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三价铁离子促进玉米秸秆厌氧发酵

Fe^{3+} enhanced anaerobic digestion process of corn straw

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中文摘要:

厌氧消化是农业废弃物资源化利用的有效途径之一。微量元素是影响有机废弃物厌氧产沼气性能的重要生态因子，其中铁对有机废弃物的厌氧发酵过程的效率和稳定性作用最为显著，而通常秸秆的含铁量很低。因此，该试验以玉米秸秆为例，研究了初始$FeCl_3$加入量分别为0.1%、0.2%、0.5%、1.5%、3%、6%（基于秸秆的挥发性组分）时秸秆厌氧发酵产沼气、产甲烷过程以及沼液沼渣特征。结果表明初始$FeCl_3$加入量为3%，秸秆的厌氧产甲烷效率相对于对照（加入量0%）提高了14%。X射线衍射分析结果表明$FeCl_3$存在时，沼渣中纤维素的结晶度显著降低。沼渣的组分分析结果表明$FeCl_3$的存在有助于提高玉米秸秆中纤维素及半纤维素的分解效率，从而提高了秸秆产甲烷效率。该研究可为农业废弃物甲烷化利用提供参考。

英文摘要:

Abstract: Anaerobic digestion is one of the effective utilization processes for the resourcization of agricultural wastes. Trace elements are one of the key biological factors that influence the biogas production capacity of organic wastes, especially for the element of iron that has a significant influence on the stability and methane yield of the anaerobic digestion process. However, the iron content in the corn stover normally is low. Therefore, in this experiment $FeCl_3$ was used as the iron source to enhance the anaerobic digestion of corn stover. The experiment was performed in batch modes using the serum bottles as reactors with a working volume of 150 mL. The mass concentration based on the volatile solids (VS) of corn stover was 50 g/L and $FeCl_3$ dosages were 0%, 0.1%, 0.2%, 0.5%, 1.5%, 3%, 6% of the corn stover VS. The characteristics of the gas and methane generation process, digester solution, and solid digester residues in the five reactors were studied.A modified Gompertz equation was used to describe the gas and methane generation process. Results showed that the methane production of the reactor with 3% $FeCl_3$ was 7.29 L • L^{-1} which was about 14% higher than that of the control reactor (6.47 L • L^{-1}). Simulation results also showed that the lag time, product yield, and formation rate were different in the reactors. Such a difference could be attributed to the nutrient iron requirements for different anaerobic microorganisms, including hydrolytic and fermentative bacteria, acetogenic bacteria, and methane-producing archaea were different.Cellulose and hemicellulose were the main ingredients of corn stalks, and were also the main biodegradable ingredients of corn stover for the anaerobic digestion process. The lignocelluloses content in the dolif digester residues were analyzed. The mass fractions of neutral detergent fiber, hemicellulose, and cellulose in the digester residue obtained from the reactor with 3% $FeCl_3$ were the lowest, which were 56%, and 6% and 18%, respectively. Moreover, the degradation efficiencies were 70%, and 90% and 83% respectively. As for the control reactor with 0% $FeCl_3$, the degradation efficiencies of neutral detergent fiber, hemicellulose, and cellulose were 62%, and 85% and 72%, respectively. This meant that the addition of 3% $FeCl_3$ promoted the degradation of cellulose and hemicelluloses, which resulted in the higher methane yield.The major limiting factor for the anaerobic digestion of corn stover was the high recalcitrance of substrate, which was mainly caused by the lignin and crystalline structure of cellulose. Normally lignin could not be digested by the anaerobic microorganisms, and only partially was released into the digester solution during the degradation of the cellulose and hemicellulose. The crystalline structure of the anaerobic digester residues were tested by X-ray diffraction (XRD). Results showed that the crystalline of the solid digester residue in the reactor with 3% $FeCl_3$ was lower compared to that of the residue from the control reactor.The results mentioned above showed that a synergistic effect happened between Fe^{3+} and anaerobic microorganisms. This resulted in the destruction of crystalline cellulose, and higher cellulose degradation efficiency and methane yield. However, the variation of Fe availability and its effect on the microbial community was not performed, which needs to be investigated in the future. In the current research, $FeCl_3$ was used as the iron source, but its cost was higher. A cheaper iron resource needs to be found, and the iron-promoted anaerobic digestion process should be optimized to further increase the methane yield and the economic efficiency.

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