Investigation on the Effect of Nanobubble Water on Anaerobic Digestion of Swine Manure

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Abstract

Environmental pollution and energy shortage have always been the hot topics around the world, prompting researchers to devote themselves to developing renewable energy and protecting the environment. As an important component of the agriculture and rural sectors, the livestock industry not only provides food and livelihoods for the world's population but also produces a large amount of livestock manure. Due to the intensive swine industry development, swine manure (SM) production is continuously increasing, which requires scientific measures for proper and effective treatment. If the large amounts of SM are properly processed, renewable energy can be produced, and the surrounding environment pollution can be avoided.

Anaerobic digestion (AD) technology can effectively treat waste and generate clean and renewable energy while protecting the environment. The treatment of SM using AD has been applied for renewable energy generation and environmental protection. However, the use of AD to treat SM also has some shortcomings, such as low efficiency, poor wet AD performance, and prone to ammonia inhibition, which limit the potential of using AD technology to treat SM. To overcome the shortcomings of low efficiency, many methods have been applied, including pretreatment, additive addition, and optimization of AD process parameters. As for the shortcomings of the poor performance of wet AD, high solid AD (HSAD) has been adopted to reduce water consumption and then the reactor volume. In addition, many methods have been attempted to alleviate ammonia inhibition such as acclimation of microorganisms and dilution of the feedstock. Although these methods demonstrate some positive effects on the AD of SM, they also cause energy and chemical consumption and are not conducive to environmental friendliness. Therefore, new environment-friendly strategies are still required for improving the AD efficiency of SM to alleviate inhibition.

Nanobubble water (NBW) refers to water with enormous nanoscale bubbles with diameter ranging from several to hundreds of nm. NBW possesses unique characteristics that are not possessed by ordinary water, which has been successfully applied in many fields. The previous reports showed that NBW enhanced methane production in the AD process of cellulose, lignin, and waste activated sludge. However, few studies could be found on its effects on the AD of SM. Whether NBW can promote the AD efficiency of SM or not is still unknown. Moreover, previous studies on application of NBW were carried out in wet AD systems under no inhibition conditions. Again, whether NBW is beneficial for the improvement of CH_4 production in HSAD or under ammonia inhibition is still unknown.

Therefore, this research was devoted to investigating the effect of NBW on the AD of SM. The main objectives of this research are as follows: (1) to investigate the effects of NBW supplementation on the AD of SM, and (2) to explore the promotion effect of NBW supplementation in HSAD

performance and alleviating the inhibition that occurs in the AD of SM.

(1) The cumulative methane production from the NBW supplementation reactor was 192–225 mL/g-VS and 19–39% higher than the control group (without NBW supplementation). The reduction rates of VS in NBW groups on day 4 (15.3–17.3%) and day 8 (30.5–35.2%) were faster than those in the control group (9.8% on day 4, and 28.8% on day 8), indicating that the supplementation of NBW might promote the hydrolysis process. Based on the analysis of soluble organics, the supplementation of NBW enhanced the production of volatile fatty acids (VFAs). In addition, the energy recovery was enhanced by 19-39% by NBW supplementation. Moreover, mechanism analysis reveals that NBW with higher proton spin-spin relaxation times and absolute value of zeta potential (16.5-21.1mV) might promote the AD process.

(2) The cumulative biogas yield was 336–345 mL/g-VS in the NBW reactors at total solids (TS) of 3–6%, about 18–24% higher than the control reactors. The cumulative methane yield was 20-25% higher than the control groups at TS of 3–6%. In addition, the cumulative methane yield was 261 mL/g-VS at TS of 8%, which was higher than the corresponding control group. Due to the acidic SM (pH 6.08) and the lower inoculum content, VFAs inhibition (VFAs concentration > 10,000 mg/L) occurred when TS was higher than 8% in this research. This inhibition was gradually alleviated under NBW supplementation when inhibitor content was below the threshold. At the same time, NBW was found to promote the consumption of soluble proteins/carbohydrates during the AD process.

(3) The cumulative biogas and methane yield were elevated by 9-25% and 12–39%, respectively, in NBW groups under ammonia inhibition. Experimental data under ammonia inhibition well fitted to the modified Gompertz model (R^2 = 0.997 to 0.999). Besides, the maximum methane production potential and the maximum methane production rate were enhanced by 11-35% and 9-30%, respectively. The rapid increase of partial alkalinity could be observed with NBW supplementation, as well as the rapid decline of VFA/total alkalinity, thus improved buffering capacity and alleviated ammonia inhibition. Moreover, compared to the control reactor, the activity of coenzyme F_{420} with NBW supplementation was enhanced by about 8-12%. Higher levels of extracellular hydrolases were also detected in the NBW groups.

Results from this study suggest that the supplementation of NBW is promising for the enhancement of methane production from AD of SM, achieving improved digestion stability under inhibition. The increased methane production and the improvement of AD system stability parameters indicate the promising application of NBW for the alleviation of inhibition during the AD of SM.

Keywords: Swine manure; Anaerobic digestion; Nanobubble water; Methane production; Inhibition; Digestion stability.