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Energy conversion study on cumbu napier CO-4

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Abstract

Agriculture has for several years formed the backbone of Indian economy, contributing approximating 30.2% of the gross domestic product employing over 77% of the population above 10 years of age (Surajit, 2012). Developing countries like India produce large quantities of agro-residues such as rice husks, bagasse, groundnut shells, cotton stalks etc. in large quantities but they are used inefficiently causing extensive degradation to the environment. The study was to analyze the energy potential of the crop Cumbu Napier CO-4 by briquetting and biogas production. The study had been originated keeping in view the vast potential of Cumbu Napier CO-4 hybrid and is utilized for the production of bio methane (biogas) and briquettes rather than using only as fodder crop so that energy, economic as well as environmental benefits, can be realized. The use of Cumbu Napier CO-4 briquettes reduces the usage of wood as a fuel for combustion and the biogas produced from anaerobic digestion of the crop would be a suitable way of its utilization for energy generation which minimizes fossil fuel consumption and significantly reduce the Green House Gas emissions. Further, sludge obtained from bio digestion is enriched organic manure, which would be very useful for enhancing agriculture productivity in farming.

Highlights

- Characteristics analysis and Briquetting of Cumbu Napier CO-4.
- Biogas production potential of Cumbu Napier CO-4.

Keywords: Cumbu napier CO-4, briquetting, anaerobic digestion, biogas

TNCN014, a high yielding interspecific hybrid between fodder Cumbu CO-8 and Napier grass FD 461 was developed at the department of Forage Crops, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University (TNAU), Coimbatore and released as CO (CN) 4. The triploid hybrid displays luxurious vegetative growth. Cumbu Napier CO-4 is well adapted to the soil and climatic conditions of Tamil Nadu. This hybrid is highly palatable for milch animals like goat and sheep. The increase in yield of this hybrid over the variety CO-3 was 33% which recorded a mean yield of 382t/ha/year (Vijayakumar *et al.* 2009).

An energy study makes an attempt to critically evaluate the studies to make a breakthrough in agricultural sector (Murugan, 2011). The problems caused by agricultural solid wastes can be significantly mitigated through the adoption of environmentally waste to energy technologies such as biomethanation (anaerobic digestion), combustion, pyrolysis etc. (Sarbjeet *et al.* 2013). In this study Cumbu Napier CO^{-4} involves in two processes of briquetting and anaerobic digestion.

The first process, briquetting is a mechanical compaction process for increasing the density of bulky material. Using briquetting machines the product briquette is formed and is a block of flammable matter which can be used as fuel. Generally briquettes are a good substitute to firewood and charcoal for domestic cooking and agro-industrial operations, thereby reducing the high demand for both. Besides, briquettes have advantages over fuel wood in terms of greater heat intensity, cleanliness, convenience in use and relatively smaller space requirement for storage (Singh *et al.* 1992) (Olorunnisola 2004). In Cumbu Napier CO^{-4} the natural lignin in the material binds the particles together to form a solid (briquette) therefore there is no need of binders to be involved in briquetting process.

Second process is the production of biogas which is the gas generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion. It is an ecofriendly substitute for energy. Biogas is about 20% lighter than air has an ignition temperature in range of 650°C to 750°C. It is an odorless and colorless gas that burns with blue flame similar to LPG gas. Its caloric value is 20 Mega Joules (MJ)/m^3 and it usually burns with 60 % efficiency in a conventional biogas stove (Suyog Vij, 2011). By adding cow dung and Cumbu Napier CO^{-4} to anaerobic high rated digesters for a retention time of 90 days biogas (methane) is formed and the fully digested slurry can be used as bio-fertilizer.

Materials and Methods

Cumbu Napier hybrid grass CO^{-4} was collected from the Department of forage crops, TNAU. The raw material was sun dried for 7 days, shredded to pass through a 2-5 mm sieve and stored at room temperature. The substrate was characterized as it gives significant information on suitability of the substrate for briquetting and biogas production.

Proximate Analysis

Proximate analysis as defined by ASTM (American Society for Testing Materials), is the determination of biomass constituents like moisture content, volatile matter, fixed carbon and ash content

Volatile Matter (VM)

Volatile Matter was determined using muffle furnace (ASTM, E-872) by keeping the dried sample in a crucible at 650°C for 6 minutes and then 750°C for another 6 minutes. The difference in weight due to the loss of volatiles was taken as the total volatile matter present in the substrate.

Moisture Content (MC)

Moisture content plays an important role in controlling energy released during burning and biogas production. By oven method (ASTM, E-871), the moisture content was determined by drying weighed amount of sample in an open petri dish in an electrical oven at 103$\pm$5°C for 1 hour and weighed again till constant weight was observed. The difference in weight, before and after drying indicates the moisture content of sample. The moisture content (wet basis) was determined by the formula,

$$\text{MC (\%)} = \frac{(\text{wet weight-dry weight})}{\text{wet weight}} \times 100$$

Ash Content (AC)

The ash content was found out (ASTM, E-830) by taking the substrate in a silica crucible and heating in a muffle furnace to 750°C for 2 hours or more till constant weight was recorded. The weight of the residue represents the ash content.

Fixed Carbon (FC)

Fixed carbon of dried material is obtained by subtracting volatile content and ash content from 100. It is given by the formula,

$$\text{FC (\%)} = 100 - [(\text{VM (\%)} + \text{AC (\%)})]$$

Calorific Value (CV)

Calorific value is the heat produced by combustion of a unit quantity of substance under specific conditions. It is expressed as energy/mole of fuel (kJ/mol), energy/mass of fuel, energy/volume of fuel. It is conventionally measured with a bomb calorimeter (ASTM D5865). The calorific value of the fuel (cal/g) was calculated by,

$$CV = \frac{(T_2 - T_1) * \text{water equivalent}}{\text{weight of the sample taken}}$$

where,

T_2 - Final temperature, °C

T_1 - Initial temperature, °C

Water equivalent - 2240 kcal/kg°C

Strength

Strength can be calculated using hardness test and water stability test. In hardness test the briquetted material was thrown from a height of 1.5 m for nearly 15 times and the strength can be found out using the amount lost. In water stability test, the briquette is kept inside water for nearly 5 minutes. With the amount of briquette disintegrated the quality can be found out.

Briquette Production

The steps involved in briquetting process are

- Collection of raw material
- Preparation of raw material (crushing)
- Compaction (briquetting)
- Cooling and storage

The samples were dried in solar tunnel dryer for 2 days to a moisture content of 8% and crushed to a particle size between 100-150 microns. The piston press type model was used for briquetting. In this technology the optimum moisture content is about 10-15% and the power consumption is about 50 kWh/ton and density of the briquette is about 1-1.28 g/cm^3 and it is operated in strokes. The production capacity of the machine is about 100 kg briquettes/hour. Hydraulic pressure exerted on the piston is 100 pascal. Size of the briquette produced is 50 mm diameter, after which it was transferred to the oven and dried at 105ºC to constant weight

Anaerobic Digestion

Anaerobic digestion is a process that takes place in the presence of biodegradable biomass (substrate), anaerobic microorganism and a milieu (digester) which is free of molecular oxygen. The process converts the biomass into energy in a gaseous mixture known as biogas. The complex process of anaerobic digestion can be divided into four phases such as hydrolysis, acidogenesis, acetogenesis and methanogenesis

Hydrolysis

Hydrolysis is first step in which un-dissolved compounds like cellulose, protein, fats are degraded into monomers (water soluble fragments) such as amino acids, glucose, fatty acids, and glycerol by consortia of anaerobic bacteria which excrete extracellular enzymes like cellulases, proteases and lipases. The monomers (amino acids, glucose, fatty acids, and glycerol) are directly available to next group of bacteria. Hydrolysis is a comparatively slow and can be the rate limiting stage in anaerobic digestion especially when the organic matter contains high concentration of lignin and cellulose. Lipids hydrolysis takes place at a much faster rate in comparison with proteins and carbohydrates.

Acidogenesis

The microorganisms engaged in hydrolysis are generally the same which carries out acidogenesis. Usually hydrolysis and acidogenesis are together referred to as fermentation reactions. Species of genera bacteriods, eubacterium, clostridium, bifidobacterium, lactobacillus, butyrivibrio are considered to dominate the fermentation reactions. The products of hydrolysis are converted into organic acids by microorganisms. These organic acids are usually termed as volatile fatty acids. Acidic acid, formic acid, lactic acid, propionic acid, succinic acid and butyric acid are majorly formed during this process. Only glycerol, amino acids and sugars undergo acidogenesis. On the other hand glycerol produces acetate, lactate, 1,3 propanol. The products of this stage are generally converted into acetate, hydrogen and carbon dioxide which are considered as potential methanogenic substrates.

Acetogenesis

The products from the acidogenic phase serve as substrate for other bacteria, those of acetogenic phase. This stage involves the action of acetogenic bacteria that convert the volatile fatty acids and alcohols formed during acidogenesis into acetate, hydrogen and carbon dioxide. Two groups of acetogenic bacteria have been isolated which are known as hydrogen and acetate producers. Both acetogens and methanogens are sensitive to higher hydrogen concentrations (pH acidic), therefore it is essential to strictly monitor the concentrations of hydrogen during the anaerobic digestion process.

When the hydrogen partial pressure is low, H_2, CO_2 and acetate are predominantly formed. The higher hydrogen partial pressure reduced the acetate formation whereas the formation of propionic acid, butyric acid and ethanol was increased. The formation of acetate indicates good potential for methane formation, the production of butyrate and propionate are deemed as disturbances. The hydrogen producing groups have the potential of breaking down propionate and other organic acids into acetate and hydrogen. This break down of propionate helps to prevent the accumulation of propionate that otherwise would have antimicrobial influences on vital microorganisms (methanogens).

Methanogenesis

Methanogenesis is the final phase of the anaerobic digestion process. In this stage, methane and carbon dioxide (biogas) are produced by various methane producing microorganisms termed as methanogens. The most important substrates for these organisms are hydrogen gas, carbon dioxide, and acetate, which are formed during anaerobic oxidation. The methane-producing group that usually dominates in the biogas process is acetotrophic methanogens, which use acetate as substrate. In their metabolism, acetate is broken into two parts in which one of the carbons is used to form methane and the other to form carbon dioxide. Hence, acetotrophic methane producers are sometimes also named as acetate-splitting methanogens. Normally, Acetate is the source of about 70% of the biogas produced in a digester. Hydrogentrophs are the methanogens which used carbon and hydrogen gas as primary source for the formation of methane.

Presently there are only two well recognized groups of methanogens that break down acetate. They are *Methanosaeta* and *Methanosarcina*, though there are also other groups of methanogens which use hydrogen gas such as *Methanococcus*, *Methanobacterium*, *Methanobrevibacter* and *Methanogenium. Methanosarcina* and *Methanosaeta* have different growth rates and also they differ regarding their capability to use acetate. Generation time, i.e. the time required for a microorganism to divide itself into two, is between 1 and 12 days for methane producers.

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

On the other hand, acetotrophic methanogens convert acetate into methane and carbon dioxide.

$$CH_3COOH \rightarrow CH_4 + CO_2$$

Lab Scale Studies for Biogas Production.

Batch digestion studies were carried out to study the biogas characteristics of Cumbu Napier. Anaerobic digestion of Cumbu Napier was carried out using 2.5 liter amber colored glass bottles with a rubber stopper. Two third of the bottle cap was covered using rubber cork so that it would be air tight. One glass tube is taken through the stopper and it acts as an outlet for the biogas. To this glass, bent tube of 40 cm long rubber tube with a pinch cork was connected. The gas production was estimated by water displacement. The following treatments were used for the study

- ❒ 100% Cow dung

  T1 : 1kg Cow dung + 1000ml of water
- ❒ 100% Cumbu Napier grass

  T2 : 1kg of Cumbu Napier + 1000ml of water
- ❒ 50:50 (Cow dung : Cumbu Napier)

  T3 : 500g of Cumbu Napier + 500g of Cow dung + 1000ml of water
- ❒ 75:25 (Cumbu Napier : Cow dung)

  T4 : 750g of Cumbu Napier + 250g of Cow dung + 1000ml of water
- ❒ 25:75 (Cumbu Napier : Cow dung)

  T5 : 250g of Cumbu Napier + 750 g of Cow dung + 1000ml of water
- ❒ 25:25 (Cumbu Napier : Cow dung)

  T6 : 250g of Cumbu Napier + 250 g of Cow dung + 1500 g of water

Results and Discussion

Characterization of substrate

Table 1. Proximate analysis of Cumbu Napier CO-4

S.No	Constituents	%
1.	Moisture content	8
2.	Volatile matter	70
3.	Ash	8
4.	Fixed carbon	14

Calorific Value

Sample 1 : (Powder)

Initial temperature = 32.15°C

Final temperature = 33.90 ° C

Calorific value = (33.90 - 32.15) * 2240

= 3920 kcal/kg

*Sample 2 : (Briquette***)**

Initial temperature = 33.52° C

Final temperature = 35.39 ° C

Calorific value = (35.39 – 33.52) * 2240

= 4188.8 kcal/kg

Since the Calorific value of Cumbu Napier briquettes is nearly equal to the calorific value of wood of about 4000-5000 kcal/kg, it is a good substitute of fuel for burning

Hardness test

*Briquette Sample 1***:**

Initial weight: 120g

Final weight: 65g

*Briquette Sample 2***:**

Initial weight: 117g

Final weight: 66g

Since nearly half the weight of briquette is retained after these many trails, the briquette is considered to be a good one

Water Stability test

Briquette Sample 1: 5 – 10 minutes

Briquette Sample 2: 11 minutes

It is inferred that both the briquettes are considered to be an excellent one since they retain its stability up to 10 minutes under water

Batch Digestion Studies (Biogas)

The biogas production started after 24 hr of the bottling and reached maximum after the second week. The batch digestion was continued up to four weeks after which the gas production started declining. The digestion period for all the treatments was found to be 20 days, when the gas production started declining. The gas production behavior was entirely different in all the treatments and study.

Average Biogas Production (in 4 days interval)

The average gas production varied from 0.03 lit/day to 0.117 lit/day. The maximum gas production was 0.286 lit/day in the 9th day. The average biogas production was found to be higher in the 12th day after which the production of the biogas starts deteriorating.

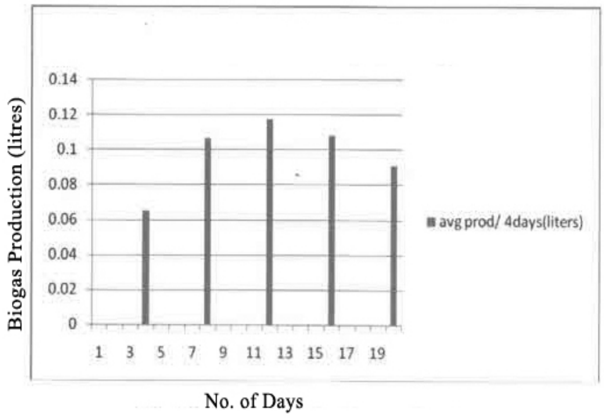

Fig. 1. Average biogas production/four days

Maximum Biogas Production

The maximum biogas produced was in treatment T6 followed by T2 and T5 with the biogas production of about 0.21 lit/day, 0.19 lit/day and 0.13 lit/day respectively with the TS of about 10%

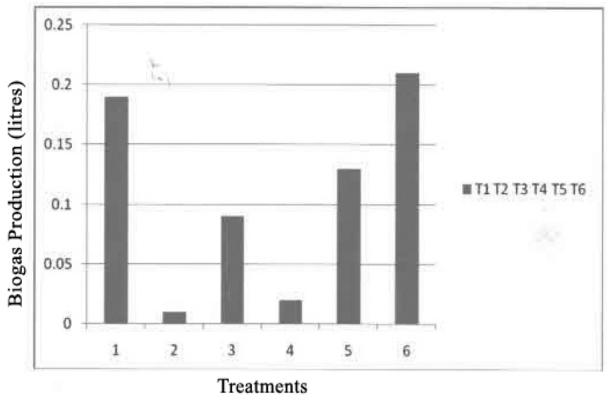

Fig. 2. Maximum biogas production of treatments in batch study

1. The gas production is found to be the maximum for the treatment in which 10% TS is maintained and the gas production was 0.1 lit/day on an average.
2. The methane content was found to be higher in treatment T6 with a methane content of about 0.2 lit/day.
3. The amount of biogas produced per day is 0.1 m^3.

Conclusion

The briquetting of Cumbu Napier CO^{-4} produced a calorific value almost equal to that of briquettes made of wood and the further results obtained through hardness and water stability test proved that Cumbu Napier CO^{-4} is a viable source of briquette and hence can be used as a source of fuel. From the study on biogas it was evident from the result that the Cumbu Napier CO^{-4} samples used in the investigation are good for biogas production. Considering the batch system, among the six treatments, the treatment T6: 250g Cumbu Napier + 250 g of Cow dung + 1500 ml of water was found to be best for recommendation. The briquettes of the crop would reduce the usage of wood for burning and the biogas produced can supplement fossil fuel thereby paving way for a sustainable future. Thus this study established a proof of concept for the use of the fodder crop Cumbu Napier CO^{-4} hybrid as an energy substitute. In this research the biogas required for the efficient frying of chips has been calculated and the stove has been designed based on the requirement. Also the gasification potential of the cashew nut shell has been studied and found that the can be significantly utilized for gasification process as it contains large volatile content and low ash content.

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References

Murugan, D. 2011. Studies on energy consumption in agricultural production in India: A critical Evaluation. *International Journal of Agriculture, Environment and Biotechnology* **4**(1): 89-94.

Olorunnisola, A.O. 2004. Briquetting of Rattan furniture waste. *Journal of Bamboo and Rattan* **3**(2): 139-149. doi: 10.1163/156915904774195133

Sarbjeet, S.S. and Anand, G. 2013. Present Status of Renewable Energy Sources in Punjab. *International Journal of Agriculture, Environment and Biotechnology* **6**(2): 317-333.

Singh, A. and Singh, Y. 1992 Briquetting of Paddy Straw. Agricultural Mechanization in Asia, Africa and Latin America. 42-44.

Surajit, 2012. Briquet Ting Machine. http://www.scribd.com/doc/91622813/Briquet-Ting-Machine Accessed 24 November 2012.

Suyog Vij, 2011. Biogas Production from Kitchen Waste. Seminar report submitted to National Institute of Technology, Rourkela.

Vijayakumar, G., Babu, C., Velayudham, K. and Raveendran, T.S. 2009. A High Yeilding Cumbu Napier Grass CO (CN) 4. *Madras Agricultural Journal*. **96**(7-12): 291-292.