World Academy of Science, Engineering and Technology
International Journal of Energy and Power Engineering
Vol:19, No:08, 2025

Enhancement of Anaerobic Digestion of Water Hyacinth Through Potassium Hydroxide Pretreatment and Co-digestion

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Abstract : Water hyacinth is a fast growing plant that is considered invasive in many tropical areas due to its potential to clog waterways. The lignocellulosic structure of water hyacinth is the primary barrier to harvesting and efficiently producing bioenergy from degrading water hyacinth via anaerobic digestion. This study investigated anaerobic mono-digestion and co-digestion of water hyacinth and dairy manure using potassium hydroxide (KOH) pretreatment to breakdown the lignin prior to digestion. Water hyacinth was pretreated with KOH at 5%, 7.5%, and 10% based on volatile solids (VS) at 37°C for 24 h. The pre-treated samples were used directly for anaerobic digestion without washing or pH adjustment, with triplicate treatments tested after pre-treatment to access effects on structural composition of the water hyacinth. Co-digestion experiments included 3:1, 1:1, and1:3 ratios of water hyacinth to dairy manure based on VS. The inoculum-to-substrate ratio was set at 2:1 for all experiments. A total of seventeen experimental points were run in triplicate in 250 mL reactors. Results showed that the pH of the pretreated samples stabilized within the range of $7.5 < pH < 8$ during mixing with dairy manure and inoculum. With mono-digestion the highest methane (CH4) yields (312 mL CH4/g VS) were achieved with 10% KOH pretreatment corresponding to 19.3% CH4 increase compared to the control. Co-digestion of untreated WH at 1:3 increased enhanced CH4 yield (390 mL CH4/g VS) corresponding to 49.1% CH4 increase compared to the control, but co-digestion (1:1) with 5% KOH had the highest CH4 yield (467 mL CH4/g VS) and the highest synergistic effect value of 1.52, corresponding to 78.5% CH4 increase compared to the control. KOH pretreatment reduced lignin content by 14.3 to 29.82% and increased cellulose content in the solid fraction by 72.0 to 104.6%, with the lowest increases at 5% and highest increases at 10% KOH. Pretreated at 7.5% exhibited a CH4 yield increase of 18% and 36%, while those pretreated at 10% showed increases of 1% and 40% as the co-substrate ratio shifted from 3:1 to 1:3. These findings highlight the critical role of nutritional balance and alkalinity of dairy manure, which increased methanogenic activity. Even at 5% KOH pretreatment and a 1:1 co-digestion ratio showed lignin degradation with co-digestion amplifying the effect of pretreatment. These results demonstrate a significant improvement in the digestion of water hyacinth through KOH pretreatment with no washing or pH adjustment needed during digestion to achieve high yields. Use of these results could reduce pretreatment costs, avoids the loss of VS during pretreatment, and eliminate wastewater generation from pretreatment processing. Co-digestion of water hyacinth and dairy manure could be a viable industrial-scale application to create non-intermittent bioenergy in the form of biogas for electricity generation in rural areas, while creating a value-added product from the invasive water hyacinth. Kinetic modeling showed the modified Gompertz and first-order models best fit the data ($R^2 = 0.97$ and 0.99).

Keywords : alkaline, biogas, lignocellulosic, methane
Conference Title : ICEWES 2025 : International Conference on Energy, Water and Environment Systems
Conference Location : Lagos, Nigeria
Conference Dates : August 07-08, 2025