IEA Bioenergy
Technology Collaboration Programme

Minhe Chicken Manure Biogas Plant

Case Story

IEA Bioenergy: Task 37: 06 2021

Circular economy management of chicken manure

Figure 1: Minhe Biogas plant with two clusters of digesters

The problems in managing chicken manure

In China, the rapid development of the poultry production sector has resulted in significant amounts of chicken manure. Chicken manure is quite ammonical, can be detrimental to the environment should it not be managed well and is not ideally suited to anaerobic digestion. The total solids (TS) content of chicken manure is typically in the range of 10% to 30% (depending on animal husbandry); the total nitrogen content accounts for between 3.2% and 4.9% of the dry weight of the manure. The main components of chicken manure include for protein, fat and fiber, which have been shown to account for 28%, 2.3% and 10.2% of the dry weight, respectively. In terms of digestibility the major disadvantage is the low carbon to nitrogen (C/N) ratio of chicken manure, which is generally between 6:1 and 12:1.

Minhe Chicken Manure Biogas Plant

The Minhe Chicken Manure Biogas Plant is located in Yantai city, Shandong Province, China. It has two clusters of biogas digesters which were constructed in two separate phases; the initial phase in 2009 and and the second phase in 2015.

Layout of the first phase of the biogas facility

In the first phase in 2009 a cluster of biogas digesters were designed and commissioned with the purpose to produce biogas for electricity. The cluster includes for eight continuous stirred tank reactors (CSTRs), each with a working volume of 3000 m^3 (see figure 1 & 2). The eight digesters are divided into two parallel sets each employing two-stage anaerobic digestion technology (figure 2). The system includes for two sets of three main digesters (first-stage) followed by one post digester (second-stage).

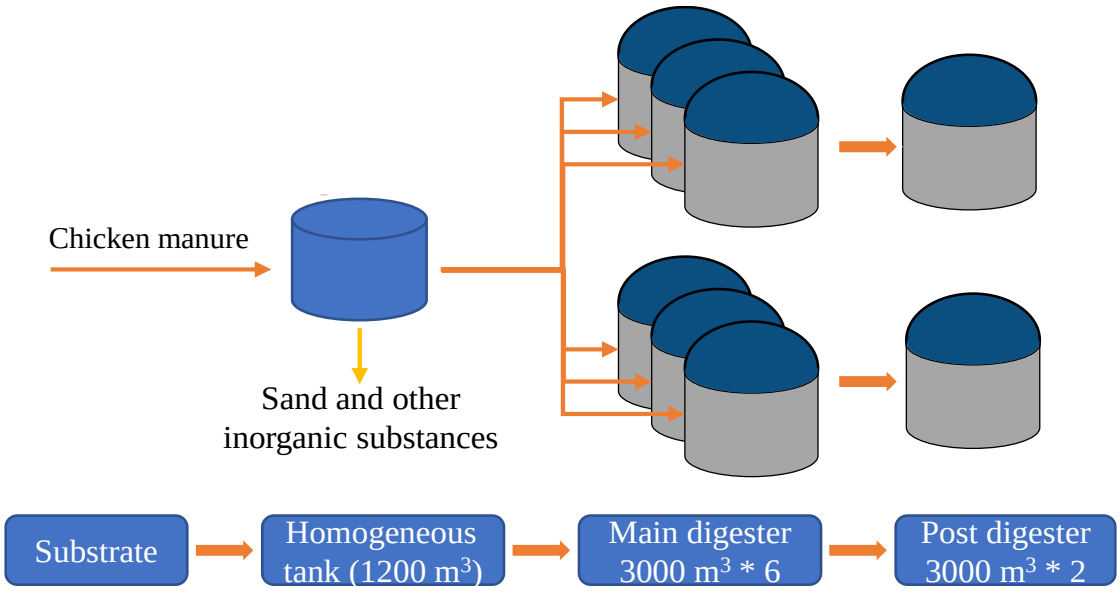

Figure 2: Process flow chart of the first phase of the biogas facility

Operation of first phase of the biogas facility

The feedstock is collected chicken manure from chicken farms owned by Shandong Minhe Animal Husbandry Co. Ltd. The facility can treat about 300 tonnes/day of raw chicken manure and 240 tonnes/day of chicken house cleaning wastewater (which contains relatively low levels of Chemical Oxygen Demand (COD)). The raw chicken manure has a total solids content of around 20% but after dilution is fed to the main digesters at a solids concentration in the range 8% to 9% TS. The digesters operate in the mesophilic temperature range (at about 37°C). The organic loading rate was set at 2.5 grams volatile solids per litre per day (gVS/(L·d)). The hydraulic retention time (HRT) was set at 33 and 11 days for the first and second stage digesters, respectively.

Biogas and electricity production in phase 1 of the facility

The daily average biogas production is 30,000 m^3/d (100m^3 biogas/t raw chicken manure) generating typically 60,000 kW_eh/d of electricity. The owner of the biogas facility can get revenues of 0.704 RMB/kW_eh (c.$0.11/$kW_eh$) including the electricity sold to the power grid and the subsidy from government. Three Jenbacher cogeneration sets each with a capacity of 1.063 MW_e (total capacity of 3.189 MW_e) operate for more than 8000 hours per year.

Co-benefits of the circular economy biogas system

This biogas plant generates multiple benefits in a circular economy system over and above energy (power and heat). It treats the chicken waste in an environmentally friendly manner reducing potential for water pollution, reducing smells, creating biofertilizer from digestates and as such minimising fossil fuel based fertilisers. Of definite interest is the savings in greenhouse production of 80,000 tonnes CO_{2e} per annum; this is equivalent to 3.14 tCO_{2e}/MW_eh of electricity. Minhe was the first agricultural biogas plant in China to avail of the Cleaning Development Mechanism (CDM). The Certified Emission Reductions (CER) have been sold to the World Bank for 6 years.

The second phase of the biogas facility

The second cluster of anaerobic digesters in phase 2 began operation in 2015. Again a two stage anaerobic digestion technology was employed. It has twelve digesters with a total working volume of 42,000 m^3 (as compared to 24,000 m^3 in phase 1) dealing with an average amount of 700 tonnes/day chicken manure (as compared to 300 tonnes per day in phase 1).

Biogas to biomethane in phase 2

The process in phase 2 is different to phase 1 in that the purpose is not to produce biogas for electricity but rather upgrade biogas to biomethane. In phase 2, around 70,000 m^3/d biogas (c. 100 m^3 biogas/t) is produced which is converted to 40,000 m^3/d of biomethane through membrane purification technology. The methane content in the final biomethane product can reach more than 97%. The end use of the biomethane is available for industry, vehicles, urban and rural households.

Biological stability of anaerobic digesters

Over the past 12 years, the biogas facility has operated in a stable manner. About 94±1, 32±1 and 30±1 g/L of total chemical oxygen demand (TCOD) enters the main digester, the post digester and the digestate, respectively. The TCOD removal efficiency has reached 66±1% in the first stage digester but only 3±1% in the second stage digester.

The relatively high methane yield and low volatile fatty acids (VFA) in the digesters in the present study are thus somewhat remarkable considering that the ammonium-N level has reached 6.0 g/L. Therefore, the long acclimation of the microbial community in the present study together with proper feeding frequency could be the reason behind its good performance.

Further reading.

[1] Bi S, Westerholm M, Hu W, et al. The metabolic performance and microbial communities of anaerobic digestion of chicken manure under stressed ammonia condition: A case study of a 10-year successful biogas plant. Renewable Energy, 2021, 167: 644-651.

[2] Dong T. Report on Innovative achievements of Shandong Minhe animal Waste Resource Utilization Project. 2021.1.23

IEA Bioenergy Task 37 "Energy from Biogas" http://task37.ieabioenergy.com

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