Development of Intermittent Illuminated Anaerobic Digestion System for Mitigating Ammonia Inhibition

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Abstract

Anaerobic digestion is regarded as a promising method to deal with the livestock waste. However, ammonia which is rich in the livestock waste works as a strong inhibitor during the anaerobic digestion process. Conventionally, most anaerobic digesters are conducted under dark condition, while it has been found that optimal illumination time played an important role on improving bio-methane production. Nonetheless, there is no study on anaerobic digestion with illumination especially regarding high ammonium concentration conditions. Therefore, in this study, an appropriate illumination process was developed to mitigate ammonia inhibition during anaerobic digestion.

Firstly, the effect of intermittent illumination system on mitigating ammonia inhibition was investigated. Serious of experiments were performed at different ammonium nitrogen concentrations under intermittent illumination condition and dark conditions. The illuminated bioreactor achieved higher methane production and ATP (adenosine triphosphate) value than that under dark condition with high ammonium nitrogen concentration. Then, the bio-zeolite fixed-bed bioreactor was used to develop a more effective illuminated ammonium-rich anaerobic digestion process. The result

showed that the illuminated fixed-bed bioreactor presented the greatest methane concentration, methane yield and quantity of methanogens. Furthermore, the illuminated bio-zeolite fixed-bed reactor achieved better performance during 118-day semi-continuous fermentation. Thereby, the intermittent illumination strategy proved to be an appropriate method in mitigating ammonia inhibition from anaerobic digestion.

Conversely, the parameters of illuminations, such as photon flux density and illumination time involved in the illuminated process is still without specific investigation. Then the bioreactors were conducted under different photon flux density for the optimal photon flux density investigation. The highest methane concentration and methane production were achieved from the bioreactors subjected to the photon flux density of 70 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Moreover, the exploration for the proper illumination time was carried out under the optimal photon flux density. The illumination time of 50 $min \cdot day^{-1}$ contributed to the highest methane yield. As above, both photon flux density and illumination time have significant impact on the illuminated process. To further understand the relationship between the light conditions and the bio-methane recovery from the ammonium-rich substrate, the number of photons which is regarded as the integration of photon flux density and illumination time, was introduced into the illuminated process as a newfangled factor firstly. The effective range of photon number for mitigating ammonium inhibition have been proved to be 1.16×10^4 - 1.86×10^4 $\mu mol\cdot day^{-1}\cdot L^{-1}$, where the methane yield could reach to the peak and was around 3 times higher than the dark condition. The higher F_{420} concentration have been achieved in the bioreactor within the effective range of photon number, indicating that illumination with effective number of photons could activate the methanogens responsible for alleviation of ammonia inhibition during the anaerobic digestion process. In addition, the influence of ammonium nitrogen concentration on effective range of photon number was studied. The results showed that despite of the change on the ammonium nitrogen concentration, the illuminated bioreactors with effective photon number of 1.25×10^4 $\mu mol\cdot day^{-1}\cdot L^{-1}$ always showed around 3 folds methane yield of the dark bioreactors. For the further scale-up of the illuminated system, the bioreactors with different working volumes under the same effective photon number condition showed similar bio-methane yield, indicating that the photon number is the key factor for optimizing the illumination condition of anaerobic digestion to treat the ammonium-rich substrate. Besides, the illuminated bioreactor with effective photon number condition was stable and well-performed under high ammonium concentration with long-term 108-day semi-continuous operation.

In summary, the illuminated anaerobic digestion system was effective to mitigate ammonia inhibition. It is the first time to propose the strategy by using an appropriate illumination process to mitigate ammonia inhibition during anaerobic digestion. The photon number based process contributed to higher efficiency and stability in ammonium-rich anaerobic digestion. It could be expected to develop a low cost, easy operated, eco-friendly solar light utilized process for ammonium-rich waste treatment and bioenergy conversion in the future.