Ammonia removal from substrates (and utilization) in order to decrease its inhibiting effects for anaerobic digestion process

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Introduction

Nitrogen (N) in the form of ammonia (NH_3) is formed as a result of the decomposition of organic nitrogen compounds, proteins, urea, uric acid and nucleic acids present in most living organisms [1]. Together with phosphorus (P), these elements are essential for the proper development of animals and plants [2]. Imbalance caused by the excessive use of mineral fertilizers may cause eutrophication, deterioration of the quality of the atmospheric air as well as pollution of surface and ground waters [3].

It is estimated that by 2050, the population of the Earth will increase to approx. 9.7 billion, which will significantly increase the demand for food [4]. Therefore, the production and use of mineral fertilizers will be also increased. There is also a growth in the breeding of pigs and poultry, which results in the production of an additional waste stream - e.g. manure [4], which must be managed in an appropriate and safe manner.

Thermal-vacuum stripping is an innovative technique for recovering nitrogen from a wide range of waste in order to reduce the use of mineral fertilizers and utilize ammonium-rich waste. The process can be used both for the removal of ammonium nitrogen directly from waste (e.g. manure, pig slurry) and from the residues after their processing (e.g. digestate). Stripping consists in transferring NH_3 to the gas phase and separating it from the treated substrate in acid solution. The produced salts are a valuable mineral fertilizer slightly polluted with organic substances [5].

Materials and methods

On the basis of preliminary studies, the optimal physicochemical conditions for thermal-vacuum stripping were selected. The process was applied to chicken manure with a high content of ammonium nitrogen (approx. 1550 mg $N\text{-}NH_4^+$/l) which is used as a substrate for methane fermentation. The process was carried out for 4 hours in order to determine its dynamics (repeated three times). Ammonium nitrogen content was determined spectrophotometrically using the modified salicylic method described by Raymond B. Willis [6]. Figure 1 presents the apparatus used in the research.

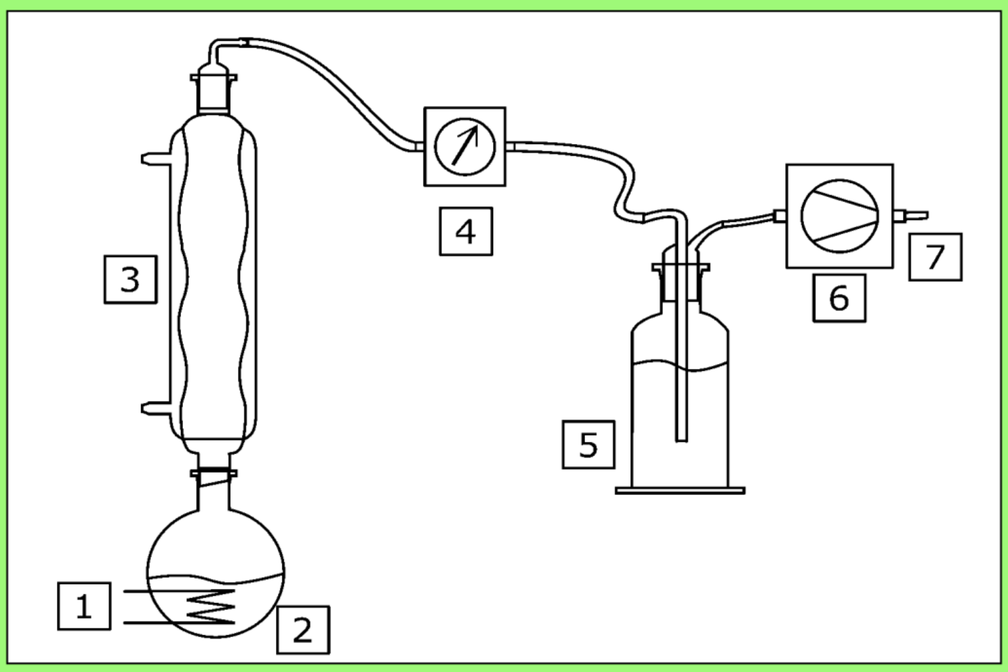

Figure 1. Diagram of the apparatus used for thermal-vacuum stripping: 1 - heater, 2 - flask with treated liquid, 3 - reflux condenser, 4 - temperature and pressure regulator, 5 - scrubber, 6 - vacuum pump, 7 - purified steam.

The impact of the stripping process on the methane fermentation process where treated manure consist a substrate was also estimated. A laboratory batch set was used to determine the amount of biogas produced from both chicken manure before and after treatment.

Results

Based on the analysis of the obtained data, it was shown that the concentration of ammonia nitrogen in the chicken manure was reduced from approx. 1550 to approx. 70 mg $N\text{-}NH_4^+$/l. Figure 2 shows the dynamics of the stripping process. It was estimated that the total efficiency of the ammonia nitrogen removal process was 92.4% (Figure 3).

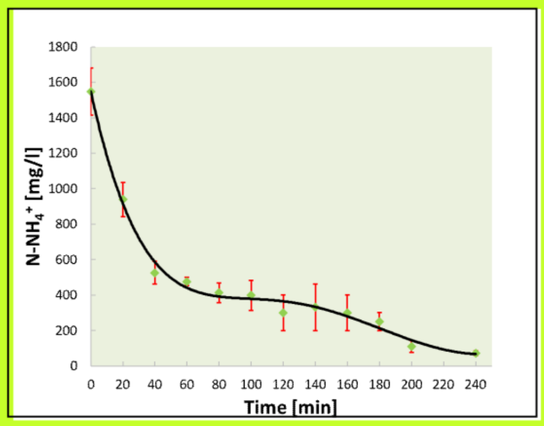

Figure 2. Dynamics of the ammonia nitrogen removal.

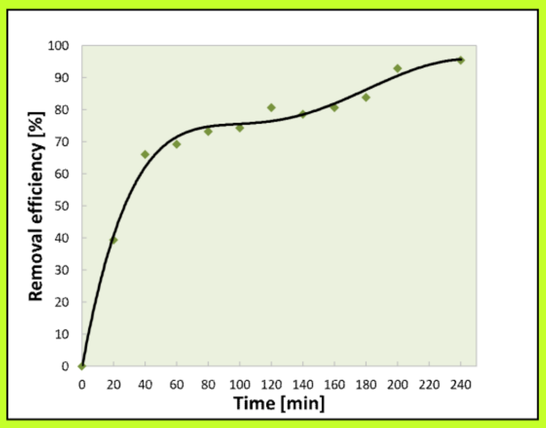

Figure 3. Dynamics of the ammonia nitrogen removal efficency.

On the basis of the laboratory biomethane potential test it was confirmed that ammonia stripping has a positive effect on the biogas yield during treated manure fermentation. After 20 days of fermentation, the amount of obtained biogas and methane was higher by 31.5% and 25.4% respectively, compared to the untreated manure.

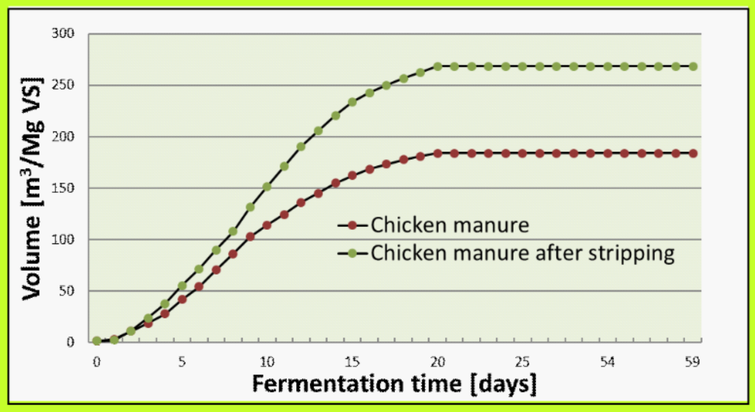

Figure 4. Cumulative daily methane yield calculated on the volatile solids (VS) of the substrate.

Conclusions

The thermal-vacuum stripping process can be an efficient, simple and low-cost solution to reduce ammonium nitrogen in various types of waste. Due to the formation of e.g. ammonium sulphate, it is possible to partially recover valuable nitrogen. The method may be particularly applicable in the pretreatment of high-nitrogen substrates for methane fermentation, increasing its biogas potential. Additionally, it can be used for the treatment of fermentation residues and the production of valuable fertilizer.

Literature

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