Original Research Article

An experimental case study on generation of Bio-energy as clean technology initiative in a Food Industry

Abstract

India is a country with huge potential for Biomass Energy (BE) generation numerically estimated as 20GW. The country is making some serious efforts in terms of both scientific interventions and fiscal incentives to economically attract more projects of BE for its renewable properties. Ministry is encouraging clean technologies (CT) to get adopted by revenue generating organizations through provisions of Emission Reduction Certificates, Carbon Credits or giving preferential tariffs. These initiatives have been welcomed by industries as they often have large amount of bio-degradable waste to send for treatment facilities. Anaerobic Digestion (AD) process has got much attention in industrial waste treatment ventures in this framework. Together with Pyrolysis, AD can be used for efficient BE generation. The biochemical breakdown process of waste releases biogas that can be utilized in electricity and steam generation and simultaneously landfill expenses can be avoided. Present study is based on an experiment of converting potato peels of a food industry to generate biogas. Standard AD process is utilized with a suitably selected pre-treatment mechanism to increase the energy efficiency of the entire industrial set-up. This venture is one the many CT initiatives taken by the industry for achieving sustainability goals of the Environment, Health and Safety division. The process is estimated to produce 16L/Kg methane with potential for energy off-set of 3000 Kcal. Further a SWOT analysis has been carried out to critically analyze the suitability of the experiment as per industrial scale.

Keywords: Anaerobic digestion, Biomass Energy, Carbon Credit, Energy Efficiency

Introduction

Biomass and agricultural waste represent a large potential renewable energy source, which could benefit with a clean fuel in the form of methane (Parawira et al., 2004) by anaerobic digestion. Anaerobic Digestion is a multi-step biological process where the organic matter is mainly converted to biogas by microorganisms (Angelidaki et al., 2003) (Figure 1). This process provides

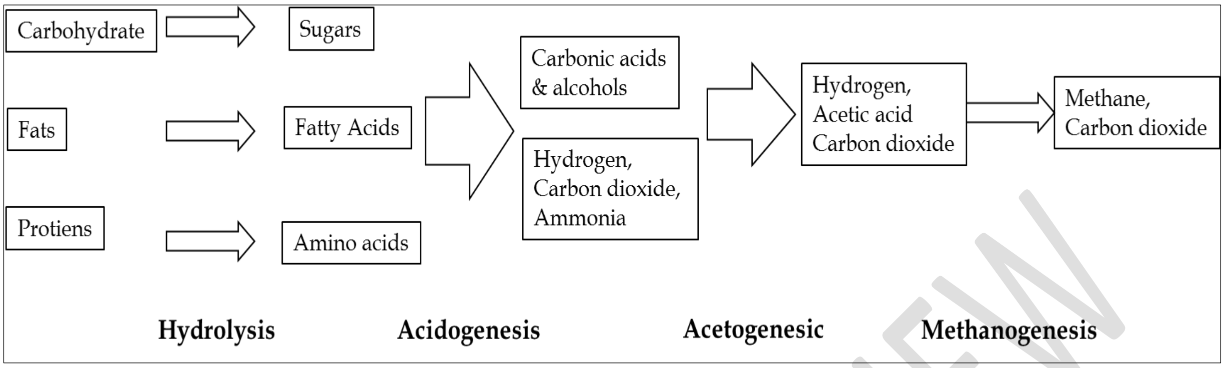

Figure 1: Stages of anaerobic digestion (Santos, 2011).

an excellent opportunity to manage solid waste at raw material extraction stage of the Life Cycle process of the industrial production unit (LCA Note). The Methane gas that is generated in this Bio-methanation process is further utilized for electricity production. This account of electricity may offset the electricity requirement of the industry which adds to the sustainability ventures of the industry. The area marked with Green line in Figure 2 shows the positional stage of this process in the industrial process of Life Cycle Analysis. This present experimental study beholds a position that maintains a cycle of waste to energy conversion in the entire procedure of Cradle-to-Gate-Grave sequence of manufacturing process in the food industry. This Bio-Methanation process is thus boosting the clean technology initiatives undertaken by the industry.

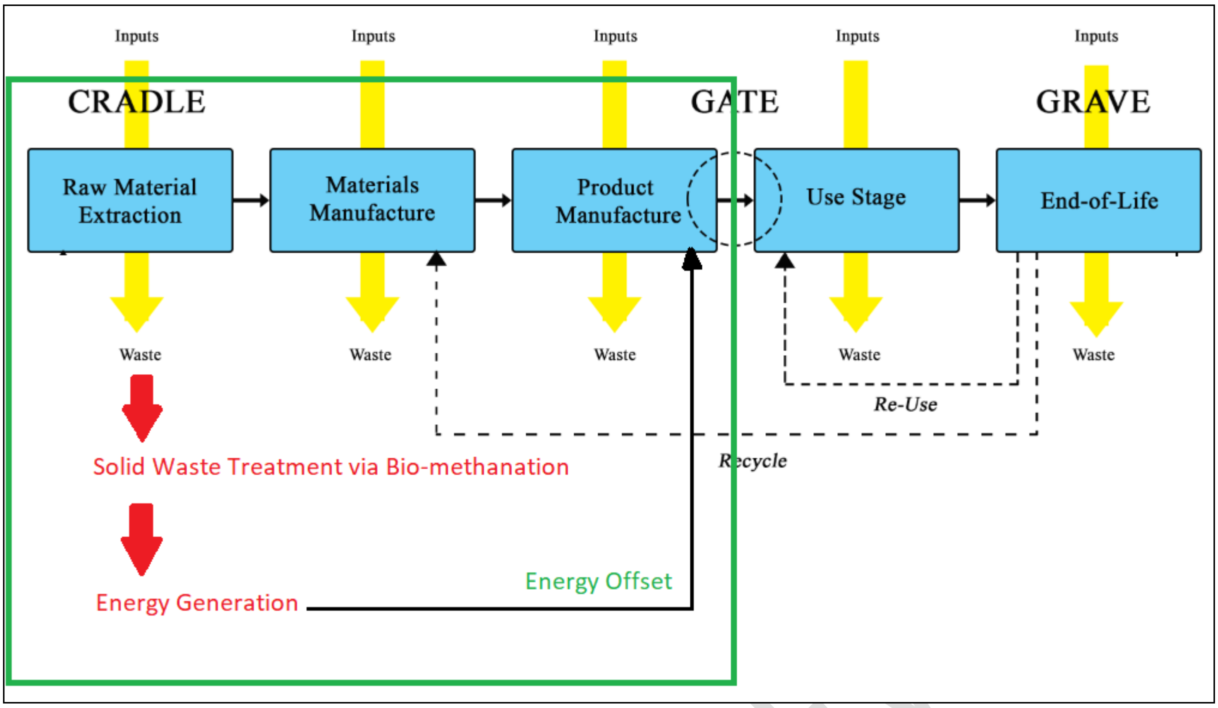

Figure 2. Bio-Methanation as a part of Industrial Material Life Cycle

Potato peel waste is a zero value by-product, which occurs in big amounts after industrial potato processing and can range from 15 to 40% of initial product mass, depending on the peeling method and other defect removal, trimming and cutting processes can generate an additional 15% waste (Mader et al., 2009). This waste could be managed by anaerobic digestion. But it is difficult to degrade potato peelings due to lignin content. Lignocellulosic materials consist mainly of three polymers: cellulose, hemicellulose and lignin (Hendriks, 2009). Lignin, a three-dimensional polymer made up of phenyl propane units, has also been detected in the plant cell wall (Bunzel et al., 2011). Lignocellulosic feed stocks require pre-treatment techniques to yield a substrate easily hydrolyzed enzyme producing microorganisms, to release sugars. (Agbor et al., 2011).

Pre-treatment of substrates can increase biogas production and volatile solids and solubilisation of substrates which make it more accessible to enzymes (Tanaka et al., 1997). A various process of different pre-treatment technologies have been suggested during the last decades. They can be classified into biological, physical, chemical and physico-chemical pre-treatments (Alvira et al., 2010). Therefore, pre-treatment severity conditions are used to maximize sugar recovery. The present study is to investigate biogas production ability of potato peelings by pre-treatment with alkali.

Materials and Methods

I. Detailed Procedure

The procedure for the digestion of potato peels is shown in the flowchart in figure 3 below. The potato peels were collected from the screen and grinded to fine mesh for proper digestion. Then the peels were subjected to alkali (8% NaOH) pre-treatment. It is soaked for 2 hours in this condition for proper breakdown of lignocellulosic materials. After that it is washed, and the pH was ensured within 6.5-7.5. The peels and the sludge are mixed in 2:1 ratio (sludge: peels) and put into the digester (only when the digester is running, or else cow dung should be added as an inoculum). After 15 to 20 days biogas will be produced and will be used for energy production in the form of electricity.

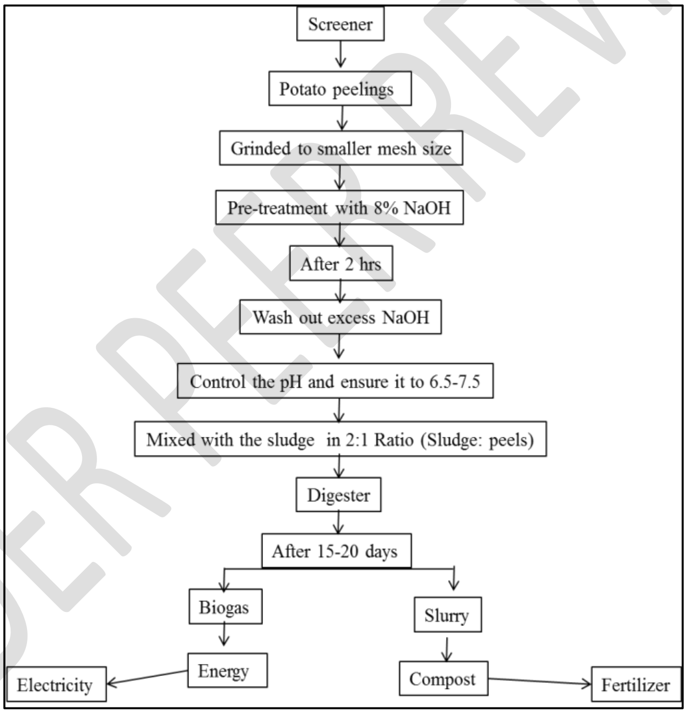

Figure 3: Procedure for anaerobic digestion of potato peels

II. Raw Materials:

Raw potato peels have high moisture and carbohydrate contents, but overall protein and lipid contents are generally low (Table 1). High content of starch (52 g 100 g-1of dry weight) makes it a good basis for fermentation (Potatoes, raw, skin, s.a.; Arapoglou et al., 2009). In addition, potato peels (PP) contain a variety of valuable compounds, including phenols, dietary fibres, unsaturated fatty acids, amides, etc. (Schieber and Saldaña, 2009; Wu et al., 2012). The chemical composition of raw potato peel per 100 gm is given in the following table (Table 1)

Table 1. Chemical composition of raw potato peel, g 100 g-1 (Pathak et al, 2017)

Compound	Minimum and maximum values	Average content
Water	83.3-85.1	84.2
Protein	1.2-2.3	1.8
Total lipids	0.1-0.4	0.3
Total carbohydrate	8.7-12.4	10.6
Starch	7.8	
Total dietary fibre	2.5	
Ash	0.9-1.6	1.3

III. Experimental Set-up:

The experiment set up was made were different proportion of alkali as shown in figure 4 was treated to observe the best result. After confirming to a successful energy generation, the highest

Figure 4: Digester setup

amount biogas yielding process is taken into consideration in the concerned food industry to offset the daily requirements of energy resources.

Result and Discussion

The experiment come out with the suggestion that the digester which is pre-treated with 8% NaOH has the highest rate of biogas production as compared to others as shown in figure 5.

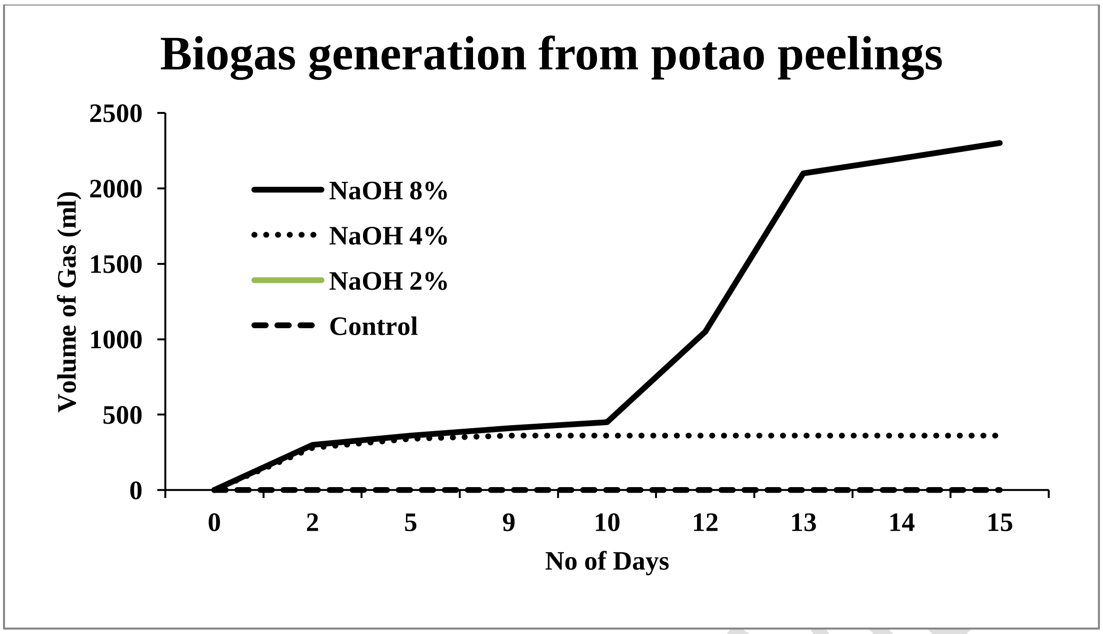

Figure 5. Gas generation of potato peelings

The gas production rate was 40 lts/ Kg of biomass on 15 days of anaerobic digestion. The methane content was found to 59% which is good for energy production because minimum methane should be 40% for energy production (Santos, 2011). Thus the bio-energy produced in the process offsets the energy requirements of the factory up to 5-7%. The evaluation of the offset energy calculation is shown below:

Evaluation of Energy Offset:

Biogas – 40 l/kg peels

Methane taking 40% per liter = 16 l/kg

The energy equivalent of $1m^3$ of biogas with 40% methane is equal to 3000 kcal.

Therefore 40 liter/kg of biogas with 40% methane= 120 kcal.

The results suggest that successful digester operation can be achieved with feed containing potato material that under similar feed VS (volatile solid), loading rate, pre-treatment, retention time and feed VS ratio, the methane yields, and process performance would be similar to that of its industrial residues. Thus, co-digestion of potatoes and/or its industrial by-products with manures on a farm-scale level would generate renewable energy and provide a means of waste treatment for industry. This contributes to the solid waste management for the industry and adds a feather towards attaining successful sustainability initiatives in the industry.

SWOT Analysis

Every system has some pros and cons in its execution and applications. A SWOT analysis is performed to find out both positive and negative outcomes of the process of bio-energy generation. It has been analyzed in four perspectives *viz.* Strength, Weakness, Opportunities and Threats. This process helps to understand the lacuna and potential of the process conveniently and thus also encourages for the issues to be resolved in expedite manner. The analysis is given in Table 2. It may be advised that present experimental approach is favorable for significant waste to energy conversion with some precautions at industrial safety level. Further research is necessary to increase the yield of Methane gas and electricity generation procedure to reduce industrial caron foot-print on a higher extent.

Table 2 Critical analysis of the Bio-methanation Process by SWOT method.

SWOT Analysis	
STRENGTH 1. Biogas generation by simple experimental set up 2. Maximum utilization of industrial raw material	**WEAKNESS** 1. Time consuming process 2. The mass ratio of Potato peel to produced methane is low
Opportunities 1. Offsetting energy requirement 2. Contribution to reduction of carbon foot-print 3. Efficient re-use of industrial waste	**Threats** 1. Possibilities of accidental flushing of Caustic Soda during pre-treatment 2. Leakage or emission of methane during storage 3. Possibilities of soil contamination due to spillage.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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