# Effect of Rice Husk Ash on the Physicochemical Properties of Compost

**Nur Ezyan Badrul Hisham and Nor Hanuni Ramli***

*Faculty of Chemical and Natural Resources Engineering, Universiti Malaysia Pahang, Lebuhraya Tun Razak 26300, Gambang, Pahang, Malaysia*

*** Corresponding author:**

*tel: +6012-3024184*
*email: drhanuni@ump.edu.my*

*Received: August 3, 2018*
*Accepted: December 4, 2018*

**DOI:** 10.22146/ijc.39704

**Abstract:** *Recently, the increase in demand for rice has led to the numerous availabilities of rice husks (RH) in Malaysia. RH is being utilized as industrial fuel to generate electricity through incineration process in the boiler. During the incineration process, rice husk ash (RHA) is being produced as the by-product and caused environmental pollution. RHA has the potential of being utilized as organic fertilizer through a composting process to control environmental pollution. Thus, this work investigated the effect of different weight compositions on the duration of the composting process and physicochemical properties of compost. The raw materials consist of POME sludge and decanter cake, and finished compost were analyzed in terms of elemental composition, pH, water holding capacity, and moisture content. The obtained results showed that addition of 7.5 wt.% of RHA could improve composting process due to the presence of silica which can maintain the moisture content within 50–60% and water holding capacity of compost at the range of 61–73%. The results of this study have clearly shown the potential of the compositing process in treating RHA. However, further studies are required to provide a deeper understanding of the mechanisms involved in facilitating the development of an optimum treatment system applicable to the industry.*

**Keywords:** *silica; rice husk ash; POME sludge; decanter cake*

## INTRODUCTION

Rice Husk (RH) is waste generated from the agriculture industry, and this waste is in abundance in Malaysia. Based on the statistic reported by the Food and Agricultural Organization (FAO), about 2.6 million tons of paddy were harvested from Malaysia in 2016. However, about 20% of the harvested paddy was husk [1]. Fernandes et al. [2] had reported that the major components of RH are cellulose (50%), lignin (30%) and organic compounds (20%). RH undergoes a burning process to generate heat used in the boiler as industrial fuel for generating steam in a turbine to provide electricity [3]. The burning process of RH under controlled temperature will produce a waste product known as Rice Husk Ash (RHA). During the incineration process, about 18–20 wt.% of RH are converted into RHA [4]. Bakar et al. [5] reported that RHA possesses more than 90% silica content and some metallic impurities which include potassium (K), iron (Fe), manganese (Mn), calcium (Ca), sodium (Na), and magnesium (Mg).

Mostly, the burning of RH disposed at the landfill usually generate RHA. This RHA can cause an environmental problem (air pollution) and space limitations. In order to prevent the environmental problem emanating from RHA, many efforts have been made to utilize RHA in the production of silica gel [6], fire bricks [1], the hydrophobic coating on glass [7], activated carbon, soil conditioner, and biofertilizer [8].

In addition, RHA can serve as a potential source for organic fertilizer through composting process. This is due to the abundance of silica in RHA that can enhance plants growth. In many plant systems, silica accumulated in the solid form created intracellular or extracellular silica bodies (phytoliths) that are crucial for the growth, rigidity, mechanical strength, predator and fungal defense, stiffness, as well as cooling [4]. Moreover, Badar and Qureshi found that composted rice husk improved the organic content of the soil that effectively improves biochemical parameters and growth of sunflower plants [9]. Thus, this study investigated the presence of RHA in the composting process in terms of physical and chemical properties.

## EXPERIMENTAL SECTION

### Materials

Palm oil mill effluent (POME) sludge and decanter cake were collected from LKPP Corporation Sdn. Bhd., Kuantan, Pahang, Malaysia. Meanwhile, RHA was obtained from Alor Setar, Kedah, Malaysia. All the raw materials were sealed in the separate airtight containers and stored at room temperature.

### Procedure

#### *Characterization of raw materials*

The raw materials which include POME sludge, decanter cake, and rice husk ash were characterized using X-Ray Fluorescence (XRF) and CHNS analyses to evaluate the physical and chemical properties. Prior to the analyses, the samples were dried in an oven (Memmert UFE500) at 110 °C for 24 h. Then, the samples were pulverized using a grinder and sieved to a particle size of 0.08 mm. For XRF analysis, standard test ASTM E1621 was used to detect the percentage of potassium, phosphorus, iron, silica, manganese, magnesium, and calcium in the samples. Meanwhile, CHNS analysis was carried out done using standard test ASTM D5291 to detect the percentage of nitrogen and carbon in the samples.

#### *Physical properties of the raw materials*

Physical properties of raw materials were measured through several properties such as pH, moisture content and water holding capacity. In order to determine the pH of samples, 5 g of samples were added to 50 mL of distilled water. Then, the suspension was thoroughly mixed for 20 min using a magnetic stirrer. After 20 min, the pH values of samples were determined using pH meter (METTLER TOLEDO S20 SevenEasy) in aqueous solution based on the standard method ASTM D1293-18. For moisture content determination, the samples were dried in an oven (Memmert UFE500) at 110 °C for 24 h. Initial and final weights of the samples were measured, and the moisture contents were calculated based on the standard method ASTM D4442-16. For water holding capacity, 100 mL of water was mixed with 100 g of sample in a pot and kept in slanting position. After the water had drained, the samples were weighed immediately. Then, the sample was dried in an oven and reweighed again. Standard method ASTM D2980-02 was used to calculate the water holding capacity of the samples.

#### *Compositing process*

The composting processes were carried out on the POME sludge, decanter cake and rice husk ash using an aerated bin of 10 L size. The process was carried out for 50 days by aerating manually twice a week using a spade. In order to study the effect of rice husk ash composition, the percentages of rice husk ash were varied according to data shown in Table 1. The weight ratio of POME sludge and decanter cake were kept constant for all the samples. Moreover, the control sample consisted of POME sludge and decanter cake in the absence of rice husk ash. The temperature and pH of compost were recorded daily for the period of 50 days using digital temperature meter (Model ZD-07 by DANOPLUS) and Takemura soil pH meter, respectively until the samples completed the composting processes.

After the process completion, all the samples were analyzed using the same characterizations employed for the raw materials. Comparison of the data on physical and chemical properties between the raw materials and finished compost was made to investigate the effect of rice husk ash on the composting process.

## RESULTS AND DISCUSSION

### Characteristics of Raw Materials

Raw materials play a crucial role in the composting process as it can affect the properties of finished compost.

**Table 1.** Compositions of samples used in the experiment

| Samples | POME sludge:decanter cake | Rice husk ash (%) |
|---|---|---|
| Control | 1:1 | 0.0 |
| A | 1:1 | 2.5 |
| B | 1:1 | 5.0 |
| C | 1:1 | 7.5 |
| D | 1:1 | 10.0 |

**Table 2.** Characteristics of POME sludge, decanter cake, and rice husk ash

| Parameters | POME sludge | Decanter cake | Rice husk ash |
|---|---|---|---|
| Moisture (%) | 68.93 | 79.06 | 61.67 |
| pH | 7.46 | 5.40 | 7.10 |
| Water holding capacity (%) | 60.92 | 70.12 | 68.45 |
| Composition of elements | | | |
| N (%) | 5.63 | 4.17 | 3.11 |
| P (%) | 5.23 | 2.39 | 0.62 |
| K (%) | 5.85 | 0.65 | 1.44 |
| Si (%) | 12.59 | 13.61 | 44.01 |
| Fe (%) | 16.58 | 6.09 | 0.10 |
| Mn (%) | 0.43 | 0.12 | 0.08 |
| Mg (%) | 1.11 | 1.65 | 0.44 |
| Ca (%) | 0.09 | 8.79 | 0.85 |

Table 2 shows the characteristics of POME sludge, decanter cake and RHA used in composting processes in terms of elements, moisture content, pH, and water holding capacity. It can be clearly seen in Table 2 that the POME sludge and RHA had pH values (7.46 and 7.10, respectively) closer to neutral which contrast with decanter cake (pH = 5.4). The pH value for decanter cake was lower compared to POME sludge and RHA because decanter cake was acidic in nature. The results obtained are in agreement with the previous finding of Sahad et al. [10] whereby a pH value of 5.03 was recorded for decanter cake.

Moreover, the highest moisture content of about 79.06% was recorded for decanted cake, this result correlated well with the reports of Abdul Razak et al. [11] and Sahad et al. [10]. The presence of high moisture content in decanter cake is important to overcome a lower level of moisture content in POME sludge and RHA. However, the moisture content level must range between 40 and 60% to avoid dehydration and anaerobic condition during the composting process [12]. As observed in Table 2, the lower moisture content of 7.26% was recorded in RHA as compared to POME sludge. This might be due to the burning process involved in the production of RHA from rice husk which required the elimination of moisture. In addition, RHA can be used as activated carbon for water adsorption since it showed the highest water holding capacity compared to other raw materials. Matichenkov and Bocharnikova had observed that silicon-rich materials were able to increase the water holding capacity of soils after a month of incubation [13]. Perhaps, 44.01% of silica presence in RHA elaborated the enhancement of RHA in retaining water during the process. A similar range of silica content in RHA was as well reported by Bakar et al. [5].

Furthermore, POME sludge contains the highest nitrogen (5.63%), phosphorus (5.23%) and potassium (5.85%) which are enough for the formulation of organic fertilizer for supporting the contents in decanter cake and RHA. Besides that, decanter cake possessed the highest amount of calcium (8.79%) and magnesium (1.65%) which can improve the organic fertilizer formulation.

## Temperature Profile

Temperature is one of the parameters indicating the phase in composting. It can be used to investigate the activities of microbes and maturity of the compost [14]. There are three phases of composting associated with peculiar groups of microorganisms [15]. The initial phase of composting is called mesophilic phase. In this phase, microbes begin to accelerate the decomposition process causing a temperature of the pile to increase from ambient temperature to 40 °C [16]. As seen in Fig. 1, sample B managed to reach 40 °C on the 6$^{th}$ day followed by sample C on the 7$^{th}$ day, sample D on the 9$^{th}$ day, and sample A on the 10$^{th}$ day. For the control sample, the temperature reached 40 °C on the 14$^{th}$ day. This trend shows that the

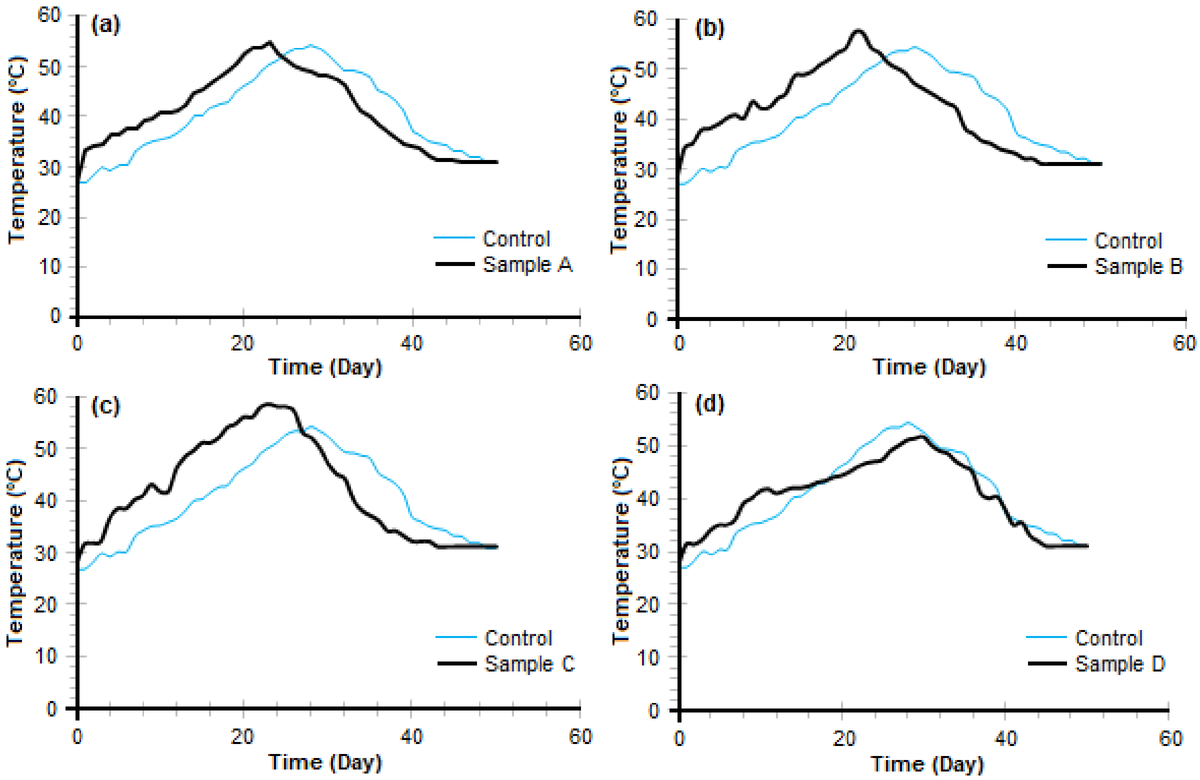


**Fig 1.** The temperature profile for (a) Sample A and control, (b) Sample B and control, (c) Sample C and control, and (d) Sample D and control

addition of RHA was able to fasten the composting process as compared to the sample without RHA.

After the initial phase, the process proceeded to the next phase which is called thermophilic phase. According to Ramli et al. [16], the temperature in composting pile will continue to increase until it reaches the thermophilic condition (temperature in the range of 50–60 °C) due to the heat released from the decomposition process. As observed in Fig. 1, sample D with the maximum percentage of RHA (at 10.0%) reflected the slowest trend in reaching 50 °C on day 27. This might be due to excessive moisture content (> 60%) observed in sample D which caused the partial anaerobic condition in the composting bin. An anaerobic condition caused the microbial activity to decrease because the microbes required sufficient moisture content to create heat. Limited diffusion and restricted oxygen utilization by microorganisms occur due to the excessive moisture content in the composting process [17]. However, sample C exhibited the fastest day in reaching the temperature above 50 °C on day 15. In fact, the temperature for sample C kept on increasing until it reached the maximum temperature of 58.5 °C on day 23. According to Qian et al. [14], the temperature of more than 55 °C for at least 3 consecutive days is required to eliminate pathogens and weed seeds in the compost. In contrary, control sample showed the slowest output in achieving 50 °C as compared to sample with the addition of RHA (except for sample D) because partial dehydration occurred in the composting bin as it attained 45.76% moisture content (refer Table 3). A previous report had shown that the moisture content must be in the range of 50–60% to avoid dehydration which can slow down the composting process [18].

The last phase in the composting process is curing phase. In this phase, the temperature will decline to ambient temperature where the C/N ratio tends to stabilize the compost for usage as the end product (fertilizer) [19].

## pH Profile

Based on Fig. 2, the pH values increased at an early stage of composting, until it reached a constant pH value

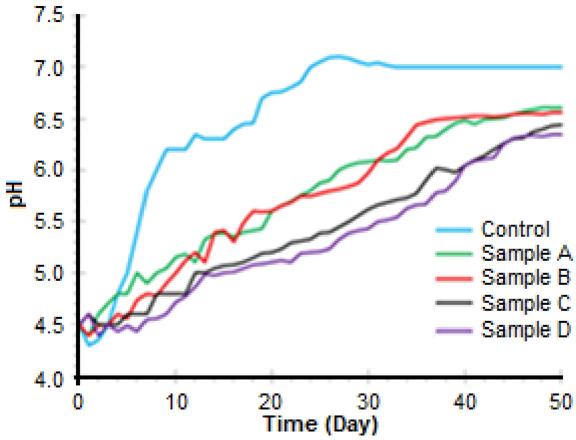


**Fig 2.** pH profile of the composting process

in the range of 7.0 to 6.0. Rihani et al. [20] had reported that the increase in pH at an initial stage of composting was due to the proteolytic bacteria which release ammonia in relation to organic degradation. However, increasing time caused the pH to drop or stable due to ammonia volatilization and oxidation causing the decreased in ammonia. Moreover, Rihani et al. [20] observed that the decrease in pH might be due to the release of humic substances which act as a buffer.

In Fig. 2, the control sample reflected the highest pH value of 7.0 on day 30, followed by samples A and B at the pH value of 6.5 on day 35. Meanwhile, samples C and D showed the lowest pH value at 6.0 on day 48. Thus, it was observed that the increase in RHA reduced the maximum pH value of compost and increased the time taken to achieve stable pH during the composting. The active surface on RHA can retain nutrient that losses during leaching or volatilization. Therefore, the constant pH achieved by the sample with higher RHA was a bit late compared to the control sample. However, the range of maximum pH for the compost with RHA falls within the ideal range of pH for vegetable growth (Fig. 2). A previous study by Miller et al. [21] illustrated that the soil pH of 6.2 to 6.8 as the optimal soil pH varies for the growth of different types of vegetables. In fact, the addition of RHA can modify the key parameters affecting microbial growth in a compost which include moisture content, nutrient availability and pH.

## Physicochemical Properties of Matured Compost

Table 3 shows the physical properties of matured compost. The results show that the moisture content is directly proportional to the water holding capacity. All the samples reflected the moisture content in the range within 45–63%. Sample D had the highest moisture content due to the higher contents of RHA in the samples. The trend shows that the higher the content of RHA in a sample, the higher the moisture content obtained. In order to achieve efficient composting process, the moisture content in the compost pile must be monitored regularly. Kim et al. had reported that allowable moisture content for the composting process was in the range of 40–60% [12]. When the moisture content is very high (> 60%), the anaerobic condition occurs where the pore spaces of solid matrices are filled with water rather than air [12]. This condition caused the composting process to become slower as observed in Fig. 1(d) due to lack of oxygen supplied to the microorganisms. Besides that, the control sample showed 45.76% of moisture content which was about 6.81% lower as compared to sample A. According to Makan et al. [5] and Zavala and Funamizu [22], at low moisture content (< 40%), dehydration will occur which caused the nutrients not available to the microorganisms. Perhaps, the minimum amount of RHA in compost formulation must be 2.5% to achieve ideal moisture content.

Table 3 shows the physical properties of matured compost. It can be observed that sample C had the highest amount of nitrogen compared to all the samples. From the raw material analysis in Table 2, the presence of RHA did not contribute much to the amount of nitrogen compound. The lowest content of nitrogen of about 2.56% was recorded for the control sample which had no RHA. Even though sample D had a higher RHA composition compared to sample C, it had the lower nitrogen content due to the partial anaerobic condition that occurred during the thermophilic phase of composting as illustrated in Fig. 1. RHA helps in generating heat by providing adequate moisture content for microbial activity through the degradation process. As the temperature increases, the $NH^{4+}$ formation also increased [23]. Cáceres et al. [17] illustrated that temperature influences the nitrogen mineralization as thermophilic temperature favors the $NH_4^+$ formation.

**Table 3.** Physical properties of matured compost

| Parameters | Control | Sample A | Sample B | Sample C | Sample D |
|---|---|---|---|---|---|
| Moisture content (%) | 45.76 ± 2.88 | 52.57 ± 6.11 | 54.67 ± 1.09 | 57.72 ± 1.24 | 62.54 ± 5.99 |
| Water holding capacity (%) | 51.38 ± 1.12 | 61.35 ± 1.39 | 63.26 ± 2.34 | 69.86 ± 1.54 | 73.58 ± 2.66 |
| Composition of elements | | | | | |
| N (%) | 2.56 ± 0.64 | 2.64 ± 0.39 | 2.81 ± 0.33 | 3.31 ± 0.38 | 2.93 ± 0.34 |
| P (%) | 7.56 ± 0.05 | 7.89 ± 0.08 | 8.03 ± 0.03 | 8.11 ± 0.07 | 8.23 ± 0.05 |
| K (%) | 9.07 ± 0.42 | 9.62 ± 0.23 | 9.64 ± 0.24 | 9.68 ± 0.16 | 9.81 ± 0.25 |
| Si (%) | 15.86 ± 0.33 | 19.57 ± 0.31 | 19.47 ± 0.35 | 20.82 ± 0.31 | 21.1 ± 0.32 |
| Fe (%) | 16.73 ± 0.71 | 17.38 ± 0.81 | 17.41 ± 0.12 | 17.86 ± 0.13 | 17.95 ± 0.17 |
| Mn (%) | 0.44 ± 0.01 | 0.46 ± 0.005 | 0.47 ± 0.013 | 0.48 ± 0.02 | 0.48 ± 0.015 |
| Mg (%) | 1.18 ± 0.03 | 1.19 ± 0.02 | 1.19 ± 0.02 | 1.19 ± 0.02 | 1.20 ± 0.02 |
| Ca (%) | 6.99 ± 0.35 | 7.03 ± 0.10 | 7.13 ± 0.03 | 7.24 ± 0.27 | 7.37 ± 0.09 |

In Table 3, the result shows that the control sample had the lowest amount of phosphorus (about 7.56%) as compared to samples with RHA. Increase in RHA caused the phosphorous content to increase proportionally. Furthermore, the RHA helps the nutrients available in the compost through surface adsorption of phosphate on the RHA in compost. According to Gupta et al. [24], the addition of RHA increased the adsorption sites and increase the availability of phosphorus in the soils.

Moreover, the application of RHA was seen to improve the amount of potassium, calcium, and magnesium in the compost. The RHA acted as sorption site to absorb these nutrients through ion exchange. A study conducted by Hamzah et al. [25] claimed that RHA had high cation exchange capacity. Due to the high cation exchange capacity of RHA in compost, potassium adsorption increased. It was also reported by Freitas et al. [26] that the adsorption of potassium on the adsorption sites increased due to high contents of Ca and Mg in the soil. The presences of several cations ($K^+$, $Ca^{2+}$, and $Mg^{2+}$) create competition for adsorption on the sorption site of RHA. However, the RHA adsorbs more potassium over calcium and magnesium due to the higher tendency of reactivity for $K^+$. In relation to this, the obtained results in this study show that higher amount of RHA contributed to higher adsorption site for potassium, calcium, and magnesium. Likewise, the results in Table 3 confirm that as Ca and Mg contents increased, the amount of potassium also increased proportionally.

In addition, RHA had the ability to adsorb (Fe and Mn) compound in the sample. The morphological properties of RHA served to absorb iron (Fe) and manganese (Mn) as the porous structure of RHA had a relatively large specific surface area [27]. The adsorption site on RHA is more favored with $Fe^{2+}$ as compared to $Mn^{2+}$. This might be due to the higher tendency of $Fe^{2+}$ reactivity compared to $Mn^{2+}$. Therefore, the result in Table 3 shows a higher percentage of Fe in the samples compared to Mn in all the samples. However, a sample with higher RHA showed the highest amount of Fe and Mn. Moreover, the result in Table 3 shows that the addition of RHA as compost was able to improve Fe contents by 0.03–0.65% and Mn contents by 0.01–0.02%. As the amount of RHA in compost increases, Fe and Mn amount increased proportionally. Control sample reflected the lowest amount of Fe (16.73%) and Mn (0.44%) because it contains no RHA which can reduce the loss of Fe and Mn through leaching.

As seen in Table 3, sample D possessed the highest amount of silica (about 21.1%). This might be due to the higher amount of RHA used in compost material. RHA contained 44.01% of silica (refer Table 2) which contributed to the higher silica content in the samples. Similar results had been reported by Anda et al. [28] whereby the application of composted rice husk significantly increased the amount of silica in soils. High silica content in RHA is advantageous for the composting process because it possesses the ability to adsorb water content and increase the moisture content. Thus, the moisture content and water holding capacity of compost are proportional to the content of silica present. The presence of silica in RHA exhibited high performance in the adsorption of water as it has a highly porous structure and large surface area [27].

## CONCLUSION

In overall, the application of RHA in compost formulation was able to give better quality compost and fasten the composting process through efficient nutrient absorption. The best formulation was observed in sample C with 7.5 wt.% of RHA, and the process was completed within 43 days. At this condition, sample C achieved N, P, K ratio of 3:8:9, the moisture content of 57.72% and water holding capacity of 69.86%. Thus, RHA can influence the physicochemical properties of compost. Moreover, the incorporation of RHA with POME sludge and decanter cake in the aerated composting process was shown to produce a better quality of compost which is environmental-friendly and can potentially reduce the use of chemical-based fertilizers that create significant problems to the environment and human health.

## ACKNOWLEDGMENTS

The authors thank Universiti Malaysia Pahang, FELDA Palm Industries Sdn. Bhd. and Central Laboratory Universiti Malaysia Pahang for their financial and technical support on this study through RDU160380 grant.

## REFERENCES

[1] Tiwari, S., and Pradhan, M.K., 2017, Effect of rice husk ash on properties of aluminum alloys: A review, *Mater. Today: Proc.*, 4 (2), 486–495.

[2] Fernandes, I.J., Calheiro, D., Kieling, A.G., Moraes, C.A.M., Rocha, T.L.A.C., Brehm, F.A., and Modolo, R.C.E., 2016, Characterization of rice husk ash produced using different biomass combustion techniques for energy, *Fuel*, 165, 351–359.

[3] Prasara-A, J., and Gheewala, S.H., 2017, Sustainable utilization of rice husk ash from power plants: A review, *J. Cleaner Prod.*, 167, 1020–1028.

[4] Pode, R., 2016, Potential applications of rice husk ash waste from the rice husk biomass power plant, *Renewable Sustainable Energy Rev.*, 53, 1468–1485.

[5] Bakar, R.A., Yahya, R., and Gan, S.N., 2016, Production of high purity amorphous silica from rice husk, *Procedia Chem.*, 19, 189–195.

[6] Rungrodnimitchai, S., Phokhanusai, W., and Sungkhaho, N., 2015, Preparation of silica gel from rice husk ash using microwave heating, *JMMM*, 19 (2), 45–50.

[7] Widati, A.A., Aryanti, D.P., Wibowo, M.A., Kunarti, E.S., Kartini, I., and Rusdiarso, B., 2018, Preparation of water repellent layer on glass using hydrophobic compound modified rice hull ash silica, *Indones. J. Chem.*, 18 (4), 587–593.

[8] Liu, Y., Guo, Y., Gao, W., Wang, Z., Ma, Y., and Wang, Z., 2012, Simultaneous preparation of silica and activated carbon from rice husk ash, *J. Cleaner Prod.*, 32, 204–209.

[9] Badar, R., and Qureshi, S.A., 2014, Composted rice husk improves the growth and biochemical parameters of sunflower plants, *J. Bot.*, 2014, 427648.

[10] Sahad, N., Som, A.M., Baharuddin, A.S., Mokhtar, N., Busu, Z., and Sulaiman, A., 2014, Physicochemical characterization of oil palm decanter cake (OPDC) for residual oil recovery, *BioResources*, 9 (4), 6361–6372.

[11] Razak, M.N.A., Ibrahim, M.F., Yee, P.L., Hassan, M.A., and Abd-Aziz, S., 2012, Utilization of oil palm decanter cake for cellulase and polyoses production, *Biotechnol. Bioprocess Eng.*, 17 (3), 547–555.

[12] Kim, E., Lee, D.H., Won, S., and Ahn, H., 2016, Evaluation of optimum moisture content for composting of beef manure and bedding material mixtures using oxygen uptake measurement, *Asian-Australas. J. Anim. Sci.*, 29 (5), 753–758.

[13] Matichenkov, V.V., and Bocharnikova, E.A., 2001, Chapter 13 The relationship between silicon and soil physical and chemical properties, *Stud. Plant Sci.*, 8, 209–219.

[14] Qian, X., Sun, W., Gu, J., Wang, X.J., Zhang, Y.J., Duan, M.L., Li, H.C., and Zhang, R.R., 2016, Reducing antibiotic resistance genes, integrons, and pathogens in dairy manure by continuous

thermophilic composting, *Bioresour. Technol.*, 220, 425–432.

[15] Oviasogie, P.O., Odewale, J.O., Aisueni, N.O., Eguagie, E.I., and Brown, G., 2013, Production, utilization and acceptability of organic fertilizers using palms and shea tree as sources of biomass, *Afr. J. Agric. Res.*, 8 (27), 3483–3494.

[16] Ramli, N.H., Badrul Hisham, N.E., Mohd Said, F., and Mariyappan, T., 2016, The effect of weight ratio on the physiochemical properties of compost from palm oil mill effluent (POME) sludge and decanter cake, *Aust. J. Basic Appl. Sci.*, 10 (17), 34–39.

[17] Cáceres, R., Malińska, K., and Marfà, O., 2018, Nitrification within composting: A review, *Waste Manage.*, 72, 119–137.

[18] Hao, X., and Benke, M.B., 2008, Nitrogen Transformation and losses during composting and mitigation strategies, *Dyn. Soil Dyn. Plant*, 2, 10–18.

[19] Evans, G., 2014, *Biowaste and Biological Waste treatment*, James & James (Science Publishers) Ltd., London.

[20] Rihani, M., Malamis, D., Bihaoui, B., Etahiri, S., Loizidou, M., and Assobhei, O., 2010, In-vessel treatment of urban primary sludge by aerobic composting, *Bioresour. Technol.*, 101 (15), 5988–5995.

[21] Miller, W., Halverson, B., and Langellotto, G., 2011, *An Educator's Guide to Vegetable Gardening*, Oregon State University, 1–28.

[22] Zavala, M.A.L., and Funamizu, N., 2005, Effect of moisture content on the composting process in a biotoilet system, *Compost Sci. Util.*, 13 (3), 208–216.

[23] Koyama, M., Nagao, N., Syukri, F., Rahim, A.A., Kamarudin, M.S., Toda, T., Mitsuhashi, T., and Nakasaki, K., 2018, Effect of temperature on thermophilic composting of aquaculture sludge: $NH_3$ recovery, nitrogen mass balance, and microbial community dynamics, *Bioresour. Technol.*, 265, 207–213.

[24] Gupta, R.K., Singh, A., Singh, Y., Thind, H.S., Singh, B., and Singh, V., 2014, Effects of rice husk ash and bagasse ash on phosphorus adsorption and desorption in an alkaline soil under wheat-rice system, *Commun. Soil Sci. Plant Anal.*, 45 (10), 1385–1398.

[25] Hamzah, A., Hapsari, R.I., and Priyadarshini, R., 2017, The influence of rice husk and tobacco waste biochars on soil quality, *J. Degrade. Min. Land. Manage.*, 5 (1), 1001–1007.

[26] Freitas, J.M.A.S., Netto, A.M., Corrêa, M.M., Xavier, B.T.L., and de Assis, F.X., 2018, Potassium adsorption in soil cultivated with sugarcane, *An. Acad. Bras. Ciênc.*, 90 (1), 541–555.

[27] Zhang, Y., Zhao, J., Jiang, Z., Shan, D., and Lu, Y., 2014, Biosorption of Fe(II) and Mn(II) ions from aqueous solution by rice husk ash, *Biomed Res. Int.*, 2014, 973095.

[28] Anda, M., Syed Omar, S.R., Shamshuddin, J., and Fauziah, C.I., 2008, Changes in properties of composting rice husk and their effects on soil and cocoa growth, *Commun. Soil Sci. Plant Anal.*, 39 (15-16), 2221–2249.