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Physical Properties of Briquette Fertilizers Made from Urea and Fly Ash-Azolla

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ABSTRACT

Coal fly ash and Azolla biomass are potential materials to be used as raw materials for the manufacture of briquette fertilizers. In this study, the coal fly ash, azolla and urea in various compositions were mixtured to make briquette fertilizers. The study was conducted to evaluate the physical properties of briquette fertilizers, *i.e* bulk density, compressive strength, porosity, and water holding capacity on various compositions of fly ash-azolla and urea. The research was arranged in a Completely Randomized Design with three replicates. The formulation of briquette fertilizers as treatments was made with the compossition (w/w, dry-weight basis) of (fly ash : azolla) + urea as follows: (40:60)90+10; (40:60)80+20; (40:60)70+30; (50:50)90+10; (50:50)80+20; (50:50)70+30; (60:40)90+10; (60:40)80+20 and (60:40)70+30. The results showed that the variation in composition of coal fly ash-azolla and urea significantly affected the compressive strength, bulk density, water holding capacity and porosity of briquette fertilizers produced. The increase in the proportion of fly ash or the decrease of azolla biomass proportion tends to increase compressive strength and bulk density, and tends to decrease the water holding capacity and porosity of briquette fertilizers produced.

Keywords: Azolla, briquette fertilizer, fly ash, urea

ABSTRAK

Abu terbang batubara dan biomassa Azolla merupakan bahan yang potensial untuk digunakan sebagai bahan baku pembuatan pupuk briket. Pada penelitian ini dilakukan pencampuran abu terbang batubara, azolla dan urea dengan berbagai komposisi untuk membuat pupuk dalam bentuk briket. Penelitian ini dilakukan untuk mengevaluasi beberapa karakteristik fisika pupuk briket pada berbagai komposisi abu terbang batubara-azolla dan urea, yang meliputi kerapatan isi, kuat tekan, porositas, dan kapasitas menahan air. Penelitian ini dilakukan dengan menggunakan Rancangan Acak Lengkap dengan tiga ulangan. Perlakuan yang diterapkan adalah formulasi pupuk briket yang dibuat dari campuran (abu terbang batubara:Azolla) + Urea dengan komposisi (b/ b, berat kering) sebagai berikut: (40:60)90+10; (40:60)80+20; (40:60)70+30; (50:50)90+10; (50:50)80+20; (50:50)70+30; (60:40)90+10; (60:40)80+20 and (60:40)70+30. Hasil penelitian menunjukkan bahwa variasi komposisi abu terbang batubara-azolla dan urea berpengaruh nyata terhadap kuat tekan, kerapatan isi, kapasitas menahan air dan porositas pupuk briket yang dihasilkan. Peningkatan proporsi abu terbang batubara atau penurunan proporsi biomassa Azolla cenderung meningkatkan kuat tekan dan kerapatan isi, dan cenderung menurunkan kapasitas menahan air dan porositas pupuk briket yang dihasilkan.

Kata kunci: Abu terbang batubara, Azolla, pupuk briket, urea

INTRODUCTION

Fertilization efficiency is known to be very low, in which around 40-70% N, 80-90% P, and 50-70% K applied in the form of fertilizers are lost to the environment and can not be taken up by plants (Trenkel 2010; Lubkowski 2014). One way to improve fertilizer use efficiency is by coating artificial fertilizers using a material that can slow down the release of nutrients from fertilizers, which is called as slow release fertilizer (Trenkel 2010; Lubkowski 2014).

The release of nutrients from coated fertilizers basically occurs through a diffusion process that passes through permeable or semi-permeable coatings (Shaviv 2005; Trenkel 2010). In general, thin and porous layers have a high release rate, while smooth, uniform and thicker layers indicate more control over nutrient release and can substantially withstand nutrient release rates. Physical characteristics of coating materials such as size, shape and surface also affect nutrient release patterns (Trenkel 2010; Ali and Danafar 2015). Therefore, the rate of release of nutrients can be controlled through characteristic manipulation of coating materials, such as thickness or physical-chemical composition.

A good fertilizer coating material must have at least 4 characteristics, namely low prices, biodegradable, non-toxic, and abundant availability (Trenkel 2010; Ali and Danafar 2015). Some inorganic minerals and organic materials have been reported to be used in the manufacture of slow release fertilizers, including silicate compounds, sulfur, gypsum, lime, cement, zeolite, fly ash, lignin, organic acids, chitosan and humic (Nainggolan *et al*. 2009; Sulakhudin *et al*. 2011; Qiu *et al*. 2011; Hou *et al*. 2014; Lubkowski 2014; Behin and Sadeghi 2016; Teixeira *et al*. 2016). Nevertheless, the process of making slow release fertilizers is still relatively complicated and relatively more expensive than conventional fertilizers, making it difficult to be accepted at the farm level (Qiu *et al*. 2011; Dong *et al*. 2016).

Coal fly ash and Azolla biomass are potential materials to be used as raw materials for the manufacture of slow release fertilizers. Coal fly ash, a by-product of coal combustion, is an amorphous aluminosilicate material and composed of particulate matter collected from flue gas stream (Singh *et al*. 2011). Coal fly ash is dominated by fine-sized particles (0.01-100 ìm) and has podzolanic properties (like cement), so it can act as an adhesive and fertilizer coating. Coal fly ash contains Ca cations as the dominant cation followed by Mg, Na and K (Kishor *et al*. 2010; Singh *et al*. 2011; Yao *et al.* 2015), which can play a role in cation exchange. In addition, this material also contains other plant nutrients, such as P, S, B, Fe, Cu, Zn, Mn and Mo, so it will enrich the nutrient content of fertilizer (Kishor *et al*. 2010; Singh *et al*. 2011; Srinavas *et al*. 2017).

Organic materials also have characteristics that are very potential to be used as a fertilizer coating material. Decomposition of organic matter will produce organic acids such as humic and fulvic acids, which are dominated by negative charges (Sposito 2008). Therefore, organic acids can bind nutrients from fertilizers through chemical reactions directly or indirectly through microbiological activity and decomposition of microbial biomass (Havlin *et al*. 2005; Sulakhudin *et al*. 2011; Teixeira *et al*. 2016). One potential source of organic material is azolla (*Azolla sp*.). Azolla is a water fern. Symbiosis of Azolla with cyanobacteria *Anabaena azollae* is able to fix nitrogen from the atmosphere around 30-60 kg N ha^{-1} (Kollah *et al*. 2015; Roy *et al*. 2016). The low C/N ratio of Azolla biomass (between 9-10) indicates that the biomass will rapidly decompose and produce available nutrients and organic acids as decomposition products (Bhuvaneshwari and Kumar 2013; Roy *et al*. 2016). The use of coal fly ash and organic matter mixtures is known to increase the efficiency of using N, P, and K fertilizers by 45.8%, 33.5% and 69.6%, respectively compared to the use of chemical fertilizers or a combination of chemical fertilizers and organic matter (Mitra *et al*. 2003; Kishor *et al.* 2010). Hermawan *et al.* (2014) also reported that the use of a mixture of coal fly ash and organic fertilizer in bulk form could increase the efficiency of fertilizer use by 42.4%.

The coal fly ash that has podzolanic properties (like cement) with a high content of alkaline oxide, and azolla biomass that is rich in N and will produce organic acids show its potential as an alternative to urea fertilizer coatings. In this study, mixing of coal fly ash, azolla biomass and urea fertilizer in various compositions was carried out to make briquette fertilizers which are expected to be able to release nutrients slowly into the soil. Physical characteristics of briquette fertilizers are known to affect the rate of release of nutrients from fertilizers into the soil (Trenkel 2010; Ali and Danafar 2015). Therefore, a study was conducted to evaluate the physical characteristics of briquettes, such as bulk density, compressive strength, porosity, and water holding capacity of briquettes on various compositions of coal fly ash, azolla and urea.

MATERIALS AND METHODS

Preparation of Briguette Fertilizer

Coal fly ash was obtained from a coal-fired thermal power station in Muara Enim District, South Sumatra. Biomass of azolla was taken from the azolla cultured pond at Department of Soil Science, Sriwijaya University. The coal fly ash is dominated by silt and clay-sized particles (713.20 g kg^{-1}), water content (21 g kg^{-1}), pH (8.74), organic-C (0.11 g kg^{-1}), total-N (0.01 g kg^{-1}), total-P (0.6 g kg^{-1}) and total-K (0.6 g kg^{-1}). The chemical characteristics of azolla biomass used in this study as follow: pH (5.75), organic-C (33.80 g kg^{-1}), total-N (18.5 g kg^{-1}), P (1.60 g kg^{-1}), and K (18.70 g kg^{-1}). Coal fly ash and biomass of azolla were air dried and sieved with 0.05 mm and 2.0 mm diameter size, respectively.

The experiment was conducted in the Laboratory of Chemistry, Biology and Soil Fertility, Department of Soil Science, Faculty of Agriculture, Sriwijaya University in September 2017 to January 2018. The research was arranged in a Completely Randomized Design with three replicates. The formulation of briquette fertilizers as treatments was made with the compossition (w/w, dry-weight basis) of (fly ash (F) : biomassa of azolla (AZ)) + urea (U) as follows: (40:60)90+10 (FAZ_1-U_1); (40:60)80+20 (FAZ_1-U_2); (40:60)70+30 (FAZ_1-U_3); (50:50)90+10 (FAZ_2-U_1); (50:50)80+20 (FAZ_2-U_2); (50:50)70+30 (FAZ_2-U_3); (60:40)90+10 (FAZ_3-U_1); (60:40)80+20 (FAZ_3-U_2) and (60:40)70+30 (FAZ_3-U_3). The coal fly ash-azolla mixture (FAZ) and urea of each composition were mixed thoroughly with 5% starch as a binder. Ionic free water was added to adjust the moisture content of about 25% and then the mixture was put into the mold and compacted. The briquette mold was made using a PVC pipe with a diameter of 1.90 cm and cut along 4 cm. The produced briquettes were dried at a temperature of ± 50°C for 24 hours.

Data Collection and Analysis

The briquette fertlizers were analysed for their physical properties including water retention capacity, porosity, bulk density, and the compressive stength. Water retention capacity of briquette fertilizer is the difference between initial weight and final weight of the briquette. Briquette fertilizer samples that have been known for their water content were weighed as initial weight. Then it was saturated with ion free water using a beakerglass for 1 hour. The samples of briquette fertilizer that were saturated with water were then weighed, as the final weight. Porosity was calculated by dividing the volume of water absorbed by the volume of briquette fertilizer. Bulk density of briquette fertilizer was calculated by dividing the dry weight of briquette fertilizer with the total volume of briquette fertilizer. The compressive strength test was carried out using the Hand Penetrometer to determine the strength of briquettes in holding the load with a certain pressure. The sample pressure was followed by the addition of the load until the sample had an initial crack. The initial crack is considered a failure, because the sample is considered to be unable to withstand the heavy load more than the load that causes the initial crack. Statistical analysis for all observed parameters was conducted by using Analysis of Variance (ANOVA) followed by Least Significance Difference (LSD) test at level of $p < 0.05$.

RESULTS AND DISCUSSION

Compressive Strength

The results of analysis of variance showed that the briquette fertilizers with the proportion of coal fly ash-azolla biomass and urea have a significant effect on the compressive strength of the briquette fertilizers produced. Table 1 shows that the level of compressive strength of the briquette

Table 1. The effect of coal fly ash-azolla and urea proportion on some physical properties of briquette fertilizers.

Treatments Code (Fly Ash:Azolla)+Urea	Parameters			
	Compressive Strength (kg m^{-2})	Bulk Density (g cm^{-3})	Water Retention Capacity (%)	Porosity (%)
FAZ_1-U_1 (40:60)90+10	1.50 ab	0.66 a	61.12 d	37.47 ab
FAZ_1-U_2 (40:60)80+20	1.43 a	0.83 b	53.25 bc	49.29 bcd
FAZ_1-U_3 (40:60)70+30	1.17 a	0.84 b	63.82 d	63.39 d
FAZ_2-U_1 (50:50)90+10	1.25 a	0.83 b	55.60 c	50.78 bcd
FAZ_2-U_2 (50:50)80+20	1.88 bc	0.93 c	51.27 b	40.49 abc
FAZ_2-U_3 (50:50)70+30	1.42 a	0.82 b	55.28 c	34.17 ab
FAZ_3-U_1 (60:40)90+10	1.90 bc	0.96 c	49.32 b	55.49 cd
FAZ_3-U_2 (60:40)80+20	2.08 c	1.09 d	44.25 a	32.15 a
FAZ_3-U_3 (60:40)70+30	1.53 ab	0.95 c	51.16 b	47.36 abcd
$LSD_{0,05}$	0.40	0.08	4.29	17.06

Note: The numbers followed by the same letters in the same column are not significantly different (p<0.05).

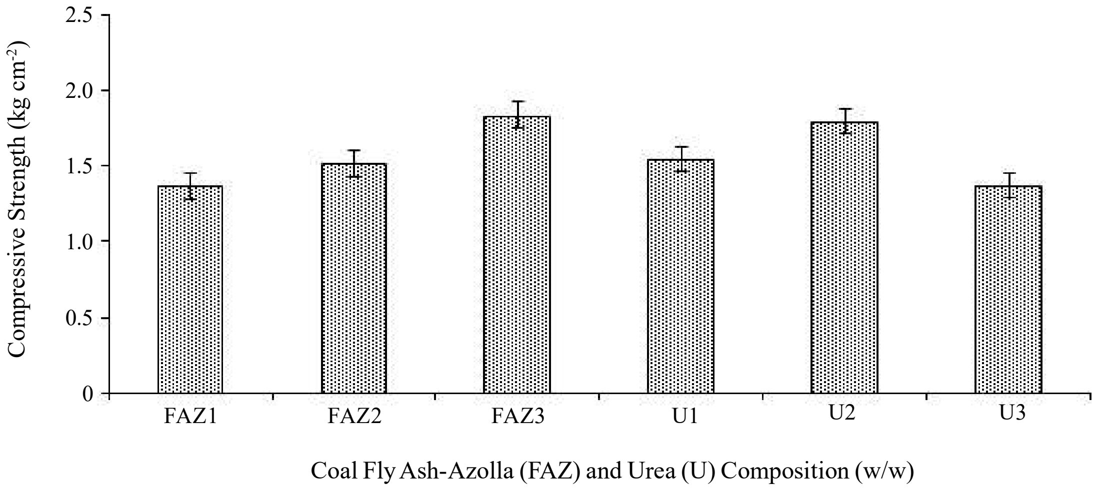

Figure 1. Compressive strength of the briquette fertilizers with various proportion of coal fly ash-azolla (FAZ) and urea (U).

fertilizers with the composition of (coal fly ash:azolla biomass) + urea (60:40)80+20 (FAZ_3-U_2) is not significantly different from FAZ_3-U_1 and FAZ_2-U_2, but significantly higher than other compositions. Table 1 also shows that the increased proportion of coal fly ash-azolla will increase the compressive strength of the briquette fertilizers. Meanwhile, the increased percentage of added urea will decrease the level of compressive strength of the briquette fertilizers.

Figure 1 shows that the composition of coal fly ash and azolla tends to affect the compressive strength of the briquette fertilizers produced. The increasing proportion of coal fly ash tends to cause the briquette fertilizers produced to be harder, and vice versa an increase in the proportion of azolla tends to reduce the compressive strength of the briquette fertilizers produced. Coal fly ash is generally podzolanic (such as cement) (Yao *et al.* 2015; Ma *et al.* 2017), so the increase in proportion will cause the compressive strength of briquette fertilizers to be increased. Meanwhile, an increase in the proportion of urea in briquette fertilizers tends to reduce the compressive strength of briquette fertilizers produced.

The compressive strength of the briquette fertilizers in the various compositions of coal fly ash and azolla biomass varies between 1.17 and 2.08 kg cm^{-2} (Table 1). Figure 1 also showed that the higher azolla biomass proportion (FAZ-1) tends to decrease the level of compressive strength, while the increased of mineral content (fly ash proportion) tends to increase the compressive strength of the briquette fertilizers. The level of compressive strength is influenced by water content, organic matter content, and mineral content (Kurnia *et al.* 2006). In this case, the composites with higher compressive strength are considered better, as they are less easily destroyed and the easily to transport of the briquette fertilizers produced.

Bulk Density

The results of the analysis of variance showed that the proportion of coal fly ash-azolla biomass and urea have a very significant effect on the bulk density of the briquette fertilizers produced. Table 1 shows that bulk density of the briquette with the composition of (coal fly ash:azolla biomass) + urea (60:40)80+20 (FAZ_3U_2) is significantly higher than other compositions of the briquette fertilizers produced. Figure 2 shows that the increased proportion of coal fly ash tends to increase the bulk density of the briquette fertilizers or the increased proportion of azolla biomass tends to decrease the bulk density of the briquette fertilizers produced. Meanwhile, changes in urea percentage addition are relatively variable and there is a tendency to increase the briquette bulk density by increasing the proportion of urea added.

Bulk density describes as the weight of the briquette fertilizers per total of the briquette volume, so that the high value of bulk density characterizes the solids contained in the briquette will be higher, the lower of the pore space and the higher of the compressive strength. The bulk density of the briquette fertilizers produced in this study varies between 0.66 - 1.09 g cm^{-3} (Table 1). The bulk density of briquette fertilizers produced is still relatively low when compared to the general bulk density of soil. Kurnia *et al.* (2006) suggest that mineral soil bulk density

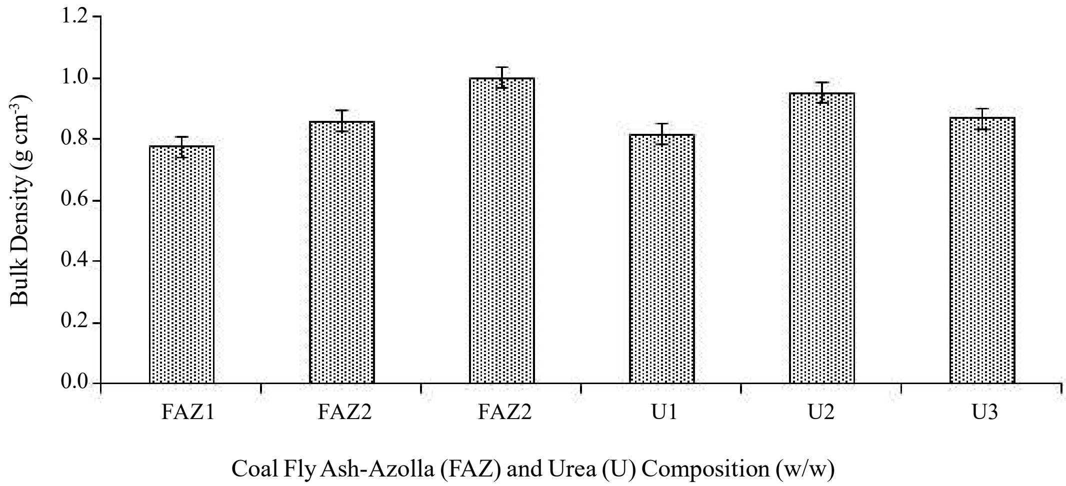

Figure 2. Bulk density of the briquette fertilizers with various proportion of coal fly ash-azolla (FAZ) and urea (U).

varies between 0.80 to 1.40 g cm^{-3}, and peat soil bulk density vary between 0.60 to 0.80 g cm^{-3}.

Figure 1 and 2 showed that the compressive strength and the bulk density level are getting higher with the increase in the proportion of coal fly ash on the briquette fertilizers produced. This condition also reflects on the porosity of briquette fertilizers, in which low bulk density will tend to have higher porosity than composites with higher bulk density (Table 1). Coal fly ash is dominated by silt and clay sized particles and has podzolanic properties (like cement) because it is dominated by aluminosilicate and calcium compounds (Singh *et al*. 2011; Yao *et al*. 2015). Therefore, an increase in the proportion of coal fly ash will result in more dense briquette fertilizer which is characterized by higher bulk density and compressive strength.

Water Retention Capacity (WRC)

The results of the analysis of variance showed that the treatment of coal fly ash-azolla biomass and urea composition significantly affected the water retention capacity of the briquette fertilizers produced. The results of the Least Significance Difference (LSD) test (Table 1) show that the WRC of the briquette fertilizers with the composition of (coal fly ash: azolla biomass) + urea (60:40)80+20 (FAZ_3U_2) is significantly lower compared to the

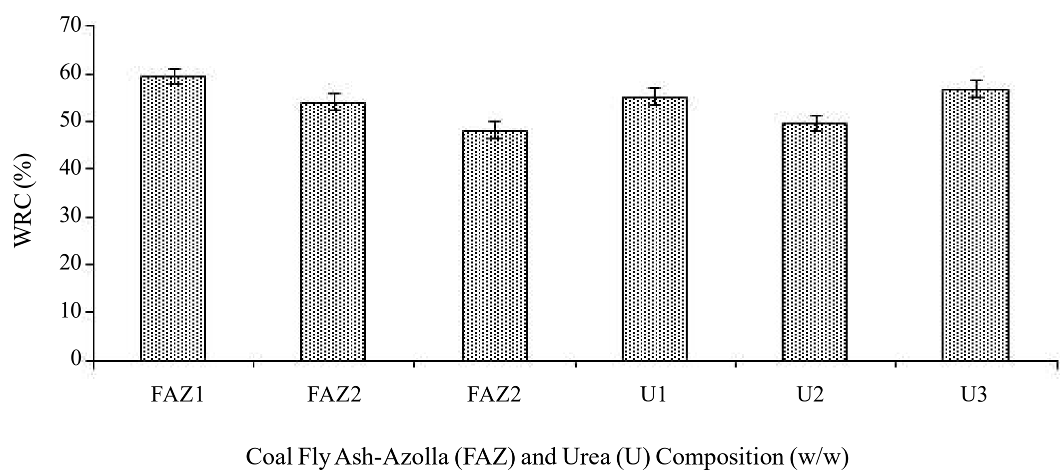

Figure 3. Water retention capacity of the briquette fertilizers with various proportion of coal fly ash-azolla (FAZ) and urea (U).

other compositions of the briquette fertilizers produced.

Figure 3 also shows that the increased proportion of azolla biomass will significantly increase WRC or an increase in the proportion of coal fly ash on briquette fertilizers will significantly lower WRC of the briquette fertilizers. Meanwhile, the increasing percentage of urea fertilizer added tends to vary. Organic materials with high water holding capacity cause WRC of the composites to increase. Water holding capacity is related to the content of organic materials and mineral materials in a material. Organic matter is known to have high water retention (Havlin *et al.* 2005; Obour *et al.* 2018), and coal fly ash which is a mineral is known to have lower water retention capacity (Carlson and Adriano 1993; Singh *et al.* 2011).

Water holding capacity is related to the ability to bind and then release water to the soil solution (Obour *et al.* 2018). Therefore, the greater the ability of the briquette to retain water, the ability to release water along with the element of fertilizer into the soil solution will also increase. Nevertheless, the briquette fertilizer with high water holding capacity tends to have a lower level of the compressive strength (Table 1), so it will be more easily destroyed and will be difficult when transporting and applying the fertilizer in the field.

Porosity

Porosity or total pore space is the volume of all pores in a volume of a material expressed in percent. Porosity reflects the degree of the passage of water mass flow (permeability) or the velocity of water flow to pass through the mass of a material. Porosity determines the value of the bulk density. The greater the number of pores, the lower the density of the mass or the higher porosity; and the lower the number of pores, the higher the density of the mass or the porosity is lower (Nimmo *et al.* 2004; Obour *et al.* 2018)

Table 1 showed that the porosity of the briquette fertilizer with the composition of (coal fly ash : azolla biomass) + urea (60:40)70+30 (FAZ_3U_3) is not significantly different from the porosity of other compositions. However, there is a tendency to increase the composite porosity by increasing the proportion of azolla biomass. Higher organic content (azolla biomass) can cause the amount of pores in the composite to increase. Soil porosity is influenced by organic matter content, soil structure, and soil texture. Soil porosity is high when organic matter is high (Nimmo *et al.* 2004; Havlin *et al.* 2005).

Figure 4 shows that the increase in the proportion of coal fly ash tends to cause the porosity of briquette fertilizers to decrease, or conversely an increase in the proportion of azolla tends to cause porosity of briquette fertilizers to increase. Meanwhile, changes in the proportion of urea tend to fluctuate the porosity of briquette fertilizer. This is probably due to the increased proportion of coal fly ash will decrease the amount of pores in the composite and cause the porosity to decrease. The size of coal fly ash particles dominated by silt and clay particles (<50 ìm) causes the composite becomes denser (Singh *et al.* 2011; Yao *et al.* 2015). The reduced number of pore causes the bulk density of the composite to be higher and is associated with

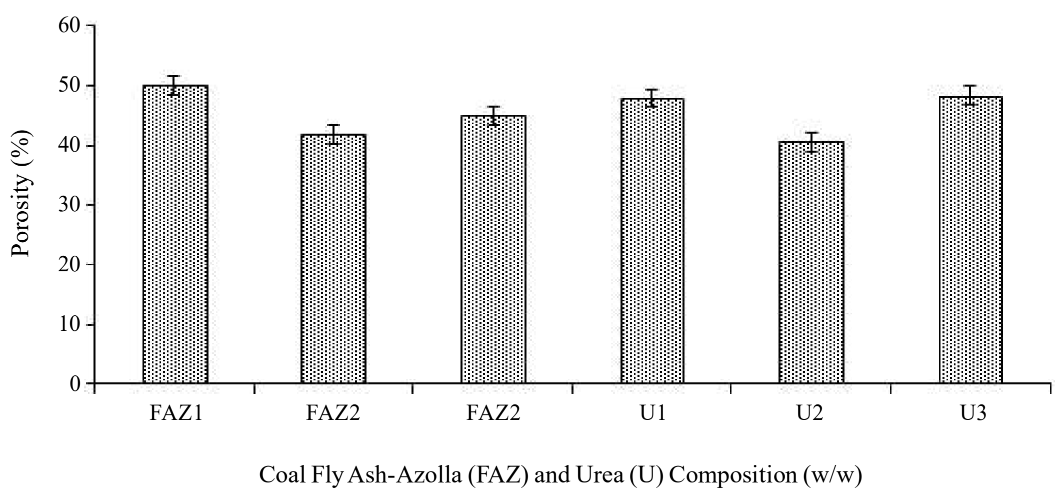

Figure 4. Porosity of the briquette fertilizers with various proportion of coal fly ash-azolla (FAZ) and urea (U).

the increased compressive strength (Table 1). As explained previously, the porosity of briquette fertilizer illustrates the speed of release of water from fertilizer ingredients to the surrounding soil. The greater the porosity, the water will be absorbed more quickly and released back to the soil solution. In relation to the release of nutrients from fertilizers, the lower porosity of briquette fertilizer can be expected to release water with nutrients from fertilizer to be slower.

CONCLUSIONS

Variation in composition of coal fly ash-azolla and urea significantly affected the compressive strength, bulk density, water holding capacity and porosity of briquette fertilizers produced. The increase in the proportion of fly ash or the decrease of azolla biomass proportion tends to increase compressive strength and bulk density, and tends to decrease the water holding capacity and porosity of the produced briquette fertilizers.

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REFERENCES

Ali S and F Danafar. 2015. Controlled-Release Fertilizers: Advances and Challenges. *Life Sci J* 12: 33-45.

Behin J and N Sadeghi. 2016. Utilization of waste lignin to prepare controlled-slow release urea. *Int J Recycl Org Waste Agric* 5:289-299.

Bhuvaneshwari K and A Kumar. 2013. Agronomic potential of the association Azolla-Anabaena. *Sci Res Reporter* 3: 78-82.

Carlson CL and DC Adriano. 1993. Environmental impacts of coal combustion residues. *J Environ Qual* 22: 227-247.

Dong, YJ, MR He, ZL Wang, WF Chen, J Hou, XK Qiu and JW Zhang. 2016. Effects of new coated release fertilizer on the growth of maize. *J Soil Sci Plant Nut* 16: 637-649.

Havlin JL, JD Beaton, SL Tisdale and WL Nelson. 2005. Soil fertility and fertilizers an introduction to nutrient management. 7thed. Prentice Hall, New Jersey.

Hermawan A, Sabaruddin, Marsi, R Hayati and Warsito. 2014. P use efficiency by corn (*Zea mays* L.) in Ultisol due to application of coal fly ash-chicken manure mixture. *Agrivita* 36: 146-152.

Hou J, YJ Dong and ZY Fan. 2014. Effects of coated urea amended with biological inhibitors on physiological characteristics, yield, and quality of peanut. *Comm Soil Sci and Plant Anal* 45: 896-911.

Kishor P, AK Ghosh and D Kumar. 2010. Use of fly ash in agriculture: A way to improve soil fertility and its productivity. *Asian J Agric Res* 4: 1-14.

Kollah B, AK Patra and SR Mohanty. 2015. Aquatic microphylla Azolla: a perspective paradigm for sustainable agriculture, environment and global climate change. *Environ Sci Pollut Res.* doi: 10.1007/s11356-015-5857-9.

Kurnia U, F Agus, A Adimihardja and A Dariah. 2006. Sifat Fisik Tanah dan Metode Analisisnya. Balai Besar Litbang Sumberdaya Lahan Pertanian. Bogor (in Indonesian).

Lubkowski K. 2014. Coating fertilizer granules with biodegradable materials for controlled fertilizer release. *Environ Eng Manag J* 13: 2573-2581.

Ma SH, MD Xu, Qiqige X, H Wang and X Zhou. 2017. Challenges and Developments in the Utilization of Fly Ash in China. *Int J Environ Sci Develop* 8: 781-785.

Mitra BN, S Karmakar, DK Swain and BC Ghosh. 2003. Fly ash - a potential source of soil amendment and a component of integrated plant nutrient supply system. 2003. Internasional Ash Utilization Symposium. University of Kentucky.

Nainggolan GD, Suwardi and Darmawan. 2009. Pola pelepasan nitrogen dari pupuk tersedia lambat (slow release fertilizer) urea-zeolit-asam humat. *J Zeolit Indonesia* 8: 89-69.

Nimmo JR. 2004. Porosity and Pore Size Distribution, In: D Hillel (eds) Encyclopedia of Soils in the Environment, London, Elsevier, V. 3, pp. 295-303.

Obour PB, JL Jensen, M Lamandé, CW Watts and LJ Munkholm. 2018. Soil organic matter widens the range of water contents for tillage. *Soil Till Res* 182: 57-65.

Qiu XK, YJ Dong, GQ Hu and YH Wang. 2011. Effects of homemade coated controlled release fertilizers on physiological characteristics, yield and quality of Chinese cabbage. *Acta Pedologica Sinica* 48: 375-382.

Roy DC, MC Pakhira and S Bera. 2016. A review on biology, cultivation and utilization of Azolla. *Adv Life Sci* 5: 11-15.

Shaviv A. 2005. Advances in Controlled Release of Fertilizers. *Adv Agronomy* 71:1-49.

Singh S, DP Gond, A PaI, BK Tewary and A Sinha. 2011. Performance of several crops grown in fly ash amended soil. World of Coal Ash (WOCA) Conference. Denver, CO, USA.

Sposito G. 2008. The chemistry of soils. 2nd Edition. Oxford University Press, Inc. New York. USA.

Srinavas P, SSV Padma, KP Sastry and KBS Devi. 2017. Analysis the effect of fly ash and vermicompost combination on herb yield, oil content and oil composition of lemongrass (*Cymbopogon flexuosus* Nees). *Int J Pure App Biosci* 5: 1710-1717.

Sulakhudin, A Syukur and BH Sunarminto. 2011. Zeolite and Hucalcia as Coating Material for Improving Quality of NPK Fertilizer in Costal Sandy Soil. *J Trop Soils* 16: 99-106.

Teixeira RS, IR. Silva, R.N. Sousa, Edson, M Mattiello and EMB Soares. 2016. Organic acid coated-slow-release phosphorus fertilizers improve P availability and maize growth in a tropical soil. *J Soil Sci Plant Nut* 16: 1097-1112.

Trenkel ME. 2010. Controlled-Release and Stabilized Fertilizers in Agriculture. Improving Fertilizer Use Efficiency. Second edition, International Fertilizer Industry Association (IFA), FAO, Paris. 160 pp.

Yao ZT, XS Ji, PK Sarker, JH Tang, LQ Ge, MS Xia and YQ Xi. 2015. A comprehensive review on the applications of coal fly ash. *Earth-Sci Rev* 141: 105-121.