



An Experimental Case Study on Generation of Bio-Energy as Clean Technology Initiative in a Food Industry

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJOPACS/2022/v10i130150

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/85288>

Received 22 January 2022

Accepted 01 April 2022

Published 09 April 2022

Original Research Article

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 renewability properties. Ministry of New and Renewable Energy (MNRE) Government of India is encouraging clean technologies (CT) to get adopted by revenue generating organizations through provisions of certificates for emission reduction, 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 to treatment facilities. Anaerobic Digestion (AD) process has got much attention in industrial waste treatment ventures in this framework. Bio-chemical breakdown process of waste releases biogas

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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 make the process of BE generation more efficient according to the scale of industrial dimensions. This venture is one of the many CT initiatives taken by the industry for achieving sustainability goals of the EHS (Environment-Health-Safety) division. The process is estimated to produce 16 lt methane gas per 1 kg of potato peel waste. This process of generation of BE is capable to off-set of 3000 Kcal amount of energy required for industrial operation. 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.

1. INTRODUCTION

Biomass and agricultural waste represent a large potential renewable energy source. This may bring lot of benefit in terms of clean fuel generation. Bio-methanation is a remarkable process in the field of bio-technology that utilizes Anaerobic Digestion (AD) [1]. AD is a multi-step biological process where the organic matter is mainly converted to biogas by microorganisms [2] (Fig. 1). This process provides an excellent opportunity to manage solid waste at raw material extraction stage of the Life-Cycle process of the industrial production unit (LCA Note [4]). 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 Fig. 2 shows the positional stage of this process in the industrial process of Life-Cycle Analysis (LCA). This present experimental study beholds a position that maintains a effective process of waste to energy conversion in the entire procedure of Cradle-to-Gate-to-Grave sequence of manufacturing process in the food industry. This bio-methanation process is thus boosting the clean technology initiatives undertaken by the industry.

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 [5]. 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 [6]. Lignin, a three-dimensional polymer made up of phenyl propane units, has also been detected in the plant cell wall [7]. Lignocellulosic feed stocks require pre-treatment techniques to yield a substrate easily hydrolyzed enzyme producing microorganisms, to release sugars [8].

Pre-treatment of substrates can increase biogas production and volatile solids and solubilisation of substrates which make it more accessible to enzymes [9]. Various processes 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 [10]. 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.

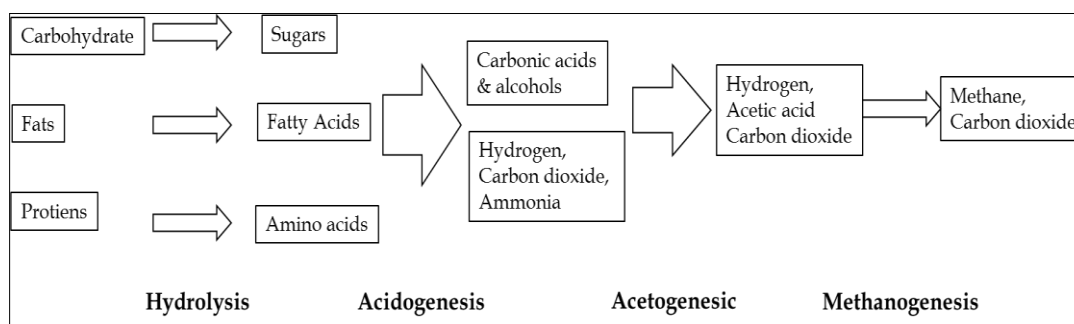


Fig. 1. Stages of anaerobic digestion [3]

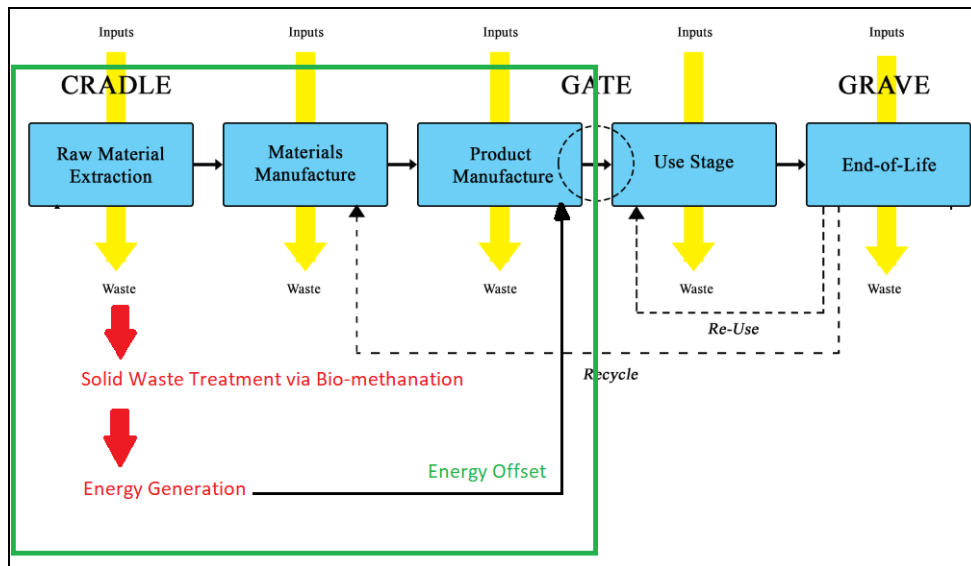


Fig. 2. Bio-Methanation as a part of Industrial Material Life Cycle

2. MATERIALS AND METHODS

2.1 Detailed Procedure

The procedure for the digestion of potato peels is shown in the flowchart in Fig. 3. 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.

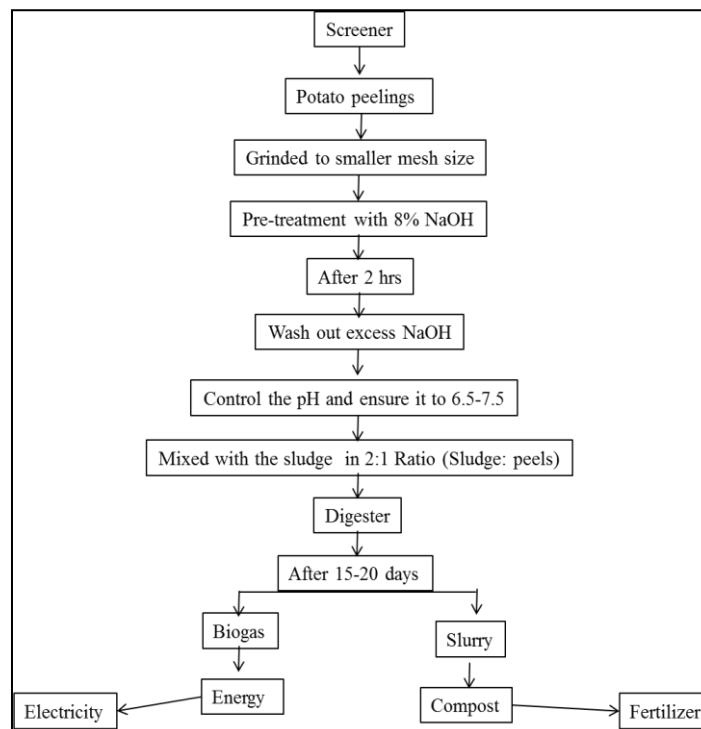


Fig. 3. Procedure for anaerobic digestion of potato peels

2.2 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⁻¹ of dry weight) makes it a good basis for fermentation (Potatoes, raw, skin, s.a.; Arapoglou et al. [11]). In addition, potato peels (PP) contain a variety of valuable compounds, including phenols, dietary fibres, unsaturated fatty acids, amides, etc. [12,13]. The chemical composition of raw potato peel per 100 gm is given in the following table (Table 1).

2.3 Experimental Set-up

The experiment set up was made for different proportion of alkali as shown in Fig. 4 was treated to observe the best result. After confirming to a successful energy generation, the highest amount biogas yielding process is taken

into consideration in the concerned food industry to offset the daily requirements of energy resources. The results of these experimental set up was moved up to industrial scale and the processes of pre-treatment with alkali followed by AD is performed. Fig. 5 shows the images of the industrial set up.

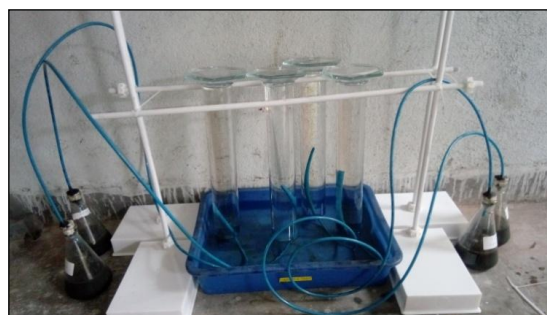


Fig. 4. Experimental setup for digester

Table 1. Chemical composition of raw potato peel, g 100 g⁻¹ [14]

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



Fig. 5. Industrial set-up for bio-methanation (a) Pre-treatment with Up-flow Anaerobic Sludge Blanketing reactor (UASBR), (b) Gas holding tank, (c) Collector, (d) Methane to Electricity generator

3. RESULTS 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 Fig. 6.

The gas production rate was 40 lt/ Kg of biomass (potato peel) on 15 days of anaerobic digestion in the industrial set-up. The methane content was found to 59% which is good for energy production because minimum methane should be 40% for energy production [3]. Thus the bio-fuel produced in the process is utilized to fulfill energy requirement of the industry. This offset in the energy usage of the factory is evaluated to be up to 5-7%. The evaluation of the offset energy calculation is shown below:

Evaluation of Energy Offset:

Biogas – 40 lt/kg peels

Methane taking 40% per liter = 16 lt/kg

The energy equivalent of 1m³ of biogas with 40% methane is equal to 3000 kcal.

Therefore 40 lt/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 helps to attain successful sustainability initiatives in the industry.

3.1 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.

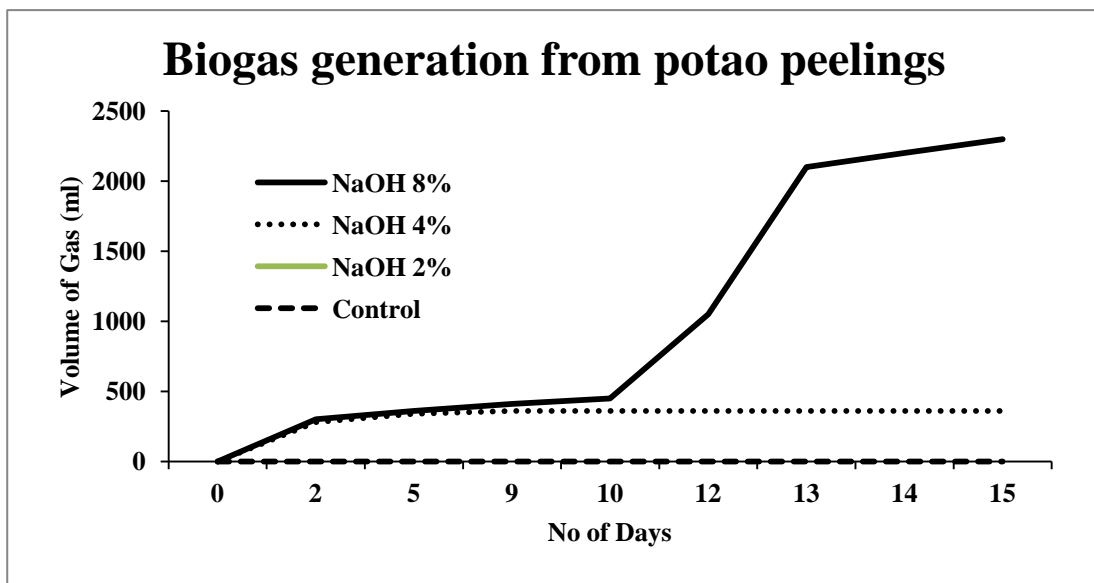


Fig. 6. Gas generation of potato peelings

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

SWOT Analysis	
<p>Strength:</p> <ol style="list-style-type: none"> 1. Biogas generation by simple experimental set up 2. Maximum utilization of industrial raw material 	<p>Weakness:</p> <ol style="list-style-type: none"> 1. Time consuming process 2. The mass ratio of Potato peel to produced methane is low
<p>Opportunities:</p> <ol style="list-style-type: none"> 1. Offsetting energy requirement 2. Contribution to reduction of carbon foot-print 3. Efficient re-use of industrial waste 	<p>Threats:</p> <ol style="list-style-type: none"> 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.

4. CONCLUSION

In October 2007, the United Nations declared 2008 as The Year of the Potato, highlighting the importance of this crop as a staple food in human nutrition. While fresh potato consumption is decreasing in many countries, more potatoes are currently processed into value-added products to meet the demand especially from the fast food and convenience food industries. This process could utilize the natural resource to fulfill our modern days' energy requirements.

This paper addresses the problem of the biochemical degradation of lignin present in potato peels which takes significant time. This experiment tries to give a solution in the form of pre-treatment with alkali to the waste that accelerates the process of degradation. It is observed that the yield of methane significantly increases from the 10th day of starting the pre-treatment with 8% NaOH. This experiment was further repeated with industrial dimensions and successfully used for BE generation. Reduction in electricity consumption and conversion of waste to energy are two main agenda to achieve good environmental performance for any industry. That is why this research is important and contemporary to the present needs of environmental management. The SWOT analysis performed here provides a critical insight to encourage such measures and simultaneously guides through the precautions to be taken for safe operations. Further research may be performed in this direction to replicate the process for other raw materials used in food industries.

DISCLAIMER

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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