A Sustainable System of Biomethane, Biofertilizer and Biodiesel

Abstract

In this study we developed and tested a sustainable system that produces high-yield outputs of biomethane, biofertilizer and biodiesel using blends of poultry manure (PM), paper pulp and algae waste sludge as the initial input.

We blended the poultry manure, algae sludge, and paper waste in varying ratios and anaerobically co-digested in batch mode. Varied blending ratios were studied for biomethane yield. The digestates (the residues left in the digester after biogas is removed) were analyzed for their value as biofertilizer and as supplementary feed to enhance microalga Chlorella vulgaris biomass for biodiesel production.

The system that we investigated is a three-step process (see Figure 1). The first step is the biogas digestion of the PM blends - producing biomethane gas plus the remaining digestates (semi-solid and aqueous). Using the semi-solid digestates as crop fertilizer is the second step. The third step is algae production using the aqueous digestates as supplemental feed.

Using PM blends with C/N ratio 26 and 30 as initial input resulted in an excellent tri-part yield of biomethane, fertilizer, and algae. The highest biomethane yield occurred when PM blends were diluted to a 1:1.5 ratio and pre-treated. The greatest algae yield occurred with C/N 26 and 30, using a two-stage supplemental feeding strategy. PM blends with C/N 26 and 30 were well-digested (their digestates were rich in nutrients), and produced satisfactory biofertilizer.

Keywords: poultry manure, biomethane, digester, biogas, biofertilizer, Chlorella vulgaris, algae production, biodiesel

1. Introduction

There is currently a world-wide need to improve the way we handle wastes and to produce energy in a sustainable fashion. Taking the waste product of one process and using it as input or fuel for another process is one way to accomplish this; it makes intelligent use of resources, decreases pollution, and increases yields. Our study demonstrates the feasibility of this approach, using wastes that are combined together into appropriate blends.

For this study, we used an initial blend of wastes: poultry manure (PM), paper, and algae sludge, in a three-step process producing biomethane, biofertilizer, and algae for biofuel. We measured the results under varying conditions.

1.1 Biomethane Production Variables

Two important factors influencing biomethane production are the C/N (carbon/nitrogen) ratio of the digester substrates and pre-treatments of the substrates.

The workable range for biomethane generation is generally known to be C/N 20/1 and 30/1 (Gene and William 1986).

External pre-treatments of the digester substrate have been shown to enhance biomethane yield (Nallathambi Gunaseelan 1995). Appropriate pre-treatments suppress inhibitory substances such as volatile fatty acids and NH3, thus enhancing biomethane production (Vedrenne, Be´line et al. 2008).

1.2 PM, Paper and Algae Waste as Biomethane Producers

Several studies reveal that nitrogen-rich poultry manure (PM), when co-digested with a high-carbon source like paper pulp, can perform well in a biogas digester - producing a considerable volume of methane (S.P. Cummings 1995; Fox and Noike 2004; Abouelenien, Nakashimada et al. 2009).

Blends of paper pulp waste and algae sludge are also reported to emit considerable biomethane (Yen and Brune 2007) when co-digested.

1.3 PM Digestates as Crop Fertilizer

After the biomethane gas is collected from the digester for utilization, the semi-solid portion of the "left over" digestates can be used as biofertilizer to improve food crop production (Abdel Magid, Abdel-Aal et al. 1995; Kaikake, Sekito et al. 2009).

A PM blend is an attractive choice for input to a biogas digester because it is rich in much-needed nutrients (nitrogen, phosphorus, etc.). Since these nutrients are mostly in organic form, they need to be broken down (via biodigestion or other means) before crops can to utilize them sufficiently.

PM has an abundance of biological nutrients (Amanullah 2007) and minerals (Nicholson, Chambers et al. 1996), and has been traditionally used as a fertilizer. Other wastes similar in nature, such as municipal organic waste (Julia Martínez-Blanco 2009) and human exreta (Heinonen-Tanski and van Wijk-Sijbesma 2005), have shown promising results as crop fertilizer. Therefore it makes sense that PM digestate (created as a by-product of PM biodigestion) is also a good candidate for fertilizer.

1.4 PM Digestates to Enhance Algae Production

Just as we can use the semi-solid portion of the digestates to fertilize soils and improve crop yield, we can use the aqueous portion of the digestates in algae production to fertilize the media culture and improve yield.

Knowing that PM is high in nitrogen and phosphorus content (Nicholson, Chambers et al. 1996), we studied the use of PM blend digestates in the described sustainable system to produce Chloerella Vulgaris algae

We investigated the following strategies of supplementary feedings of PM digestates: no supplementation, single-stage supplementation, and two-stage supplementation.

The alga Chloerella Vulgaris was chosen because it is known for high lipid content and rapid growth (Xu, Miao et al. 2006; Chisti 2007; Bastianoni, Coppola et al. 2008; Wu 2008; Widjaja, Chien et al. 2009).

1.5 The Need for Nitrogen in Algae Production

Large amounts of nitrogen are needed for algae production for biofuel; a ton of algal biomass could require 45 Kg of nitrogen, based on an algae composition of $CO_{0.48}H_{1.83}N_{0.11}P_{0.01}$ (Grobbelaar 2004).

Furthermore, an algal biomass production limit of 263 tons per hectare per year in a bioreactor would require more than 11 tons of nitrogen per year (Chisti 2007). Therefore utilizing a source of "free" supplementary nitrogen - such as PM digestate - is attractive idea.

1.6 Manure Waste in Biodiesel Production

Sewage sludge (similar in nature to our PM blends) was used to increase lipid content in Limpomyces starkeyi for biodiesel production (Angerbauer, Siebenhofer et al. 2008). Therefore, the same effect is likely with digestates from anaerobic digestion on microalga Chlorella vulgaris cultivation.