Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 105 (2017) 62 – 67

Energy Procedia

The 8th International Conference on Applied Energy – ICAE2016

The Effect of Feeding Frequency and Organic Loading Rate on the Anaerobic Digestion of Chinese Rice Straw

A. M. Zealand[a], A. P. Roskilly[b] and D. W. Graham[a]

a School of Civil Engineering and Geosciences, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK
b Sir Joseph Swan Centre for Energy Research, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK

Abstract

China produces over 200 tonnes of rice straw (RS) a year. This is an underutilized energy source that is often burned in the fields causing pollution and health problems for populations near and far. Anaerobic digestion (AD) can produce methane (CH_4) rich biogas (45-55%) from waste RS as an alternative to burning whilst being affordable.

Five 2L reactors were used to test the effect of feeding frequency (FF) and organic loading rates (OLR) on the anaerobic digestion of rice straw with input rates of between 5 feeds per week and one feed every 3 weeks. Two OLRs were used: 1gVS/L/d (OLR1) for 56 days and 2gVS/L/d (OLR2) for 83 days.

At the lower OLR1, the best average biogas yield was 300ml/L of reactor/d at 50% CH_4 and at OLR2 the best reactor achieved a mean biogas yield of 447ml/L/d at 52%CH_4. The best performing FF at OLR1 was 1/21 day whilst at OLR2 the 5/7 day FF produced the highest volume and quality of biogas.

Results confirm that biogas from rice straw anaerobic digestion could be used with combined heat and power (CHP) technology to potentially produce 0.5-0.8MWh of electricity per day per tonne of rice straw.

Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.

Keywords: Rice Straw; Anaerobic Digestion; Frequency; OLR; China

Nomenclature

AD	Anaerobic Digestion	OLR	Organic Loading Rate (1gVS or 2gVS)
CHP	Combined Heat and Power	RS	Rice Straw
FF	Feeding Frequency	TS (VS)	Total Solids (Volatile Solids)
GHG	Greenhouse Gas	VFA	Volatile Fatty Acids

Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.
doi:10.1016/j.egypro.2017.03.280

1. Introduction

China is the world leader in rice production with ~195million tonnes with an average of 6.5 tonnes of rice hectare in China (closely followed by India with ~148million tonnes)[1]. Around 680 million tonnes of rice were produced in 2009, equating to around 920million tonnes of rice straw (RS) [2].

RS is a fibrous, lignocellulosic biomass with high volatile solids and low bulking density [2, 11] and represents around 62% of total crop residues in China. It tends to be produced in large quantities but as a crop is subject to growth and harvest cycles. It was traditionally used for foodstuff but as mechanization increased it is often burned *in situ*, taken for domestic fuel, or used as fertilizer [3, 4]. Open burning represents 13,359 tonnes of methane (CH_4) and 800 tonnes of nitrous oxide (N_2O) released to the atmosphere each year from India alone [5]. The exposure to soot and smoke causes respiratory issues amongst farmers and local people [6]. Incorporation of RS into the soil is difficult, due the relatively short time between harvest and seed, but can improve crop yield [4]. However, as RS decomposes in anoxic conditions the resultant CH_4 makes up 10-15% of world CH_4 emissions [2, 7, 8]. Developments in emissions targets and the energy value of waste products have increased the interest in harnessing energy from RS [9, 10]. Using RS in an anaerobic digestion (AD) system could be advantageous compared with other bioenergy crops as it does not divert land use from crop production.

Although RS is abundant and has high carbon, the process of digesting the complex lignocellulose structure – the world's most abundant biomass – is extremely difficult [12]. The recalcitrance of RS results in a lower CH_4 potential than other agricultural and bioenergy biomass i.e. CH_4 yield: RS 193-240L/kgTS compared with Rape: 300-350L/kg TS [13, 14]. AD of RS is not an optimized process and pre-treatments are often used to improve its biodegradability [15-17]. This causes a large input of RS to the waste cycle and conventional AD feeding frequency options (little and often) is difficult without a large storage capability. There have been few studies into the effect of extended starvation periods and bouts of plentiful feeding regimes of AD systems. The studies often focus on a narrow time margin such as Bombardiere, Espinosa-Solares [18] at 1-12 feeds/day. There are more studies focused on the OLR an AD system can tolerate but none using just RS as a substrate unless co-digested with something else, for example: RS and pig manure at 3-12kgVS/m^3d [19]. Infrequent FF inputs of RS into an AD system with increasing OLR was investigated for these reasons.

2. Methods

RS was obtained from China (Xiamen University) but no information regarding variety, harvesting or drying techniques was provided. The RS was provided as uncut lengths of straw that were homogenized to the desired size of 425µm. The anaerobic sludge inoculum was stock from within Newcastle University Environmental Engineering department and was acclimatized to RS in the reactors for two HRTs (100 days). The chemical characteristics of the RS and inoculum used are presented in Table 1.

Table 1 RS and inoculum characteristics

Parameter	Unit	RS	Inoculum
TS	%DW	96.1	2.3
VS	%DW	87.3	71.2
Moisture Content	%DW	3.8	97.7
Ash	%DW	12.3	28.8
C	%DW	40.1	54.6
N	%DW	0.66	4.72
C:N	Ratio	60.4	11.6