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Cost effective pretreatment of Cassava peels for enhanced Biogas production

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***Abstract**: Cassava is one of the major root crop of the humid tropics, its peel constitutes about 20 to 35 % of the dry weight. The peel being a lignocellulosic material acts as a potential candidate for Biogas production after various pretreatments. At the same time, the peel being waste does not compete with food security. However, it is rich in cyanogenic glycosides- linamarin and lotaustralin which inhibits methanogenesis. In the case of physical pretreatment, the particle size reduction to make the substrate more accessible to the bacterial consortia and the addition of activated carbon in order to increase the surface area for the bacteria to adhere and secrete extracellular enzymes tremendously increased the cumulative Biogas production. This pretreatment made the process 94.15 % more efficient than the control. Alkaline pretreatment using sodium hydroxide in order to reduce the lignin content and to make the cellulose more accessible to the bacteria increased Biogas production by 11 % compared to the control. P. florida is a fungus which produces lignase and cellulase in order to derive nutrition for itself from the substrate. In this study, we have used the lignase producing ability of the fungus in order to expose cellulose in cassava peel. Pretreating peel with P florida made the process 3.8 % more efficient compared to the control.*
***Key words**: Cassava peel, anaerobic digestion, Biogas, Pretreatment, Delignification.*

I. Introduction

Energy is one of the most crucial factors for the development of any Nation. The dependence on fossil fuels as primary energy source has led to global climate change, environmental degradation, and human health problems. 80% of the world's energy consumption still originates from fossil fuels [4].Bio-energy (energy produced from biomass) can be seen as one of the key options. Among the many bio-energy related processes being developed, those processes involving microorganisms are especially promising, as they have the potential to produce renewable energy on a large scale, without disrupting the environment or human activities [14].

With the aid of technology, one can gain an access to efficient utilization of agro Industrial products aimed at obtaining value added products like Biofuels, Biochemicals and Biomaterials. Bioprocessing of Agro Industrial residues can help solve environmental problems associated with the disposal of these materials. Methane production from the crop residues could be an interesting option for disposing these materials and also for increasing the domestic biofuel production [2]. Biogas technology in which biogas derived through anaerobic digestion of biomass such as agricultural waste, municipal and industrial waste is one of such alternative way that the world should adopt to minimize its energy and environmental problems [5]. Biogas production is a complex biochemical process that takes place in the absence of oxygen and in the presence of highly sensitive micro organisms that are mainly bacteria [7-9].

Cassava is one of the major root crops produced in the World with an annual global production of approximately 252 million tons [6]. It is a cheap source of carbohydrates for the human populations in the humid tropics [13]. In the processing of cassava, the roots are normally peeled to rid them of two outer coverings i.e., the outer covering and a thick leathery paranchymatous inner covering. The peels constitute about 20-35 % of the weight of tuber, especially in the case of hand peeling [11].

Cassava peel is a lignocellulosic material and due to this reason, it can act as an alternative substrate for Biofuel production. To achieve this maximally, cassava peel has to be pretreated so as to remove lignin and hemicelluloses, reduce cellulose crystallinity and increase the porosity of lignocellulosic material [3]. Moreover, it contains linamarin and lotaustralin which are cyanogenic glycosides. Peel is 1 to 4 mm thick and may account up to 10-12% of the total dry matter of the root [10]. Generally, these Peels are regarded as waste and are usually discarded and allowed to rot, this leads to pollution and environmental hazards. In contrast, these peels can act as raw materials for manufacturing useful products of higher value like Biogas or may be used as food or feed after biological pretreatment without competing with the food security [1].

Production of methane-rich Biogas through anaerobic digestion of cassava peels provides a versatile way of producing renewable energy, as methane can be used in replacement for fossil fuels in both heat and power generation and as a vehicle fuel, thus contributing to cutting down the emissions of greenhouse gases and slowing down the climate change. Methane production through anaerobic digestion has been evaluated as one of the most energy-efficient and environmentally benign ways of producing vehicle Biofuel [12].

II. Materials and Methods

Materials used: Freshly collected Cassava peel, Pleurotus florida spawn, Activated carbon, 1 L conical flasks, one holed and two holed rubber stoppers, rubber tubings, water bath with temperature control, fresh cow dung as inoculum, autoclave, Blender, mortar and pestle , 250 ml glass beakers, 500 ml glass measuring cylinders.

Methods: 2.1 Production of biogas using physically pretreated cassava peel- In order to demonstrate the effect of increased surface area , fresh cassava peel was taken and washed three times with tap water and allowed to drain for about 30 minutes. The resulting material was subjected to size reduction to about 2 to 3 mm using a blender for 1 minute. Cassava peel is rich in terms of its carbon content and thus stands as a potential candidate for Biogas production. However, as it contains cyanogenic glycosides- linamarin and lotaustralin , most of the bacteria are intolerant to it. Drying Cassava peel in sun potentially reduces the cyanide content of the peel [8]. Hence, 100.0 grams of the resulting material was layered uniformly on a plastic tray and exposed to sun drying for a period of 12 hours (from 10 am to 4pm) for two consecutive days. The dried material was then reduced to a fine powder using a mortar and pestle. 6.0 grams of this dried fine powder, which is equivalent to 30.0 grams of wet cassava peel was taken and blended thoroughly with 600 ml of water and 30.0 grams of freshly collected cow dung, which was used as the inoculum. The entire slurry was poured into a 1 L conical flask and closed with one holed rubber stopper and the flask was placed in a water bath filled with water with a constant temperature of 35^{o} C. The initial pH of the slurry in all the cases was recorded as 7.5. In order to ensure mechanical stability, especially as the water level in the water bath were higher than the level in the flask, it was attached to a rugged clamp and the supporting strand. The fermentation gases (biogas) were quantitated using water displacement system. In the Water displacement method for quantitation of biogas, the fermentation gases evolved as a part of the biochemical process (Methanogenesis) are conveyed through a rubber tubing to an inverted 1 liter conical flask closed with 2 holed rubber stoppers. The gas gets collected at the top of the inverted conical flask, which displaces an equal quantity of water through rubber tubings to a measuring jar. The amount of water displaced in 24 hours can be used for all further calculations. In a yet another setup, to the resulting slurry, 6.0 grams of activated carbon (1% w/v) was added in order to increase the surface area and to quench the remaining cyanide in the cassava peel. The entire slurry was poured into a 1 L conical flask and closed with one holed rubber stopper and the fermentation gases (Biogas) that evolved during anaerobic digestion were quantitated using water displacement method for a period of 10 days.

A similar setup was made using 30.0 grams of dried and powdered cassava peel (app. 1 cm^2 pieces) blended with 600 ml of water and 30.0 grams of freshly collected cow dung. This setup served as the control.

2.2 Production of biogas using chemically pretreated cassava peel- Fresh cassava peel was taken and washed three times with tap water and allowed to drain for about 30 minutes. The resulting material was subjected to size reduction to about 2 to 3 mm using a blender for 1 minute. 30.0 grams of this material was suspended in 100 ml of 0.1 % sodium hydroxide solution for a period of 24 hours. The delignified material was washed several times with running water till the pH became 7. This material was then subjected to sun drying for 12 hours, the resulting material weighing 5.4 grams was made to a fine powder by using a mortar and pestle. This powder was blended with 600 ml of water and 30.0 grams of freshly collected cow dung (inoculum) and the resulting slurry was subjected to Biomethanation.

The control setup was made using 6.0 grams of dried powder of cassava peel which is equivalent to 30.0 grams of wet cassava peel. This powder was blended with 600 ml of water and 30.0 grams of freshly collected cow dung (inoculum) and the resulting slurry was subjected to Biomethanation.

2.3 Production of biogas using Biologically pretreated cassava peel- Fresh cassava peel was taken and washed three times with tap water and allowed to drain for about 30 minutes. The peel was exposed to steam under pressure (15 psi , 121^{o} c) for 3 minutes. The substrate after steaming was cooled to room temperature and it was packed in black polythene (dimensions- 15x20 cm) bag, alternatively layered with Pleurotus florida spawn. 5 % w/w P florida spawn was used as the inoculum. After layering the P florida spawn over the substrate, the packet was closed and tied with a thread. Several pin holes were made uniformly all over the packet for aeration (80-100 holes). This packet was incubated in a dark room for fifteen days in order to facilitate the growth of P.florida mycelium on the substrate. After fifteenth day, the packet was opened and 30.0 grams of the material digested by the fungus was taken and exposed to sun drying for 12 hours (10 am to 4 pm) for two consecutive days and then was made into a fine powder using a mortar and pestel. The resulting material weighed 5.8 grams. This powder was blended with 600 ml of water and 30.0 grams of freshly collected cow dung (inoculum) and the resulting slurry was subjected to Biomethanation.

The control setup was made using 6.0 grams of dried powder of cassava peel which is equivalent to 30.0 grams of wet cassava peel. This powder was blended with 600 ml of water and 30.0 grams of freshly collected cow dung (inoculum) and the resulting slurry was subjected to Biomethanation.

III. Results and Discussion

3.1 Production of biogas using physically pretreated cassava peel- The increase in surface area makes the substrate more accessible to the bacterial consortia in the digester. A proportional increase was observed in biogas production with increased surface area. The control with app. 1 cm^2 dried cassava peel showed a cumulative Biogas production of 616 ml over a period of 10 days. The setup in which the peel was made into a fine powder to provide increased surface area, showed a cumulative Biogas production of 819 ml. While the setup with 1 % (w/v) activated carbon apart from fine cassava peel powder showed a cumulative Biogas production of 1196 ml, as activated carbon provides a very large surface area for the bacteria to adhere and secrete extracellular enzymes. Thus, the setup with 1 % (w/v) activated carbon gave the highest yield, which was 94.15 % more efficient than the control. (Shown in figure 1)

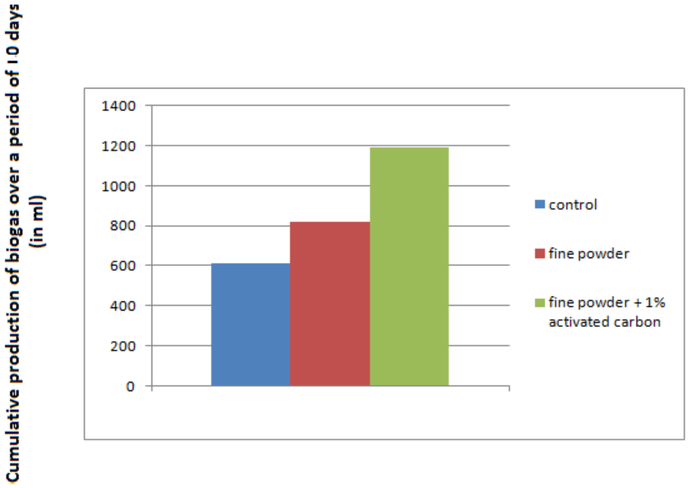

Figure 1- Effect of physical pretreatment

3.2 Production of biogas using chemically pretreated cassava peel- Cassava peel being a lignocellulosic material, the cellulose is not exposed to the bacteria because of the complex structure of lignin. Removal of lignin exposed the cellulose for the bacteria to act upon. Thus, in the setup with chemically pretreated cassava peel, an increase in cumulative Biogas production was seen. The control gave a cumulative Biogas production of 819 ml while the chemically pretreated peel showed a cumulative Biogas production of 909 ml, thus it was 11 % more efficient when compared to the control. (Shown in figure 2)

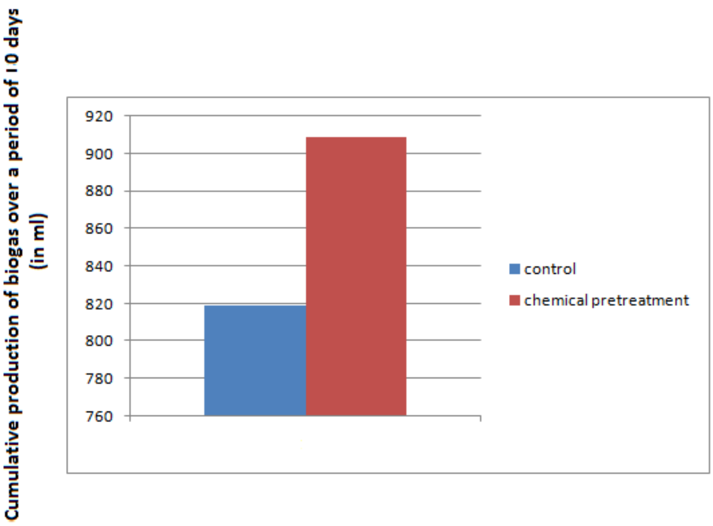

Figure 2- Effect of Chemical pretreatment

3.3 Production of biogas using Biologically pretreated cassava peel- Pleurotus florida produces lignase enzyme which can potentially degrade lignin in the cassava peel so as to expose the cellulose for anaerobic digestion in the digester. The setup with biologically pretreated cassava peel gave a cumulative yield of 850 ml .while, the control gave a cumulative yield of 819 ml. Thus, the setup with Biologically pretreated cassava peel was 3.8 % more efficient when compared to the control. (Shown in figure 3)

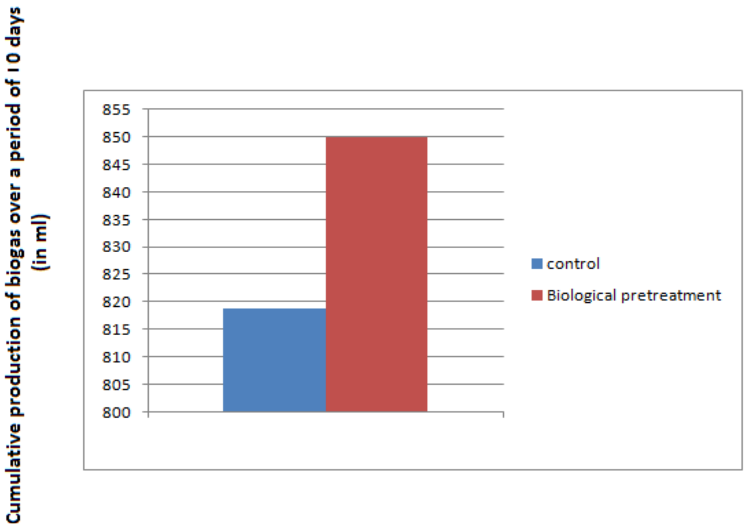

Figure 3- Effect of Biological pretreatment

Cassava peel is rich in its lignocellulosic content. However due to the presence of cyanogenic glycosides- linamarin and lotaustralin and due to its complex structure, various kinds of pretreatments are required to make the substrate more accessible to the bacterial consortia involved in the process of anaerobic digestion. From this data, it is evident that pretreatment definitely has an impact on Biogas production. Physical pretreatment was found to be most effective in terms of the cumulative production. It was found to be 94.15 % more efficient compared to the control. Whereas, Chemical and Biological pretreatments were found to be 11 % and 3.8 % more efficient respectively. The pretreatment methods used in our study are essentially cost effective, as Sun drying does not add much to the cost of production especially in a country like India. The other chemicals used in this study like sodium hydroxide and activated carbon too are not expensive and are readily available in bulk quantities at a cheap rate.

IV. Conclusion

This study reveals that, Cassava peel as such is not a good substrate for Biogas production without appropriate pretreatments. Addition of activated carbon increases the surface area for the bacteria to adhere and secrete extracellular enzymes and thus Biogas production also increased proportionally. Particle size reduction, delignification and action of enzymes by Pleurotus florida also had a profound effect on the accessibility of the substrate to the bacterial consortia during anaerobic digestion to produce Biogas.

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