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Energy production by systematic treatment of banana waste, A remedy to pollution control and global warming

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Abstract: India being agriculture based country; it is the leading producer of banana crop. The banana waste generated in two forms, one is at the time of re-cropping and the other is due to natural calamities like excess and lack of rains. This on decomposition releases Green House Gases (GHG) like CH_4, CO_2, H_2S etc. These GHG can be controlled by systematic treatment of banana waste. During the treatment CH_4 released can be used as a substitute to fossil fuels for energy production. Ramananuthanapalli, Ippatla, Gunakanapalli of Lingala mandal of Kadapa district, Andhra Pradesh, India is chosen for case study of present work. The study area lies in the Survey of India Toposheet No. 57j3 between north latitudes of $14^0$15’ and $14^0$30’ and eastern longitudes of $78^0$00’ and $78^0$15’ and comprises of 464 hectors of banana cultivation which produces a waste of about 1,20,000 tons of waste per crop over a period of 8-9 months. Improper disposal of this huge waste producing energy content equivalent nearly 38, 40,000 litres of diesel. Further it produces around 10,000 tons of biofertilizer which can be utilized for improving soil fertility and high yield. In the present study zeolites have been used for segregation of gaseous mixture from the digester.

Keywords: Green House Gases, CH_4, Banana, Bio fertilizer.

INTRODUCTION

Banana is the second largest produced fruit accounting 16% of the world’s total fruit production. Over 27% of worlds banana production produced in India[1] Lingala mandal of Kadapa district, the main crop is banana. Which processes a huge quantity of waste during the period of recropping and by natural calamities? Farmers usually dispose this generated through burning or left the waste for natural decomposition. In both these methods high quantity of GHG is developed and released into environment causing environmental pollution and ultimately global warming. 464 hector of banana crop area in the present study producing 1, 20,000 tons of waste. Improper disposal of such a huge waste account for production of 40, 80,000 m^3 of CH_4, 25, 16,000 m^3 of CO_2 and 2, 04,000 m^3 of other GHG per crop[2] . A small region in the globe is producing such high amount of GHG, what could be the account of such regions in the entire globe. Hence, the present study is taken up to utilize such huge amount of GHG by converting them in energy sources. By adopting the systematic treatment of anaerobic digestion process, we can control environmental pollution and GHG and global warming.

Zeolites have unique property of porous structure that could either be used in the absorption technique or as a sieve[3]. In the present study, zeolites have been utilized as absorbents during the segregation of selective gases from the consequent gaseous mixture coming out of the digester.

MORPHOLOGICAL CONTENT OF BANANA PLANT

The morphological content of banana plant is given in **Table 1**. Chemical composition of different morphologic regions of banana plant are Glucose, Xylose, Galactose, Arabinose, Mannose, Rhamnose, Lignin, Cellulose, Holocellulose, Ash, Patassium, Calcium, Magnesium, Silicon, Phosphorous, Pentosans, Starch, and Proteins.

Table-1: Chemical composition of different morphologic regions of banana plant

	Pseudo stem	Petioles/mid rib	Leaf blade	Floral stalk	Leaf sheath	Rachi
Glucose	74.0*	68.1*	60.0*	79.8*	74.2*	13.8*
Xylose	13.1*	23.6*	17.5*	3.9*	13.8*	14.0*
Galactose	2.5*	1.1*	3.8*	2.9*	2.2*	1.7*
Arabinose	9.1*	4.9*	15.5*	51.1*	7.5*	4.1*
Mannose	1.3*	1.5*	2.3*	2.1*	1.5*	2.9*
Rhamnose	--	0.8*	0.9*	0.7*	0.8*	0.7*
Lignin	12.0*	18.0*	24.3*	10.7*	13.3*	10.5*
Cellulose	34-40*	31.0*	20.4*	15.7*	37.3*	31.0*
Holocellulose	60-65*	62.7*	32.1*	20.3*	49.7*	37.9*
Ash	14.0*	11.6*	19.4*	26.1*	19.0*	26.8*
Potassium	33.4**	9.4**	11.6**	23.1**	21.4**	28.0**
Calcium	7.5**	32.3**	8.0**	0.6**	5.5**	0.6**
Magnesium	4.3**	2.9**	1.1**	0.5**	1.9**	0.3**
Silicon	2.7**	7.0**	24.9**	7.8**	2.7**	1.2**
Phosphorous	2.2**	0.7**	0.7**	0.7**	0.9**	1.7**
Pentosans	--	16.2*	12.1*	8.0*	12.4*	8.3*
Starch	--	0.4*	1.1*	26.3*	8.4*	1.4*
Proteins	--	1.6*	8.3*	3.2*	1.9*	2.0*
* Expressed in terms of % molar proportions, ** Expressed in % of ash basis[1] ,						

METHODOLOGY

The organic compounds of banana plant are Glucose, Cellulose, Starch, Proteins and fats. Which on systemic treatment convert into methane (CH_4). The collected banana waste from the source should be passed through a systematic treatment of anaerobic digestion, breaking down of organic materials in the absence of oxygen, through biological activity of microorganisms and release of CH_4, CO_2, H_2S and N_2. This process called as anaerobic digestion. The treatment consists of three stages hydrolysis, acidification, methenization.

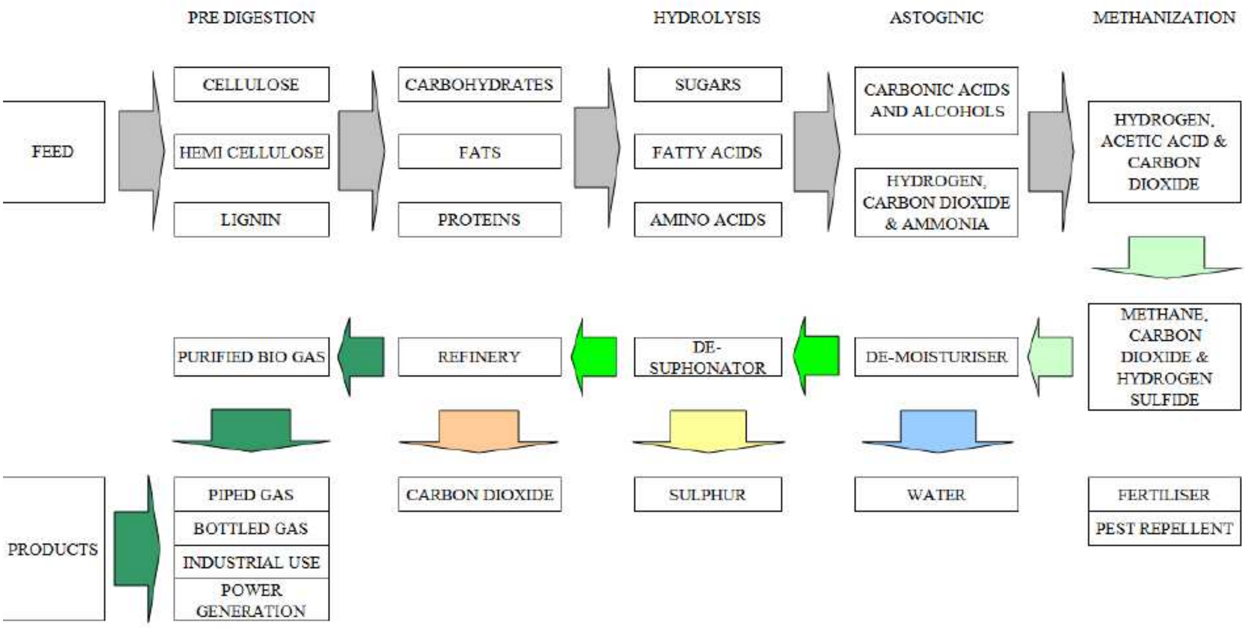

Fig.1 Block diagram of Banana waste treatment

Hydrolysis: This process also called liquefaction. In the first stage of the process, the fermentative bacteria convert the insoluble organic matter such as cellulose into molecules of sugars, aminoacids and fatty acids. The complex polymeric matter hydrolyzed to monomer by hydrolytic enzymes secreted by microbes, for instance cellulose converted into sugars, hemi cellulose converted into fatty acids and lignin converted into amino acids [4].

Hydrolysis/Liquification reactions:

Lipids → Fattyacids

Polysaccharides → Monosaccharides

Proteins → Amono Acids

Nucleic Acids → Purines & Pyimidines.

Acidification: In the second stage, acetogenic bacteria known as acid formers convert the product of first phase to simple organic acid, carbon dioxide and hydrogen. The principle acids produced are acitic acid (CH_3COOH), Propionic acid (CH_3CH_2COOH), butyric acid ($CH_3CH_2CH_2COOH$) and ethnol (C_2H_5OH). The products formed during acitogenesis are due to number of different microbes like Sytrophobacter wolini, a roponie decomposer and syptrophomonos wofei, abutyrate decomposer. Other acid forners are clostridium species, peptococcus, anerobus lactobacillus and actinomyces[5]. The reaction shown below.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH+2CO_2$$

Methenisation: In the last stage, methane produced by bacteria called methogens in two ways, in the first, by means of cleavage of acidic molecules to generate carbon dioxide and methane, and in the second, by the reduction of carbon dioxide with hydrogen. However, methane production is higher by reduction of carbon dioxide[6].

$CH_3COOH \rightarrow CH_4 + CO_2$

(Acitic Acid) (Methane) (Carbon dioxide)

$2C_2H_5OH+CO_2 \rightarrow CH_4 + 2CH_3COOH$

(ethanol) (Methane) (Acitic acid)

$CO2+4H_2 \rightarrow CH_4+2H_2O$

Progressive and synthesizing factors: Important factors governing the production of biomethane are temperature, pH, C:N ratio, hydrolic retention time (HRT), mixing etc. Anaerobic bacteria, especially methanogens and enzymes are sensitive to the above factors.

Temperature: Temperature has a significant impact on the biogas production process. The range of temperature differs for diverse kind of fermentative bacteria.

Table – 2 Ranges of Temperatures

Fermentation optimum	**Temperature range**	**Temperature**
Psychrophilic	0-20^{0}C	15^{0}C
Mesophilic	15-45^{0}C	35^{0}C
Thermophilic	45-75^{0}C	55^{0}C

Although anaerobic digestion can be carriedout both in mesophilic and thermophilic temperature range, thermophilic digestion results in more and faster biogas production and better pathogen and virous kill[7].

pH value: The acid concentration within the digester and their growth can be inhibited by acid conditions. The acid concentrations in aqueous system is expressed by pH value i.e., the concentration of hydrogen ions. At neutral conditions water contain a pH 7 while alkaline solutions are at a pH higher than 7. It has been determined[8] that on optimum pH value for anaerobic digestion lies between 5.5 and 8.5. During digestion, the two processes of acidification and methanogenesis requires different pH levels for optimal process control. The retention time of digester affects the pH value and reactor acetogenesis occurrence at a rapid phase. Acetogenesis can leads to accumulation of large amounts of organic acids result in pH below 5. Excessive generation of acid can inhibit methogensdue their sensitivity to acid conditions. Reduction in pH can be controlled by the addition of lime or recycled filtrate obtained during residue treatement. In fact the use of recycled filtrate can even eliminate the lime requirement. As the digester reaches methogenesis stage, the concentraton of ammonia and the pH value increases to above 8. Once the methane production[9] is stabilized, the pH level stays between 7.2 and 8.2

C/N Ratio: The relationship between the amount of carbon and nitrogen present in organic materials is represented[9] by the C/N ratio Optimum C/N ratios in anaerobic digesters are between 20-30. A high C/N ratio is an indication of rapid consumption of nitrogen by methanogens and results in lower gas production. On the other hand, a lower C/N ratio causes ammonia accumulation and pH values exceeding 9.5, which is toxic to methanogenic bacteria. Optimum C/N ratios of the digester materials can be achieved by mixing materials of high and low C/N ratio, such as organic solid waste mixed with sewage or animal manure.

Hydraulic retention time: The required retention time for completion of anaerobic digestion reactions varies with differing technologies, process temperature and waste composition. The retention time for wastes treated in mesophilic digester ranges from 10 to 40 days [9]. Lower retention times are required in disasters operated in the thermophilic range. A high solids reactor operating in the thermophilic range has a retention time of 14 days.

Mixing: The purpose of mixing in a digester is to blend the fresh material with digester containing microbes. Furthermore, mixing prevents scum formation and avoids temperature gradients within the digester. However excessive mixing can disrupt the microbes so slow mixing is preferred. The kind of mixing equipment and amount of mixing varies with the type of reactor and the solid content in the digester[9].

Biogas composition: The obtained during anaerobic digestion comprisesof methane, carbon dioxide, some inert gases and sulfur compounds.

Table 3: Typical Biogas Composition

Methane	55-70% by volume
Carbon dioxide	30-45% by volume
Hydrogen sulphide	200-4000 ppm by volume
Energy content of Anaerobic Digestion product	20-25 20-25MJ/standard m^3
Energy content of CH_4 per ton MSW	167-373 MJ/Ton MSW
Regional Information Service Centre for South East Asia (RISE-AT) 1998.	

CO_2 trapping: Pressure swing adsorption (PSA) is another possible technique for upgrading of biogas. PSA is a technology used to separate certain components from a mixture of gases under pressure according to the species molecular characteristics and affinity for an adsorption material.

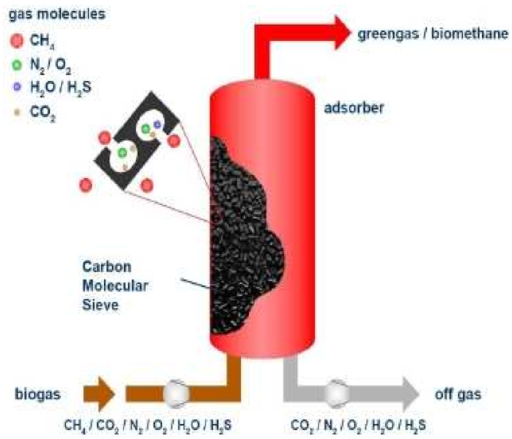

Fig. 2 Diagram showing CO_2 trapping

The above figure shows selective adsorption of different gas molecules. The adsorption material adsorbs H_2S irreversibly and thus poisoned by H_2S. For this reason, a H_2S removing step is often included in the PSA process. Disturbances have been caused by dust from the adsorption material getting stuck in the valves. Special adsorption materials used as a molecular sieve, preferentially adsorbing the target gas species at high pressure. However, there is inability to discriminate between different gases; adsorbents for PSA systems are usually selectively porous materials to separate various gases like activated carbon, silica gel, alumina and zeolite. The process then swings to low pressure to desorb the adsorbent material.

Disrobing the adsorbent material leads to a waste stream, containing concentrations of impurities. The upgrading system consists of four absorber vessels filled with adsorption material, as can be seen in figure. During normal operation, each adsorber operates in the alternating cycle of adsorption, regeneration and pressure bild-up. During the adsorption phase, biogas enters from the bottom into one the adsorbers. When passing the absorber vessel, CO_2, O_2, and N_2 adsorbed on the adsorption material surface. The gas leaving the top of the adsorbed vessel contains more than 97% CH_4. The methane rich stream is substantially free form siloxane components, VOC's, water and has a reduced level of CO_2. Before the adsorption material completely saturated with the adsorbed feed gas components, the adsorption phase is stopped and another adsorber vessel that has been regenerated is switched into adsorption mode to achieve continuous operation.

Regeneration of the saturated adsorption material performed by a stepwise depressurization of the adsorber vessel to atmospheric pressure and finally to near vacuum conditions during this process the trapped CO_2 is filled in and can be used respective application. Initially, a pressure balance with an already regenerated adsorber vessel reduces the pressure. This followed by a second depressurization step to almost atmospheric pressure. The gas leaving the vessel during this step contains significant amounts of CH_4 and is recycled to the as inlet. These significant amounts of CH_4 rapped within the voids of the adsorbent particles. Before the adsorption phase starts again, the adsorber vessel is repressurized stepwise to the final adsorption pressure. After a pressure balance with an adsorber that has been in adsorption mode before the final pressure build up achieved with feed gas[10] .

Hydrogen sulphide gas trapping: Hydrogen sulphide formed from digestion of protein and other material that contain sulphur. Since hydrogen sulphide is highly corrosive it recommended to separate early in the biogas upgrading process. It can be remoed in the digestion chamber, in the gas stream or in the upgrading process. Some o the most common methods for removing hydrogen sulphide are infact internal, iron chloride dosing to the digester slurry or air/oxygen dosing to the digester. Hydrogen sulphide reacts with iron hydroxide or oxide to form iron sulphide (FeS). When the material is saturated, it can either be regenerated or changed. In the regeneration, iron sulphide is oxidized with air and iron oxide or hydroxide is recovered together with elemental sulphur.

The iron oxide containing material can be oidised steel wool (rust coated), wood ships cocered with ironoxide or pellets made of red mud, a saste product from alluminium production. Wood chips are particularly popular in the US since they have low cost and have a large surface to volume ratio. The highest surface to volume ratio is found in pellets. Pellets are common at German and Swiss sewage treatment plants that don't have dosing of iron chloride.

Nutritional values of bio-digester waste: The bio-digester waste contains micronutrients like iron, magnesium, calcium, sulphur, zinc, manganese etc., required for good health and well-being of the plants natural immune system.

Table-4: Nutritional values of bio-digester waste per Kg. in gms

Nitrogen	2.85
Phosphorous	3.50
Potassium	49.30
Sodium	15.00
Calcium	13.20
Sulphur	4.20
Magnesium	2.30
Iron	0.40
Zinc	0.09
Maganese	0.08

CONCLUSIONS

In the study area nearly 1, 20,000 tons of banana agriculture waste is produced from 464 hectors of crop area every year. This waste by natural decay liberating 40, 80,000 m^3 of CH_4, $25{,}16{,}000^3$ of CO_2 and 2, 04,000 m^3 of other GHC in to the atmosphere which results chronic global warming and environmental pollution. Systematic treatment of such a huge waste can replace fossil fuels in energy production and in many other applications. The trapped GHG is cylindered and utilized for respective applications such as cooking gas, automotive fuel or electricity production.

The CH_4 produced from the banana waste in the study area is utilized to replace the fire wood, thus controlling the deforestation. In Automotives the CH_4 replace fossil fuels and minimize the air pollution. The GHG released out of banana waste can produce 15,096 MW electricity in 8-9 months. In addition, the digestrate is a bio fertilizer which contains micronutrients like Iron, Mg, Ca, Sulpher, Zinc, manganese etc., required for good health and well being of plants natural immune system. The utilization of such a bio fertilizers minimizes the soil pollution and increases the yield.

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