur kadar air kompos remah secara gravimetri.
j. Memasukkan pupuk kompos remah ke dalam mesin mixer 8 HP. Kemudian menambahkan air hingga kadar air kompos mencapai 30-35%. Pada saat yang bersamaan, pupuk mineral fosfat ditambahkan sebanyak 6% ke dalam kompos.
k. Melumat pupuk kompos remah menjadi adonan dengan kecepatan mixer sekitar 90 rpm selama kurang lebih 15 menit hingga adonan menjadi kenyal dan kalis.
l. Memasukkan adonan kompos ke dalam mesin extruder extruder (20 HP) untuk dicetak menjadi pellet dengan ukuran diameter 1 cm.
m. Pellet yang keluar dari cetakan ditampung dengan nampan. Dengan pemasangan pisau pemotong di depan lubang cetakan, maka panjang potongan pellet menjadi seragam 2-2,5 cm.
n. Penjemuran pellet pupuk kompos di bawah terik matahari selama 1-2 haris.
o. Pengukuran karakteristik pupuk kompos pellet dengan pengkayan fosfat.

Abstrak

PROSES PEMBUATAN PUPUK KOMPOS PELET DENGAN PENGKAYAAN FOSFAT

Invensi Proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat meliputi tahapan: penyiapan bahan-bahan TKKS bekas media jamur merang, kotoran sapi, kotoran ayam, serbuk sabut kelapa, arang sekam, dan limbah lumpur industry MSG dengan perbandingan 50:30:5:5:5:5. Bahan-bahan difermentasi sampai menjadi kompos matang kemudian dilumatkan dengan penambahan air 30-35% dan pupuk fosfat (16%) sebanyak 6%, sampai menjadi adonan yang kenyal. Adonan dicetak dengan menggunakan mesin extruder 20HP, dengan diameter 1 cm dan dipotong menjadi panjang 2cm. Pellet dikeringkan dengan cara dijemur di bawah terik matahari selama 1-2 hari. Pupuk kompos pellet kemudian disimpan di dalam karung plastik dan diukur karakteristiknya. Karakteristik pupuk kompos pellet yang dihasilkan yaitu: masa jenis curah 517,65 kg.m^{-3}, masa jenis pellet individual 1008,88 kg.m^{-3}, lama waktu direndam air sampai hancur 35,30 jam, higroskopisitas 0,35 % jam^{-1}, kekuatan kompresi 2,08 MPa, soliditas (daya tahan getaran) 45,17%, Durabilitas indeks 96.28%, pH 6,64, kadar P 4,19 %.

KESIMPULAN

Penelitian pembuatan pupuk kompos pellet telah menghasilkan luaran berupa:

1. Publikasi seminar internasional (sudah dilaksanakan
2. Publikasi jurnal internasional bereputasi, Q2 (dalam proses revisi)
3. Draf paten sederhana (proses usulan)

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Lampiran 1

Tabel 1. Luaran penelitian

No	Jenis luaran		Indikator Capaian		
			2021	2022	2023
1	Artikel ilmiah	Internasional	1		2
2	Seminar (Prosiding)	Nasional	1	2	2
3	Kekayaan Intelektual (KI)	Hak Cipta	1		
4	Teknologi Tepat Guna: pupuk pellet		1		
5	Buku ISSN				1

Tingkat Kesiapan Teknologi (TKT) 4 bidang pertanian yaitu: Komponen teknologi telah divalidasi dalam lingkungan laboratorium. Dengan indikator sebagai berikut:

1. Produsi pupuk kompos pellet telah dilakukan.
2. Karakteristik pupuk kompos pellet telah diukur
3. Uji pot pupuk kompos pellet pada beberapa tanaman telah dilakukan.
4. Uji plot dan sosialisasi pupuk kompos pellet di mitra petani sudah dilakukan
5. Analisis usaha pupuk kompos pellet sudah dibuat
6. Rancangan kemasan pupuk kompos pellet sudah ada
7. Perjanjian kerja sama dengan mitra usaha sudah dibuat
8. Pemasaran produk pupuk kompos pellet dilakukan

Bidang Fokus Riset: Pangan dan Pertanian
Tema: Teknologi ketahanan dan Kemandirian pangan

LAPORAN AKHIR (DRAF)
PEMBUATAN DAN PENGUJIAN PELLET PUPUK KOMPOS BERBAHAN CAMPURAN TKKS BEKAS MEDIA JAMUR MERANG

Skema Penelitian Terapan Dengan Nomor Kontrak:
3973/ UN26.21/PN/2021 Tanggal 14 Juli 2021

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UNIVERSITAS LAMPUNG
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RINGKASAN

Tanaman membutuhkan nutrisi di sepanjang siklus hidupnya. Pupuk diberikan dalam rangka untuk memenuhi kebutuhan tanaman tersebut. Secara umum pupuk diberikan atau diaplikasikan di awal saat pengolahan lahan, kemudian sekitar 15-10 hari setelah tanam, dan saat menjelang berbungan atau sekitar umur 35-40 hari. Pengaplikasian pupuk tiga kali ini cukup merepotkan petani karena selain menambah tenaga juga menambah biaya. Selain itu, masalah rendahnya kadar hara NPK pada pupuk kompos membuat petani malas menggunakannya. Volume pupuk kompos yang besar juga membatasi penggunaannya. Di sisi lain, penambahan bahan-bahan organik ke lahan sangat diperlukan untuk mempertahankan keberlanjutan dalam jangka Panjang.

Tujuan jangka panjang penelitian adalah untuk menghasilkan pupuk kompos pellet dengan pengkayaan unsur NPK dan tiga karakteristik rapuh, sedang, dan keras. Ketiga jenis pupuk kompos pellet tersebut hanya perlu diaplikasian sekali di awal tanam. Pupuk pellet yang rapuh akan langsung hancur, yang sedang akan hancur sekitar 20 hari, dan yang keras akan hancur sekitar 35 hari setelah aplikasi. Dengan demikian petani lebih mudah mengaplikasikannya dan hanya perlu mengaplikasikan pupuk kompos pellet sekali saja di awal tanam dalam satu siklus tanam. Sehingga biaya dan tenaga dalam proses produksi tanaman dapat dihemat, yang akhir harga komoditas bisa lebih kompetitif. Keuntungan lain adalah berupa penurunan volume curah sehingga memudahkan dalam pengepakan, penyimpanan, dan transportasi.

Pupuk kompos dibuat dari campuran bahan-bahan seperti tandan kosong kelapa sawit bekas media jamur, kotoran sapi, kotoran ayam, serbuk sabut kelapa, arang sekam, lumpur limbah MSG yang tersedia di Daerah provinsi Lampung. Dengan metoda mengadonan dan pengepresan, campuran bahan-bahan kompos di pelletkan. Variasi penambahan air dan penambahan pupuk NPK pada waktu pengadonan dapat menghasilkan pupuk kompos pellet dengan tiga karakteristik tersebut di atas.

Pada Tahun I (2021), penelitian digunakan untuk mengkaji pengaruh kadar air atau penambahan air dan konsentrasi NPK pada waktu pengadonan terhadap karakteristik pupuk kompos pellet. Hasil Penelitian I menunjukkan bahwa kadar air dan pengayaan NPK berpengaruh nyata terhadap beberapa sifat fisik kompos pelet,

yaitu: berat jenis curah (517,65 – 587,60 $kg.m^{-3}$), berat jenis pelet (1059,55 – 1329,91 $kg.m^{-3}$), kuat tekan (2,08 - 7,78 $MN.m^{-2}$), soliditas (42,66 - 91,91%), PDI (62,11 - 97,68 %), waktu hancur (74,44 - 147,56 jam), dan pH (6,29-6,96). Semua pelet yang dihasilkan bersifat higroskopis. Ketahanan pelet sangat dipengaruhi oleh kadar air sedangkan pH dipengaruhi oleh kadar pengayaan NPK. Kandungan fosfor dan kalium dapat dipertahankan dengan menggunakan mesin pelletizer tipe auger, sementara nitrogen mengalami penurunan. Akhirnya, percobaan menunjukkan bahwa perlakuan kadar air 10-15% dan kadar NPK 3% (W1N2) menghasilkan pelet kompos dengan kelarutan terendah, sedangkan perlakuan kadar air 20-25% dan kadar NPK 0% (W2N1) dan perlakuan kadar air 30-35% dan kadar NPK 0% (W3N1) menghasilkan pelet kompos dengan kelarutan tertinggi.

Pada Tahun II (2022), penelitian digunakan untuk menguji pupuk kompos pellet dengan tanaman di pot. Pupuk kompos pellet diuji pada tanaman sayuran, padi, jagung, kedele. Rancangan pupuk pellet adalah pellet yang rapuh diperkaya dengan pupuk NPK, pellet yang sedang diperkaya dengan urea, dan pupuk pellet yang keras diperkaya dengan urea dan KCl. Pengujian dilakukan dengan cara membandingkan antara aplikasi pupuk pellet rancangan dengan aplikasi pupuk konvensional dengan dosis rekomendasi umumnya. Tingkat dan laju kehancuran pupuk kompos pelet di media tanam diamati. Selain itu parameter agronomis tanaman seperti pertumbuhan dan hasil panen juga didata.

Pada Tahun **III (2023)**, penelitian digunakan untuk menguji plot pupuk kompos pellet di lahan petani dan promosi. Pupuk kompos pellet hasil rancangan pada penelitian Tahun II diperkenalkan kepada petani mitra dan diuji di lahan. Kegiatan terdiri dari promosi dan sosialisasi produk pupuk kompos pellet kepada petani tanaman pangan, industri, dan hortikultura. Dari aspek usaha, produk pupuk kompos pelet dan kemasan dengan beberapa ukuran termasuk desainnya akan dikembangkan. Pupuk pellet juga dikembangkan ke arah spesifik jenis tanaman terutama untuk tanaman bunga. Masalah administrasi dan perjanjian usaha diselesaikan pada penelitian tahap Tahun III.

Kata Kunci: kompos, organik, pellet, pupuk sawit,

DAFTAR ISI

LATAR BELAKANG

Pemanfaatan tandan kosong kelapa sawit (TKKS) untuk media tumbuh budidaya jamur merang dapat menambah keuntungan, dibandingkan dengan pemanfaatan langsung lainnya semisal dikomposkan langsung [1, 2, 3, 4], sebagai sumber energi [5, 6], maupun sebagai mulsa [7]. Satu ton TKKS kering bisa menghasilkan jamur merang minimal seberat 70 kg [8]. Jika harga jamur merang segar Rp 40.000,- per kg, maka panenan jamur merang tersebut setara dengan pendapatan Rp 2.800.000,- dalam satu silkus. TKKS bekas media jamur selanjutnya juga sangat bagus untuk dimanfaatkan sebagai pupuk kompos [9, 10, 11], dan bisa menghasilkan pendapatan yang tidak sedikit. Hasil penelitian menunjukkan bahwa 1 kg pupuk kompos (bahan TKKS bekas media jamur merang dicampur dengan limbah pertanian yang lain) menghasilkan sayuran selada merah organik sebanyak 207 g [12]. Jika harga sayuran selada merah organik berharga Rp 60.000,- per kg, maka pemanfaatan 1 ton pupuk kompos tersebut setara dengan pendapatan sebesar Rp 12,4 juta lebih dalam satu siklus.

Namun demikin, seperti limbah pertanian umumnya, permasalahan pemanfaatan pupuk organik dari limbah TKKS secara langsung maupun TKKS bekas media jamur juga terletak pada volumenya yang bersifat *bulky* [13]. Pembuatan pellet pupuk organik bertujuan untuk menurunkan volume, sehingga memudahkan dalam pengemasan, transportasi, penyimpanan, dan aplikasinya. Selain itu, berdasarkan data penelitian-penelitian sebelumnya, pupuk organik yang dihasilkan mengandung hara yang cukup rendah [14, 15, 16], sehingga aplikasinya masih perlu dikombinasikan dengan pupuk anorganik. Pemberian pupuk kompos dan pupuk anorganik dalam waktu yang tidak bersamaan menambah waktu dan menambah tenaga kerja.

Dalam penelitian ini, akan dicoba juga membuat formula pupuk pellet campuran kompos TKKS bekas jamur, limbah pertani yang lain, dan pupuk anorganik yang bisa diaplikasikan sekali saja di awal tananam. Tingkat densitas pellet dibuat bertingkat: rendah, sedang, dan tinggi. Pellet dengan densitas rendah akan mudah hancur ketika terkena air, yang densitas sedang tidak langsung hacur, dan yang densitas tinggi paling akhir hancur ketika terkena air. Pembedaan densitas pellet bertujuan untuk memfasilitasi pengguna yang membutuhkan aplikasi pupuk tidak hanya sekali dalam

satu siklus tanam. Ketika pellet dengan ketiga jenis densitas tersebut diberikan di awal tanam, maka pellet yang densitas rendah akan langsung hancur saat tanam, yang densitas sedang akan hancur pada saat tanaman berbunga, dan yang densitas tinggi akan hancur pada saat berbuah. Jadi substansi dari pembedaan densitas pellet adalah *rapid*, *moderate*, dan *slow release*. Dengan pembedaan densitas tersebut, maka nutrisi dapat diberikan secara efektif (tepat waktu dan dosis), dan efisien dalam penggunaan tenaga karena hanya sekali aplikasi. Penelitian pembuatan kompos pellet sudah banyak dilakukan, tetapi pupuk pellet dengan densitas yang berbeda-beda belum diteliti.

Penelitian dilakukan dalam tiga tahun. Tahun I digunakan untuk membuat pupuk pellet campuran TKKS bekas media jamur, limbah pertanian yang lain, dan mempelajari pengaruh kadar air dan penambahan NPK terhadap karakteristik pupuk kompos pelet. Tahun II, hasil pellet terbaik pada Tahun I diuji agronomis pada pot (*pot experiment*). Tahun III, penelitian untuk menguji plot pupuk pellet pada tanaman hortikultura dan tanaman pangan bersama petani mitra.

TINJAUAN PUSTAKA

Sejak Tahun 2011, Tim Unila mengembangkan pupuk organik berbasis sumberdaya lokal, yang dinamakan ”Organonitrofos” [14]. Pupuk Organonitrofos granul dibuat dari bahan campuran kotoran sapi segar (disediakann oleh PT Juang Jaya, Gambar 1a) dan batuan fosfat (dari tambang rakyat Selagai Lingga) yang tersedia secara lokal dan diperkaya dengan penambahan mikroba N-*fixer* dan P-*solubilizer* [17]. Pupuk organik tersebut yang mengandung C-organik = 13,91%, N-organik=2,30%, P-larut=1,64%, diproduksi oleh CV Organik Super Agro (CV OSA, Gambar 1b), Tanjung Bintang Lampung Selatan. Pupuk organik granul tersebut banyak digunakan untuk tanaman pangan dan perkebunan. Untuk tanaman berbuah, pupuk organik granul tersebut masih perlu dikombinasi kan dengan pupuk anorganik.

a b

Gambar 1. a. Bahan baku kotoran sapi segar di PT Juang Jaya, b. Proses produksi pupuk Organonitrofos granul di CV Organik Super Agro

Pada Tahun 2013, pupuk Organonitrofos remah dikembangkan untuk diproduksi (Gambar 2a) dan digunakan oleh kelompok tani. Bahan baku dikembangkan lagi dengan menggunakan bahan-bahan limbah yang tersedia secara lokal, yaitu: kotoran sapi segar (PT Juang Jaya), limbah indusri MSG (dari PT Kirin Indonesia, Lampung Timur), serbuk sabut kelapa (dari PT Chrezz, Lampung Selatan), limbah kotoran ayam (dari peternak ayam di sekitar), dan arang sekam (dari perusahaan tahu tempe rumahan). Pupuk organik remah tersebut banyak digunakan oleh petani hortikultura dan tanaman pangan (Gambar 2b). Untuk tanaman berbuah, pupuk organik remah ini juga masih perlu dikombinasikan dengan pupuk anorganik. Komposisi NPK-Org = 45-36-120-1,000 kg ha^{-1} telah diketahui menjadi komposisi terbaik [15]. Pada tahun 2015, Organonitrofos diperkaya dengan penambahan *biochar* dan diberi nama

”Organonitrofos Plus” [18]. Data menunjukkan bahwa dengan penambahan *biochar* 5000 kg ha^{-1}, aktivitas mikroba tanah pada tanaman jagung manis meningkat.

a b

Gambar 2. a. Produksi pupuk Organonitrofos remah dikelompok tani, b. Deplot tanaman cabai

Tandan kosong kelapa sawit (TKKS) bekas media jamur merang berpotensi untuk bahan campuran pupuk Organonitrofos. Hasil penelitian menunjukkan bahwa pupuk Organonitrofos dari bahan campuran TKKS bekas media jamur merang 50% dan kotoran sapi, kotoran ayam, serbuk sabut kelapa, limbah industri MSG, dan arang sekam (50%) mengandung C organik = 16,11%, N = 1,26%, P = 3,04%, K= 0,42% [16]. Untuk tanaman sayuran daun, pupuk Organonitrofos ini berkinerja cukup bagus [12]. Namun untuk tanaman pangan, pupuk Organonitrofos ini juga masih perlu dikombinasikan dengan pupuk anorganik.

Penggunaan pupuk organik Organonitrofos dan kemudian menambahkan pupuk anorganik untuk tanaman pangan dan tanaman hortikultura yang berbuah, dianggap cukup merepotkan petani, karena harus menambah tenaga dan biaya. Jika pupuk organik dan pupuk anorganik bisa digabungkan dan diaplikasikan dalam waktu yang bersama-sama di awal atau sebelum tanam, maka hal ini bisa menghemat waktu dan tenaga yang tidak sedikit. Fortifikasi atau penambahan nutrisi pupuk kompos dengan pupuk anorganik pernah diteliti oleh [19].

Penelitian mesin pupuk pellet dengan bahan organik sebagai bahan baku sudah banyak dilakukan. Pelletisasi bertujuan untuk meningkatkan densitas sehingga memudahkan penanganan, penyimpanan, transportasi, dan aplikasi. Sedikit berbeda dengan pellet pakan [20], pellet pupuk lebih mirip dengan pellet/briket bahan bakar [21], yang membutuhkan kemampatan atau densitas yang tinggi. Lawong et al. [22] membuat pellet kompos dengan densitas 745.40 kg m^{-3}, dan Imatong and Bagtang [19] juga melaporkan densitas pellet kompos yang tidak jauh berbeda yaitu 889.92

kg.m^{-3}. Demikian juga, Mieldazys et al. [23] mendapatkan densitas pellet kompos diameter 6 mm sebesar 789kg.m^{-3}. Namun Zafari and Kianmehr [24] berhasil membuat pellet kompos dengan densitas lebih besar dari 1000 kg m^{-3}, dengan kadar air bahan baku 40%, kecepatan piston 2 mm/s, tebal die 12 mm, dan diameter die 0,9 mm.

Untuk mendapatkan konsistensi pellet, Ofori-Amanfo et al. [25] menggunakan tapioka dan tanah liat sebagai perekat pellet kompos. Nikiema et al [26]. juga melaporkan pembuatan pellet excreta dengan bahan perekat dari tapioka. Sementara, Hettiarachchi [27] menyatakan bahwa dengan tekanan dan kadar air bahan yang tepat, pellet kompos dapat diproduksi tanpa perekat. Daniyan et al [28] melaporkan bahwa pellet kompos tanpa bahan perekat tidak hancur dalam uji rendam air selama satu bulan. Dalam uji yang lain, dengan penambahan tepung beras 3%, pellet kompos hancur dalam 3 hari.

Kekerasan atau kemampatan pupuk pellet ditentukan pada waktu diproduksi. Zafari and Kianmehr [29] mendapatkan pellet kompos dengan densitas tertinggi ketika menggunakan kadar air bahan baku 40%. Pocius et al [30] menyatakan kekuatan pupuk pellet tergantung dari parameter rheologi dan geometri. Pupuk pellet dengan densitas rendah akan mudah hancur ketika terkena air, dan mudah melarutkan nutrisi anorganik yang dicampurkan di dalam pupuk pellet tersebut. Karakteristik pupuk seperti ini tentu sangat cocok untuk diaplikasikan di awal atau sebelum tanam. Biasanya, beberapa tanaman pangan membutuhkan pemupukan lebih dari sekali, minimal dua kali (saat tanam dan saat berbunga). Beberapa tanaman hortikultura seperti cabai bahkan memerlukan pemupukan berkali-kali. Kebutuhan ini bisa difasilitasi oleh aplikasi pupuk pellet dengan beberapa tingkat densitas. Pupuk pellet dengan kemampatan tinggi akan sulit hancur ketika terkena air sehingga lebih lambat melarutkan nutrisi anorganik yang dicampurkan di dalamnya. Jika pupuk pellet dengan densitas rendah - tinggi (seusai proporsi) diberikan sekali saja di awal tanam, maka kebutuhan tanaman akan nutrisi akan terpenuhi sesuai tahapan pertumbuhannya, karena pupuk pellet akan hancur dan nutrisi larut secara berurutan sesuai tingkat densitasnya. Dengan teknik seperti ini, tenaga dan biaya aplikasi pupuk bisa lebih efisien dan nutrisi lebih efektif karena tersedia tepat waktu dan tepat dosis. Hettiarachchi [27] menyatakan bahwa pemilihan bahan perekat yang tepat dapat mengontrol waktu kehancuran pellet sehingga pupuk pellet dapat didesain untuk melepaskan nutrisi dengan waktu dan dosis susauai dengan kebutuhan tanaman.

Berdasarkan hasil-hasil penelitian yang ada dan uraian tersebut di atas, peta jalan penelitian pembuatan pupuk pellet campuran TKKS bekas media jamur dengan bahan-bahan kompos yang lain, dan juga dengan penambahan pupuk anorganik, disusun seperti pada Gambar 3. Proses pembuatan pupuk pellet berbeda dengan pupuk granul yang membutuhkan bahan tepung yang halus bebas serabut. Mesin pupuk pellet bisa menerima bahan-bahan serbuk kasar dan berserabut. Bahan TKKS tidak akan menjadi tepung halus ketika dihancurkan, tetapi akan banyak mengandung serat-serat kecil tidak hancur. Pemilihan bentuk pellet salah satunya didasarkan pada kenyataan tersebut. Tahun I mempelajari sifat-sifat fisik dan kimia pellet. Tahun II menguji agronomis pupuk pellet di pot dengan beberapa tanaman di greenhouse. Tahun III menguji dan sosialisasi pupuk pellet di petani mitra dengan beberapa tanaman sayuran dan tanaman pangan.

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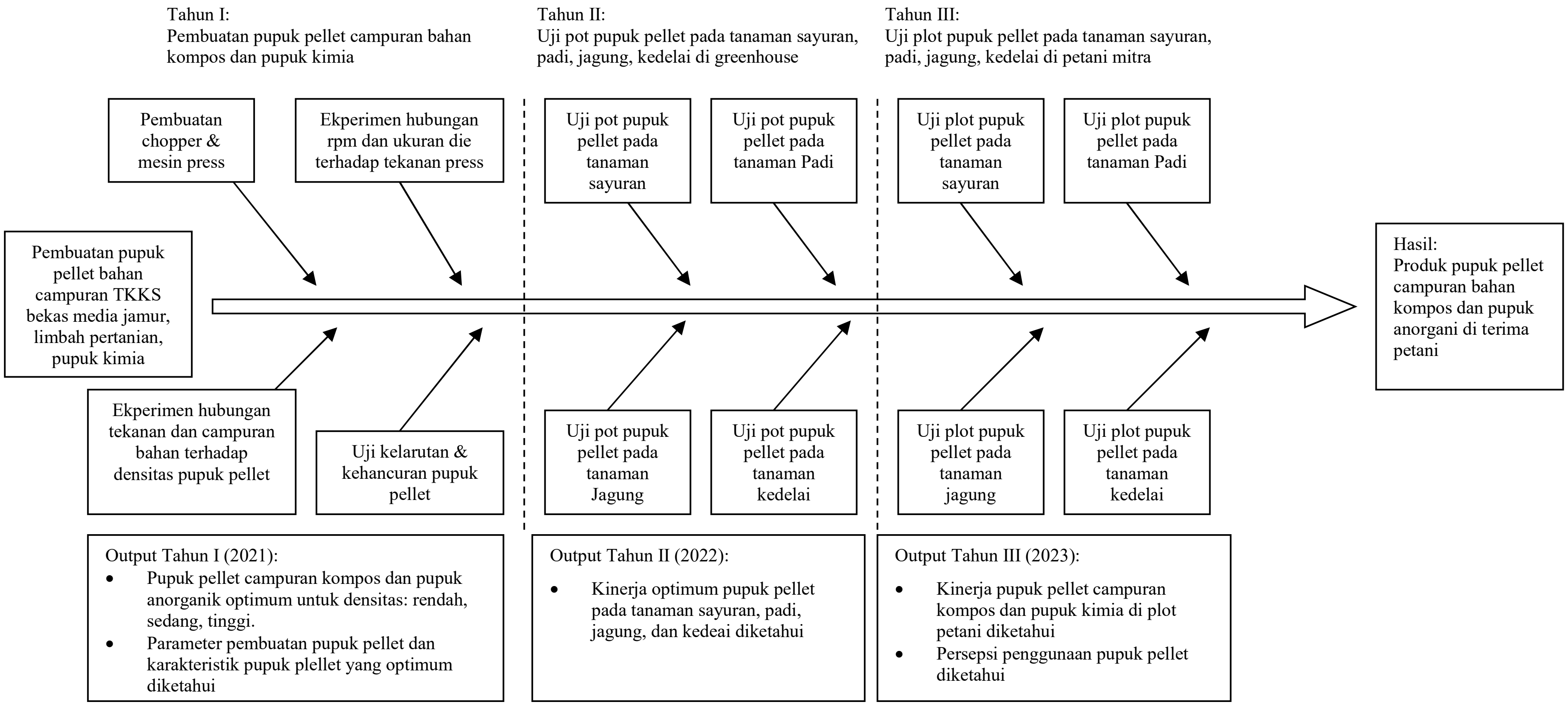


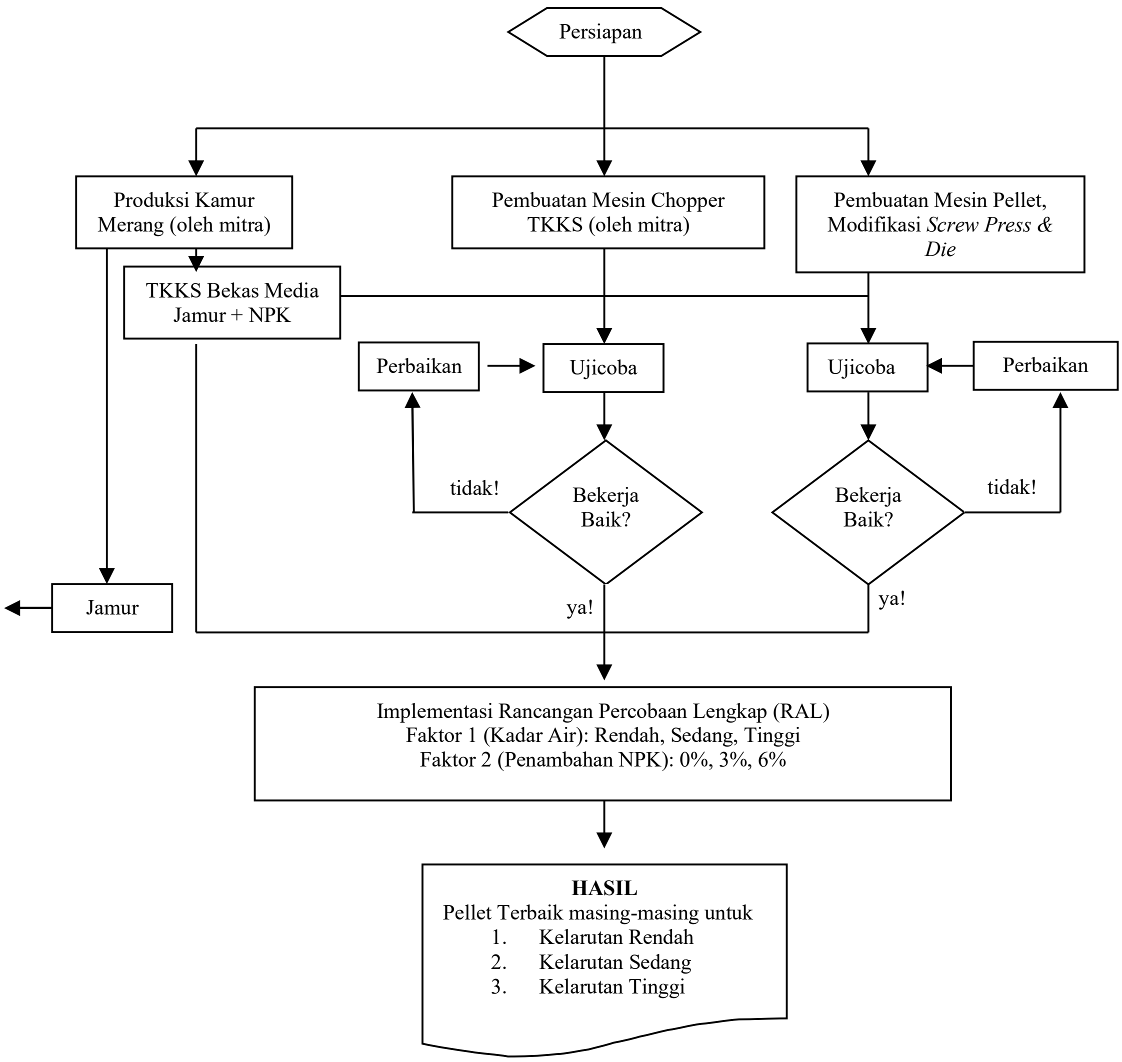
Gambar 3. Peta jalan penelitian pembuatan pupuk pellet

METODE

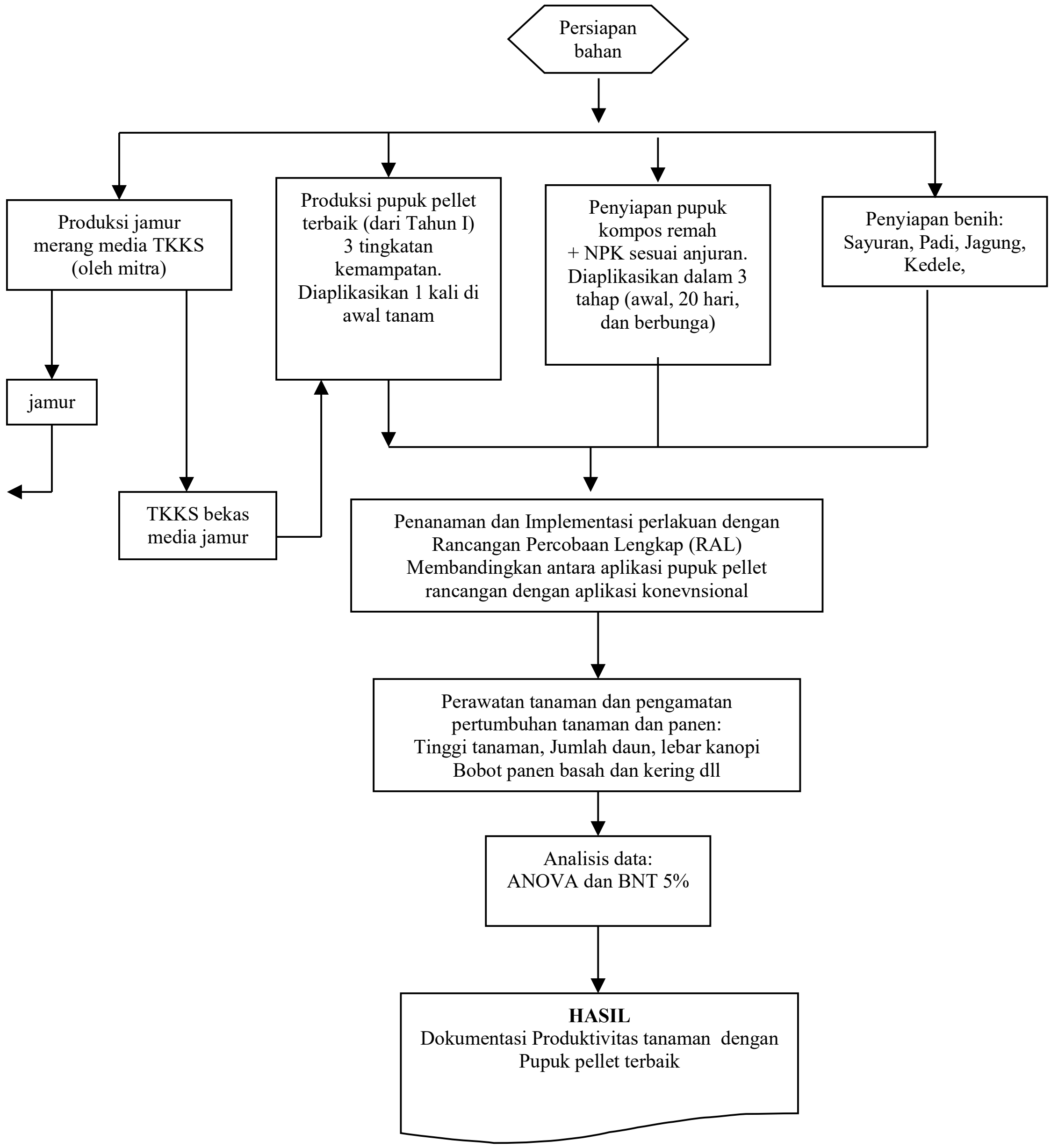
Penelitian dilakukan dalam tiga tahun. Penelitian Tahun I dimulai dengan menyiapkan TKKS bekas jamur (dari mitra produsen jamur), membuat mesin chopper TKKS (oleh bengkel mitra), mesin *screw press* pupuk pellet (oleh bengkel mitra), mesin pelumat/pengadon, dan memproduksi dan menguji pupuk pellet (oleh Tim Unila). Bengkel mitra sudah sangat berpengalaman dalam produksi alsintan, namun peneliti perlu melakukan modifikasi power motor, bentuk *screw press* dan ukuran *die.* Kajian digunakan untuk mempelajari pengaruh kadar air and penambahan NPK terhadap karakteristik pellet yang dihasilkan. Pada tahap ini, eksperimen menggunakan rancangan acak lengkap (RAL) dengan 2 faktor yang disusun secara faktorial. Fator 1 (kadar air) terdiri dari 3 taraf; kadar air rendah 10-15% (K1), kadar air sedang 20-25% (K2), dan kadar air tinggi 30-35% (K3). Faktor 2 (konsentrai penambahan NPK) terdiri dari 3 taraf: kadar NPK 0% (N1), kdar NPK 3% (N2), kadar NPK 6% (N3). Selanjutnya data karekteristik pupuk pellet diuji dengan ANOVA dan dilanjutkan dengan BNT 0,05%. Parameter yang diamati mencakup: densitas curah pellet, densitas pellet, kekuatan tekan, soliditas, pellet durability index (PDI), hygroskopisitas, pH, dan kandungan NPK. Diagram alir penelitian Tahun I disajikan pada Gambar 4.

Penelitian Tahun II digunakan untuk melakukan uji pot pupuk pellet yang diaplikasikan ke tanaman. Kinerja pupuk pellet dibandingkan dengan kinerja metoda pemupukan secara konvensional pada tanaman. Uji pot di dalam *greenhouse* dengan menggunakan 4 tanaman yaitu sayuran, jagung, kedele, padi. Faktor 1 adalah tipe pupuk: pellet (P) dan remah (R). Tahapan pelaksanaan penelitian Tahun II disajikan pada Gambar 5.

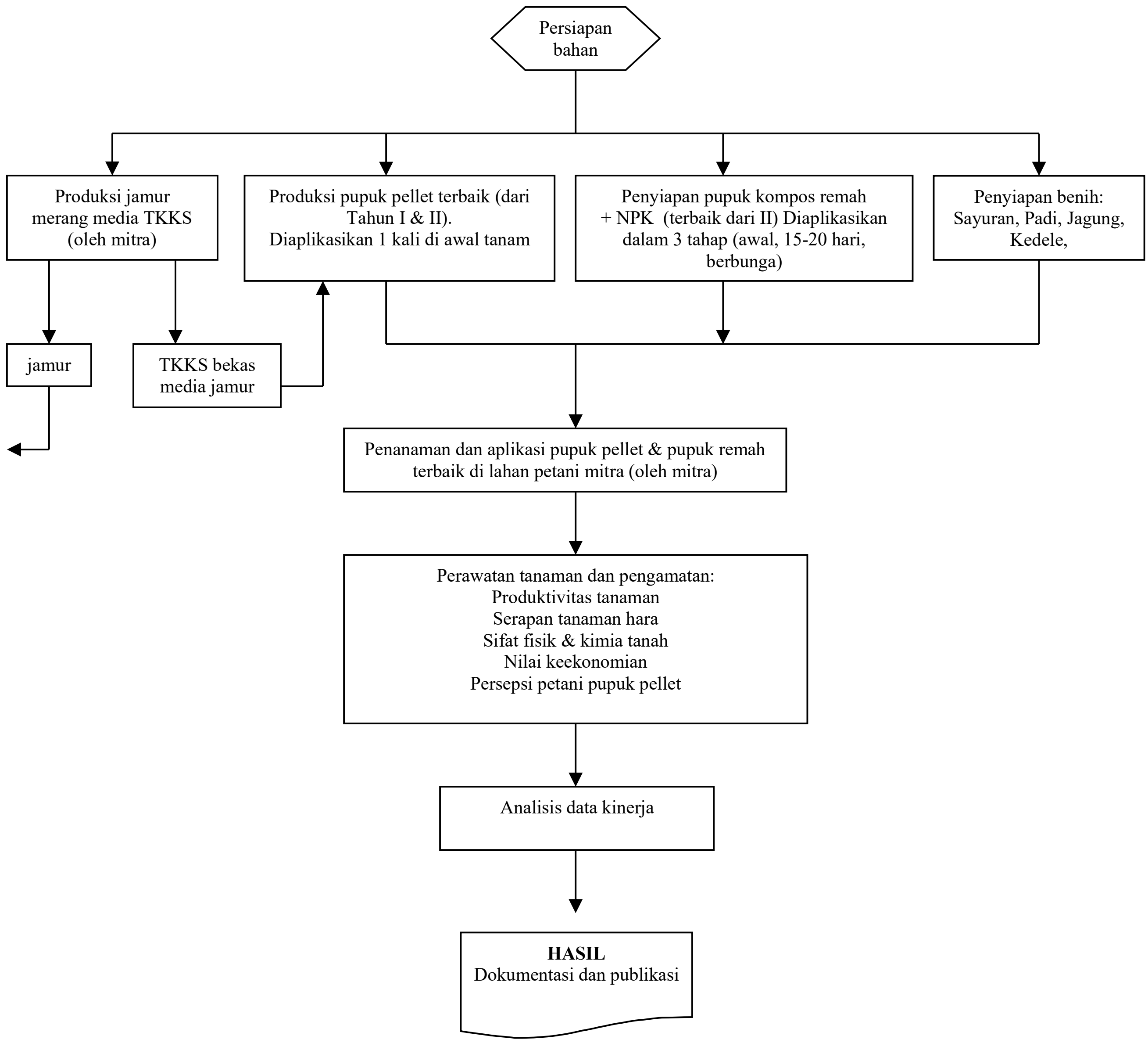
Penelitian Tahun III digunakan untuk sosialisasi pupuk kompos pellet pada petani mitra dengan tanaman sayuran, jagung, kedele, padi. Persepsi petani mitra dan nilai keekonomian penggunaan pupuk pellet akan di kaji. Tahapan penelitian pada Tahun 3 disajikan pada Gambar 6.



Gambar 4. Bagan alir pelaksanaan penelitian Tahun I: produksi jamur merang, pembuatan mesin chopper, pembuatan mesin pres dan modifikasi *screw press* dan *die*, eksperimen pengaruh kadar air dan penambahan NPK terhadap fisik dan kualitas pupuk pllet



Gambar 5. Bagan alir pelaksanaan penelitian Tahun II: Ujian pot pupuk pellet di greenhouse



Gambar 6. Bagan alir pelaksanaan penelitian Tahun III: Uji plot pupuk pellet di petani mitra

HASIL DAN PEMBAHASAN

Hasil Seminar

1. Link seminar: http://environment.triacon.org/gcal.html
2. Link bukti korespondensi dan bahan seminar: https://drive.google.com/drive/folders/1gfnwVIWSnLQ0U9qPBIJg34N78-TcTi9C

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EFFECT OF WATER CONTENT AND NPK ENRICHMENT ON SOME PROPERTIES OF A PELLETIZED COMPOST FERTILIZER

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ABSTRACT

Practical methods of fertilizer applications to enhance farm productivity with sustainability concern and least environmental risk have been getting a lot of attention. This research study aimed to evaluate the effect of mill water content and NPK enrichment on some properties of pelletized compost fertilizer. Three equal piles of compost were sprayed with different levels of liquid NPK, namely: 0% (N0), 3% (N1), and 6% (N2) on the basis of compost dry weight. Each of the three different NPK level piles was divided into other three piles, each of which was subjected to be sprayed with additional water in order to meet three different levels of water contents, namely: 10-15% (W1), 20-25% (W2), and 30-35% (W3) which were required in the experiment. Total piles of nine treatment combinations between water content and NPK enriched compost levels were pelletized and dried under the sun. After the sun drying, each of the nine pellet piles was sampled with three replicates and tested for physical and chemical properties namely: bulk and pellet densities, hygroscopicity, compressive strength, solidity, pellet durability index (PDI), disintegration time, pH, and chemical content. By doing these steps, the requirement of completely randomized design with factorial arrangement was considerably fulfilled. The data sets were analyzed by using analysis of variance and followed by LSD multiple comparation. The results showed that water content and NPK enrichment significantly affected some physical properties of compost pellets, namely: the bulk density (517.65 to 587.60 $kg.m^{-3}$), pellet density (1059.55 to 1329.91 $kg.m^{-3}$), compressive strength (2.08 to 7.78 $MN.m^{-2}$), solidity (42.66 to 91.91%), PDI (62.11 to 97.68 %), disintegration time (74.44 to 147.56 hours), and acidity (6.29-6.96). All produced pellets were hygroscopic. Pellets durability was much affected by water content levels whilst pH was affected by NPK enrichment levels. Phosphorus and potassium contents were manageable by using auger-type pelletizer, whilst nitrogen loss from the pelletizing process was noticeable. At last, the experiment revealed that W1N2 treatment produced the lowest dissoluble compost pellet, while the W2N1 and W3N1 produced the highest dissoluble compost pellets.

Keywords: compost, enrichment, fortification, pellet, slow release.

INTRODUCTION

The continuous use of chemical fertilizers in modern agriculture has exposed many negative effects on the environment. Soil becomes increasingly poor due to leaching process (Hartemink, 2007; Rahmaliza, 2014). The population of soil microorganisms is also suppressed because of a lack of organic matter (Miransari, 2013). The lack of organic matter also causes the soil to become hard and sticky that its water holding capacity diminishes (FAO, 2005), and plant roots become difficult to develop (Juarsah et al., 2008). In addition to being easily eroded, fertilizer and pesticide residues are easily carried away by runoff, causing pollution downstream (Las et al., 2006).

The direct loss experienced by farmers is the use of higher doses of chemical fertilizers while productivity does not get improved.

The supply of organic matter on farm land can be done by giving compost fertilizer. In general, compost fertilizers are made from agricultural residues or wastes. One advantage of compost fertilizer is its capability to improve physical properties of soil, promoting the growth of plant roots, and stimulating the growth of microorganisms population of which becomes more dynamic (Pertiwi and Lululangi, 2019). The mineralization process becomes faster and nutrient enrichment of the soil is enhanced. According to Dreval et al. (2020) organic matter can significantly improve soil nitrogen nutrient if compared to the application of nitrogen fertilizers. However, organic or compost fertilizers have a number of challenges. One disadvantage of compost fertilizers is that the volume is huge, that transportation becomes the primary hindrance (Simanungkalit, 2006). Slower plant response to absorb the nutrients is also another problem (Hasbianto, 2013). Low nutrient content of compost fertilizer is other reason why farmers are reluctant to use compost fertilizers.

Application of compost fertilizer coupled with chemical fertilizers is common practices among farmers to enhance production. Belay et al. (2001) stated that the response of plants to the application of inorganic fertilizers is strongly influenced by the presence of organic matter in the soil. However, the application of chemical fertilizers and organic fertilizers at the same time raises other problems such as the increasing energy and application costs. Other effort that has been made is the application of fortification technology (Marwanto et al., 2019). Fortification is known as a nutrient enrichment of compost fertilizers, usually with the addition of NPK mineral fertilizers (Ndung'u et al., 2009; Mieldazys et.al., 2017). Pelletizing compost fertilizer is another method to make it easier in application of the compost fertilizer. Compost pellets is supposed to be more convenient in handling, packaging, storage, and transportation (Lubis et al., 2016). Compost pellets can reduce volume up to 50-80% in addition to reducing dust in handling (Hara, 2001). Therefore, pelletizing coupled with NPK enrichment of compost fertilizer may potentially become the problem solution of compost application.

The manufacture of compost fertilizer pellets is done by applying high pressure so that the compost fertilizer material becomes denser and the volume becomes smaller (Mieldazys et al., 2017). The characteristics of the fortified compost pellet produced are absolutely influenced by some factors such as pressure levels (Tumuluru, 2018), particle size of the material, moisture content of the material, and the level of added NPK mineral fertilizer. Mieldazys et al. (2017) makes compost pellets from cattle manure with moisture content of 28%, and results in bulk density of 584±16.8 $kg.m^{-3}$ and pellet density of 789±40.4 $kg.m^{-3}$. The density of pellets depends on the pressure applied during pelletizing process. This study aims to determine the effect of mill water content and NPK enrichment on some properties of compost pellets from formulated powder compost.

MATERIALS AND METHODS

Raw material preparation.

The formulated compost used in this research was made from raw materials such as: spent mushroom substrate (used empty fruit bunch or EFB), fresh cattle manure, chicken litter, coconut peat, rice husk ash, and MSG industry sludge. The used EFB was collected from research facility of the University of Lampung, Indonesia (Triyono et al. 2019) whilst the other materials were gathered from other available local resources. Some chemical properties of the formulated powder compost were C=16.11±0.59%, N=1.26±0.59%, P=3.04±0.19%, and K=0.42±0.04%.

The formulated compost was ground by using a 20 hp machine, and screened by using a 0,3 cm screen size. The main purpose of the grinding and screening were to homogenize the aggregate sizes and remove rough impurities. The formulated compost was split into 3 piles (about 36 kg each) and sprayed with three different levels of liquid NPK fertilizer, namely: 0% (N0), 3% (N1), and 6% (N2) based on the compost dry weight. Further, each of the three different NPK level piles was again split into three piles, and each of which was sprayed with water in order to get three different levels of water contents, namely: 10-15% (W1), 20-25% (W2), and 30-35% (W3). So, there were 9 treatment combinations between three levels of NPK enrichment and three levels of water content. The nine treatment combinations of compost were kept in air tight plastic bags and ready to be pelletized.

Pellet production

Each of the 9 groups of moisturized compost was separately milled to form a dough, then pelletized using a 20 hp screw pelletizer. The outcoming pellets from 1 cm diameter dies were casted on a flat tray on which the pellets were cut into 2 cm long. On the trays, the pellets were dried under the sun for two or three days to get storable moisture contents. Afterall, each of the 9 groups of dried pellets was stored in a air tight plastic bag, and labeled.

Experiment design and data analysis

Three replicates were randomly sampled from each of the 9 air tight plastic bags of the pellets with the 9 treatment combinations. By doing these procedures, requirement of completely randomized design (CRD) with factorial arrangement was considerably fulfilled. So, the experiment included two factors: three NPK enrichment levels (N0, N1, N2) and three water contents (W1, W2, W3) with three replicates, making a total of 27 experimental units. This experimental design was implemented to every testing and measurement. Some physical and chemical properties of the pellets included in the testing and measurement were bulk and pellets densities, hygroscopicity, compressive strength, solidity, Pellet Durability Index (PDI), disintegration time, pH, and chemical contents. The data sets were analyzed by using analysis of variance and followed by LSD multiple comparation, using Statistical Analysis System (SAS) software.

Bulk density of pellets was measured by weighing of 500 ml pellet bulk. Pellet density was measured by measuring the diameter and length of individual pellets. Hygroscopicity was determined by placing samples in a room at controlled temperature and humidity of 26-28^{o}C and ±80%, respectively. Compressive strength was determined by placing (vertical axis position) an individual pellet on a digital scale and compressed from the top with a hydraulic press till broken. The axial load reading (kg) on the display was recorded by using video camera and the maximum load could be easily read from the video, then the load was converted to compressive strength (MPa). The solidity of pellets was tested by dropping a 200-g metal weight from 40 cm height (equivalent to 800 Joule energy) to a standing pellet, then largest surviving pellet mass was weighted and read as pellet solidity in percentages. Pellet Durability Index (PDI) was measured by using a modified method because of absence of standard apparatus. An individual pellet was inserted into a transparent plastic jar, and shaked by a rotating 5.5-cm displacement elbow at $\pm 20Hz$ for 10 minutes. The largest surviving pellet mass was weighted and read as pellet durability index in percentages. Complete disintegration time of individual pellet was determined by emerging a pellet in a jar of water, and the time till complete disintegration was recorded. Acidity (pH) and chemical contents were determined by using laboratory standard methods.

RESULTS AND DISCUSSIONS

Bulk density of compost pellets

Bulk densities of produced biofertilizer pellets were tested and the Analysis of Variance showed that the interaction effect of water contents and NPK enrichment on both of the bulk and pellet densities were significant at the level of α=0.05. The results of LSD comparison were shown on Figure 1.

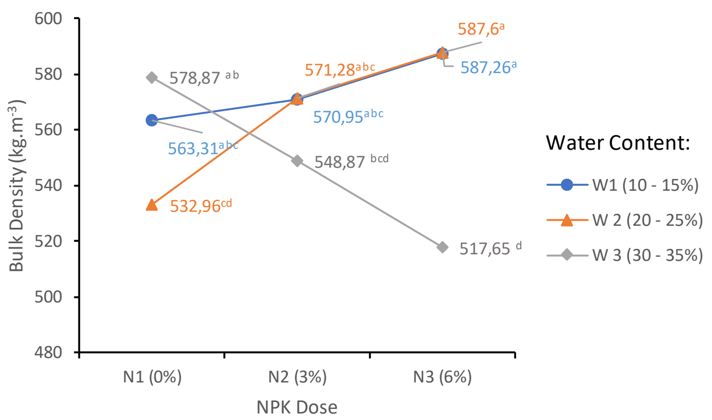

Figure 1. The interaction effect of water contents and NPK Doses on the bulk densities of compost pellet

The bulk density of compost pellets ranged between 517,65-587.60 kg.m^{-3}, but tendency to change with water contents and NPK doses were noticeable. With the increasing NPK levels, the bulk density of compost pellet remained constant at low water content W1(10 – 15%), tended to increase at moderate water content W2((20 – 25%), and tended to decrease at high water content W3(30 – 35%). Conversely, with the increasing water content, at no NPK enrichment N1(0%) the bulk density was the lowest at moderate water content W1(20 – 25%), remained constant at moderate NPK enrichment N1(3%), and tended to decrease at high NPK dose N3(6%). So, this finding suggested that water content of pellet mill may not more than ± 25% otherwise the bulk density of the pellet will be even lower. Most of the treatment combinations, however, showed that W1N1, W3N1, W1N2, W2N2, W3N2, W1N3, and W2N3, statistically produced highest bulk densities with average of 575,64 kg.m^{-3}.

The average of the highest bulk densities in this research was within the range of 312 to 701 kg.m^{-3} which was reported by Romano et.al. (2014). Mieldazys et al. (2017) also reported their finding of pellet bulk density of 584±16.8 kg.m^{-3}. From powder manure raw material bulk density of 556.4± 5.81 kg·m^{-3} Mieldazys et al. (2017) gained little increase of the bulk density of pellets. Hettiarachchi et.al. (2019) also reported that the increasing

bulk densities from 300-400 kg/m^{-3} of powder compost to 825-870 kg.m^{-3} of compos pellets. In our research, the bulk density of powder compost (before pelletized) was noted about 338 kg.m^{-3}, so the bulk density (after pelletized) increased about 70,33%. In spite of water content variations, other factors especially interstitial spaces (among the individual pellets in a pile) affected the bulk density of pellets. The interstitial space was affected by the size of the pellets as bigger diameters and longer the pellets the larger the interstitial space among the individual pellets. That was indicated in the data reported by Romano et.al. (2014). In our research study, the diameter and length of the pellets were 10 mm and 20 mm respectively. Whereas, Romano et.al. (2014) and Mieldazys et al. (2017) used diameter of about 5 mm and length of about 13 mm.

One important objective of the pelletized compost fertilizer is to get higher bulk density so that this make it more convenient in handling, storage, and transportation. This research study and others succeed to reveal the improved bulk density of pelletized compost. Other advantages in making use of compos pellets may be achieved in practical and easier applications, both manual or mechanized. The use of compost pellets was also environmentally friendly since its application does not generate dust. When dried and stored properly, the compost pellets would not moldy and could be stored in a long period of time.

Pellet density of compost pellets

Pellet density of compost pellets referred to the compactness of a single individual compost pellets. Analysis of Variance showed that interaction effect between water content of mill and NPK enrichment levels was significant at $\alpha = 0.05$. LDS multiple comparison analysis is shown on Figure 2. Just like the bulk density figure, the pellet density increased at low and moderate compost water content (W1 and W2), and tended to decrease at high water content (W3). Statistically the best treatment combinations (resulting highest particle densities) were found on W2N1, W3N1, W1N2, W2N2, W3N2, W1N3, W2N3, and the average of the highest pellet density was 1225.3 kg.m^{-3}. The importance of pellet density of compost pellets corresponds to the dissolubility of the pellet fertilizers and the rates of nutrient releases. The dissolubility of the pellets was supposed to increase with decreasing pellet density. Low pellet density of the compost pellets may be required for fast release fertilizers, while high pellet density of the compost pellets may be more appropriate for the purpose of slow release fertilizers.

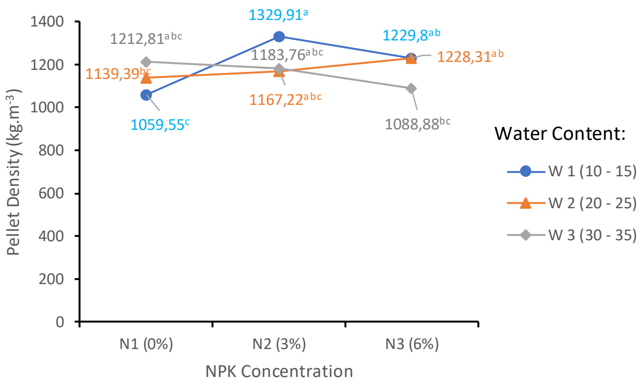

Figure 2. The interaction effect of water contents and NPK Doses on the pellet densities of compost pellets

The average of highest pellet densities found in this research study was quite high as compared to results of other researches. Mieldazys et al., (2017) reported and found that compost pellet density was 789±40.4 kg.m^{-3} which was much lower than found in this research. The particle density in this research was corroborated by what Zafaria et al. (2014) reported. Zafaria et al. (2014) found the particle density of compost pellets was about 1200 kg/m^{-3}. Mani et al, (2006) states that particle density is affected by compression, particle sizes of raw material, water contents, and chemical content especially for protein since protein melts easily at high temperature during pelletizing. In this research, effect of mill water content and NPK enrichment levels was visible, as at low and moderate water content (10-25%) the particle density tended to increase and high particle density could be achieved. In contrast, at high mill water content (30-35%) and high level of NPK enrichment, the particle density tended to be lower. But overall, the particle densities found in this research were considerably high (ranging from 1059.55 to 1329.91 kg.m^{-3}).

If pellets with low particle densities is desired (which is likely to break more easily when fertilizer is applied to the field), a lot of water during pellet mill preparation was necessarily to be added. On the other hand, if high particle density pellets are desired (not easily disintegrated when applied to the field), the amount of water added for pellet mill preparation should be limited.

Full disintegration Time

Disintegration test was carried out in order to determine the duration of compost pellets withstanding when immersed in water till fully disintegrated. The disintegration test with presence of water was in fact to simulate disintegration time of pellets in farm soil. Even the disintegration rates in water does not the same as the actual rates in farm soil, at least the relationship between water content of compost mill and NPK enrichment with the disintegration rates of pellets can be described.

Analysis of variance showed that interaction effect between water content and NPK enrichment levels on full disintegration time of compost pellets was not significant, but the individual effects of water content and NPK enrichment levels on full disintegration time of compost pellets was significant at $\alpha = 0{,}05$. The LSD multiple comparisons of the two factors were placed on Figure 3 and 4.

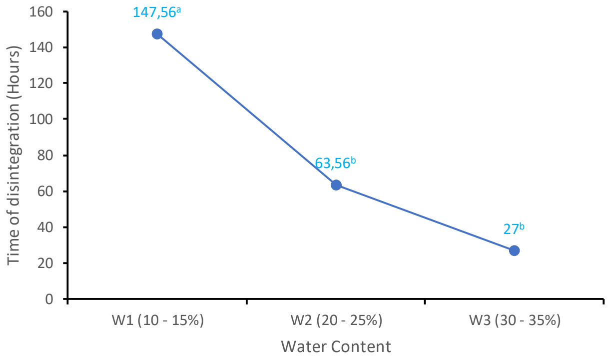

Figure 3. Effect of water content on disintegration time of compos pellets

As we can see on Figure 3, full disintegration time of compost pellet decreased with the increasing water content of compost mill. At low water content (W1) of compost mill, full disintegration time of compost pellets was 147,56 hours, at W2 full disintegration time of pellets significantly decreased to 63.56 hours, and at W3 full disintegration time of pellets decreased to 27 hours even not significantly different from that at W2. Nikiema et al. (2013) mentions that disintegration of compost pellets is a complex phenomenon which is usually accelerated by many factors such as; swelling of molecules, modification of surface tension, pH, temperature, chemical content, water content of compos mill, and binding agent additions. The longest of full disintegration time (147,56 hours) found in this research was in fact still longer than that reported by Nikiema et al. (2013). The longest time of disintegration reported by Nikiema et al. (2013) was 120 hours when they worked on fecal sludge processing for fertilizer pellets.

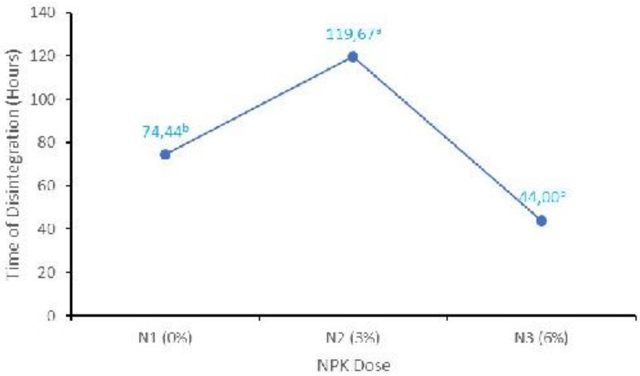

Figure 4. Effect of NPK enrichment on disintegration time of compos pellets

Figure 4 shows the effect of NPK enrichment levels on the disintegration time of compos pellets in water. Inorganic fertilizers were known as hygroscopic compounds, as shown on the Figure 4, that the disintegration was accelerated by NPK enrichment. However, the pattern of the disintegration time that low for N1 (plain compost pellets with 0% NPK enrichment), increased for N2, and decreased for N3 needed to be explained carefully. The disintegration time of 74.44 hours for N2 was in fact relatively high because Nikiema et al. (2013) reported that disintegration time of plain compost pellets (without enrichment nor binder agent) was 57 hours. For enriched pellets of N2 (3% NPK enrichment) in this research, the disintegration time was 119,67 hours, practically the same as Nikiema et al. (2013) finding of 120-hour disintegration when they used about 6% ammonium sulphate (($(NH_4)_2SO_4$) to enrich dewatered fecal sludge pellets. But for N3 (6% NPK enrichment) the disintegration time decreased significantly to 44.00 hours. The possible explanation of such behaviour might be found in the

physicochemical properties of the NPK fertilizer. The NKP fertilizer might have promoted gelatinization process of powder compost material when it was applied at 3%. But when it was applied at 6%, the NPK fertilizer enrichment was too much that tended to absorb much water resulting in faster disintegration of pellets.

Pellet Hygroscopicity

Hygroscopicity test was required to determine the stability of water content when compost pellets were stored in a room at temperature and relative humidity of 26-28 ºC and ±80% respectively. Analysis of Variance showed that effects of water content and NPK enrichment on the second day of storage were not significant, and their interaction was not significant either. Figure 5 shows the average of pellet water content along the 12 day storage after taken from oven (0%). The water content changed very quickly from 0% to 8.47% just in 2 days, and was stable at about 9.38% after 6 days of the storage, which just returned to initial water content of pellets (ranging from 8.32 to 9.65%).

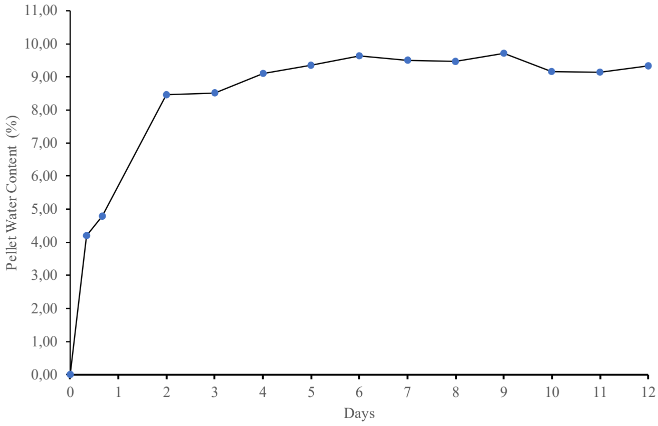

Figure 5. Average of pellet water content along 12 day storage

Compressive Strength

Compressive strength (MPa) of pellet refers to how high vertically axial load (N) can be gradually applied to an individual pellet till broken. Analysis of variance showed that interaction effect of mill water content and NPK enrichment on compressive strength of pellets was significant. Effect of water content was significant too but effect of NPK enrichment was not. Graphical representation of LSD multiple comparison was shown on Figure 6. If read vertically, it was very visible that there was no different compressive strength at N1, decreasing with increasing water content at N2 and N3. But the highest compressive strength was 7.78 MPa found at the treatment of W1N2 (10-15% water content and 3% NPK enrichment).

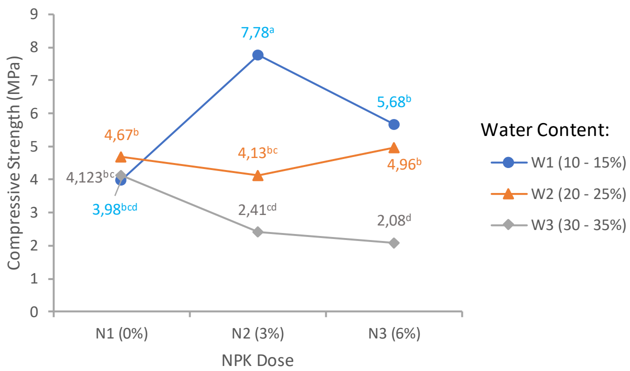

Figure 6. Effect of water content and NPK enrichment on compressive strength of compos pellets

The highest compressive strength of 7.78 MPa was higher than what Zafaria and Kianmehr (2014) reported. Zafaria and M.H. Kianmehr (2014) found the highest compressive strength of municipal solid waste pellets to be 113.2 N which was equivalent to 4 MPa with 6 mm die diameter. They used pelletizing method with 60-70 MPa piston type hydraulic press. Other research was done by Hettiarachchi et al (2019) who worked with municipal solid waste, used piston type hydraulic press with 30 HP motor, and found 2 MPa of highest compressive strength of pellets (64.3 N load with 6 mm diameter die). In our research, gelatinization process or dough making of

powder compost was incorporated before pellet was produced using an auger type press machine which was powered by a 20 HP diesel engine. This method of pelletizing proved to be able to produce high strength pellets with relatively low power. Drawback of this pelletizing method was the produced pellets need longer drying time.

Pellet Solidity Against Impact Load

The pellet solidity refers to how an individual pellet can be resistant when it is dropped by a metal weight from a particular height. Mass of the largest surviving part of the pellet was weighted and its percentage was compared. Analysis of variance showed that interaction effect between mill water content and NPK enrichment on the impact strength was significant. Effect of NPK enrichment was significant too but effect of water content alone was not. Graphical presentation of LSD comparison was shown on Figure 7.

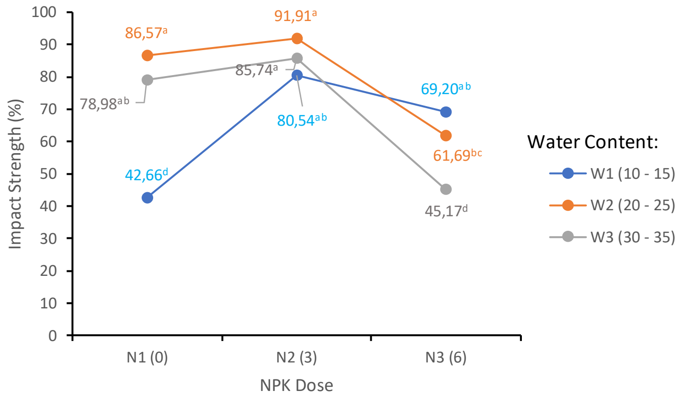

Figure 1. Effect of water content and NPK enrichment on impact strength of compos pellets

From Figure 7, we can see that at low water contents (W1) the impact strength of pellets tended to increase while at high water content (W1, W3) the impact strength of pellets tended to decrease. Statistically; however, the best impact strengths ranged from 66.20-91.91% with average of 82,16%.

Pellet Durability Index (PDI)

Pellet durability indicates the ability of the pellet to resist attrition during a shaking or vibrating test. In this research durability of an individual pellet was tested by using a shaking motion. This test is to simulate any impacts of abrasive actions on pellets during storage and transportation. The pellet was being abraded during the vibration and the largest surviving mass of the pellet was weighted, then its percentage, so called as pellet durability index (PDI) was compared. Analysis of variance showed that interaction effect between mill water content and NPK enrichment on the pellet vibration durability was not significant. The effect of NPK enrichment alone on the pellet vibration durability was not significant either but the effect of mill water content was significant. The LSD comparison of the effect of mill water content on the vibration durability is shown on Figure 8.

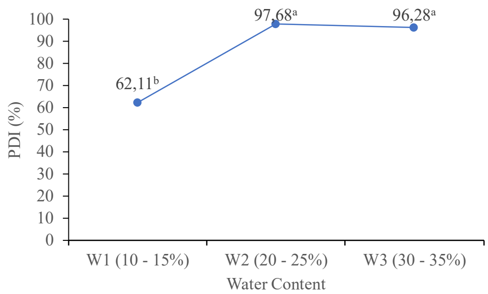

Figure 8. Effect of water content and NPK enrichment on durability of compos pellets

On Figure 8, we can see that durability increased with the increasing mill water content from 62.11% at W1 to 97,68% at W2, and stable to W3. This phenomenon indicated that compost water content could stimulate gelatinization when dough making process, and strengthen particle bounds of pellets resulting in higher PDI. Similar trend was observed in previous research of pelletizing fecal sludge for fertilizer (Nikiema et al. 2013).

Acidity (pH)

By definition, pH is negative logarithmic of the hydrogen-ion concentration, simply meaning more H^+ (hydrogen) ions, the more acidic. Interaction of the mill water content and the NPK enrichment significantly affected pellet acidity (pH) but all of the values were close and not more than neutral pH of 7. The pellet pH values decreased with increasing NPK doses ranging from 6.29 to 6.96. The highest pellet pH belonged to the treatment combination of W2N1 whilst the lowest belonged to W1N3. The effect of the inorganic fertilizer enrichment on the pellet pH was stronger at high mill water content (W3) being low pH at W3N3 and high at W1N3.

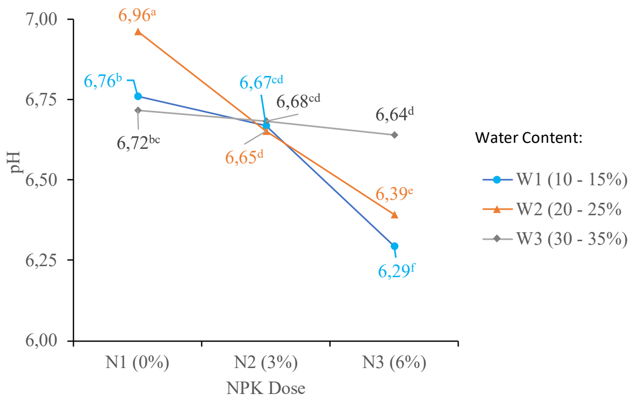

Figure 9. Effect of water content and NPK enrichment on pH of compos pellets

The varying pH values were definitely because of the presence of NPK fertilizer addition. Ammonium based component of the NPK fertilizer was the primary reason of the decreasing pH values through nitrification process. Nitrifying microbes breakdown ammoniacal nitrogen (ammonium) and release H^+ ion (Sparks, 2016). This reaction was promoted by the presence of tremendous numbers of microbes in the compost materials, and even more active in higher water content environment. Other mechanism was that the existence of ammonium sulfate in NPK fertilizer can be hydrolyzed and release H^+ ion (Kaya, 2014). Fortunately the decreasing pellet pH was not much, and still in the tolerable ranges of plant requirement.

Nutrient Contents

Figure 10 shows nutrient status of the raw compost (powder) and NPK enriched compost pellets. Among the three nutrient statuses (NPK), nitrogen content was the only nutrient that decreased from raw compost to compost pellet. Nitrogen content of raw compost was about 1.26±0.59%, decreasing to 0.55±0.04% in plain compost pellet, to 0.53±0.15% in 3% NPK enriched compost pellet, to 0.59±0.08% in 6% NPK enrich compost pellet. The decreasing nitrogen content could be because that nitrogen is bound in ammonium fertilizer which easily shifts to free ammonia and escape as nitrogen gas, and this mechanism was promoted by high temperature when compost was compressed to become pellets. As mentioned before the fact that pH was around neutral could be a significant role too in the volatilization process of nitrogen as observed by Mani et al, (2006). This result suggested that more appropriate methods of producing compost pellets may need to be investigated in order to maintain nitrogen content conservation.

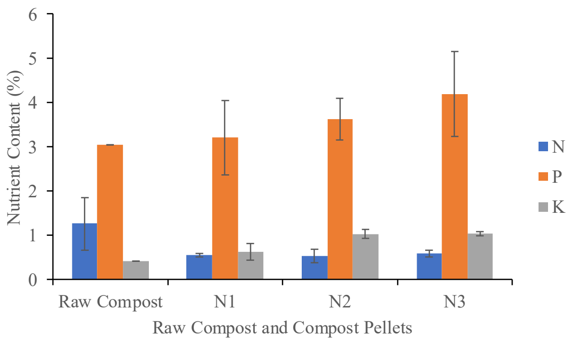

Figure 10. Effects of NPK enrichment on nutrient content of the compost pellets

Phosphorus content looked more conservative, as seen on Figure 10, than other two nutrients (N dan K). The P content was increasing with the increasing NPK enrichment levels, ranging from 3,62±0.47% at 3% NPK enrichment level to 4.19±0.97% at 6% NPK enrichment level, whilst P content for raw compost was 3.04±0.19% and 3.20±0.85% for plain compost pellet. Potassium content showed little conservation, as K increased to maximum of 1.03±0.06% at 6% NPK enrichment level, whilst K contents was 0.42±0.04% for raw compost and 0.63±0.19% for plain compost pellet.

Conclusions

Interaction between water contents and NPK enrichment levels was significant on some physical properties of compost pellet parameters such as bulk density, pellet density, compressive strength, pellet solidity, acidity. High performances of bulk density, pellet density, compressive strength, and disintegration time could be found at the treatment combination of 10-15% water content and 3% NPK enrichment (W1N2), but high solidity was found in all treatments of water content levels. Pellet durability against vibration was much affected by water content than by NPK enrichment levels, but pH was much affected by NPK enrichment rather by water content, and decreased with increasing NPK enrichment levels. All resulted pellets were hygroscopic that approaching to initial water content in just 2 days of storage. Phosphorus and potassium enrichments of pellet were manageable by using auger-type pelletizer but nitrogen might need other method of pelletizing.

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Draf Paten Sederhana

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PROSES PEMBUATAN PUPUK KOMPOS PELET DENGAN PENGKAYAAN FOSFAT

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DESKRIPSI

PROSES PEMBUATAN PUPUK FOSFAT PELLET DARI KOMPOST YANG DIPERKAYA

Bidang Teknik Invensi

Invensi ini berhubungan dengan suatu proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat dan bahan-bahan: tandan kosong kelapa sawit (TKKS) bekas media jamur merang, kotoran sapi, kotoran ayam, serbuk sabut kelapa, arang sekam, limbah lumpur industri MSG. Secara spesifik pembuatan pupuk kompos pellet dengan pengkayaan fosfat dilakukan melalui dua tahap yaitu proses fermentasi bahan kompos dan proses extrusi adonan kompos. Kompos dibuat dari bahan-bahan limbah organik yang salah satunya kaya akan kandungan fosfor, yaitu lumpur limbah industri MSG, dilanjutkan dengan pembuatan pellet dengan menggunakan mesin extruder tipe ulir (auger).

Latar Belakang Invensi

Penggunaan pupuk kimia secara terus-menerus dalam pertanian modern banyak menimbulkan efek negatif terhadap lingkungan. Tanah menjadi semakin miskin akibat proses pelindian. Populasi mikroorganisme tanah juga tertekan karena kekurangan bahan organik. Kekurangan bahan organik juga menyebabkan tanah menjadi keras dan lengket sehingga daya ikat air berkurang, serta akar tanaman sulit berkembang. Nutrisi mudah terbawa aliran permukaan sehingga menimbulkan pencemaran di hilir. Kerugian langsung yang dialami petani adalah penggunaan pupuk kimia dosis tinggi sementara produktivitas tetap tidak membaik.

Penyediaan bahan organik pada lahan pertanian dapat dilakukan dengan pemberian pupuk kompos. Pada umumnya pupuk kompos dibuat dari sisa atau limbah pertanian. Salah satu keunggulan pupuk kompos adalah kemampuannya untuk memperbaiki sifat fisik tanah, mendorong pertumbuhan akar tanaman, dan merangsang dinamika populasi mikroorganisme. Namun, pemanfaatan pupuk organik atau kompos memiliki sejumlah tantangan. Salah satu kelemahan pupuk kompos adalah volumenya yang besar sehingga menjadi kendala utama dalam penyimpanan, pengemasan, transportasi, dan aplikasi. Kandungan hara pupuk kompos yang rendah

(terutama NPK) juga menjadi alasan lain mengapa petani enggan menggunakan pupuk kompos.

Peletisasi dan pengkayaan (fortifikasi) pupuk kompos berpotensi bisa menjadi solusi alternatif dari permasalahan tersebut. Dengan rekayasa peletisasi, volume pupuk menjadi lebih kecil sehingga lebih memudahkan dalam pengemasan, transportasi, penyimpanan, dan aplikasi. Fortifikasi dikenal sebagai teknik meningkatkan kualitas nutrisi kompos dengan cara menambahkan pupuk mineral ke pupuk kompos. Dengan teknik fortifikasi, pupuk kompos menjadi lebih menarik bagi petani untuk menggunakannya.

Pembuatan pellet untuk beberapa tujuan telah banyak dilakukan, misalnya pellet arang untuk energi, pellet pakan ternak, pellet pakan ikan. Pellet rerumputan untuk pakan ternak telah banyak dibuat. Pellet kompos dari bahan tinja, kotoran sapi, sampah domestik, juga sudah banyak dilakukan. Namun proses pembuatan pupuk kompos dengan bahan-bahan limbah organik yang diformulasikan dan pembuatan pelletnya dengan pengkayaan fosfat belum pernah dilakukan.

Uraian Singkat Invensi

Invensi yang diusulkan ini pada dasarnya adalah suatu proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat dengan menggunakan mesin extruder tipe auger, dari bahan-bahan limbah organik yang diformulasikan. Bahan-bahan limbah organik terdiri dari TKKS sawit bekas media jamur merang, kotoran sapi, kotoran ayam, serbuk sabut kelapa, dan limbah lumpur industri MSG, serta penambahan pupuk mineral fosfat. Konsep invensi proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat dari campuran bahan-bahan kompos yang diformulasikan dan kemudian difermentasikan. Setelah selesai, kompos remah digiling dan diayak agar halus dan homogen. Setelah halus, kompos remah di lumat dengan menggunakan mesin mixer sampai menjadi adonan. Pada waktu pembuatan adonan, air dan pupuk fosfat ditambahkan. Banyaknya air dan konsentrasi pupuk fosfat yang ditambahkan berpengaruh terhadap tingkat kekerasan pellet yang dihasilkan. Setelah dimixer, adonan pupuk kompos di cetak dengan mesin extruder menjadi pellet ukuran diameter 5-10 cm memanjang kemudian dipotong-potong dengan panjang tertentu, dan dijemur di bawah terik matahari. Setelah kering, pupuk kompos pellet dapat dikemas dalam kantung plastic kedap udara dan disimpan.

Uraian Lengkap Invensi

Pembuatan pupuk kompos pellet dengan pengkayaan fosfat dimulai dengan mengumpulkan bahan-bahan yaitu: TKKS sawit bekas media jamur merang, kotoran sapi, kotoran ayam, serbuk sabut kelapa, dan lumpur limbah industri MSG. di antara bahan-bahan tersebut yang mengandung fosfor tinggi adalah limbah lumpur industri MGS (21,74%). Kemudian bahan-bahan dicampur dengan perbandingan; TKKS : kotoran sapi : kotoran ayam : serbuk sabut kelapa : arang sekam : lumpur limbah industri MSG = 50 : 30 : 5 : 5 : 5 : 5. Campuran bahan kompos ditumpuk membentuk unggun sambil disiram air secara bertahap. Tumpukan bahan kompos kemudian ditutup terpal, kemudian difermentasikan selama 3 bulan. Bahan kompos diaduk-aduk, dibalik, dan disiram air secara rutin setiap 1-2 minggu. Alas bagian bawah tumpukan kompos harus berdrainase baik agar tidak ada air yang menggenang di kompos. Setelah 3 bulan, sudah cukup matang, kompos dibongkar, digiling, dan diayak dengan saringan berukuran 5 mm. Kompos remah yang dihasilkan kemudian dikemas dalam karung untuk disimpan sementara.

Selanjutnya pembuatan pupuk kompos pellet dengan pengkayaan fosfat dari bahan kompos remah dimulai. Kompos remah dimasukkan ke dalam mesin mixer berkekuatan 8 HP, ditambahkan air 30-35% dan pupuk mineral fosfat sebanyak 6%. Bahan kemudian dilumat dengan mesin mixer selama kurang lebih 15 menit, dan setelah kenyal/kalis, adonan diangkat. Adonan ini menghasilkan pellet dengan tingkat kekerasan yang redah sehingga cepat hancur dan larut ketika diaplikasikan di awal tanam, atau bersama dengan pengolahan tanah. Adonan untuk mendapatkan pellet yang keras dan padat sehingga waktu hancurnya lebih lama bisa lakukan pada tahapan ini.

Setelah menjadi cukup kenyal dan kalis, adonan kompos dimasukkan ke dalam mesin extruder 20 HP, dicetak menjadi pellet. Penggunaan daya mesin extruder ini sangat rendah jika dibandingkan dengan mesin extruder pencetak pellet untuk energi yang mencapai 200 HP. Mesin pellet untuk pakan ternak menggunakan daya rendah karena memang untuk menghasilkan pellet yang tidak begitu padat sehingga nyaman untuk dimakan oleh ternak. Sedangkan dalam proses pencetakan pellet untuk pupuk kompos ini, selain kekerasan, daya larut nutrisi pupuk juga sangat penting untuk diperhitungkan.

Pellet yang keluar dari mesin extruder berdiameter sesuai dengan lubang cetakan (die) dan memanjang. Kemudian pellet dipotong-potong sehingga

panjangnya seragam. Setelah ditampung pada nampan, pellet di jemur di bawah terik matahari 1-2 hari hingga kering simpan pada kadar air antara 8-10%. Setelah kering, pupuk kompos pellet dikemas dalam karung plastik yang kedap udara dan disimpan. Kemasan harus kedap udara agar kadar air tidak benyak berubah yang berakibat bisa jamuran. Karakteristik pupuk kompos pellet dengan pengkayaan fosfat disajikan pada Tabel 1.

Tabel 1. Karakteristik pupuk kompos pellet dengan pengkayaan fosfor

No	Parameter	Nilai	Satuan
1	Masa jenis curah pellet	517,65	kg. m^{-3}
2	Masa jenis pellet	1008,88	kg. m^{-3}
3	Lama waktu hancur total	35,30	jam
4	Higroskopisitas	0,35	%/jam
5	Kekuatan kompresi	2,08	MPa
6	Soliditas	45,17	%
7	Durabilitas Indeks	96,28	%
8	pH	6,64	-
9	Kadar P	4,19	%

Klaim

Suatu proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat dengan langkah-langkah sebagai berikut;

a. Mengumpulkan bahan-bahan kompos yaitu TKKS bekas media jamur merang, kotoran sapi segar, kotoran ayam, serbuk sabut kelapa, arang sekam dikumpul.
b. Mencampur hahan-bahan dengan perbandingan volume masing-masing; 50:30:5:5:5 secara berurutan seperti pada butir a, dengan menggunakan cangkul atau garpu.
c. Membuat unggun atau tumpukan secara vertical setinggi 1-15 m. Dimensi horizontal ditentukan oleh banyaknya bahan kompos yang diolah.
d. Menyiram dengan air sampai basah merata pada tumpukan bahan setiap kira-kira 10-20 cm tinggi. Alas bawah dibuat porus agar aliran drainase cukup baik sehingga tidak ada air yang menggenang di dalam tumpukan bahan kompos.
e. Menutup tumpukan bahan kompos dengan terpal agar terlindung dari terik matahari dan air hujan.

f. Membuka tutup terpal, mengaduk bahan kompos dengan cangkul atau garpu, dan menyiram air dengan gembor sampai basah merata setiap minggu kemudian ditutup dengan terpal kembali. Setelah pengompos berusia 1 bulan, frekuensi pembalikan dan penyiraman bisa diturunkan menjadi 2-3 minggu sekali. Dan setelah berusia 2 bulan, kompos tidak perlu lagi dibalik dan disiram.
g. Membongkar dan memanen kompos setelah fermentasi berjalan 3 bulan. Kemudian kompos dihampar diatas terpal dan dijemur agar kadar air menurun sampai sekitar 15-20%.
h. Menggiling kompos dengan mesin chopper dan mengayaknya dengan ukuran saringan 5 mm. Penggilingan dan pengayakan kompos untuk memperkecil bongkahan kompos agar lebih lembut untuk dan membersihkan kompos dari kotoran kasar. Setelah itu, kompos halus dikemas dalam karung agar tertata rapih.
i. Mengukur kadar air kompos remah secara gravimetri.
j. Memasukkan pupuk kompos remah ke dalam mesin mixer 8 HP. Kemudian menambahkan air hingga kadar air kompos mencapai 30-35%. Pada saat yang bersamaan, pupuk mineral fosfat ditambahkan sebanyak 6% ke dalam kompos.
k. Melumat pupuk kompos remah menjadi adonan dengan kecepatan mixer sekitar 90 rpm selama kurang lebih 15 menit hingga adonan menjadi kenyal dan kalis.
l. Memasukkan adonan kompos ke dalam mesin extruder extruder (20 HP) untuk dicetak menjadi pellet dengan ukuran diameter 1 cm.
m. Pellet yang keluar dari cetakan ditampung dengan nampan. Dengan pemasangan pisau pemotong di depan lubang cetakan, maka panjang potongan pellet menjadi seragam 2-2,5 cm.
n. Penjemuran pellet pupuk kompos di bawah terik matahari selama 1-2 haris.
o. Pengukuran karakteristik pupuk kompos pellet dengan pengkayan fosfat.

Abstrak

PROSES PEMBUATAN PUPUK KOMPOS PELET DENGAN PENGKAYAAN FOSFAT

Invensi Proses pembuatan pupuk kompos pellet dengan pengkayaan fosfat meliputi tahapan: penyiapan bahan-bahan TKKS bekas media jamur merang, kotoran sapi, kotoran ayam, serbuk sabut kelapa, arang sekam, dan limbah lumpur industry MSG dengan perbandingan 50:30:5:5:5:5. Bahan-bahan difermentasi sampai menjadi kompos matang kemudian dilumatkan dengan penambahan air 30-35% dan pupuk fosfat (16%) sebanyak 6%, sampai menjadi adonan yang kenyal. Adonan dicetak dengan menggunakan mesin extruder 20HP, dengan diameter 1 cm dan dipotong menjadi panjang 2cm. Pellet dikeringkan dengan cara dijemur di bawah terik matahari selama 1-2 hari. Pupuk kompos pellet kemudian disimpan di dalam karung plastik dan diukur karakteristiknya. Karakteristik pupuk kompos pellet yang dihasilkan yaitu: masa jenis curah 517,65 $kg.m^{-3}$, masa jenis pellet individual 1008,88 $kg.m^{-3}$, lama waktu direndam air sampai hancur 35,30 jam, higroskopisitas 0,35 % jam^{-1}, kekuatan kompresi 2,08 MPa, soliditas (daya tahan getaran) 45,17%, Durabilitas indeks 96.28%, pH 6,64, kadar P 4,19 %.

KESIMPULAN

Penelitian pembuatan pupuk kompos pellet telah menghasilkan luaran berupa:

1. Publikasi seminar internasional (sudah dilaksanakan
2. Publikasi jurnal internasional bereputasi, Q2 (dalam proses revisi)
3. Draf paten sederhana (proses usulan)

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Lampiran 1

Tabel 1. Luaran penelitian

No	Jenis luaran		Indikator Capaian		
			2021	2022	2023
1	Artikel ilmiah	Internasional	1		2
2	Seminar (Prosiding)	Nasional	1	2	2
3	Kekayaan Intelektual (KI)	Hak Cipta	1		
4	Teknologi Tepat Guna: pupuk pellet		1		
5	Buku ISSN				1

Tingkat Kesiapan Teknologi (TKT) 4 bidang pertanian yaitu: Komponen teknologi telah divalidasi dalam lingkungan laboratorium. Dengan indikator sebagai berikut:

1. Produsi pupuk kompos pellet telah dilakukan.
2. Karakteristik pupuk kompos pellet telah diukur
3. Uji pot pupuk kompos pellet pada beberapa tanaman telah dilakukan.
4. Uji plot dan sosialisasi pupuk kompos pellet di mitra petani sudah dilakukan
5. Analisis usaha pupuk kompos pellet sudah dibuat
6. Rancangan kemasan pupuk kompos pellet sudah ada
7. Perjanjian kerja sama dengan mitra usaha sudah dibuat
8. Pemasaran produk pupuk kompos pellet dilakukan