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The effect of microwave pretreatment on biogas production from agricultural straws

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HIGHLIGHTS

- ▶ Barley, spring wheat, winter wheat and oat straw were examined.
- ▶ Microwave pretreatment were performed at 200 and 300 °C.
- ▶ The biogas production performance was investigated.
- ▶ Specific methane yields were not improved by microwave irradiation.
- ▶ Conversion yield and cumulative biogas production have inverse relations.

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ABSTRACT

Biogas production from microwave-pretreated agricultural residual straws that are used as feedstock was investigated in a laboratory batch study. Barley, spring wheat, winter wheat and oat straw were examined. To investigate the effect of changing the physicochemical structure of the straws on biogas production, the pretreatment processes were applied to two sample groups. The first group contained milled straw and the second group comprised milled wet straw that was prepared by the addition of deionized water. Both groups were subjected to microwave irradiation until oven temperatures of 200 or 300 °C were attained. Sixty-six identical batch anaerobic reactors were run under mesophilic conditions for 60 days. Preliminary test results showed that the microwave pretreatment of the different straws did not improve their anaerobic digestion. An increase in the treatment temperature led to lower biogas production levels. An inverse relationship between the thermal conversion yield and cumulative biogas production was observed.

1. Introduction

Studies on the conversion of whole crop cereals and their residues into energy and valuable chemicals show very promising future applications. In recent years, the anaerobic digestion process has been used to obtain energy from lignocellulosic residues in co-digestion, because it provides a higher content of carbon for the digestion. The different types of lignocellulosic biomass vary in the percentages of the major constituents, i.e., cellulose, hemicelluloses, lignin, organic extractives and inorganic minerals, depending on their origin and species (Mohan et al., 2006). The cellulose chains are packed by hydrogen bonding in "elementary microfibrils." These fibrils are attached to each other by hemicelluloses and by other polymers such as pectin and are covered by lignin. The microfibrils often associate as bundles or macrofibrils. These strong chains form a crystalline ribbon that makes cellulose resistant to biological treatments by making it less available for microbial and enzymatic hydrolysis. Consequently, the most rate-limiting stage of biomass degradation is reported to be the hydrolysis stage of the digestion process. Similarly, lignocellulosic biomass must be pretreated to make it less resistant and more exposed for improved hydrolysis efficiency (Zhu et al., 2010). Pretreatment is a process that makes biomass more hydrolysable than it is in its hydrolysis-resistant native state. There are many pretreatments technologies, such as thermal, biochemical, mechanical and enzymatic treatments (Estevez et al., 2012; Jackowiak et al., 2011). To observe the pretreatment effects, anaerobic batch experiments are employed to determine the biochemical methane potential of the pretreated biomass (Jackowiak et al., 2011; Zhu et al., 2010).

In thermal pretreatment, heat is either transferred into the material through convection, conduction or radiation using conventional heating, or it is delivered directly into the material through molecular interaction with an electromagnetic field using microwave energy. The electromagnetic energy of the microwave radiation is converted to thermal energy. The microwave technique has many potential advantages, as it penetrates materials, deposits energy and generates heat throughout the volume of the material.

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