UNIVERSITI PUTRA MALAYSIA

PHYSICO-CHEMICAL TRANSFORMATION AND STABILITY OF JATROPHA POD BIOCHAR IN AN ACIDIC MINERAL SOIL AND PINEAPPLE STUMP BIOCHAR IN TROPICAL PEAT

CHEAH POH MENG

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By

CHEAH POH MENG

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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Dear Dad, Fook Thin,

Beloved Mom, Foong Khew

Brother and Sister, Chooi Ying, Poh Weng

Grandparents, Cheah Wei and Kim Thye

Thank you for all the support and love

Special Thanks to Shir Yih
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August 2014

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Biochar is classified as stable C sequester that can last hundreds to thousands of years. Though, it is a vague explanation as biochar experienced various transformations resulted from different climatic pattern and soil type. It is safe to assume stability of similar biochar varies depending on environmental factor. Assessing resident time of biochar in soil is a taunting task since current estimation methods are flawed and time consuming. Abiotic and biotic oxidation is the main degradation mechanisms of biochar. Moreover, biochar field decomposition study in Malaysia at acidic mineral soil and tropical peat soil are yet to be conducted. It is hypothesized biochar decomposition in Malaysia is rapid due to high amount of annual rainfall. Besides, accelerating biochar decomposition with oxidation could provide quick estimation of the biochar resident time in soil. Biochar could serve as a mean in managing the high amount of biomass waste produced from Jatropha and pineapple cultivation. The study was undertaken to examine the physico-chemical transformation of Jatropha pod (JP) biochar in an acidic mineral soil and pineapple stump (PS) biochar in tropical peat soil respectively. Furthermore, hydrogen peroxide (H₂O₂) was used to simulate the JP and PS biochars litterbag decomposition model.

The raw Jatropha pod was collected from Universiti Agriculture Park, Plot D, UPM. Meanwhile, raw pineapple stump was collected from Peninsula Plantation, Simpang Renggam, Malaysia. Both PS and JP biochars were produced by partially combusting the dried raw samples for 3 hours at 250°C and 275°C respectively in a carbolite furnace. The physico-chemical properties were characterized using surface area analyzer based on Brunauer, Emmet and Teller (BET) theory, Fourier Transform Infrared Spectroscopy (FTIR), Nuclear Magnetic Resonance Spectroscopy (NMR), Differential Scanning Calorimetry (DSC) and Scanning Electron Microscopy (SEM).
Field decomposition of JP and PS biochars was determined using the litterbag method. Furthermore, hydrogen peroxide ($\text{H}_2\text{O}_2$) was utilized to replicate biochar litterbag field decomposition.

The BET surface area of JP biochar increased significantly after 16 months buried in acidic mineral soil implying physical fragmentation. Adsorption of organic matter was unlikely due to the increasing BET surface area. Instead, interaction with minerals such as Fe could have contributed to the resident time of JP biochar. Increase of O functionalities (phenolic, carboxylic and hydroxyl) implied JP biochar suffered severe oxidation shown by FTIR and NMR analysis. The JP biochar litterbag field decomposition was fitted into hyperbolic decay model with 3 parameters.

However, the BET surface area of PS biochar decreased significantly after 16 months under tropical peat soil. This could be attributed to adsorption of organic matter but the declining C content indicated contrarily. This also implied PS biochar was less susceptible to physical fragmentation. Instead, increasing Fe in PS biochar overtime suggested interaction between biochar and Fe from peat by ligand bridging. Further study was needed to verify this phenomena and its effect on recalcitrance of biochar. Increasing O functionalities hinted surface oxidation shown in the FTIR spectrum of PS biochar. However, C structure of PS biochar was not oxidized or protected from degradation. This could be attributed to lower microbial activities in peat. The PS biochar litterbag field decomposition was also fitted into hyperbolic decay model with 3 parameters. The forecasted mean resident time of JP and PS biochars were 104 years in acidic mineral soil and 333 years in tropical peat respectively.

Oxidation process played a major role in biochar decomposition. Both JP and PS biochars field decomposition pattern were able to be simulated and accelerated with 30% $\text{H}_2\text{O}_2$. However, the estimated results might be underestimated as the $\text{H}_2\text{O}_2$ simulation was unable to replicate the chemisorption on biochar. Further research was needed to improve this simulation method.
TRANSFORMASI FIZIKAL KIMIA ARANG DALAM TANAH MINERAL BERACID & GAMBU TROPIKA DAN ESTIMASI KESTABILAN ARANG MELALUI SIMULASI MAKMAL

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yang diisi dengan arang. Tambahan, hidrogen peroksida digunakan untuk meniru penguraian lapang arang dengan beg nilon.


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I certify that a Thesis Examination Committee has met on 6 August 2014 to conduct the final examination of Cheah Poh Meng on his thesis entitled "Physico-chemical Transformation and Stability of Jatropha Pod Biochar in an Acidic Mineral Soil and Pineapple Stump Biochar in Tropical Peat" in accordance with the Universities and University College Act 1971 and the Constitution of Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The committee recommends that the student be awarded the Doctorate of Philosophy.

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