

**BIOGAS PRODUCTION POTENTIAL OF PRE-TREATED  
FODDER RESIDUE**

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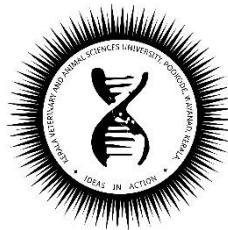
**THESIS**

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**DEPARTMENT OF LIVESTOCK PRODUCTION MANAGEMENT  
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**DECLARATION**

I hereby declare that this thesis, entitled “ BIOGAS PRODUCTION POTENTIAL OF PRE-TREATED FODDER RESIDUE ”is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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# **Introduction**

## 1. INTRODUCTION

India has achieved tremendous development in Animal Husbandry sector in becoming world's largest producer of milk. In tune with the global scenario, the country witnessed a change in farm structure from sustainable small holder to medium and large scale intensive farms. Intensification of farming sector under constraint land availability results in accumulation of waste in and around farms which are potent pollutants. Traditional grazing systems has been replaced by a cut and carry system where fodder is produced at different location and is transported to the farm for use as feed source. This results in heavy wastage due to variability in palatability and maturity of fodder. Utilisation of these wastes will increase the sustainability of the farm and ensure economic and environmental stability. Global interest has grown over utilisation of biomass for energy production and reducing the carbon footprint. The fodder residue wasted in livestock farms offers a good source as feed stock for biomethanation and energy production reducing the carbon emissions. Biogas technology has the advantage that the input for energy production is waste materials which are cheap and available throughout the year. The end product of anaerobic digestion namely slurry can be utilised as manure for cultivation of crops.

Biomethanation is a process by which organic material is microbiologically converted under anaerobic conditions to biogas. The biogas technology has immense potential in animal farming and agriculture where the leftover dung and residues can be utilised so as to convert it into energy and a soil ameliorant. In an energy deficit country like India which is developing faster than developments in energy sector, alternate source of energy are always important. The agro climatic condition in the country is suitable for optimum production of biomethanation units.

Biogas production Technology is a farmer friendly technology with conversion of farmyard waste into methane along with nutrient rich fertilizer. Under the National Biogas Programme, around 48.6 lakhs biogas plants have been

installed over the time by the Ministry of New and Renewable Energy, Government of India. High percentage of non-functioning bio-digesters, occur due to improper maintenance or lack of adequate knowledge on biogas technology. To overcome these, there is a need to understand the different factors affecting anaerobic digestion and to find out the viable options in selection of substrate, design and operating conditions of biomethanation units, for sustainable production in different agro-climatic conditions. The anaerobic digestion technology has been time tested as energy conserving and environmental friendly.

Current cattle population in Kerala is 13.2 lakh cattle heads according to 2012 (19<sup>th</sup>) livestock census. Livestock enterprises in Kerala is having small and medium farms. Indigenous fodder and collected weeds form the main source of roughage for the livestock sector. Increased maturity and lignification due to late harvest results in wastage of the weeds and fodders. This results in heaping of waste in farm premises with loss of nutrients as volatile fractions and leachate which are potent challenge to environment. Removal of weeds from public places is now done using weed cutters where in the weeds are shredded into fine particles and is left over to degrade resulting in nutrients loss. The weeds and leftover grasses from farms and other sources could be utilised for energy production by anaerobic digestion which results in locally produced green energy and soil conditioner in the form of slurry. The bottleneck of utilizing weeds is the high lignin content and hence methods to break the lignin bonds will help to utilise it for better bio-digestion. Hence technologies to digest the lignin bond will have high practical utility in biomethanation of fodder waste. Co-digestion is the simultaneous digestion of more than one type of waste in the same unit with increased methane output and is widely practiced over a single feedstock-digestion. The present study includes the Co-digestion of cattle dung along with fodder residue. This will serve as a platform for further studies and will help in giving proper advice to the farmers in the field of waste management and efficient energy utilization of biogas plants.

The main objectives of the study were:

1. Compare the quantity and heat generation potential of biogas produced from fodder residue co digested with cow dung, using portable bio-digester
2. Assess the fertilizer value of sludge obtained

# ***Review of Literature***

## 2. REVIEW OF LITERATURE

### BIOGAS

Biogas is a versatile renewable energy source and a carbon neutral fuel from organic waste which help in reducing global warming, by decreasing dependency on fossil fuel. The abundant availability of lignocelluloses worldwide together with the high carbohydrate content makes it optimal feedstock for biogas production. For effective digestion of lignocelluloses by bacteria, the plant material must be broken down (Uzodinma and Ofoefule, 2009). Furthermore, the imbalance in the ratio of carbon and nitrogen of the plant raw materials can limit the rate of organic conversion into methane. So efforts are needed to minimize these limitations so as to popularize this technology in the rural areas. The available literature on various factors affecting the biogas and the co-digestion of fodder residue with cow dung has been reviewed and presented under the following head.

#### 2.1 Biogas Technology

Nagamani and Ramasamy (1999) reviewed that biogas technology as an alternative source of energy, and this technology could meet the basic need for cooking fuel in rural parts of India.

Kashyap *et al.* (2003) reviewed that, “In India alone, there are an estimated over 250 million cattle and if one third of the dung produced annually from these is available for production of biogas, more than 12 million biogas plants can be installed.”

The production of methane from anaerobic digestion depends on the kind of material added to the digester, the hydraulic retention time (HRT), the temperature, and the solids loading. (Yadvika *et al.*, 2004).

Petersson *et al.* (2007) stated that Bioenergy from renewable resources is already today a viable alternative to fossil fuels; As there is a rapid growth in demand for bioenergy several raw materials have to be considered. Lignocellulose

is the most abundant organic material on earth and is therefore a promising raw material for bioenergy production.

Saseendran *et al.* (2009) stated that biogas technology could prevent the pollution of soil and water and provide pathogen free sludge as a fertilizer for organic cultivation.

“In India around 980 million tonnes of cattle dung produced every year which could produce 41,000 million cubic meters of biogas per annum ie, sufficient to produce 196 MW of electric power.” (Khoiyangbam *et al.*, 2011)

Methane, a greenhouse gas, plays an important role in global warming. “Current atmospheric concentration of CH<sup>4</sup> have risen from 722± 25ppb in 1750-1803± 2ppb in 2011 and is increasing at the rate of 0.8–1% per year, which has a significant effect in global warming.” (IPCC, 2013)

## **2.2 Biogas**

Biogas is about 20 percent lighter than air and has an ignition temperature in the range of 650° to 750° C. It is an odourless and colourless gas that burns with clear blue flame similar to that of LPG gas. (Sathianathan,1975)

Biogas is produced by the anaerobic digestion of biodegradable material such as manure, sewage, plant residue, and agricultural wastes. (Cuellar *et al.*, 2008).

Biogas, a renewable source of energy which is also environmentally friendly, is generated through anaerobic digestion of biomass waste (animal dung, plant residue, waste waters, agro industrial wastes and solid wastes). (Uzodinma and Ofoefule, 2009)

Biogas was the mixture of gas produced by methanogenic bacteria while acting on upon biodegradable materials in an anaerobic condition. (Porrás and Gebresenbet, 2003; Bajracharya *et al.*, 2009)

### 2.2.1 Quantity of Biogas

Pal *et al.* (1986) stated that, In tropical Indian conditions it had been estimated that the average yield of biogas in  $\text{m}^3$  per  $\text{m}^3$  capacity of digester for a small  $6 \text{ m}^3$  digester was  $0.35 \text{ m}^3$  at standard temperature pressure for a daily slurry feed of  $100 \text{ kg}$  (50% wet dung + 50% water).

Singh *et al.* (1997) stated that the average gas production from one kg of dung was  $0.057 \text{ m}^3$  per day.

Nagamani and Ramasamy (1999) stated that the potential biogas production of cattle waste was  $0.046 \text{ m}^3$  per kg.

Porras and Gebresenbet (2003) reported that the potential biogas production from cattle (cows and buffaloes) dung was  $0.032\text{-}0.045 \text{ m}^3$  per kg.

Rajendran *et al.* (2012) reported that, In floating drum type biogas digesters, the volume of biogas accumulated under the drum was easily calculate from the position of the drum

Paudel (2012) calculated the amount of gas produced in the portable biogas plant by measuring the height of gasholder, and the observations were analysed at 24 hour interval.

Shejir (2014) reported that average biogas production potential of cattle waste during summer and winter season was  $0.0739 \text{ m}^3$  in a portable bio digester of  $0.5 \text{ m}^3$  capacity.

### 2.3 Anaerobic Digester

Anaerobic digester was an operational device which converted fermentable organic matter into combustible gas and excellent organic manure by a process of microbial digestion in the absence of air (Khoiyangbam *et al.*, 2011).

Rajendran *et al.* (2012) classified household anaerobic digesters into Fixed dome (Chinese or hydraulic) digesters, Floating drum digesters and Plug flow

digesters. The fixed dome type digesters are usually built underground. Floating drum type biogas plants are made up of two integral units, one a gas holder and the second a digester with inlet and outlet pipes. Plug flow digesters or tubular digesters were the portable models built over the ground.

### **2.3.1 Floating Drum type**

Meher *et al.* (1994) reported that the performance of floating dome biogas plant was better than the fixed dome biogas plant. There was an increase of 11.3% biogas production in floating dome biogas plant.

Singh *et al.* (1997) stated that Floating drum type plant was made up of two main units, the gas holder and a digester with inlet and outlet pipes. In this type, different number of plants like KVIC, Pragathi, Ganesh, Ferro-cement, etc., has been approved by the Ministry of Non-conventional Energy Sources (MNES), New Delhi.

Rajendran *et al.* (2012) stated that out of all the different digesters developed, the floating drum model developed by India and the fixed dome model developed by China have continued to perform until today. Small scale digesters have less maintenance and more or less adaptable to the climatic condition of many developing countries. He also concluded that house hold digesters were useful for farmers and rural people to meet their energy needs and had advantages like one to reduced waste production and valuable energy generation.

Divya *et al.* (2014) reported that floating dome biogas plant had got increased efficiency in gas production when compared with fixed dome biogas plant.

## **2.4 Anaerobic Digestion**

Anaerobic digestion process occurs by bacteria existing in oxygen-free environments decompose organic matter into energy and it could be any organic material from plants, animals or their waste (Wilke, 2000).

Burton and Turner (2003) stated that the anaerobic digestion of organic substances was a complex process involving (i) enzymatic hydrolysis and the formation of sugars, amino acids and fatty acids; (ii) acidogenesis of volatile fatty acids (VFAs) and (iii) methane and carbon dioxide.

Agrahari and Tiwari (2011) reviewed that “anaerobic decomposition was a two-stage process, as specific bacteria fed on certain organic matter. In the first stage, acidic bacteria dismantled the complex organic molecules into peptides, glycerol, alcohol and the simpler sugars. When these compounds were produced in sufficient quantities, a second type of bacteria converted these simpler compounds into methane”.

Anaerobic digestion was a biochemical process in which organic matter in absence of air (oxygen) was converted to a mixture of methane and carbon dioxide. “Anaerobic digestion was a four step process namely hydrolysis, acetogenesis, hydrogenesis and methanogenesis in which complex organic materials were converted to the end products of methane and carbon dioxide.” (Mondal and Biswas, 2012; Rajendran *et al.*, 2012).

Anaerobic digestion was a potential environment friendly technique which produced energy in the form of biogas and the residue could be used as soil conditioner. (Sridevi and Ramanujam, 2012)

#### **2.4.1 Factors affecting Anaerobic Digestion**

Khalid *et al.* (2011) reviewed that the biogas yield was affected by many factors including type and composition of substrate, microbial composition, temperature, moisture and digester model etc.

The yield of biogas from any substrate is highly dependent on the C/N ratio of the material, concentration, pH, temperature. (Ponsa *et al.*, 2008)

Dioha *et al.* (2013) reported that various factors such as biogas potential of feedstock, design of digester, inoculum, nature of substrate, pH, temperature, volatile fatty acids, loading rate, hydraulic retention time, C : N ratio etc. influence the biogas production.

Divya *et al.* (2014) suggested that, all the parameters such as feedstock characteristics, hydrogen ion concentration (pH), temperature, substrate loading rate, hydraulic retention time, total solids and volatile solid contents, C: N ratio, bioreactor design etc. should have to be maintained optimum during anaerobic digestion for obtaining better biogas production.

#### **2.4.1.1 Temperature**

An and Preston (1999) found that the average air temperature from maximum and minimum thermometer ranged between 25.3 to 27.3°C, and this range of temperature was suitable for microbial population.

El-Mashad *et al.* (2003) reported three temperature zones ie, thermophilic zone (above 45 °C), mesophilic zone (22-45°C) and psychrophilic zone (below 20°C) during anaerobic digestion process. The effective and efficient anaerobic digestion was carried at both thermophilic and mesophilic temperature. However 30-35°C was considered as the optimum temperature.

Khoiyangbam *et al.* (2004) found that the methane emission mounted with the increase in monthly temperature. The methane emission rates also increased correspondingly from the slurry displacement chambers of biogas plants during these months. The ambient and slurry temperatures of the biogas plant were recorded by using an ordinary mercury thermometer when the gas samples were taken.

The operation in the mesophilic range is more stable and requires a smaller energy expense (Fernandez *et al.*, 2008; Ward *et al.*, 2008).

Ward *et al.* (2008) has shown optimal growth temperatures for some methanogenic bacteria: “37–45°C for mesophilic *Methanobacterium*, 37–40°C for *Methanobrevibacter*, 35–40°C for *Methanobolus*, *Methanococcus*, *Methanoculleus*, *Methanospirillum* and *Methanobolus*, 30–40°C for *Methanoplanus* and

*Methanocorpusculum* and 50–55°C for thermophilic *Methanohalobium* and *Methanosarcina*.”

Adelekan and Bangboye (2009) reported that biogas production was greatest when the digester temperature was in the range of 32-40 °C. For optimum production the digestion temperature should occur in the mesophilic range of 32-40 °C.

The relative humidity and maximum minimum temperatures of the experimental area were recorded accurately by using Digital Hygrotherm (%) and Zeal’s maximum and minimum thermometer respectively (Smitha, 2010).

Khalid *et al.* (2011) observed that temperature had a significant effect on the microbial community, process kinetics and methane yield. Lower temperatures were known to decrease microbial activity, substrate utilization rates and biogas production. In contrast, high temperature lowered biogas yield due to production of volatile gases such as ammonia which suppressed the activity of methanogenic bacteria.

#### **2.4.1.2 pH**

FAO, (1996) reported that, the pH will be low at the beginning as a result of acid production and if increased gradually resulting in nitrogen digestion and formation of ammonia. The biogas production will be stabilized when the pH got stabilized between 7.2 and 8.2.

An and Preston (1999) recommended that the pH value of the slurry should be maintained above 7.0 for maximum gas production. The pH of the input and effluent material were analysed using digital pH meter.

Nagamani and Ramasamy (1999) reported that optimum pH for biogas yield was 7.0-7.2 though the gas production was satisfactory between pH 6.6 and 7.6. The pH of the digester was a function of level of carbon dioxide present,

alkalinity of bicarbonate and the amount of volatile fatty acids produced in the system.

Thy (2003) noted that during initial period of fermentation pH inside the digesters falls below five due to large amount of organic acid by acid-forming bacteria.

Yadvika *et al.* (2004) recommended that by feeding the biogas digester at an optimum loading rate, the pH of the digester can be kept within 6.8–7.2.

Factors like volatile fatty acids, ammonia, carbon dioxide and acetic acid have an impact on the pH and might inhibit the activity of the microbes. (Nijaguna, 2002 ;Yadvika *et al.*, 2004)

Ward *et al.* (2008) found that a pH range of 6.8–7.2 was ideal for anaerobic digestion.

Al Seadi *et al.* (2008) stated that the optimum pH level for mesophilic digestion was between 6.5 and 8.0 and the process was severely inhibited when the pH value decreased below 6.0 or rises above 8.3

Lee *et al.* (2009) reported that methanogenesis in an anaerobic digester occurs efficiently at pH 6.5– 8.2, while hydrolysis occurs at 5.5 and acidogenesis at 6.5.

Khoiyangbam *et al.* (2011) stated that the proper pH for anaerobic fermentation was between 6.8 and 8.0 and efficient digestion occurred at neutral pH. Any deviation of pH would hamper biogas production. During the anaerobic digestion, the pH dropped off to 6.2 and then the pH increased and stabilized between 7 and 8.

Sridevi and Ramanujam (2012) stated that the optimum pH range for the growth of methanogens was 6.8 to 7.4 and that it should be maintained throughout the anaerobic digestion process.

Rajendran *et al.* (2012) reviewed that most of the methanogens grew at a pH range of 6.7–7.5.

The pH of anaerobic digestion was recorded using digital pH meter. (Itodo and Awulu 1999; Radhakrishnan, 2013).

#### **2.4.1.3 Carbon Nitrogen Ratio (C:N)**

For efficient biogas plant operation, the C:N ratio of input substrate should be kept within the desired range since the nutrient composition has an impact on the optimal growth and activity of microorganism (Nijaguna, 2002).

For getting optimum C:N ratio, cattle manure has been utilized as co-digest substrate with other waste material such as organic industrial waste and household waste and have been suggested by different studies in order to optimise the methane yield (Nijaguna, 2002)

A C:N ratio ranging from 20 to 30:1 is considered optimum for anaerobic digestion. If the C:N is very high, nitrogen will be consumed rapidly by methanogens for meeting their protein requirement and will no longer react with left over carbon content of the material. As a result gas production will be low. Otherwise ammonia formation occurred and nitrogen will be accumulated. (Porrás and Gebresenbet 2003)

For optimum functioning microbes usually need 25-30:1 ratio of C to N with the largest part of carbon being easily digestible. (Yadvika *et al.*, 2004)

Igoni *et al.* (2008) reported that the carbon was determined using the Walkey-Black method, the nitrogen was determined with the usual macro-kjedahl method.

Bouallagui *et al.* (2009) suggested that a C/N ratio between 22 and 25 seemed to be best for anaerobic digestion of fruit and vegetable waste.

Guermoud *et al.* (2009) and Lee *et al.* (2009) reported that the optimal C/N ratio for anaerobic degradation of organic waste was 20–35.

#### **2.4.1.4 Pre-treatment**

Recycling of digested slurry along with filtrate had been tried to conserve water and to enhance biogas production. (Malik and Dahiya, 1990)

Crop residues like maize stalks, rice straw, cotton stalks, wheat straw and water hyacinth enriched with partially digested cattle dung enhanced gas production in the range of 10–80 percent. (El Shinnawi *et al.*, 1989 ;Somayaji and Khanna, 1994)

Milling (cutting the lignocellulosic biomass into smaller pieces) is a mechanical pre-treatment of the lignocellulosic biomass. The objective of a mechanical pre-treatment is a reduction of particle size and crystallinity. The reduction in particle size leads to an increase of available specific surface and a reduction of the degree of polymerization (DP). (Palmowski and Muller, 1999)

Geetha *et al.* (1994) found that sugarcane bagasse pre-treated with *Phanerochaetechryso sporium* for three weeks under ambient temperature conditions produced higher gas with cattle excreta.

Pre-treatment of fodder using NaOH causes swelling of fibers leading to higher internal surface area, reduction in the degree of polymerization, less crystallinity, breaking down the structural linkages between lignin and carbohydrates. Hsu (1996)

According to Sustainable Development Department, FAO (1996) one kg of pre-treated crop waste and water hyacinth have the potential of producing 0.037 and 0.05 m<sup>3</sup> respectively.

Pre-treatment enhanced the degradation of volatile solids and thus increase biogas yield (Tiehm *et al.*, 2001).

Alkali treated (one percent NaOH for seven days) plant residues (lantana, wheat straw, apple leaf litter and peach leaf litter) supplemented to cattle dung resulted in almost twofold increase in biogas and CH<sub>4</sub> production. (Yadvika *et al.*, 2004)

Jerger *et al.* (2011) reported an improvement in rate of methane gas production using three different species of forest residues, previously treated with a solution of NaOH to 17 percent.

#### ***2.4.1.5 Substrate composition and degradability***

Caulfield and Moore (1974) noted that extent of the hydrolysis depends on the particle size and available surface rather.

The substrates were analysed for Moisture (dry matter), Crude Protein, Crude Fat (ether extract), Crude Fibre (AOAC, 1990).

Lotte *et al.*, (1996) found that animal manure had a good nutrient balance and could be easily made into slurry and the relative biodegradability ranges from 28-70 per cent.

The potential for biogas production varies with feedstock. The substrates generally used as feedstock in small scale biogas plants includes animal waste, human waste, kitchen waste and crop residues. (Porras and Gebresenbet, 2003)

Lignocellulosic biomass including agricultural residues, paper wastes and kitchen wastes, were ideal resources for biogas production. (Bayer, 2007).

#### ***2.4.1.6 Loading rate and dilution***

Sasse (1988) observed eight per cent solid contents in the fermentation slurry prepared from fresh cattle manure with 16 per cent solids when mixed with water in the proportion of 1:1.

An and Preston (1999) stated that the biogas yields differed according to loading rate and increased linearly with the loading rate.

Porras and Gebresenbet (2003) stated that loading rate is the amount of raw materials fed per unit volume of digester capacity per day. In India's condition about six kg of dung per m<sup>3</sup> of digester was recommended in case of a cow dung plant. If the biogas plant is overfed, acids would accumulate and methane production will be inhibited. Dilution and consistency of inputs: Before feeding the digester, the excreta especially fresh cow dung has to be mixed with water at the ratio of 1:1 on a unit volume basis. The dilution should be made to maintain the total solids from 7 to 10 percent.

The rate at which substrate is supplied to the digester is referred to as organic loading rate and the gas production was highly dependent on this. There was an optimum loading rate for a particular size of biogas plant, which would produce maximum gas at that rate and beyond which further increase in the quantity of substrate will not proportionately produce more gas. (Yadvika *et al.* 2004)

Iteun *et al.* (2007) found that the best proportion for dilution of substrate and water was 1:1 for better gas production which ensured eight per cent of total solids.

Rajendran *et al.* (2012) reported that the solid concentration in the household biogas digesters varied between five to ten per cent. The biogas production decreased considerably when the solid concentration increased to nineteen per cent.

#### **2.4.1.7 Hydraulic Retention Time (HRT)**

Tomar (1995) opined that the HRT was the time taken by the substrates for maximum gas production. About 70-80 per cent of the substrate completed their digestion at Hydraulic Retention Time and it varied with temperature and substrate. In Indian condition, the HRT varied from 30 to 60 days and in Kerala condition it was 30 days.

According to Yadvika *et al.* (2004) HRT was the average time spent by the input sludge inside the digester before it comes out. In tropical countries like India, the HRT varied from 30 to 50 days. A shorter HRT was likely to face the risk of washout of active bacterial population while longer retention time required a larger volume of the digester.

Adelekan and Bamgboye (2009) stated that the HRT in anaerobic digesters could be determined by calculating the number of days required for displacement of the fluid volume of the culture. At a given organic loading rate, the HTR was lower when feeds with high water content was loaded.

HRT varied between 20 and 100 days for mesophilic household digesters. Decreasing HRT from 90 days to 60 days and increasing the organic loading rate by diluting the substrate from 1: 4 to 1: 2 would be beneficial for the better performance of the digester (Ferrer *et al.*, 2011; Rajendran *et al.*, 2012).

### **2.5 Co-Digestion**

Crop residues like rice straw, maize stalks, water hyacinth, wheat straw and cotton stalks got co-digested with partially digested cattle dung which enhanced gas production in the range of 10-80%. (El Shinnawi *et al.*, 1989; Somayaji and Khanna, 1994)

Co-digestion is the simultaneous digestion of more than one type of waste in the same unit (Agunwamba, 2001).

Yadvika *et al.* (2004) reported that today's energy demanding life style, there is a need for exploring and exploiting new sources of energy which are renewable and environmentally harmless. Nowadays various cellulosic biomass (cattle dung, agricultural residues, etc.) are available in plenty which have very good potential to cater to the energy demand, especially in the domestic sector.

## **2.6 Heat Generation Potential**

The amount of biogas used in boiling and cooking was determined from the operating pressure of the plant measured from a manometer that was placed between the stove and the plant. The results obtained showed that 0.14 l of water was boiled in 1 minute while 5.13 g of rice and 2.55 g of beans cooked in a minute. (Itodo *et al.*, 2007).

The calorific value of biogas is around 6.0 – 6.5 kWh / m<sup>3</sup>, depends on the volume of methane present, which comes between 55 – 70%. (Deublein and Steinhauser, 2011).

## **2.7 Sludge**

Ames (1976) reported that the digested sludge contained excellent nutrients such as N, P, K, Ca, Mg, Fe, S and other trace elements.

Nagamani and Ramasamy (1999) stated that there was a significant positive correlation between the mineralization and slurry levels.

Thy (2003) found that bio digesters had an important role for reduction of pathogens in sludge and conversion of organic nitrogen to ammonia nitrogen.

FAO (2007) reported that biogas slurry consisted of 93 per cent water and 7 per cent dry matter (4.5 per cent organic and 2.5 per cent inorganic matter).

### **2.7.1 Manurial value of slurry**

Balasubramanian and KasturiBai (1992) evaluated the nutrient status of slurry added to the digester and observed the total Kjeldal nitrogen and total potassium recovered after biogas production. The total phosphorous showed a 30 per cent decrease and ammonia nitrogen showed 70 per cent increase compared to the influent.

According to sustainable Development Department, FAO (1996) after extraction of biogas (energy) the slurry comes out of the digester as by-product of the anaerobic system. It is almost pathogen free stabilised manure and it could be used to maintain soil fertility and enhance crop production.

FAO (2007) reported that “the percentage of NPK content of slurry on wet basis was 0.25, 0.13 and 0.12 while on dry basis it was 3.6, 1.8 and 3.6 respectively.”

Uzodinma and Ofoefule (2009) stated that the effluent of anaerobic digestion process was a residue rich in essential inorganic elements needed for healthy growth of plant also known as bio fertilizer and it had no detrimental effects on the environment.

Weiland (2010) mentioned that the anaerobic digestion process resulted in mineralization of organically bounded nutrients especially nitrogen, by reducing C/N ratio.

Deshmukh (2012) reported that sludge and effluent possesses high manurial value and it could be used as a supplement to fertilizers in agriculture.

### **2.7.2 Parasitic Load (Eggs Per Gram)**

Balsari *et al.* (2005) reported that animal waste caused environmental pollution when applied to land without appropriate control and management.

The egg count of the parasites in the substrate and sludge could be assessed by using Whitlock McMaster worm egg counting chamber (Paniker, 2007).

Saseendran *et al.* (2009) stated that biogas technology could prevent pollution of soil and water and it provided pathogen free sludge as fertilizer for organic cultivation.

Weiland (2010) opined that anaerobic digestion process would be able to inactivate weed seeds, bacteria, viruses, fungi, and parasites in the feedstock which was of great importance if the digestate was used as fertilizer

# ***Materials & Methods***

### 3. MATERIALS AND METHODS

The study was conducted to compare the quantity and heat generation potential of biogas produced from pre-treated fodder residue co-digested with cow dung using portable biodigester. The facilities available at College of Veterinary and Animal Sciences, Kerala Veterinary and Animal Sciences University, Mannuthy, were utilized for the study.

#### 3.1 LOCATION OF STUDY

The study was conducted at University Livestock Farm and Fodder Research and Development station (ULF&FRDS), College of Veterinary and Animal Sciences, Mannuthy, Thrissur which is situated 22.25 m above mean sea level at 10° 53'' N Latitude and 76° 26'' E Longitude.

#### 3.2 PERIOD OF STUDY

The experiment was conducted February–March 2015. The observations were taken for 42 days.

#### 3.3 CLIMATOLOGICAL DATA

##### 3.3.1 Micro climatic variables

Micro-climatic variables were measured inside the shed where the biogas plants were placed. The maximum and minimum temperatures were recorded daily using Zeal's maximum and minimum thermometer. The relative humidity was recorded daily using HTC-1 digital hygrometer. The observations were recorded daily at eight am by placing the instruments at the top level of biogas plants.

### 3.3.2 Macro-climatic variables

The meteorological data over a period from February to March 2015 were obtained from the meteorological observatory unit, CADEX, College of Veterinary and Animal Sciences, Mannuthy.

## 3.4 DESIGN OF EXPERIMENT

### 3.4.1 Biogas plants

The Portable floating drum biogas plants of 0.5 m<sup>3</sup> capacity, designed by Agro Biotechnology Agency for Rural Employment Development (ABARD), Kerala Agricultural University, Vellanikara were utilised for the study. The schematic sketch of portable floating drum biogas plant is given in Plate.1.

### 3.4.2 Substrates

The cattle dung and fodder residue from the ULF&FRDS were used as substrates for biogas production.

### 3.4.3 Treatments

- ❖ **T1-** One kg cow dung with one kg chopped fodder residue along with two liters of water loaded daily for co-digestion.
- ❖ **T2-** One kg cow dung co-digested with one kg chopped fodder residue soaked in two liters of water for seven days loaded daily
- ❖ **T3-** One kg cow dung co-digested with one kg chopped fodder residue soaked in two liters of slurry for seven days loaded daily.
- ❖ **T4-** One kg cow dung co-digested with one kg chopped fodder residue soaked in two liters of one percent NaOH for seven days loaded daily.

The experiment was conducted for six weeks on February- March 2015. One kilogram of fresh excreta of cattle mixed with pre-treated fodder residue which was diluted with water to 10 percent dry matter level and loaded daily in the morning (eight am) to four different plants. Volume of biogas produced was

recorded (Paudel, 2012) at constant pressure for the following days till a constant gas production was obtained (42 days). The biogas volume (Parajuli, 2011) was recorded daily.

### 3.5 PHYSICO-CHEMICAL CHARACTERS OF SUBSTRATES

#### 3.5.1 Chemical analysis of substrates

Fresh samples of the substrates were collected and was analysed for dry matter and crude fiber content (AOAC, 1990) before the start of experiment.

#### 3.5.2 Temperature

The temperature of the substrates was recorded in the morning (8 AM) daily before loading using mercury bulb thermometer (Khoiyangbam *et al* ., 2004).

#### 3.5.3 pH

The pH of the substrates were recorded in the morning (8 am) daily before loading using Eutech digital PCStestr- 35 (Radhakrishnan, 2013).

#### 3.5.4 Manurial value

Manurial value of the substrates were determined fortnightly for the Nitrogen (N), Phosphorus (P) and Potassium (K) contents on DM basis (Paudel, 2012).

### 3.6 DIGESTA

The temperature and pH of the digesta were recorded daily in the morning (8 AM) before loading, using mercury bulb thermometer (Khoiyangbam *et al*., 2004) and Eutech digital PCStestr 35 (Radhakrishnan, 2013) respectively.

### 3.7 BIOGAS PRODUCTION

#### 3.7.1 Biogas production

The volume of gas produced in each treatment was measured daily in the morning (8 AM) before loading. The increase in height of gas holder was recorded and volume was calculated (Paudel, 2012) using the equation given below.

$$\text{Volume of the biogas, } V = \pi r^2 h$$

Where,  $r$  denotes radius of gas holder and  $h$  denotes the increase in height after gas production.

### 3.8 HEAT GENERATION POTENTIAL

Heat Generation Potential was assessed by burning test (time required to boil one L of water at room temperature) fortnightly.

### 3.9 CARBON NITROGEN RATIO

Carbon Nitrogen ratio of the substrate were assessed and recorded fortnightly (Walkley and Black, 1934)

### 3.10 COLLECTION OF SLUDGE (SLURRY)

The slurry was collected continuously by placing plastic buckets under the slurry outlet.

#### 3.10.1 Physico-chemical characters of slurry

##### 3.10.1.1 Chemical analysis of slurry

DM and Crude Fibre of the slurry (sludge) were determined (AOAC, 1990) fortnightly, throughout the experiment period.

### ***3.10.1.2 Temperature***

The temperature of the slurry from each biogas plant was recorded fortnightly in the morning (8 AM) using mercury bulb thermometer (Khoiyangbam *et al.* , 2004).

### ***3.10.1.3 pH***

The pH of the slurry from each biogas plant was recorded fortnightly in the morning (8 am) using Eutech digital PCStestr 35 (Radhakrishnan, 2013).

### ***3.10.1.4 Manurial value***

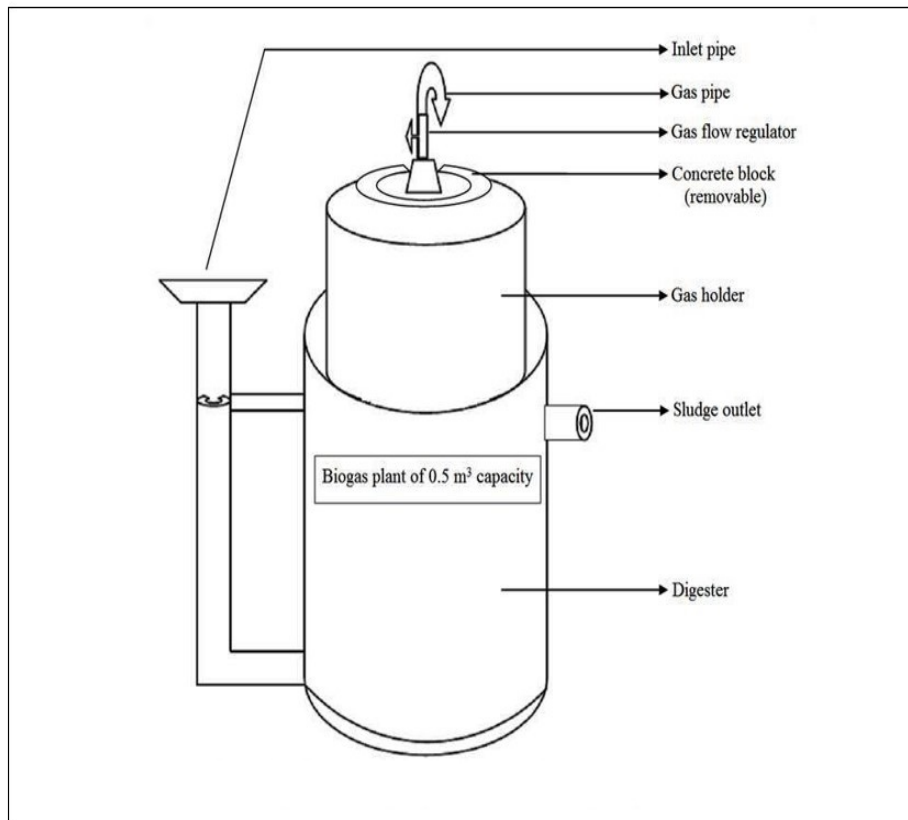
Manurial value of the slurry from each biogas plant was determined fortnightly for the Nitrogen (N), Phosphorus (P) and Potassium (K) contents on DM basis (Paudel, 2012).

### **3.10.2 Parasitic load**

The Parasitic load of the sludge and substrate were assessed once in a week in the morning using Whitlock McMaster worm egg counting chamber (Paniker, 2007).

## **3.11 STATISTICAL ANALYSIS**

The data obtained on various parameters during the course of study were statistically analysed using analysis of variance (one-way ANOVA) as described by Snedecor and Cochran (1994).



**Plate 1. Schematic sketch of portable floating drum biogas plant (0.5m<sup>3</sup> capacity)**



Portable Floating drum type Biogas plant of 0.5 m<sup>3</sup> capacity



Substrate

# **Results**

## 4. RESULTS

### 4.1 CLIMATOLOGICAL DATA

#### 4.1.1 Micro-climatic variables

Temperature ( $^{\circ}\text{C}$ ) and relative humidity (%) within the shed were recorded daily at 8 AM. The average daily ambient temperature ranged from 24.1 to 35.5 $^{\circ}\text{C}$  during the period of study. The relative humidity ranged from 41 per cent to 88 per cent.

#### 4.1.2 Macro-climatic variables

The macro-climatic variables considered for the present study included maximum and minimum atmospheric temperature ( $^{\circ}\text{C}$ ), relative humidity (%) and rain fall (mm). The daily average atmospheric temperature ranges from 24.1 to 35.5 $^{\circ}\text{C}$ . The mean weekly minimum and maximum temperature ranged from 26.4 $^{\circ}\text{C}$  to 31.9 $^{\circ}\text{C}$ . The daily average relative humidity ranged from 41 per cent to 88 per cent. No rainfall was recorded during the observation period.

### 4.2. PHYSICO-CHEMICAL CHARACTERS OF SUBSTRATES

#### 4.2.1 Temperature

The temperatures of the substrates were recorded before loading into plants. The mean values ( $^{\circ}\text{C}$ ) were  $25.05 \pm 0.44$  (T1),  $25.02 \pm 0.47$  (T2),  $25.02 \pm 0.45$  (T3),  $25.18 \pm 0.44$  (T4).

#### 4.2.2 Chemical composition

The details of the chemical characteristics of the substrates are furnished in **Table 4.1**.

The moisture content of substrates under different treatments were  $73.14 \pm 0.48$ ,  $78.20 \pm 0.32$ ,  $83.16 \pm 0.28$ ,  $85.07 \pm 0.41$  per cent respectively for groups T1, T2, T3 and T4 respectively. NaOH pre-treated fodder with dung (T4) was having the lowest dry matter content. The corresponding values for crude fibre content were  $26.86 \pm 0.48$ ,  $21.80 \pm 0.32$ ,  $16.84 \pm 0.28$  and  $14.93 \pm 0.41$  per cent

respectively for groups T1, T2, T3 and T4 respectively. From the table it is clear that T4 was having lowest T1 with highest dry matter content. The pH of T4 was higher ( $7.34 \pm 0.03$ ) than T3 ( $6.83 \pm 0.02$ ), T2 ( $6.62 \pm 0.02$ ) and T1 ( $6.62 \pm 0.02$ ). The N, P, K content was higher in T4 than other substrates.

**Table 4.1 Chemical composition and pH of substrate**

Sl. No.	Parameter	T1( C )	T2(D+W)	T3(D+S)	T4(D+N)
1	Moisture (%)	$73.14^d \pm 0.48$	$78.20^c \pm 0.32$	$83.16^b \pm 0.28$	$85.07^a \pm 0.41$
2	Dry matter (%)	$26.86^a \pm 0.48$	$21.80^b \pm 0.32$	$16.84^c \pm 0.28$	$14.93^d \pm 0.41$
3	Crude fiber (%) *	$25.80^a \pm 0.12$	$24.34^b \pm 0.19$	$23.59^c \pm 0.14$	$22.69^d \pm 0.08$
4	pH	$6.62^c \pm 0.02$	$6.62^c \pm 0.02$	$6.83^b \pm 0.02$	$7.34^a \pm 0.03$
5	Nitrogen (%)	$2.45 \pm 0.08$	$2.23 \pm 0.06$	$2.49 \pm 0.03$	$2.70 \pm 0.09$
6	Phosphorous (%)	$1.44 \pm 0.02$	$1.13 \pm 0.04$	$1.29 \pm 0.04$	$1.51 \pm 0.06$
7	Potassium (%)	$0.96 \pm 0.05$	$0.97 \pm 0.03$	$0.88 \pm 0.02$	$1.10 \pm 0.06$

\* on dry matter basis

Means bearing the different superscript within the same column differ significantly ( $P < 0.05$ )

#### 4.3 PHYSICO-CHEMICAL CHARACTERS OF DIGESTA

**Table 4.2 Mean temperature and pH of digesta.**

Substrate	Digesta temperature	Digesta pH
T1(C)	$31.43^c \pm 0.10$	$6.62^d \pm 0.02$
T2(D+W)	$31.30^d \pm 0.06$	$6.87^c \pm 0.02$
T3(D+S)	$31.65^b \pm 0.09$	$7.03^b \pm 0.02$
T4(D+N)	$32.73^a \pm 0.13$	$7.62^a \pm 0.03$

Means bearing the different superscript within the same column differ significantly ( $P < 0.05$ )

From the table it was clear that T4 group was having higher digester temperature and lower pH during the observation period.

**Table 4.3 Mean ( $\pm$ SE) Carbon Nitrogen Ratio of different treatments**

Sl. No.	Substrate	C:N
1	<b>T1(C)</b>	32.59 <sup>a</sup> $\pm$ 0.19
2	<b>T2(D+W)</b>	31.58 <sup>b</sup> $\pm$ 0.05
3	<b>T3(D+S)</b>	29.49 <sup>c</sup> $\pm$ 0.34
4	<b>T4(D+N)</b>	26.41 <sup>d</sup> $\pm$ 0.23

Means bearing the different superscript within the same column differ significantly ( $P < 0.05$ )

From the table it is clear that C:N of group T3 & T4 shows optimum as desired range comes with 25-30:1.

**Table 4.4 Mean ( $\pm$ SE) Heat Generation Potential of different treatment groups**

Sl. No.	Substrate	Heat Generation Potential(time in min)
1	<b>T1(C)</b>	32.33 $\pm$ 0.56
2	<b>T2(D+W)</b>	30.67 $\pm$ 0.49
3	<b>T3(D+S)</b>	28.17 $\pm$ 0.41
4	<b>T4(D+N)</b>	27.33 $\pm$ 0.33

From the table it is clear that group T4 requires less time to boil than that of other groups and it might be due to increased methane potential in group T4.

#### 4.4 VOLUME OF BIOGAS

##### 4.4.1 Comparison of biogas production between substrates

Biogas produced from T4 (D+N) shows higher production than T1, T2 and T3.

**Table 4.5 Mean ( $\pm$ SE) volume of biogas produced from different substrates**

Sl. No.	Substrate	Gas production (m <sup>3</sup> )
1	T1(C)	0.073 $\pm$ .0005 <sup>c</sup>
2	T2(D+W)	0.074 $\pm$ .001 <sup>c</sup>
3	T3(D+S)	0.078 $\pm$ .001 <sup>b</sup>
4	T4(D+N)	0.096 $\pm$ .001 <sup>a</sup>

Means bearing the different superscript within the same column differ significantly ( $P < 0.05$ )

##### 4.4.2 Trend in biogas production during the observation period

The trend in the biogas production during the observation period is given in Fig.1. Biogas production became stabilized when HRT was achieved. T4 (D+N) had shown the highest gas production than the other treatments during observation period.

#### 4.5 FACTORS AFFECTING BIOGAS PRODUCTION

##### 4.5.1 Temperature and pH of substrate and digesta

Temperature of substrate did not show any significant difference as the values are almost constant throughout the observation period. pH of the substrates shows significant difference with an optimum pH for T4.

##### 4.5.2 Micro-climatic variables and gas production

The average daily ambient temperature ranged from 24.1 to 35.5 °C during observation period. The relative humidity ranged from 41 per cent to 88 per cent during observation period.

### 4.5.3 Macro-climatic variable

The daily average atmospheric temperature ranges from 24.1 to 35.5 °C. The mean weekly minimum and maximum temperature ranged from 26.4 °C to 31.9 °C. The environmental temperature was higher during the entire observation period.

## 4.6. PHYSICO-CHEMICAL CHARACTERS OF SLUDGE (SLURRY)

### 4.6.1 Chemical composition of sludge

The details of the chemical characters of the sludge are furnished in Table 4.6.

The moisture content of T1, T2, T3 and T4 of sludge on fresh basis were  $90.36 \pm 0.13$ ,  $90.57 \pm 0.10$ ,  $91.46 \pm 0.11$  and  $93.6 \pm 0.13$  per cent respectively. The crude fibre content of T1, T2, T3 and T4 of sludge  $19.66 \pm 0.2$ ,  $18.63 \pm 0.09$ ,  $17.94 \pm 0.08$ ,  $17.29 \pm 0.04$  respectively. The pH of the sludge was higher in T4 than other substrates.

**Table 4.6 Chemical composition and pH of sludge**

Sl. No.	Parameter	T1( C )	T2(D+W)	T3(D+S)	T4(D+N)
1	Moisture (%)	$90.36 \pm 0.13$	$90.57 \pm 0.10^{ab}$	$91.46 \pm 0.11^c$	$93.6 \pm 0.13^d$
2	Dry matter (%)	$9.64 \pm 0.13^a$	$9.43 \pm 0.10^{ab}$	$8.54 \pm 0.11^c$	$6.40 \pm 0.13^d$
3	Crude fiber (%)**	$19.66 \pm 0.21^a$	$18.63 \pm 0.09^b$	$17.94 \pm 0.08^c$	$17.29 \pm 0.04^d$
4	pH	$6.43 \pm 0.02$	$6.73 \pm 0.02$	$6.80 \pm 0.04$	$7.57 \pm 0.02$
5	Nitrogen (%)	$2.75 \pm 0.07^{ac}$	$2.48 \pm 0.05^b$	$2.84 \pm 0.05^a$	$2.78 \pm 0.07^{ab}$
6	Phosphorous (%)	$1.23 \pm 0.03^{bb}$	$1.10 \pm 0.04^{bd}$	$1.13 \pm 0.04^{bc}$	$1.39 \pm 0.05^a$
7	Potassium (%)	$0.96 \pm 0.05^{aa}$	$0.85 \pm 0.04^b$	$0.84 \pm 0.04^{bb}$	$0.96 \pm 0.06^a$

\*\* on dry matter basis

#### 4.7 COMPARISON OF FERTILIZER VALUE OF SUBSTRATES AND SLUDGE

The comparison of N P K content of substrate and sludge is presented in the Table 4.7.

There existed a significant increase ( $P < 0.05$ ) in N content of sludge but there was no difference in P and K content ( $P > 0.05$ ) of the sludge.

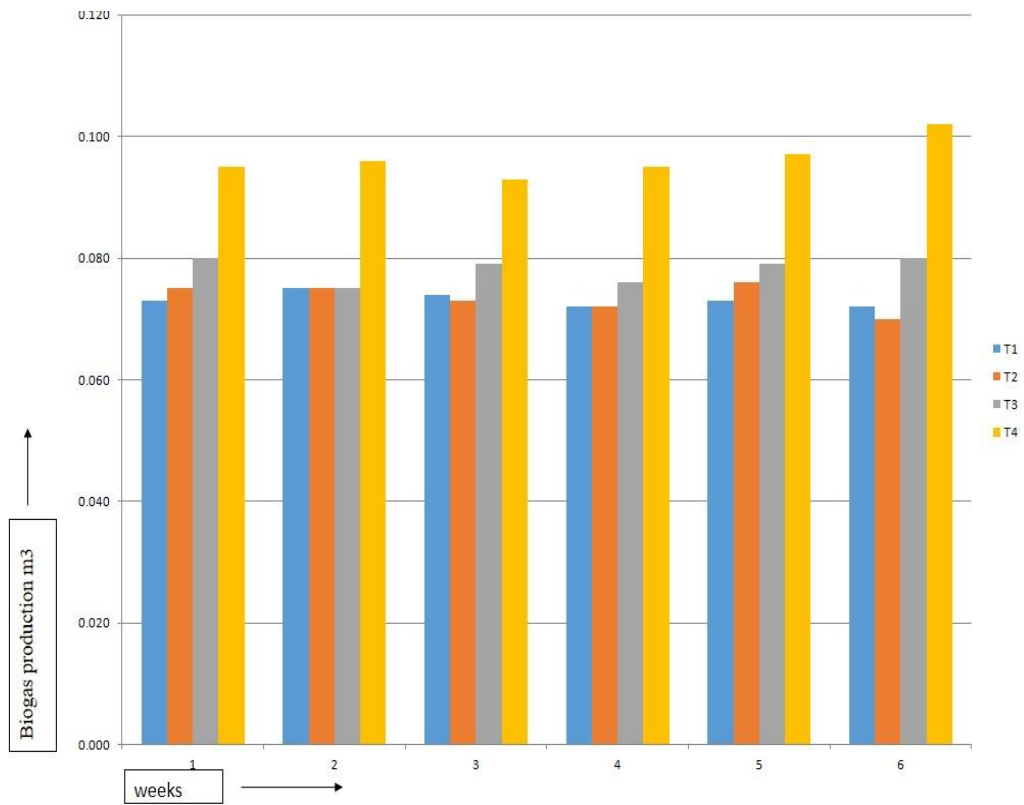
**Table 4.7 Comparison of NPK content of substrates and sludge**

Sl. No.	Treatment	Parameter	Substrate/Sludge	Mean $\pm$ Std. Error
1	T1(C)	N	Substrate	2.45 $\pm$ 0.08 <sup>ab</sup>
			Sludge	2.75 $\pm$ 0.07 <sup>ac</sup>
		P	Substrate	1.44 $\pm$ 0.02 <sup>aa</sup>
			Sludge	1.23 $\pm$ 0.03 <sup>bb</sup>
		K	Substrate	0.96 $\pm$ 0.05 <sup>bc</sup>
			Sludge	0.94 $\pm$ 0.05 <sup>aa</sup>
2	T2(D+W)	N	Substrate	2.23 $\pm$ 0.06 <sup>c</sup>
			Sludge	2.48 $\pm$ 0.05 <sup>b</sup>
		P	Substrate	1.13 $\pm$ 0.04 <sup>c</sup>
			Sludge	1.10 $\pm$ 0.04 <sup>bd</sup>
		K	Substrate	0.97 $\pm$ 0.03 <sup>bb</sup>
			Sludge	0.85 $\pm$ 0.04 <sup>b</sup>
3	T3(D+S)	N	Substrate	2.49 $\pm$ 0.03 <sup>ab</sup>
			Sludge	2.84 $\pm$ 0.05 <sup>a</sup>
		P	Substrate	1.29 $\pm$ 0.04 <sup>b</sup>
			Sludge	1.13 $\pm$ 0.04 <sup>bc</sup>
		K	Substrate	0.88 $\pm$ 0.02 <sup>bd</sup>
			Sludge	0.84 $\pm$ 0.04 <sup>bb</sup>
4	T4(D+N)	N	Substrate	2.70 $\pm$ 0.09 <sup>a</sup>
			Sludge	2.78 $\pm$ 0.07 <sup>ab</sup>
		P	Substrate	1.51 $\pm$ 0.06 <sup>aa</sup>
			Sludge	1.39 $\pm$ 0.05 <sup>a</sup>
		K	Substrate	1.10 $\pm$ 0.06 <sup>a</sup>
			Sludge	0.96 $\pm$ 0.06 <sup>a</sup>

Means bearing the different superscript within the same column differ significantly (P<0.05)

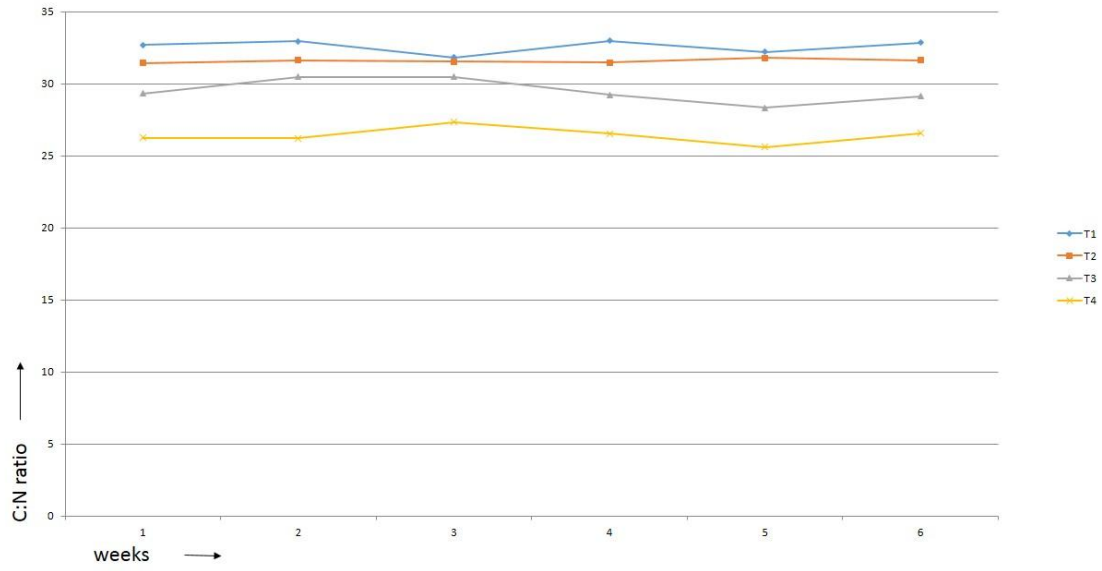
#### 4.8 PARASITIC LOAD OF SUBSTRATE AND SLUDGE

No parasitic ova were detected in cattle dung and sludge as deworming is regularly done in cattle farm.

**Fig.1. Trend in biogas production during the observation period**

X axis-Weeks

Y axis- Biogas production m<sup>3</sup>

**Fig.2. Mean weekly Carbon Nitrogen Ratio during the observation period**

X axis- Weeks

Y axis- C:N ratio

## ***Discussion***

## **5. DISCUSSION**

### **5.1 CLIMATOLOGICAL DATA**

#### **5.1.1 Micro-climatic variables**

The average daily ambient temperature ranged from 24.1 to 35.5°C during the observation period. The results obtained in the present study was similar to the observations of Nishanth (2009) who reported that the micro climatic temperature in University Livestock farm, Mannuthy ranged from 24.2°C to 34.12°C. The relative humidity ranged from 41 to 88 per cent during the observation period. The findings obtained were also in accordance with the observations of Nishanth (2009) who reported that the relative humidity in the University Livestock farm, Mannuthy ranged from 55.7 to 85.16 per cent.

#### **5.1.2 Macro-climatic variables**

The maximum environmental temperature recorded during the present study (37.6°C) was comparatively higher during the entire observation period. Marykutty and Nandakumar (2000) reported that the maximum temperature recorded was 36.2°C in the month of March. The mean weekly temperature ranged from 24.1°C to 35.5°C. These observations in the present study were similar with the results of Smitha (2010).

No rain fall was recorded during the observation period and the results obtained were in agreement with Joseph (2011).

### **5.2. PHYSICO-CHEMICAL CHARACTERS OF SUBSTRATES**

#### **5.2.1 Temperature**

The mean temperatures of the substrates were different among treatment groups with T4 (25.18 ± 0.44) having statistically higher temperature than of other treatments T1 (25.05 ± 0.44), T2 (25.02 ± 0.47), T3 (25.02 ± 0.45). Variation of substrate temperature might be due to the chemical reaction.

#### **5.2.2 Chemical composition**

The dry matter content ( $26.86 \pm 0.48$ ) and crude fibre content of group T1 ( $25.80 \pm 0.12$ ) was higher than other three substrates and may be due to less fibre disintegration in T1. pH of the substrate was higher in T4 ( $7.34 \pm 0.03$ ). Increase in pH may be due to addition of NaOH in T4.

### 5.3 PHYSICO-CHEMICAL CHARACTERS OF DIGESTA

An increase in the digesta temperature was observed during the observation period. The mean temperature values were  $31.43 \pm 0.10$ ,  $31.30 \pm 0.06$ ,  $31.65 \pm 0.09$  and  $32.73 \pm 0.13$  for T1, T2, T3, T4 respectively and was higher than that of substrate temperature. Increase in (T4) digesta temperature might be due to chemical reaction. According to Yadvika *et al.* (2004), biogas production was positively correlated with digesta temperature. The mean pH of the digesta during the observation periods were  $6.62 \pm 0.02$ ,  $6.87 \pm 0.02$ ,  $7.03 \pm 0.02$  and  $7.62 \pm 0.02$  for T1, T2, T3, T4 respectively. The observed pH of digesta of different substrates were in accordance with the earlier results of Yadvika *et al.* (2004), Al Seadi *et al.* (2008) and Khoiyangbam *et al.* (2011). Al Seadi *et al.* (2008) opined that the optimum range of pH for mesophilic digestion was between 6.5 and 8.0. The author also reported that the digestion process was severely inhibited when the digesta pH was decreased to below 6.0 or increased to above 8.3. Khoiyangbam *et al.* (2011) stated that the proper pH for anaerobic fermentation was between 6.8 and 8.0 and efficient digestion occurs at neutral pH. The authors also opined that during the start-up of anaerobic digestion, pH drops to 6.2 and after 10 days of digestion process, the pH began to rise and get stabilized between 7 and 8.

### 5.4 VOLUME OF BIOGAS

#### 5.4.1 Comparison of biogas production between substrates

Difference ( $P < 0.01$ ) was observed in biogas production among different substrates. It was found to be highest for T4 ( $0.096 \pm 0.001$ ) followed by T3

( $0.078 \pm 0.001$ ) and lowest for T2 ( $0.074 \pm 0.001$ ) and T1 ( $0.073 \pm 0.0005$ ). The results were similar with Hassan (2004), who studied the relationship between different fodder types and biogas production. The gas production was highest for NaOH treated ( $0.0538 \text{ m}^3$  biogas per kg dung) and in the slurry treated ( $.0487 \text{ m}^3$  biogas per kg dung). Zoabi (2010) suggested that fodder residue were suitable for anaerobic digestion and higher biogas production. Shejir (2014) reported that average biogas production potential of cattle excreta during summer and winter season was  $0.0739 \text{ m}^3$  in a potable bio digester of  $0.5 \text{ m}^3$  capacity. On the contrary, Porras and Gebresenbet (2003) reported that the estimated biogas yield from cattle excreta was  $0.036 \text{ m}^3$  per kg. The biogas yield was affected by many factors including type and composition of substrate (Khalid *et al.*, 2011). An and Preston (1999) found that the biogas yields differed with loading rate and elevated linearly as the loading rate increased. In contrast Yadvika *et al.* (2004) reported that optimum feed rate for a particular size of plant produce maximum amount of gas and further increase in the quantity of substrate did not resulted in linear production of more biogas. Yasin and Wasim (2011) found that the gas production was lower in water dung treatments with reduced feeding rate. However elevated feeding rate showed increase in overall gas production from  $0.62$  to  $1.07 \text{ m}^3$  per day. Rajendran *et al.* (2012) opined that the solid concentration in the household biogas digesters varied between 5 and 10 per cent and when the solid concentration was increased to 19 per cent, biogas production decreased considerably. The higher gas production observed in the present study could be due to the interaction of various factors like higher Total Solids level of substrates, dilution factor of substrate, microbial load, difference in crude fibre digestion and the study was conducted in summer season and is optimum for agro climatic conditions of Kerala.

#### **5.4.2 Trend in biogas production during the observation period**

In the initial stage of anaerobic digestion, the biogas production was fluctuating and became stabilized when hydraulic retention time (HRT) was achieved. This results are in conformity with the earlier work done by Paudel

(2012) who stated that the production of volatile fatty acids (VFA) by acid forming bacteria reduced the pH and also inhibited the growth of methanogenic bacteria, resulting in reduced gas production. Further elevation of gas production occurred due to nitrogen digestion (forming  $\text{NH}_4^+$ ) and the gas production become stabilized between pH 7.2 and 8.2.

## 5.5 CORRELATION OF DIFFERENT FACTORS AFFECTING BIOGAS PRODUCTION

### 5.5.1 Dry matter and crude fiber content of the substrate

The results showed that there was an increase in gas production as the DM level of the substrate decreases and reaches the optimum level. According to Rajendran *et al.* (2012) the solid concentration in the household biogas digesters varied between 5 and 10 per cent and when the solid concentration was increased to 19 per cent, biogas production decreased considerably. The crude fibre of substrate had no correlation with gas production. The obtained results were in agreement with Anzar (2014) who noted that the crude fibre content did not have any significant relationship with gas production. The absence of correlation of crude fibre level of substrate with gas production might be due to the effect of other factors such as atmospheric temperature and microbial population, which masked the effect.

### 5.5.2 Temperature and pH of digesta

The digesta temperature and pH showed a significant positive correlation ( $P < 0.01$ ) with gas production. According to Yadvika *et al.* (2004), biogas production was positively correlated with digesta temperature. This finding is in agreement with the results of the present experiment. A neutral pH was favorable for biogas production, since most of the methanogens grew at a pH range of 6.7 to 7.5 (Rajendran *et al.* , 2012; Yasin and Wasim, 2011). The pH of the digesta in all

the plants was in this range. There was a reduction in the digesta pH in the initial stages, due to the production of volatile fatty acids (VFAs). An and Preston (1999) found that the average maximum and minimum air temperature ranged between 25.3°C to 27.3°C and this range of temperature was suitable for mesophilic bacteria. Chawala (1986) reported the presence of three temperature zones i.e., thermophilic zone (above 45°C), mesophilic zone (22-45°C) and psychrophilic zone (below 20°C) during anaerobic digestion process. The effective and efficient anaerobic digestion was carried at both thermophilic and mesophilic temperature. However, temperature range of 30- 35°C was considered as the optimum temperature. In general there is a positive correlation between the substrate temperatures, digesta temperature and digesta pH with gas production.

### **5.5.3 Micro-climatic variables and gas production**

The results of the present study revealed a positive correlation ( $P < 0.01$ ) between the average daily temperature and gas production of all the substrates and a negative correlation ( $P < 0.01$ ) between relative humidity and gas production. Khoiyangbam *et al.* (2004) found that the methane emission rises with the increase in monthly temperature and correspondingly methane emission rates from the slurry displacement chambers of biogas plants were higher ( $P < 0.01$ ) during these months.

In the present study drastic changes in micro climate could be prevented by proper covering and roofing of experimental shed which in turn helped the smooth running of anaerobic digestion.

### **5.5.4 Macro-climatic variables**

The results showed that there was significant positive correlation between daily average temperature and maximum temperature with gas production of all the substrates. Also a significant negative correlation was observed between daily average relative humidity and gas production. This finding is in agreement with that of Khalid *et al.* (2011) who found a significant effect of temperature on the

microbial community especially methanogens and methane yield. Paudel (2012) opined that lower temperatures during the anaerobic digestion decreased microbial growth, substrate utilization rates and biogas production. In contrast, high temperature lowered biogas yield due to the production of volatile gases such as ammonia which suppresses methanogenic activities (Weiland, 2010).

### **5.6 Carbon Nitrogen Ratio**

From the table 4.3 it is clear that group T1 ( $32.59 \pm 0.19$ ) had the highest carbon nitrogen ratio and group T4 had lowest ( $26.41 \pm 0.23$ ). According to Weiland (2010) an optimum C:N ratio is within the range of 20-30:1. Group T4 was having the optimum C: N ratio and an elevated biogas production. According to Porras and Gebresenbet (2003), C: N ratio ranging from 20 to 30 is considered optimum for anaerobic digestion. If the C:N is very high, nitrogen will be consumed rapidly by methanogens for meeting their protein requirement and it will not be available for further multiplication of methanogens and with excess carbon. As a result the gas production will be low. Otherwise ammonia formation occurred and nitrogen will be accumulated.

### **5.7 Heat Generation Potential**

Heat Generation Potential shows that group T1 ( $32.33 \pm 0.56$ ) requires more time to boil than other groups T2 ( $30.67 \pm 0.49$ ), T3 ( $28.17 \pm 0.41$ ) and T4 ( $27.33 \pm 0.33$ ). T4 with highest heat generation potential with least time. The increase in heat potential of T4 could be due to higher methane concentration.

## **5.8. PHYSICO-CHEMICAL CHARACTERS OF SLUDGE (SLURRY)**

### **5.8.1 Chemical composition of sludge**

The results showed that T1 sludge showed highest DM content during the entire observation period. The CF content of T1 sludge on DM basis was higher ( $19.66 \pm 0.21$  per cent) than other three substrates. The pH was higher in T4 sludge

( $7.57 \pm 0.02$ ) than T3 sludge ( $6.80 \pm 0.04$ ) T2 ( $6.73 \pm 0.02$ ) and T1 sludge ( $6.43 \pm 0.02$ ). The N content was higher in T3 slurry compared to other sludge.

#### 5.9 COMPARISON OF FERTILIZER VALUE OF SUBSTRATES AND SLUDGE

A significant increase in N content of sludge was observed from digesters when different treatments were used but there was no significant difference in P and K content of the substrate and sludge.

Similar findings were also reported by Deshmukh (2012) who found that the sludge and remaining effluent possess good manurial value (N, P, K) and it can be used as a supplement to fertilizers in agriculture. Weiland (2010) reviewed that the anaerobic digestion resulted in mineralization of organically bounded nutrients which in turn increased the short-term N fertilization effect.

#### 5.10. PARASITIC LOAD OF SUBSTRATE AND SLUDGE

. No parasitic ova were detected in cattle dung and sludge as deworming is regularly done in cattle farm.

# **Summary**

## 6. SUMMARY

The main objective of this study was to compare the quantity of biogas produced from excreta of cattle with various treatments using portable biogas digester, carbon nitrogen ratio of the substrates, heat generation potential and to assess the fertilizer value of sludge obtained. The study was conducted at University Livestock Farm and Fodder Research and Development Scheme, Kerala Veterinary and Animal Sciences University, Mannuthy, Thrissur. For this purpose, the study period was selected from February to March 2015.

The research was conducted using four portable floating drum biogas plants of 0.5 m<sup>3</sup> capacity designed by Agro Biotechnology Agency for Rural Employment Development (ABARD), Kerala Agricultural University, Vellanikara, to study the biogas production potential of pre-treated fodder residue with retention period of 25 to 30 days in the mesophilic temperature range. The experiment was conducted in summer season as there is high gas production during that period. There were four treatments, one kilogram of dung mixed with various treatments.

In the experiment, one kilogram of fresh excreta of cattle along with chopped pre-treated fodder residue were diluted with water to 10 percent dry matter level and loaded daily (morning) in four different plants. Volume of biogas produced was noted at constant pressure for the following days till a constant gas production was obtained (around 30 days). The biogas volume was recorded for the next 42 days.

The various parameters studied included environmental factors ( micro and macroclimatic temperature and humidity), precipitation, physico-chemical characters of substrates and sludge (temperature, pH, dry matter, crude fibre), manurial value of substrates and sludge (N,P,K content), digesta temperature and pH, biogas production (quantity and composition), quantity of sludge, parasitic load of substrate and sludge.

With regard to the micro-climate, the average daily ambient temperature ranged from 24.1°C to 35.5°C during observation period. The micro-climatic relative humidity ranged from 41 per cent to 88 per cent during observation period.

The daily average atmospheric temperature during observation period ranged from 24.4°C to 31.9°C. The daily average relative humidity was 41 per cent to 88 percent during observation period. The weekly average rainfall during the observation period was zero as no rain fall was recorded during the observation period.

The mean temperature (°C) values in the observation period were  $25.05 \pm 0.44$  (T1) and  $25.02 \pm 0.47$  (T2),  $25.02 \pm 0.45$  (T3) and  $25.18 \pm 0.44$  (T4). The moisture content of the substrates were  $73.14 \pm 0.48$  (T1),  $78.20 \pm 0.32$  (T2),  $83.16 \pm 0.28$  (T3),  $85.07 \pm 0.41$ (T4) per cent. T4 was having the lowest dry matter content. The crude fibre content of T1 on dry matter basis was higher than other three substrates. The pH of the T4 was higher ( $7.34 \pm 0.03$ ) than T3 ( $6.83 \pm 0.02$ ), T2 ( $6.62 \pm 0.02$ ) and T1 ( $6.62 \pm 0.02$ ). The Nitrogen content was higher in slurry as compared to that of substrates

The mean temperature (°C) of digesta were  $31.43 \pm 0.1$ ,  $31.30 \pm 0.06$ ,  $31.65 \pm 0.09$  and  $32.73 \pm 0.13$  using T1, T2, T3 and T4 substrates respectively. The mean pH of the digesta during the observation period were  $6.62 \pm 0.02$ ,  $6.65 \pm 0.02$ ,  $6.83 \pm 0.02$ ,  $7.34 \pm 0.03$  T1, T2, T3 and T4 respectively as substrates.

The volume of biogas (m<sup>3</sup>) was highest from T4 ( $0.096 \pm 0.001$ ) followed by T3 ( $0.078 \pm 0.001$ ), T2 ( $0.074 \pm 0.001$ ) and T1 ( $0.073 \pm 0.0005$ ). There was significant difference ( $P < 0.05$ ) in biogas production between treatments. Comparison of mean values showed that biogas production in the T4 was significantly ( $P < 0.05$ ) higher than T1.

There was significant negative correlation between the dry matter levels of substrate with gas production. The temperature of substrate and digesta, and pH of

digesta had a significant positive relation ( $P < 0.05$ ) with gas production, but the substrate pH had no significant ( $P > 0.05$ ) correlation with gas production.

A significant ( $P < 0.01$ ) positive correlation was found between mean daily temperature (micro-climate) and gas production of all the substrates. A significant negative correlation ( $P < 0.01$ ) was observed between relative humidity and gas production.

The mean Carbon Nitrogen Ratio of T1 ( $32.59 \pm 0.19$ ) was having highest T2 ( $31.58 \pm 0.05$ ), T3 ( $29.49 \pm 0.34$ ) and T4 with lowest ( $26.41 \pm 0.23$ ).

The mean Heat Generation Potential was T1 ( $32.33 \pm 0.56$ ), T2 ( $30.67 \pm 0.49$ ), T3 ( $28.17 \pm 0.41$ ) and T4 ( $27.33 \pm 0.33$ ). T1 is significantly higher than that of other substrates ( $P > 0.05$ ).

The moisture content of T1, T2, T3 and T4 sludge on fresh basis were  $90.36 \pm 0.13$ ,  $90.57 \pm 0.10$ ,  $91.46 \pm 0.11$  and  $93.6 \pm 0.13$  per cent respectively. The T1 sludge was having the highest dry matter content. The crude fibre content of T1 sludge on dry matter basis was higher at  $19.66 \pm 0.21$  per cent than three substrates T2 ( $18.63 \pm 0.09$ ), T3 ( $17.94 \pm 0.08$ ) and T4 ( $17.29 \pm 0.04$ ). The pH of the sludge was higher in T4 sludge ( $7.57 \pm 0.02$ ) than T3 sludge ( $6.80 \pm 0.04$ ), T2 sludge ( $6.73 \pm 0.02$ ) and T1 sludge ( $6.43 \pm 0.02$ ).

The Nitrogen content was higher in sludge as compared to substrate. A significant increase ( $P < 0.01$ ) in N content of sludge from digesters were observed when different treatments were used, but there was no significant difference ( $P > 0.05$ ) in P and K content of the substrate and sludge.

The eggs per gram of freshly collected excreta of cattle was analysed. No parasitic ova were detected in cattle excreta and sludge as it is regularly dewormed in the farm.

From the above results it can be inferred that the quantity of methane concentration of biogas produced from T4 was higher than other treatments. The results of manurial value showed that sludge have higher N content than substrate.

From the results it can be concluded that, fodder residue pre-treated with NaOH has the highest biogas production potential and quality among other treatments and it is revealed that the sludge is having significantly higher ( $P < 0.05$ ) manurial value than the substrate.

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**BIOGAS PRODUCTION POTENTIAL OF PRE-TREATED  
FODDER RESIDUE**

**SARATH KRISHNAN**

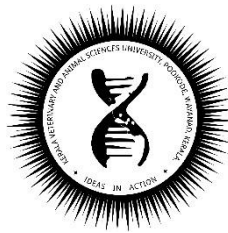
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**ABSTRACT OF THE THESIS**

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## ABSTRACT

The present study was undertaken to study the biogas production potential of pre-treated fodder residue. The research work was conducted at University Livestock Farm and Fodder Research and Development Scheme, Mannuthy using portable floating drum biogas plants of 0.5 m<sup>3</sup> capacity. The study was conducted for 42 days, with daily loading rate of one kg cow dung and one kg chopped fodder residue (T1), one kg cow dung mixed with one kg chopped fodder residue soaked in water for seven days (T2), one kg cow dung and one kg chopped fodder residue soaked in biogas slurry for seven days (T3), one kg cow dung mixed with one kg chopped fodder residue soaked in one % NaOH for seven days (T4), and all the treatments were further diluted to 10% dry matter level. Volume of gas was taken throughout the entire observation period at constant pressure. Carbon Nitrogen ratio of the substrate and Heat Generation potential of biogas were analysed. The fertilizer value [Nitrogen (N), Phosphorus (P) and Potassium (K) content of sludge were analysed fortnightly.

Results indicated that there exists significant difference between treatments in case of volume of biogas production, carbon nitrogen ratio. The mean values of biogas volume in m<sup>3</sup> were in the order of group T4 at the highest (0.096 ± 0.001) followed by T3 (0.078 ± 0.001), T2 (0.074±.001) and T1 (0.073±.0005). The mean value of Carbon Nitrogen ratio shows that T4 (26.41±0.23) had optimum C:N ratio than T3 (29.49±0.34), T2 (31.58±0.05) and T1 (32.59±0.19). The sludge was observed to have better fertilizer value than the substrate.