ABSTRAK

Pabrikasi Pupuk Lepas Lambat Karbon Aktif/Alginat/Nanoselulosa Teradsorpsi Fe(II) dari Limbah Tandan Kosong Kelapa Sawit sebagai Mikronutrient Tanaman

Pupuk lepas lambat merupakan inovasi yang dikembangkan untuk meningkatkan efisiensi pemupukan serta mengurangi dampak negatif penggunaan pupuk kimia berlebih terhadap lingkungan. Mikronutrien besi (Fe), khususnya Fe(II), berperan penting dalam biosintesis klorofil, transport elektron, dan aktivasi enzim antioksidan pada tanaman. Namun, pupuk Fe konvensional sering mengalami kehilangan nutrien akibat pencucian (leaching) sehingga efisiensi serapan tanaman menurun. Penelitian ini bertujuan untuk mengembangkan komposit karbon aktif/alginat/nanoselulosa berbasis limbah tandan kosong kelapa sawit (TKKS) sebagai bahan pembawa pupuk lepas lambat Fe(II) yang ramah lingkungan. Penelitian meliputi preparasi TKKS, pembuatan karbon aktif dan nanoselulosa, karakterisasi material, serta sintesis komposit karbon aktif/alginat/nanoselulosa yang dibentuk menjadi beads melalui gelasi ionik dan dimuat dengan ion Fe(II) menggunakan larutan $FeCl_2$ 0,1 M. Hasil penelitian menunjukkan bahwa komposit KaAlgNs113 memperlihatkan jumlah Pelepasan Fe paling besar pada hari ketiga sebesar 0.667 mg/g. KaAlgNs113 juga memiliki stabilitas struktural tinggi serta kemampuan pelepasan Fe(II) secara bertahap dan terkontrol. Pemanfaatan limbah TKKS sebagai bahan dasar komposit juga mendukung prinsip pembangunan berkelanjutan melalui pengurangan limbah biomassa dan pencemaran lingkungan. Dengan demikian, komposit karbon aktif/alginat/nanoselulosa-Fe(II) berpotensi menjadi alternatif pupuk lepas lambat yang efektif, ekonomis, dan ramah lingkungan untuk meningkatkan produktivitas pertanian.

Kata kunci : Pupuk lepas lambat, karbon aktif, alginat, nanoselulosa, tandan kosong kelapa sawit

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ABSTRAK

Fabrication of Activated Carbon/Alginate/Nanocellulose Slow-Release Fertilizer Adsorbed with Fe(II) from Oil Palm Empty Fruit Bunch Waste as a Plant Micronutrient

Slow-release fertilizers have been developed to improve fertilization efficiency while minimizing the adverse environmental impacts associated with the excessive use of conventional chemical fertilizers. Iron (Fe), particularly Fe(II), is an essential micronutrient that plays a crucial role in chlorophyll biosynthesis, electron transport, and the activation of antioxidant enzymes in plants. However, conventional iron fertilizers are highly susceptible to nutrient losses through leaching, resulting in reduced nutrient use efficiency. This study aimed to develop an environmentally friendly Fe(II) slow-release fertilizer carrier based on an activated carbon/alginate/nanocellulose composite derived from oil palm empty fruit bunch (OPEFB) biomass. The research involved the preparation of OPEFB, the production of activated carbon and nanocellulose, material characterization, and the synthesis of activated carbon/alginate/nanocellulose composite beads using the ionic gelation method. The composite beads were subsequently loaded with Fe(II) ions by immersion in a 0.1 M $FeCl_2$ solution. The results demonstrated that the KaAlgNs113 composite exhibited the highest Fe release, reaching 0.667 mg/g on the third day. Furthermore, the KaAlgNs113 composite showed high structural stability and provided gradual and controlled Fe(II) release. The utilization of OPEFB waste as the primary raw material also supports sustainable development by reducing biomass waste and mitigating environmental pollution. Therefore, the activated carbon/alginate/nanocellulose–Fe(II) composite has considerable potential as an effective, economical, and environmentally friendly slow-release fertilizer for enhancing agricultural productivity.

Key Word : slow-release fertilizer, Fe(II), activated carbon, alginate, nanocellulose, oil palm empty fruit bunches