Bioenergy: An Alternative Energy Source for the Banana Value Addition in District Khairpur Pakistan

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Abstract: Agroindustry plays a significant role in agricultural and industrial relationship, but it is badly affected by energy crisis. Case study taken in research work is about this problem. Bioenergy system resulted as potential alternative energy source that can fill the energy requirements of value addition of agricultural commodities. 2.42 cubic meter (2.5 kg) biogas produced from 102 kg concentrated slurry of banana waste/ biomass. The generated amount of biogas in batch digester biogas plant gives 97 minutes burning time which is sufficient for steaming and frying processes of banana value addition. Other processes such as drying, grinding, de-oiling and flavour mixing involved electricity which can be generated with large amount of biogas through flow thru/ continuous type biogas plants on daily basis. Experiment was conducted in Government established banana value addition facility which can process daily 04 bunches of bananas. The daily banana waste generated in the centre is utilized in this experiment.

Keywords: *Agroindustry, Anaerobic digestion, Post-harvest, Untapped biomass, Value Addition*

1. Introduction

Value addition is the process of increasing shelf life, economic value and consumer demand of agricultural commodities as well as decreasing post-harvest losses and wastages of untapped biomass and related environmental issues [22]. Case study taken in this research work is about the energy needs of banana value addition processing. Banana is an important fruit crop of Pakistan and mostly available throughout year. Bananas have a very short post-harvest life at normal conditions. About 30% of world banana production wastes every year due to post-harvest losses and diseases [1]. The annual production of banana in Pakistan was estimated 134,600 tons in 2015-16 [13]. Sindh province contributes 90 % of total banana production of country, where the soil and climatic conditions are favourable for its successful cultivation. In Sindh, 25% of banana is cultivated in District Khairpur with average annual production of 35,324 tons. It is the second largest fruit crop of District Khairpur after dates. [24]. Looking at importance of crop Pakistan Agriculture Research council has established three (03) Banana Value Addition Facility Centres in District Khairpur with the help of SAARC Development Fund; where various value-added banana products i.e. banana jam, banana pickle, banana squash, banana fig, banana chips and banana flour can be prepared. The purpose of establishing this kind of village-based agroindustry is to produce value added products from raw agriculture material for stabilizing market rates, generating employment, improving livelihood of relevant farming community and reducing post-harvest losses [23]. A local NGO is operating one of these banana value addition facilities for empowering village women to get respected income through value addition of agriculture commodities, but due to uncertain and unaffordable power supply, they cannot run the centre properly. In current energy crises of Pakistan, industries and common peoples are badly exaggerated by uncertain and expensive electricity and they are looking for alternative to offload the problems of; load shading and complexities of bill correction [13]. The solution lies in; energy alternatives and conservation.

2. Related Work

Previous studies haven't any specific work on this topic in Pakistan. But, in other SAARC and African countries, a significant development is found. India is a biggest country of the SAARC region and largest one in the world by banana production. An African country Uganda is the second largest producer of banana in the world where banana waste is used to get energy for banana value addition/ processing industry [7].

3. Methodology

Methodology contains four steps; In first step a medium size batch digester biogas plant was erected in the premises of BVAFC. In second step pre-treated feedstock was poured into digester, in third step operation of plant observed, then, temperature, pressure and gas production were observed after every 03 days. In fourth and final step total generated gas was calculated.

3.1. Erection of biogas plant

Plant was erected with 1 plastic water tank (digester), 2 plastic drums (primary & secondary gas collectors cum water scrubbers), 1 steel bottle (H_2S scrubber filled with iron sponge) and 1 gas holder (innertube; 8.25-16 of Mazda Truck). Digester cap stabbed with collar bush adopter and pipe nipple by which ¼' pvc pipe connects primary gas collector cum scrubber, where heavy carbons settled down and generated gas goes into iron sponge filled steel bottle to

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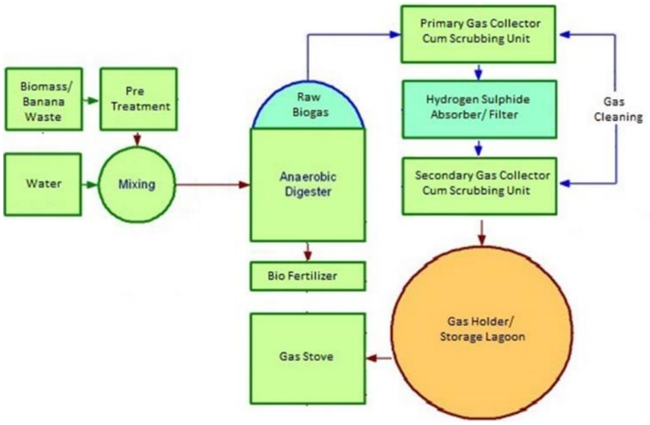
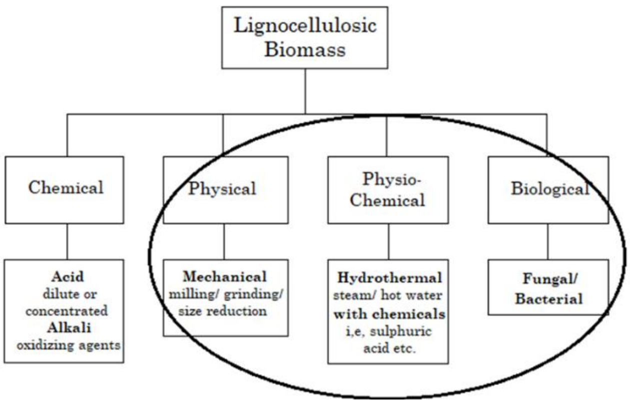
absorb hydrogen sulphide. Then gas comes into secondary gas collector cum scrubber (quarterly filled with water); where remaining carbons settled down again and bottoming water pressurizes gas toward gas holder (innertube). 1' pvc pipe connects the gas digester and primary gas collector cum scrubber to transfer the overflow of slurry. 2 safety valves were fitted to control the gas and overflow of slurry. Finally, gas goes to stoves. 10 psi pressure gauge was used to measure the developed pressure.



Schematic diagram of experimental set up

3.2. Pretreatment of feedstock

Mechanical, hydro-thermal and biological pre-treatments of biomass (banana waste) were applied before feeding digester. [19]



Four bunches of unripe bananas (16.5 kg, 14 kg, 15.5 kg & 18 kg) were purchased. After steaming and bananas were peeled; 23 kg banana pulp was extracted and remaining 41 kg banana waste was shredded in smaller size. After pretreatment, feedstock/ concentrated slurry was poured into digester and sealed.

3.3. Operation of biogas plant

Following parameters were maintained in the operation of biogas plant;

3.3.1. Temperature

Anaerobic digesters are best operated in mesophilic condition (30-40°C) [7]. Average temperature recorded during experiment was 33 C.

3.3.2. pH:

Optimum pH lies between 6.5 & 7.5 [26]. pH of slurry concentration made for digestion was checked with digital pH meter which was 6.7.

3.3.3. C:N ratio:

Usually a C:N ratio b/w 20–30 is considered to be optimal for anaerobic digestion. Sometimes high C:N ratio biomasses such as; sawdust, sisal waste and banana fruit peel may be limited by nitrogen. To balance the C:N ratios, pre-treatment and some animal dung overcome deficiency in either carbon or nitrogen [7]. Both pre-treatments and cattle dung are used to maintain the C:N ratio in this experiment.

3.3.4. Slurry concentration:

Total 101 kg slurry (41 kg Banana waste + 10 kg cow dung + 51 kg water) was used as feedstock.

3.3.5. Retention Time (RT):

Retention time of anaerobic digestion in experiment was 40 days [9].

3.3.6. Mixing or stirring:

Slurry was mixed with 2 kg dung + 2 kg water and stirred after every 10 days interval (with specially made iron bar stirrer).

3.3.7. Observation

The system was observed up to 40 days, Atmospheric temperature, inflation of inner tube and pressure of generated gas was recorded by every three days. After every ten days, generated gas was tested and burning duration was noted. After evacuating system, cap of digester was opened; 02 kg dung mixed with 02 kg water was added in digester and stirred with iron bar (specially made) and then cap was sealed.

2.4. Measurement of biogas production

Four intervals named; yield-1, yield-2, yield-3 & yield-4 are given in observation table to make calculation easy. Gas yield/ production was measured by; Burning period methods and Mathematical calculations.

Yield 1	Yield 2	Yield 3	Yield 4	Total Burning Time
31 minutes	28 minutes	23 minutes	15 minutes	97 Minutes

2.4.2. Mathematical calculation

Biogas plant/ system comprises 05 gas containers/ components, where 04 are cylindrical and 01 is torus. So that two types of methods were applied to measure the volume; than combined gas law used to determine the volume of gas. Therefore, calculations were made in three steps; i) determining volume of cylindrical components of biogas plant ii) determining volume of torus component (inner tube) of biogas plant and iii) determining biogas production.

i) Cylindrical Measurement

Volume of cylindrical components of biogas plant was calculated by following formula;

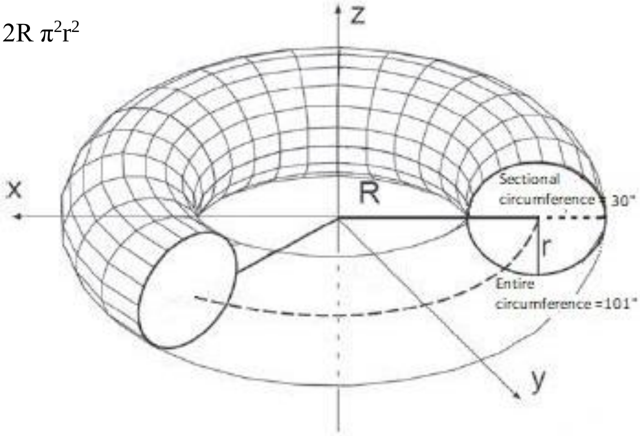
$$V = \pi r^2 h$$

Total volume of cylindrical containers was 0.685 m^3

ii) Measurement of gas holder / inner tube (torus)

Size of torus (inner tube) varies upon pressure. According to observation table of the experiment biogas yield is harvested in four (4) intervals. In each interval there are different temperatures, pressures and volumes of inner tube which was depended on different temperature and pressure at different time. Size expands when pressure increases and reduces when pressure decreases. Volume of innertube (torus) was measured through following equation in each interval;

$2R\,\pi^2 r^2$



iii) **Production of biogas**

Production of biogas was determined yield wise by applying following equation of Combined Gas Law;

$$V_2 = \frac{(P_1 V_1 T_2)}{(P_2\, T_1)}$$

Yield 1	Yield 2	Yield 3	Yield 4	Total Yield /Production
0.861 m^3	0.860 m^3	0.859 m^3	0.857 m^3	3.437 m^3

Total weight of generated gas was calculated by following equation;

$$W = \frac{molar\ mass\ of\ gas\ (g)\ x\ volume\ of\ gas\ (l)}{molar\ volume\ of\ gas\ (l)}$$

$$W = \frac{16.4 \text{ x } 3437}{22.4} = \frac{56366}{22.4} = 2505 \text{ grams} = 2.5 \text{ kg}$$

3. Results and Discussion

Total 3.42 m^3 (2.5 kg) biogas and 98 kg biofertilizer was produced from 102 kg slurry (concentration of 41 kg banana waste + 10 kg cattle dung + 51 kg water). Amount of produced gas can burn up to 97 minutes, which is sufficient for steaming and frying processes of banana value addition in the centre.

4. Conclusion

Bioenergy production was the major component of this research work and positive results are useful to fill the energy requirements of steaming and frying processes in the centre. It is also useful for utilizing biomass or managing waste that could generated in the centre on daily basis.

5. Suggestions

In this research work a batch digester biogas plant was used to utilize a specific amount of waste that can be generated in subjected banana value addition facility centre on daily basis. If we use a flow- thru digester biogas plant (continuous type) and utilize more banana waste, we can produce more biogas on daily basis, which can be used for electricity generation, positive results are useful to make agriculture and environment sustainable.

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