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# Enhancement of Bio-Gas Yield from Dry and Green Leaves by Inoculation

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**Abstract:** This paper presents the study of influence of inoculants on bio-gas yield from dry and green leaves. Various parameters such as Carbon and Nitrogen ratio, volatile matter, pH content, temperature, retention time and percentage of inoculation affect the efficiency of bio-gas production, were also studied. Bio-gas is a combustible gas produced from anaerobic decomposition of organic matter, it mainly consists of 55 - 65% methane, 30 - 40% $CO_2$ and rest being the other gases and impurities like $H_2$, $H_2S$ and $N_2$. Dry and green leaves, a waste from forest and garden are being produced in huge quantities and are causing environmental pollution and fire hazards and disposal. Garden waste is very light, highly compressible and hygroscopic, it can absorb eight times its own weight of water. Dry and green leaves have a calorific value between 4100-4400 k Cal/kg. In this work it is proposed to pulverize the raw material and inoculants to enhance the fermentation process in the mini bio-gas plant. Inoculation is the active sludge from a working plant from which the solid matter has been filtered out. It is biologically active since it contains the methanogenic bacteria which produced biogas. A mini bio-gas plant with the capacity of 250 litres is used to produce bio-gas from dry and green leaves has been studied. The addition of inoculants enhances the bio-gas yield in the mini bio-gas plant, the amount of inoculants 5%, 10% and 15 %( by weight of the total slurry) for dry and green leaves. The dry leaves yield higher bio-gas than the green leaves for a given percentage of addition of inoculants.
**Keywords:** Biomass energy, Bio-gas, Inoculants, pH content.

## 1. Introduction

One of the methods of the producing the bio-gas is by digestion, which is a biological process that occurs in the absence of oxygen and in presence of anaerobic organisms at ambient pressures and temperatures of 30 - 70˚C. Developing countries in rural areas have variety of available biomass materials, including fuel wood, agriculture waste and animal waste [1-3]. In particular, many countries have large cattle and buffalo herds whose considerable waste has much energy potential. Traditionally, these wastes are carefully collected in India and used as fertilizer, except in places where villagers are forced by scarcity of fuel wood to burn dung-cakes as cooking fuel [4]. Since bio-gas plants yield sludge fertilizer, the bio-gas fuel and the electricity generated is a valuable additional bonus. The bonus output that has motivated the large bio-gas generation programmes in number of developing countries, particularly in India and China.

## 2. Literature Survey

The anaerobic decomposition principles was first used for treatment of municipal waste at Dedar in 1973. It inspired Dr. S. V. Desai of the division of soil chemistry, IARI (Indian Agricultural research Institute) and he designed gas plant for fermenting cow dung to obtain fuel gas. Prof M. V. Joshi developed a batch type digester in 1951, which switched over to bio-gas technology on full scope. Khadi village industry commission (KVIC) started implementing Gobar gas plant scheme, in a planned way in 1962. In the beginning the programme was concentrated in the state of Gujarat, now it has spread over the entire country. In November 1981, national program of bio-gas development was initiated. During the first year of implementation, 29369 units were setup and in the second year it increased to 57500 units [5-7].The department of non-conventional source of energy of Union government has proposed 150000 units to promote bio-gas technology. Most of the work done since is pertaining to cow dung digestion only. Very recently, the attention is being given to digestion of vegetable and other agricultural waste. The results obtained were very encouraging. The bio-gas can be generated from all organic materials which are rich in cellulose.

## 3. Mechanism of Gas Production

Vegetable waste, which is rich in cellulose content when grouped and placed out of contact with Oxygen or atmospheric air will gives rise to large number of bacteria, which act upon waste to decompose them. The group of bacteria involved in generation of methane is named as "Methanogenic bacteria", [8-10]. The anaerobic fermentation consists of hydrolysis, acid formation and methane formation.

### 3.1 Hydrolysis

This is the first stage of digestion, here the complex substances such as cellulose, hemicelluloses, etc., present in the vegetables or any other wastes are broken down by enzymatic hydrolysis into suitable carbohydrates i.e. sugar. These occur in about a day at 25˚C, in an active digester.

### 3.2 Acid formation

This is a second stage, here the soluble organic compounds are converted in to volatile fatty acid, such as acetic acid, propping acid or lactic acid.

### 3.3 Methane formation

This is the third stage, here the volatile acids are converted in to methane ($CH_4$) and carbon dioxide ($CO_2$) by specific bacteria.

### 3.4 By-products in the bio-gas plants

In the process of anaerobic digestion of the feed solid matter in the bio-gas plant produces many by-products, they are Biogas, Scum, Supernatant, Spent slurry, digested sludge and inorganic solids. If the content of digester are not stirred or disturbed for few hours, then these by-products form layers. Table.1 below describes the different layers of by products in bio-gas plants. In the most cases the heaviest inorganic solids form the bottom most layers and the lightest gas forms at the top.

Table.1: By products in a bio-gas plant.

| S.No. | Layering | By-product | Usable Fraction |
|---|---|---|---|
| **1** | Gas | Bio-Gas | Combustible gas |
| **2** | Fibrous | Scum | Fertilizer |
| **3** | Liquid | Effluent | Fertilizer |
| **4** | Liquid | Spent slurry | Biological active |
| **5** | Solid | Sludge | Fertilizer |
| **6** | Solid | Inorganic Solids | Waste |

### 3.5 Characteristics of good raw materials

Any cellulose materials of plants or animal origin which is bio degradable can be used as raw material for production of bio-gas. As the production of biogas involves micro-organisms, the raw material should contain adequate nutrient essential for their growth and metabolism. The suitable raw materials are animal waste, human waste, crop waste, garden waste, kitchen waste and agricultural based industrial waste etc., and they have following characteristic for good quality biogas generation:

(i) Particle size:
Particle size signifies the fermentation process for bacterial attack and also reduces the retention period considerably.

(ii) Proper C/N ratio:
The Carbon/Nitrogen ratio should maintain properly, if Carbon/Nitrogen ratio is high, the process is limited by the nitrogen availability and if it is too low, Ammonia may be formed to be toxic to bacteria population. It has been found that C/N ratio by weight 30:1is optimum. The C/N ratios of various materials are shown in Table.2

(iii) Volatile solid concentration:
Volatile solid concentration in feed material is also one of the important parameters, ordinarily 7-9% of concentration is considered to be optimum for gas production.

Table.2: Carbon/ Nitrogen ratios of different material.

| Source | Material | N% | C/N |
|---|---|---|---|
| **Animal waste** | Urine<br>Cow dung<br>Poultry manure | 15-18<br>1-7<br>6.3 | 0.8<br>0.25<br>-- |
| **Plant waste** | Grass chippings<br>Sea weed<br>Wheat straw<br>Mixed grasses | 4<br>1.9<br>1.3<br>2.4 | 12<br>19<br>128<br>19 |
| **House hold waste** | Raw garbage<br>Potato tops | 2.2<br>1.5 | 25<br>25 |

## 4. Case Study of Mini Bio-Gas Plant

The mini bio-gas plant study describes the constructional details by assuming constant pressure in the gas holder. The mini plant consists of digester is shown in Fig.1 with essential devices like gas holder andgas circuit. The digester is provided with an inlet feed pipe for feeding the raw material. About 250litres of slurry containing 8-10% solid are required as initial charge for the digester.
The percentage of solid concentration selected is 9%
The amount of solid =9/100 *250=22.5kg

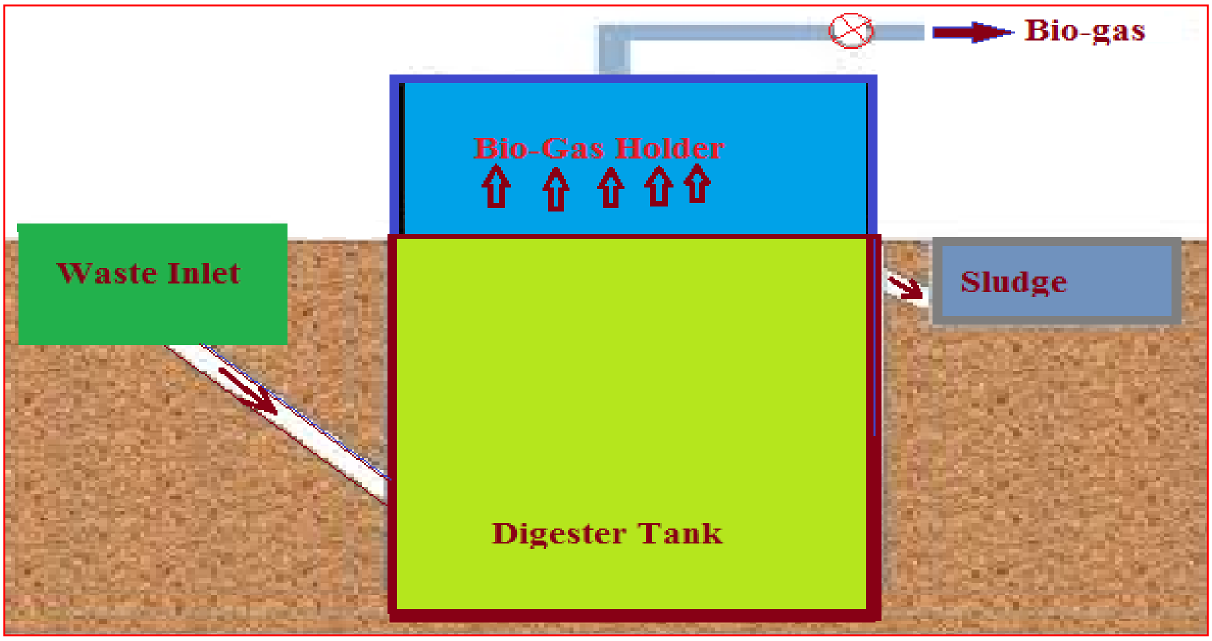


Fig.1: Schematic layout of Bio-gas digester.

The raw material is inserted in to the digester and 100 litres of water were added. The material were stirred with wooden stick and allowed to soak in water for 2 days. After 2 days, 20 litres of inoculation were added as seed material. Inoculation is the active sludge from a working plant from which the solid matter has been filtered out. It is biologically active since it contains the methanogenic bacteria which produced biogas.Significant gas production was notified from $10^{th}$ day onwards. Initially more amount of $CO_2$ gas was started collecting into the gas holder.

**4.1 Gas yield**

The average gas yield per kg of charge is shown on Table.3, the average gas yield is found to be maximum for dry leaves. The maximum gas production during the third week for dry leaves was 0.75 $m^3$/kg (15% of inoculation), and it was found to be 0.7$m^3$ /kg for the green leaves during the fourth week. This is also owing to enhanced fermentation process by the methanogenic bacteria in the dry leaves. The other reason could also be faster degradation of dry leaves.

Table.3: Bio-gas yield from dry and green leaves.

| Weeks | Bio gas yield m3/kg | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No inoculation | | 5%Inoculation | | 10%Inoculation | | 15%Inoculation | |
| | Dry leaves | Green leaves | Dry leaves | Green leaves | Dry leaves | Green leaves | Dry leaves | Green leaves |
| 1 | 0.1 | 0.09 | 0.15 | 0.15 | 0.2 | 1.7 | 0.3 | 0.22 |
| 2 | 0.6 | 0.25 | 0.5 | 0.4 | 0.7 | 0.5 | 0.7 | 0.54 |
| 3 | 0.55 | 0.45 | 0.6 | 0.45 | 0.7 | 0.55 | 0.75 | 0.65 |
| 4 | 0.45 | 0.5 | 0.6 | 0.55 | 0.6 | 0.6 | 0.65 | 0.7 |
| 5 | 0.44 | 0.35 | 0.45 | 0.41 | 0.45 | 0.4 | 0.45 | 0.4 |
| 6 | 0.25 | 0.22 | 0.25 | 0.22 | 0.25 | 0.22 | 0.25 | 0.22 |

**4.2 Effect of inoculation on bio-gas yield**

The variation of gas yield in dry and green leaves with the addition of inoculants are shown in Fig.2 &Fig.3. The inoculants are active slurry taken from an active bio gas plant operating with cow dung as raw material. It is seen form the plots that the inoculants accelerate the process of fermentation during the first week. It also observed that the influence of inoculants decrease gradually from week to week as leaves start degrading by methanogenic bacteria. The effective amount of inoculants for dry leaves is 10% as shown in Fig.2where as it is 15% for green leaves as shown in Fig.3.

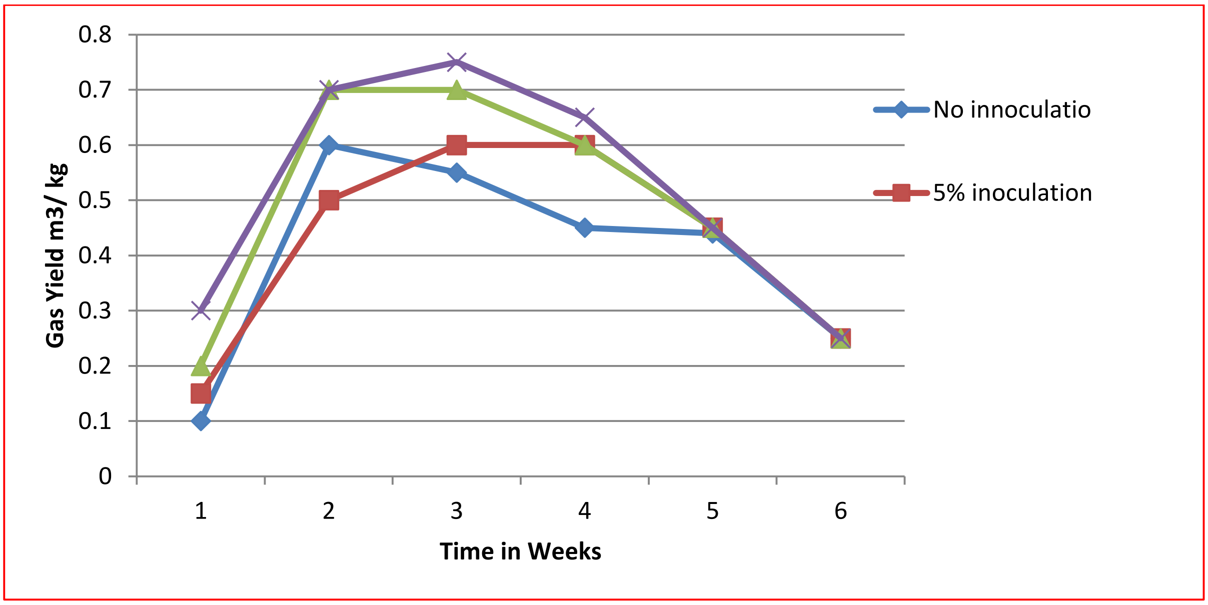


Fig.2: Effect of inoculants on gas generation for dry leaves.

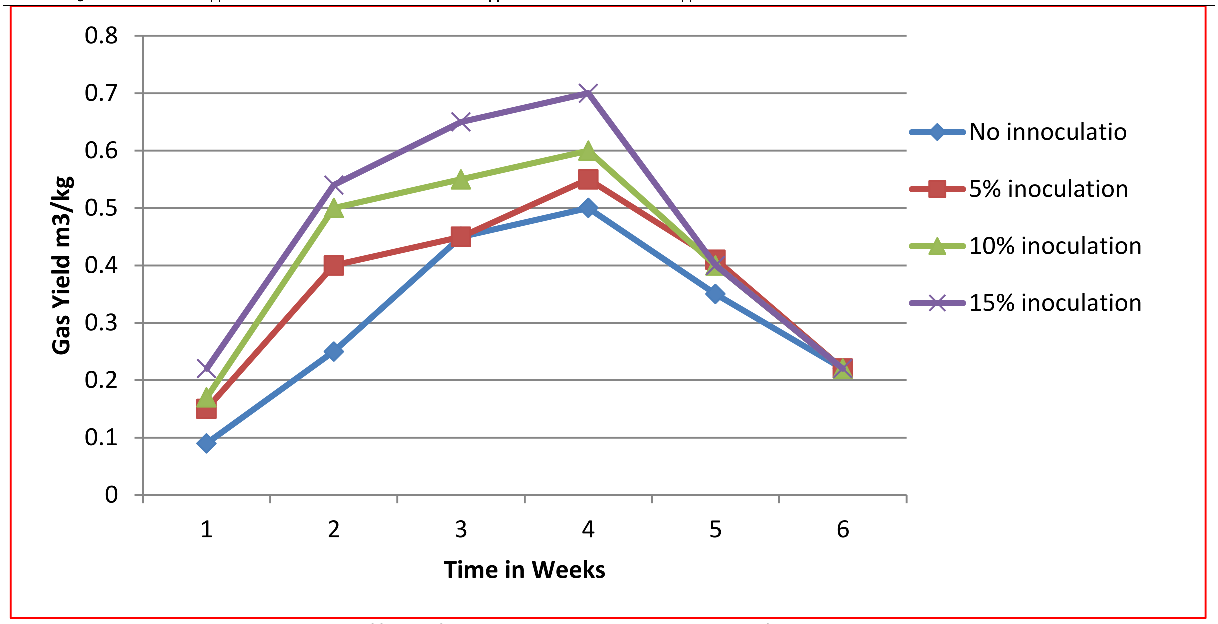


Fig.3: Effect of inoculants on gas generation for green leaves.

**4.3 Effect of solid concentration on bio-gas yield**

The maximum amount of dry leaves by weight added to water is 9%.The maximum amount of green leaves by weight added to water is 10%.Any additional amount of leaves either of dry or green added beyond optimum unit would simply increase the solid content in the Bio-gas plant. This additional amount of leaves will be excess which would not degraded by methanogenic bacteria. Therefore, a general tendency of more solid content indirectly more cellulose content resulting increased gas yield is a false statement.

**4.4 Effect of temperature on bio-gas yield**

The methanogenic bacteria can work over a wide range of temperature from 20˚C to 50˚ C. But 30˚Cis found to be the optimum temperature for maximum gas production.

## 5. Conclusions

The following conclusions are drawn from the present case study, the garden waste i.e. dry and green leaves can be used to yield the bio-gas. The bio-gas production for dry leaves is found greater than green leaves. Without addition of inoculants the maximum gas yield for dry leaves and green leaves were found to be 0.55 $m^3$/kg and 0.5 $m^3$/kg respectively. With the addition of inoculants (up to 15%) the maximum gas yields were found to be 0.75 $m^3$/kg for dry leaves and 0.7 $m^3$/kg for green leaves. The inoculants were active during the first period of digestion process only.The amount of yield also depends on the amount cellulose content of leaves. Dry leaves has high cellulose content, hence gas yield is more in dry leaves. Optimum temperature of bio gas plant operation should be 30˚C. Pulverization of leaves increases the bio gas yield.

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