Faculty of Engineering

Synthesis of Tapioca Starch/Palm Oil Encapsulated Urea-Impregnated Peppercorn Biochar Controlled-Release Fertilizer for Soil Amendment

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Synthesis of Tapioca Starch/Palm Oil Encapsulated Urea-Impregnated Peppercorn Biochar Controlled-Release Fertilizer for Soil Amendment

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

The slow-release property of biochar-based fertilizer is still facing limitation and it can be overcome by integrating encapsulating technology and biochar-based fertilizer. Starch has been introduced as an encapsulating material due to its low-cost and biodegradable nature, but the slow-release property is limited by its hydrophilicity. Hence, this study aimed to formulate the tapioca starch/PO encapsulated urea-impregnated peppercorn waste derived biochar controlled-fertilizer pellet (EUIB pellet), followed by investigation of the effect of EUIB pellet on the nitrogen release rate and kinetic, nitrogen leaching, water retention and okra plant growth. The CCD was utilized to investigate the effect of pyrolysis temperature, residence time and urea:biochar ratio on the nitrogen content. The optimum condition to synthesize urea-impregnated peppercorn derived biochar-based fertilizer powder (UIB powder) was 400 °C pyrolysis temperature, 120 minutes residence time and 0.6 urea:biochar ratio which resulted in a nitrogen content of 16.07%. The acidic surface functional groups and hydrophilicity decreased with increasing pyrolysis temperature. In contrast, the changes of acidic surface functional group and hydrophilicity were insignificant when residence time increased. The biofilm formulated using 8g of tapioca starch and 0.12 µL showed the lowest water absorption ability and was employed to encapsulate the urea-impregnated biochar-based. The EUIB pellet had the greater crushing strength than urea-impregnated peppercorn derived biochar-based fertilizer pellet (UIB pellet). The UIB and EUIB pellets achieved complete nitrogen release after 90 minutes and 330 minutes, respectively. The Korsmeyer-Peppas model best described the nitrogen release mechanism of UIB and EUIB pellets. The enhancement of water retention ratio of UIB and EUIB pellets were more significant in the sandy-textural soil than clayey-textural soil. The nitrogen content of pure urea and UIB pellet was completely leached from the sand after two and three leaching activities while the nitrogen of EUIB pellet was completely leached from the sand after five leaching activities. The EUIB pellet has enhanced the shoot length, root length, number of leaves, area of leaves, wet weight and dry weight of the okra plant as compared to UIB pellet, pure urea and control experiment. In conclusion, the EUIB pellet formulated in this study has the potential to be utilized as a slow/controlled-release fertilizer for soil amendment.

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Keywords: Peppercorn waste biochar; tapioca starch/palm oil biofilm; slow/controlled-release fertilizer; leaching; water retention

Sintesis Kanji Ubi Kayu/Minyak Sawit Terkapsul Urea Diresapi Lada Biochar Baja Pelepasan Terkawal untuk Pindaan Tanah

ABSTRAK

Sifat pelepasan lambat bagi baja berasaskan biochar masih terbatas dan ia boleh diatasi dengan menyepadukan teknologi pembungkusan dan baja berasaskan biochar. Kanji telah diperkenalkan sebagai bahan pembungkus kerana sifat kos rendah dan boleh terbiodegradasi, tetapi sifat pelepasan perlahan dihadkan oleh hidrofiliknya. Oleh itu, kajian ini bertujuan untuk merumuskan kanji ubi kayu/PO terkapsul urea-impregnated lada jagung yang diperolehi pelet baja terkawal biochar (EUIB pellet), diikuti dengan penyiasatan kesan pelet EUIB ke atas kadar pelepasan nitrogen dan kinetik, larut lesap nitrogen, air. pengekalan dan pertumbuhan pokok bendi. CCD digunakan untuk menyiasat kesan suhu pirolisis, masa tinggal dan nisbah urea:biochar ke atas kandungan nitrogen. Keadaan optimum untuk mensintesis serbuk baja berasaskan biochar (serbuk UIB) yang diresapi urea biji lada adalah suhu pirolisis 400 °C, masa tinggal 120 minit dan nisbah 0.6 urea:biochar yang menghasilkan kandungan nitrogen sebanyak 16.07%. Kumpulan berfungsi permukaan berasid dan hidrofilik menurun dengan peningkatan suhu pirolisis. Sebaliknya, perubahan kumpulan berfungsi permukaan berasid dan hidrofilik adalah tidak penting apabila masa tinggal meningkat. Biofilem yang dirumus menggunakan 8g kanji ubi kayu dan 0.12 µL menunjukkan keupayaan penyerapan air yang paling rendah dan digunakan untuk membungkus berasaskan biochar yang diresapi urea. Pelet EUIB mempunyai kekuatan penghancuran yang lebih besar daripada pelet baja berasaskan biochar (pelet UIB) biji lada yang diresapi urea. Pelet UIB dan EUIB mencapai pelepasan nitrogen lengkap selepas 90 minit dan 330 minit, masing-masing. Model Korsmeyer-Peppas menggambarkan mekanisme pelepasan nitrogen bagi pelet UIB dan EUIB. Peningkatan *nisbah pengekalan air bagi pelet UIB dan EUIB adalah lebih ketara dalam tanah bertekstur berpasir berbanding tanah bertekstur liat. Kandungan nitrogen urea tulen dan pelet UIB telah larut lesap sepenuhnya daripada pasir selepas dua dan tiga aktiviti larut lesap manakala nitrogen bagi pelet EUIB terlarut sepenuhnya daripada pasir selepas lima aktiviti larut lesap. Pelet EUIB telah meningkatkan panjang pucuk, panjang akar, bilangan daun, luas daun, berat basah dan berat kering pokok bendi berbanding pelet UIB, urea tulen dan eksperimen kawalan. Kesimpulannya, pelet EUIB yang dirumus dalam kajian ini berpotensi untuk digunakan sebagai baja pelepasan perlahan/terkawal untuk pindaan tanah. .*

Kata kunci: *Biochar sisa lada; biofilem kanji ubi kayu/minyak sawit; baja perlahan/pelepasan terkawal; larut lesap; pengekalan air*

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LIST OF ABBREVIATIONS

AAc	Acrylic acid
Aam	Acrylamide
APS	Ammonium persulfate
BCN	Corncob biochar impregnated with nutrient
BCRNF	Biochar/bentonite/PVA/urea
CCD	Central composite design
CEC	Cation exchange capacity
DAP	Diammonium phosphate
EC	Electrical conductivity
EUIB	Tapioca starch/PO encapsulated urea-impregnated peppercorn waste derived biochar controlled-release fertilizer
IPDI	Isophoronediisocyante
KPS	Potassium persulfate
MAP	Monoammonium phosphate
MBA	N,N'-Methylenebiscarylamide
MMt	Montmoriilonite
NUE	Nutrient Use Efficiency
PHG-g-CNT/urea	Polymer hydrogel-g-natural cotton ball microfiber/urea
PLB	Poultry litter biochar
PMDI	Polymethylenediisocyanate
PO	Palm oil
PVA	Polyvinyl alcohol
PVP	Polyvinylpyrrolidone

RSE	Relative standard error
Si-PU	Poldimethylsiloxane-polyurethane
TDI	2,6-diisocuamatotoluene
TSP	Triple superphosphate
UIB	Urea-impregnated peppercorn waste derived biochar fertilizer

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Soil fertility often refers to the ability of soil to support the growth of agricultural plants. Typically, soil fertility is governed by the physical, biological and chemical properties of the soil (Igalavithana et al., 2017). Low soil fertility is a major concern in most of the region around the world. For instance, the soil from the arid and semi-arid regions usually has very low water retention capacity and nutrient contents (Khalifa & Yousef, 2015). Anthropic activities such as agricultural practices and rapid industrialization may lead to low soil fertility by degrading the soil. Climate change has also resulted in low fertility soil. Degradation of soil could affect the soil quality such as nutrient depletion, salinization and reduce the water retention capacity which restrict the food production. According to the United Nation Food and Agriculture Organization (FAO, 2011) and El-Naggar et al. (2019), 25% of the global agricultural land is classified as highly degraded, 44% is moderately degraded and around 10% is recovered from degradation. Improvement of water retention in the soil could enhance the plant available water content in the soil for the plant growth during drought season. Additionally, it also reduces the water surface run-off which can retain nutrient from leaching (Zheng et al., 2013). Low available nutrient content and water retention in low fertility soil are the main challenges faced by agricultural sector as these factors could reduce the crop production as well as increase the frequency of the irrigation and decrease the fertilizer efficiency. Organic and inorganic fertilizers are widely used to improve soil quality, however long-term use of inorganic fertilizers for soil fertility and crop yield could affect the environment while organic fertilizers mineralize rapidly and need to be replenished frequently to support the plant growth (Syuhada et al., 2016; Oladele et al., 2019). Besides, excessive fertilizer application causes air and groundwater pollution through leaching and volatilization, thus it reduces the nutrient use efficiency by the crops and limits the growth performance.

The rapid population and industrial growth in Malaysia over the years have gradually increased the generation of solid waste. Among the various industries, the agricultural sector is one of the largest contributors of solid waste. The rapid expansion of the agricultural industry has affected the environment with abundant of the solid waste. According to Fadzil & Othman (2021), 998 million tonnes of agricultural waste were generated per year globally and about 15% of the total waste produced in Asia consisted of agricultural waste. Moreover, it has been reported that about 0.122 kg/cap/day of agricultural waste is produced in Malaysia, and the generation of the agricultural waste has been predicted to increase to 0.210 kg/cap/day by 2025 (Fadzil & Othman, 2021). Pepper waste is one of the agricultural wastes abundantly produced from the pepper plantation and pepper production industry which needs to be properly managed. The disposal of the accumulated pepper waste by open burning would cause environmental pollution (Holilah et al., 2021).

Several technologies have been used to reduce the agricultural solid waste which include landfill, thermal, thermochemical and biochemical methods. The biochemical method consists of composting, anaerobic digestion and fermentation; thermal method consists of incineration whereas thermochemical method includes combustion, pyrolysis and gasification. Conventionally, landfilling is the most common practice to manage the solid waste, yet it requires a high capacity of space. It has been reported that 40 hectare of land area is required for landfilling (Owusu-Nimo et al., 2019). Furthermore, it also contributes