



Valorization of animal manure via pyrolysis for bioenergy: A review

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ABSTRACT

The continuous development of the economy and the constant improvement of living standards have stimulated the development of animal husbandry. This development has been accompanied by the massive production of animal manure with various bad odors and high heavy metal content, constituting severe damage to ecological security and human health. Traditional disposal methods, including composting and anaerobic digestion, are difficult to achieve satisfactory results due to long processing time, water and soil eutrophication, and toxic gas emissions. However, converting animal manure into bioenergy through pyrolysis is a clean, safe, and promising technique to reduce the amount of waste and produce valuable products. Co-pyrolysis with other materials can decrease the content of heavy metals in biochar and ameliorate the properties of products. The application of catalysts influences the pyrolysis process and product properties positively. The objective of this review is to analyze the properties of animal manure and discuss the recovery of biofuel from harmful animal manure by pyrolysis. A comprehensive analysis of animal manure pyrolysis and related product characteristics will provide a foundation for the sustainable management and scientific disposal of hazardous manure waste.

1. Introduction

The rapid expansion of modern society, the sharp increase in population, and the continuous improvement of life quality have led to an enormous demand for meat products and the swift development of animal husbandry. Consequently, large amounts of livestock manure and poultry litter are produced annually (Tańczuk et al., 2019). Fig. 1 (a) illustrates the total production of animal manure in various countries and regions during the past decade. Approximately 3.98 billion tons of manure were generated in China in 2017, which occupied first place globally, and the figures in the United States and the European Union were approximately 1.4 billion tons. Fig. 1 (b) depicts the growth of animal manure production since the reform and opening up of China. With the economic level being raised, the manure yield experienced a

dramatic rise, which increased nearly six times in the past 40 years. Meanwhile, the consumption of fossil fuels is soaring to satisfy the rapid development of urbanization and industrialization, which causes a series of environmental problems, such as global warming, air pollution, acid rain, ozone layer depletion, and desertification, constituting an enormous threat to the sustainable development of the environment and human beings (Wang et al., 2021b).

As heterogeneous compounds generated at the end of the animal husbandry cycle, livestock manure and poultry litter are mainly composed of feces, urine, undigested feed, waste bedding, dead skin, and resulting microbiota, lignocellulose, proteins, and inorganic matter, such as S, N, P, K, Ca, Mg, Cl, and Mo. The composition is primarily related to diet, age, species, and specific animal management routes (Kumar et al., 2019). However, the antibiotics, hormones, pathogenic bacteria, and heavy metals, such as Cu, Pb, Cd, and Zn in manure, have

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