HOKKAIDO UNIVERSITY

Title	Synthesis of biochar-based slow-release fertilizer from nutrient-rich organic waste [an abstract of dissertation and a summary of dissertation review]
Author(s)	Islam, Md. Mahmudul
Degree Grantor	北海道大学
Degree Name	博士(農学)
Dissertation Number	甲第15143号
Issue Date	2022-09-26
Doc URL	https://hdl.handle.net/2115/87146
Rights(URL)	https://creativecommons.org/licenses/by/4.0/
Type	doctoral thesis
File Information	Md Mahmudul_Islam_abstract.pdf, 論文内容の要旨

Hokkaido University Collection of Scholarly and Academic Papers : HUSCAP

学位論文内容の要旨

博士の専攻分野名称：博士（農学）　　氏 名：Md. Mahmudul ISLAM

学位論文題名

Synthesis of biochar-based slow-release fertilizer from nutrient-rich organic waste

（栄養豊富な有機性廃棄物を原料とした緩効性バイオ炭肥料の合成）

High-yielding modern agriculture relies heavily on synthetic chemical fertilizers to meet the increasing global demand for food production. However, most of these fertilizers are non-renewable, costly, and have substantial environmental consequences. Additionally, plants cannot utilize a significant portion of these inorganic fertilizers because of fast solubility and subsequent loss from the root zone, resulting in low economic returns. Therefore, integrated nutrient management is essential to sustain future crop production by identifying renewable fertilizer sources with greater nutrient use efficiency (NUE).

Returning nutrient-rich agricultural waste to soil could be a reasonable alternative to chemical fertilizers. To ensure the safe and efficient recycling of these materials, pathogens and contaminants must be removed, and stabilization of C and nutrients is also required. In this regard, thermochemical treatment of biomass to produce biochar (highly recalcitrant) is repeatedly being suggested. While many studies have revealed biochar's numerous agronomic benefits, its nutrient-supplying potential was not well understood. In this study, biochar's potential to become a carbon-based multi-nutrient fertilizer was investigated. Biochars were produced from nutrient-rich chicken (CMB) and dairy manure (DMB), and nutrient-poor Japanese larch at 300 and 500 ℃. NPK release in soil from biochars was compared to the recommended fertilizer dose of sweet corn. The findings showed that CMBs and DMBs could supply adequate NPK and PK respectively, for optimum plant growth. Further analysis revealed that dissolution of amides ($-CONH_2$), ortho-phosphates, and sylvite (KCl) was the major mechanisms behind most NPK releases. In general, a higher production temperature (500°C) reduced N content and release from manure biochars, whereas increased the P content and release. This initial study revealed that CMBs can substitute chemical fertilizers while storing carbons in soil.

Although CMB produced at 300 ℃ could retain approximately 50% of its N and P even after 120 days, the fast initial dissolution of NPK remains a major hurdle in producing biochar-based fertilizers (BBFs) with superior NUE. Therefore, in the next phase of the study, I proposed co-pyrolysis of 10 to 25% (w/w) Ca-bentonite with chicken manure as a simple slow-releasing BBF synthesis technique. To estimate actual nutrient release, pristine and modified CMBs were incubated in contrasting quartz sand and clay loam soil. Fourier transform infrared spectroscopy (FTIR) and energy-dispersive X-ray spectroscopy showed that readily soluble ortho-Ps became less-soluble Ca/Mg-Ps by the co-pyrolysis. In addition, because of K adsorption in crystalline bentonite, 22% slower K release was observed in CMB with 25% Ca-bentonite than the pristine CMB. On average, P and K release from CMBs in coarse sand was respectively 38% and 24% higher whereas greater N release (49%) occurred in clay-loam soil. Even though Ca-bentonite-incorporated CMBs exhibited promising slow-release (P and K) performance, it had no impact on retarding N release.

The next phase of the study focused on delaying N-containing amide dissolution to synthesize a complete slow-releasing BBF. Functional chitosan (biopolymer) was selected as a durable coating material for CMB since it can form grafts with acrylamide under simple microwave irradiation. The chitosan coating (with or without pH adjustment) was performed on both CMB and B25CMB, which promoted beneficial granulation. Moreover, easily soluble primary amides on CMB transformed into less soluble secondary amides by irradiation-induced grafting. A hydrostatic nutrient release test demonstrated that chitosan-coating (without pH adjustment) and additional microwave irradiation progressively retards the N and K release from CMB, but unfortunately accelerates N and P release from B25CMB. Enhanced P release from B25CMB was minimized by adjusting the pH (6.25) of chitosan. In general, microwaved chitosan-coated CMBs showed a remarkable effect in retarding NPK dissolution, however, were not much efficient for B25CMB. Overall, the findings of this study suggested that biochars produced from nutrient-rich feedstocks at low-temperature might be a comprehensive multi-nutrient source and an effective tool for climate-smart nutrient circulation. Further modification of these BBFs by simple and need-based methods would help to improve their NUE.